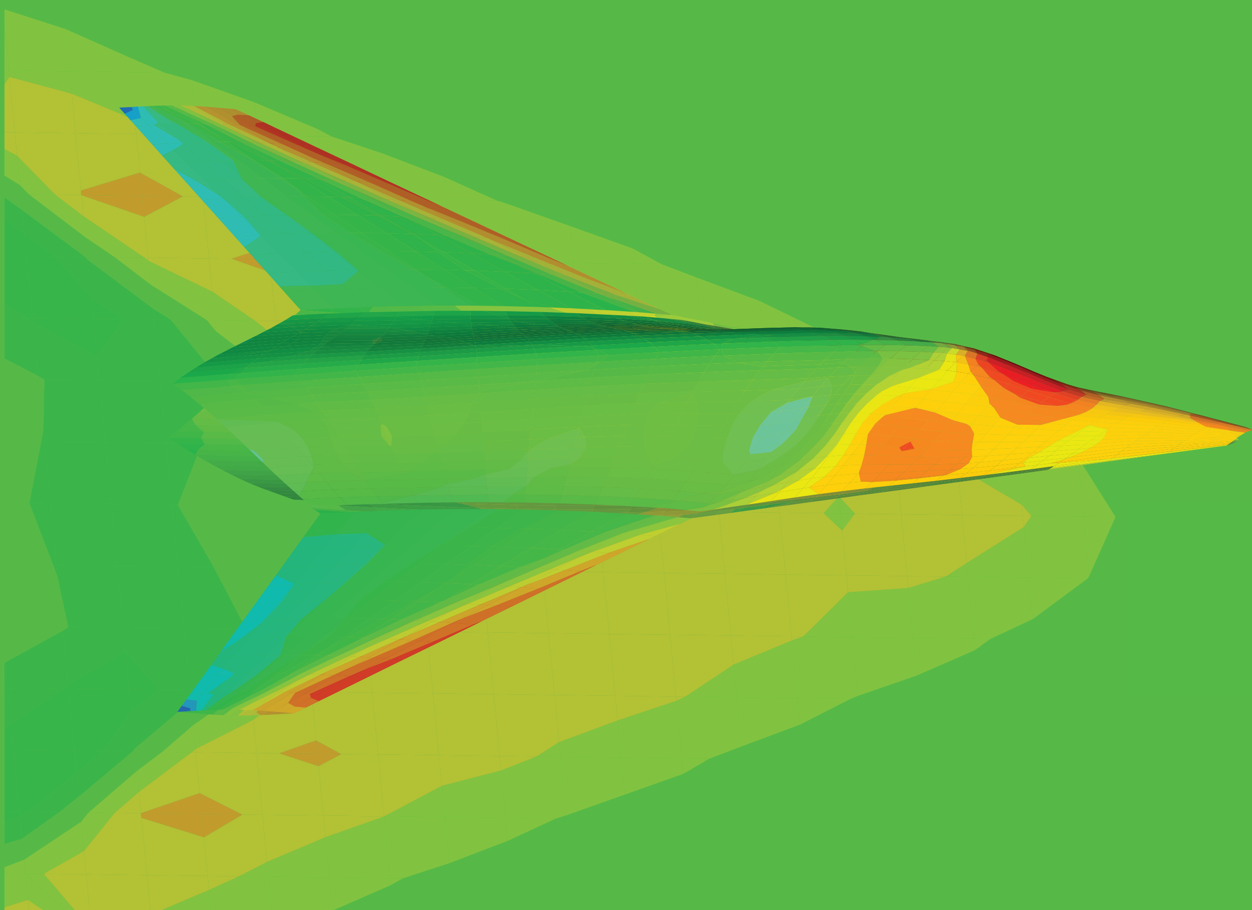
ZONAIR v. 4.7

User's Manual

Engineering Software for Aerodynamics and Flight Loads



ZONA TECHNOLOGY INC

ZONAIR

Version 4.7

USER'S MANUAL

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ZONA TECHNOLOGY INC

ZONA Technology, Inc. • 9489 E. Ironwood Square Drive • Scottsdale, AZ 85258
Tel: (480) 945-9988 • Fax: (480) 945-6588 • E-mail: info@zonatech.com

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FOREWORD

ZONAIR UPGRADES

This section lists the enhancements made to the ZONAIR software system.

Version 4.7 Enhancements

1. A new bulk data card called **WT1CFD** is introduced to first internally generate a **WT1AJJ** and a set of **WT1FRC** bulk data cards then process the **WT1AJJ** bulk data card for generating the corrected AIC matrix using the force correction method.

2. The **WT1CFD** bulk data card is activated by a **WT1CFD** case control command.

3. A new test case whose input file called "F6_Fine.inp" is added whose description is documented in Chapter 8 of the application's manual. This test case is a ZONAIR model of the DLR F-6 configuration. The objectives of this testcase is (1) to present the best panel modeling approach of the wing tip, and (2) to show the impact of panel density near the wing trailing edge on aerodynamic solution.

4. ZONA's Design Variable Linking Scheme (ZLINK) module is included within the ZONAIR software. ZLINK is used to describe, and is completely responsible for, the geometrical shape change (i.e., morph) that takes place. It allows for the input of design variables, independent and dependent variable definitions, and arbitrary general functions of virtually any complexity. Five new bulk data cards called **DESFUN**, **DESDEP**, **DESIND**, **DESSEN**, and **DESVAR** are introduced to set up the ZLINK input. A new executive control command called **DESSEN** is introduced to invoke the ZLINK module. The details of the ZLINK module can be found in Section 4.2.7 of the User's Manual.

5. Two new entries CIRCLE and NLINE are added to the **AUTOTIP** bulk data card. The entry CIRCLE is character string can be either "FLAT" or "CIRCLE" (default="FLAT"). The entry NLINE is the number of lines of grid to model the wing tip (default=1). Please see Remark 8 of the **AUTOTIP** bulk data card.

6. New options of the entry AUTOTIP are added to the **THKWING** bulk data card. AUTOTIP can be either "BOTH", "BOTHC", "ROOT', "ROOTC', "TIP", TIPC", or "NONE" (default="NODE"). Please see remarks of the **THKWING** bulk data card.

7. A new bulk data card called **LESUCT** is introduced to activate the inclusion of additional lift due to vortex roll-up from the wing leading edge using the Polhamus leading edge suction analogy.

Version 4.6 Enhancements

8. A new executive control command called CPU is available which allows parallel computation using OpenMP to accelerate the computational speed.

9. A new module called JIGSHP is developed to determine the jig shape from the cruise shape. A new case control command called JIGSHP and a new bulk data card called **JIGSHP** are added into the program to activate the JIGSHP module.

10. A new bulk data card called **CPSPLNL** is added to interpolate the wind tunnel measured pressure coefficients to ZONAIR panels using linear interpolation scheme.

11. Two new bulk data cards called **PANADD** and **PANRMV** are added to facilitate the list of panel identification numbers for spline and pressure interpolation as well as component loads definition.

12. A new bulk data card called **CPFACT** is added which allows the user to apply a factor to the pressure derivatives due to structure modes, control surface deflection, and the trim variables on selected panels.

13. A new bulk data card called **FEMSAVE** is available to save the structural modal solution imported by the **'ASSIGN FEM**=' executive control command. This saved structural modal solution can be retrieved by specifying entry FORM='ACQUIRE' in the **'ASSIGN FEM=**' executive control command.

14. Three new input bulk data cards, namely **DYNSAVE**, and **LMDSAVE** have been incorporated into version 4.6. The **DYNSAVE** bulk data card can save and retrieve the data entities created by the GENDYN module. The **LMDSAVE** bulk data card can save and retrieve the matrices created by **LOADMOD** bulk data card.

15. A new entry FRICT is added into the **CAERO7** and **MATBODY** bulk data cards to compute the skin friction drag.
16. A new bulk data card called **TREFFTZ** is incorporated to define a Trefftz plane for computing induced drag.

17. Two new options are added to the entry DATA1 of the **INPCFD1** bulk data card. The first is DATA1=”FUN3D” to import the CFD solution computed by the FUN3D code. The second is DATA1=”CFX” to import the CFD solution computed by the commercial CFD software CFX™ to replace the aerodynamic rigid pressure distribution computed by ZONAIR.

Version 4.5 Enhancements

18. A new module called JIGCP is developed to correct the pressure distribution measured by wind tunnel test or computed by CFD on the cruise shape to the jig shape. A new case control command called JIGCP and a new bulk data card called **JIGCP** are added into the program to perform such a correction process.

19. A new bulk data card called **PLTPANS** is incorporated that allows the user to graphically display a set of aerodynamic panels and/or a set of structure grid to verify the **SPLINEi** and **LOADMOD** input.

20. The bulk data card **CPSPLN** has been changed to output a graphic file that allows the user to verify the input data for pressure spline.

Version 4.4 Enhancements

1. The THERMAL bulk data card has been modified to allow the aeroheating analysis with structural flexibility effects by referring to a FLEXLD bulk data card.

2. A new chapter (Chapter 9) has been added into the Applications' Manual. This chapter describes how to perform an aeroheating analysis with structural flexibility effects of a missile-like configuration.

3. In the **FLEXLD** bulk data card, an option to include the follower force effect for flexible loads analysis is added. This option is activated by specifying a negative dynamics pressure in the **FLEXLD** bulk data card.

Version 4.3 Enhancements

1. The aerodynamic center on each CAERO7 box is moved from 50% chord to 25% chord if the Mach number is less than one. This modification gives closer agreement between ZONAIR and vortex lattice method solutions.

2. A new bulk data card called **SPLINEF** is added to the spline module. **SPLINEF** allows the user to create a different spline matrix for transferring the aerodynamic forces from aerodynamic panels to structural grid points.

3. Version 4.2 calculates the area of each CAERO7 box based on that of the flat plate. Version 4.3 calculates the area of each CAERO7 based on the area defined by the **PAFOIL7** bulk data card. The modification enlarges the area of the CAERO7 boxes and changes the resulting forces of the CAERO7 Model.

Version 4.2 Enhancements

1. A new module called "FLEXLD" is created in Version 4.2 to compute the aerodynamic pressures and force/moment coefficients with static aeroelastic effects. To invoke the FLEXLD module, the user must specify a new FLEXLD case control command that refers to a new **FLEXLD** bulk data card.

2. A new bulk data card called **CPSPLN** is implemented to map the wind tunnel measured pressure coefficients onto ZONAIR aerodynamic model. The **CPSPLN** bulk data card refers to the **AEROGEN** bulk data card to replace the aerodynamic pressures computed by the **AEROGEN** bulk data card on the rigid aircraft by the wind tunnel measured aerodynamic pressures.

3. A new bulk data card called “**TRIMINP**” is incorporated in the trim module to replace the program computed derivatives of the aerodynamic forces of a trim variable by the user supplied values. The **TRIMINP** bulk data card is referred to by the **TRIMVAR** bulk data card where the user supplied values are imported by the **INPCFD**, **INPCFD2** or **CPSLIN** bulk data card.

4. Two new chapters (Chapter 7 and Chapter 8) are included in the Applications Manual. Chapter 7 documents a trim analysis of the AGARD 445.6 wing case where the program computed aerodynamic forces of the rigid aircraft are replaced by the user supplied values. The user supplied values are obtained by the CFD analysis and the wind tunnel measurement. Chapter 8 shows the modeling guidelines for modeling complex configurations. Four whole aircraft configurations are included in Chapter 8; A-380, F-15, F-18 and a conceptual design aircraft.

Chapter 1

INTRODUCTION

1.1 WHAT IS ZONAIR?

ZONAIR is an engineering software system that utilizes a unified high-order subsonic/supersonic/hypersonic panel methodology as the underlying aerodynamic force generator to efficiently create aerodynamic and loads databases for 6 d.o.f. simulation and critical loads identification. ZONAIR is formulated based on the unstructured surface panel scheme that is compatible to the finite element methods. This enables the direct adoption of off-the-shelf finite element pre- and post-processors such as PATRAN, I-DEAS, FEMAP, etc. for ZONAIR panel model generation. The specific capabilities of ZONAIR include:

- A unified high-order subsonic/supersonic/hypersonic panel methodology as the underlying aerodynamic force generator.
- Unstructured surface panel scheme compatible to the finite element method.
- Direct adoption of off-the-shelf FEM pre- and post-processors for rapid panel model generation.
- Vortex roll-up scheme for high angle-of-attack aerodynamics.
- Trim module for flexible loads and aeroheating module for aeroheating analysis.
- Pressure mapping from CFD mesh to ZONAIR panels.
- AIC correction using wind-tunnel measured loads for accurate flexible loads generation.
- Aerodynamic and loads database for 6 d.o.f. simulation and critical loads identification.

ZONAIR consists of many submodules for various disciplines that include (1) AIC matrix generation module, (2) 3-D spline module, (3) trim module, (4) aeroheating module, (5) vortex roll-up module, and (6) aerodynamic stability derivative module. The interrelationship of ZONAIR with other engineering software systems such as the pre-processor, structural finite element method (FEM), Computational Fluid Dynamic (CFD) method, six degree-of-freedom (6 d.o.f.) and critical loads identification is depicted in Figure 1.1.

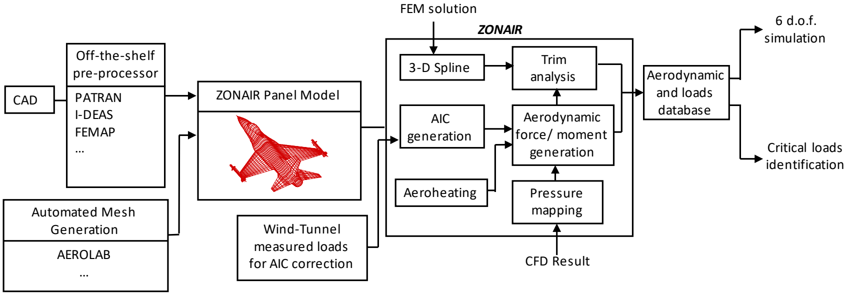


Figure 1.1 Interrelationship of ZONAIR with Other Engineering Software Systems

1.2 FINITE-ELEMENT BASED HIGH ORDER PANELING SCHEME

The ZONAIR panel model is normally constructed by first discretizing the configuration into many grid points and then connecting these grid points with either the quadrilateral or triangular panels. This type of panel construction is very similar to the structural finite element method. In fact, some of the NASTRAN bulk data cards are directly adopted for ZONAIR input. In order to ensure the continuity of singularity distribution over the entire panel model, unit singularity strength is first assigned at each grid point and piecewisely linear singularity is distributed over the panels, which are surrounding this grid. Such an elementary singularity distribution is shown in Figure 1.2. Clearly, the superposition of the elementary singularity distribution of all grid points can result in a continuous singularity distribution over all panels.

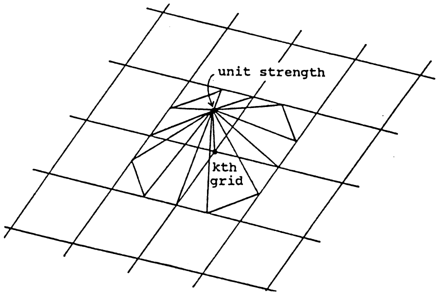


Figure 1.2 Elementary Singularity Distribution at Grid Points

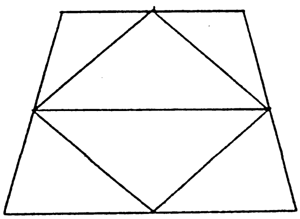


Figure 1.3 Subdivision of Quadrilateral Panel into Sub-triangular Panels

Furthermore, because the four corner points of a quadrilateral panel may not locate on the same plane, each quadrilateral panel is subdivided into six triangular panels for the continuity of panel geometry (Figure 1.3).

At each panel, both Dirichlet boundary condition ($\phi_L = 0$) and Neumann boundary condition $\left(\frac{\partial \phi}{\partial n} = -\vec{V} \cdot \vec{n}\right)$ are imposed for solving the source and doublet strengths (Figure 1.4). Also, the zero-force condition $\left(\frac{\partial \phi}{\partial x} = 0\right)$ is imposed on the wake to satisfy the wake condition.

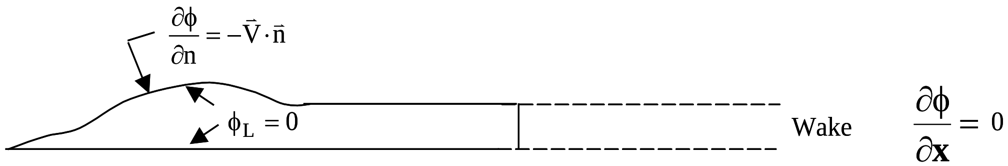


Figure 1.4 Dirichlet and Neumann Boundary Conditions on Panels and Zero-Force Condition on Wake Surface

1.3 NO REQUIREMENT FOR MODELING WAKE SURFACES

Unlike other high-order panel methods such as PANAIR, VSAERO, and QUADPAN where the wake surfaces must be explicitly modeled, ZONAIR requires only the specification of the line segments along the trailing edge of the wing and body where the wake surface starts; no wake surface modeling is required by ZONAIR. These line segments for wake modeling are shown in Figure 1.5. Internally, ZONAIR sweeps these line segments to infinity and creates a flat wake surface. Because an exact solution can be obtained by integrating the wake integral from the line segment to infinity, the wake effects can be included by only evaluating the exact integral solution along each line segment.

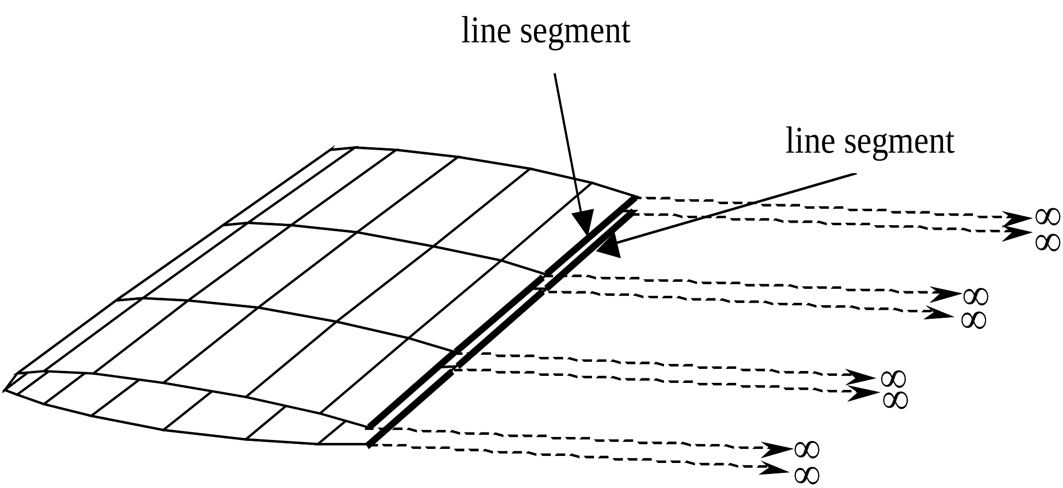


Figure 1.5 Line Segments for Wake Modeling

1.4 NASTRAN BULK DATA INPUT FOR ZONAIR

ZONAIR input is very similar to the NASTRAN bulk data input. In fact, some NASTRAN bulk data cards can be directly adopted for ZONAIR modeling. Also, multiple subcases can be specified in one ZONAIR job for different flight conditions. This direct adoption of some NASTRAN bulk data cards for ZONAIR modeling is shown in Figure 1.6.

```
TITLE= $naca l51f07 wing-body test case,the last model
ECHO = SORT
SUBCASE = 1
        AERO=1
SUBCASE = 2
        AERO=2
BEGIN BULK
$  Wake Modeling
CBAR         483       1     271      282
.................................
CBAR         484       1     273      283
$  Grid Point Locations
GRID           1            .000    .000     .000
.................................
GRID         586          29.313  12.000     .000
$  Triangular Panels
CTRIA3         1       1       1       2        3
.................................
CTRIA3         6       1       1       7        8
$  Quadrilateral Panels
CQUAD4         7       1       2       9       10       3
.................................
CQUAD4       558       1     193     200      201     271
$  Wing Tip Line Vortex
CROD         580       1     586     568
$  Wake-on-Body Impingement Behind Wing-Body Junction
RBE2        1001      51      52
             211     311     412     963      319
ENDDATA
```

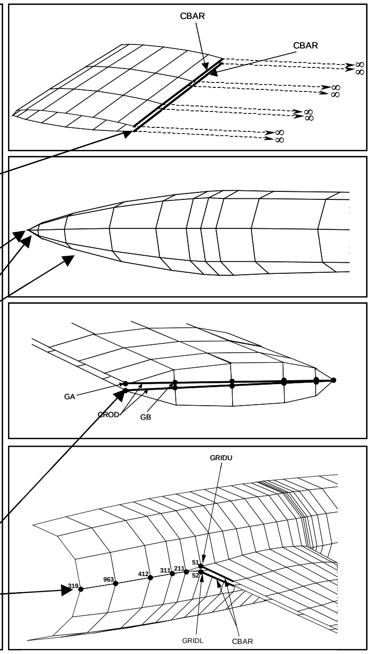
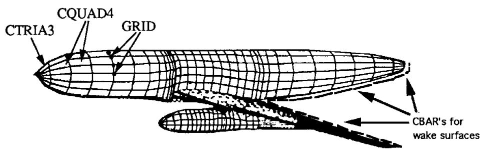


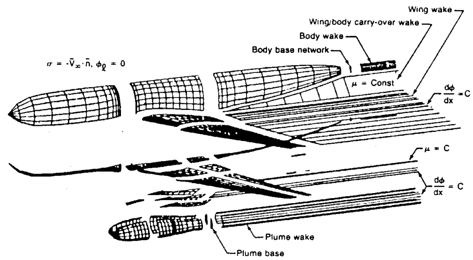
Figure 1.6 NASTRAN Bulk Data Input for ZONAIR

1.5 DIRECT ADOPTION OF OFF-THE-SHELF FEM PRE-PROCESSOR FOR PANEL MODEL GENERATION

Figure 1.7 presents the comparison between ZONAIR unstructured paneling scheme and PANAIR's paneling scheme where the advantages of adopting the unstructured grids is shown. Another advantage in using unstructured grids is that it allows arbitrary grid point selection for a given configuration. In order to demonstrate this feature, a sphere is modeled by using regularly spaced/shaped panels (called Regular Panels) and randomly spaced/shaped panels (called Random Panels) whose pressure distribution results are shown in Figures 1.8(a) and 1.8(b), respectively. Clearly, this arbitrary grid point selection capability of the unstructured grids can greatly reduce the user burden in the grid generation process. The similarity between the ZONAIR and MSC.NASTRAN input format enables the direct adoption of the pre- and post-processors of MSC.NASTRAN for ZONAIR model generation and result display. There are many off-the-shelf NASTRAN pre- and post-processors such as

PATRAN, AEROLAB, I-DEAS, FEMAP, etc. that are all capable of importing IGES files from the CAD systems. Therefore, one can generate a ZONAIR aerodynamic model that is based on the surfaces defined by the CAD system, rendering a tremendous saving of model generation effort.

<table>
<tr>
<td>ZONAIR
Unstructured Grids


</td>
<td>PANAIR
Structured Grids


</td>
</tr>
<tr>
<td>
• Similar to structural FEM (MSC.NASTRAN), the entire configuration is defined by “grids”. CTRIA3’s and CQUAD4’s defines the connectivity between the grids.
• Only the starting lines of the wake need to be defined (via CBAR elements). There are no input requirements for the surface wake.
• PATRAN, FEMAP, I-DEAS, etc., can be employed directly for pre- and post-processing.
</td>
<td>
• The entire configuration is first divided into several “networks”. Each network is further divided by m x n set of grids. Matching of doublet singularity between adjacent networks requires additional input.
• The location of the wake surfaces must be explicitly modeled.
• No commercially off-shelf software can be used directly for pre- and post-processing.
</td>
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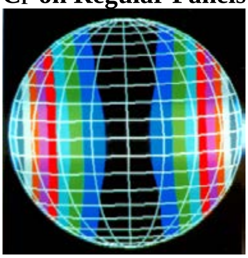
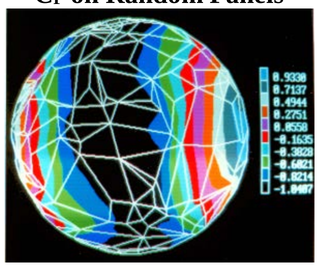
</table>

Figure 1.7 Comparison of ZONAIR and PANAIR Paneling Schemes

<table>
<tr>
<td>C_P on Regular Panels


(a)</td>
<td>C_P on Random Panels


(b)</td>
</tr>
</table>

Figure 1.8 Regular and Random Paneling of a Sphere at M=0.0 and α=0.0 deg

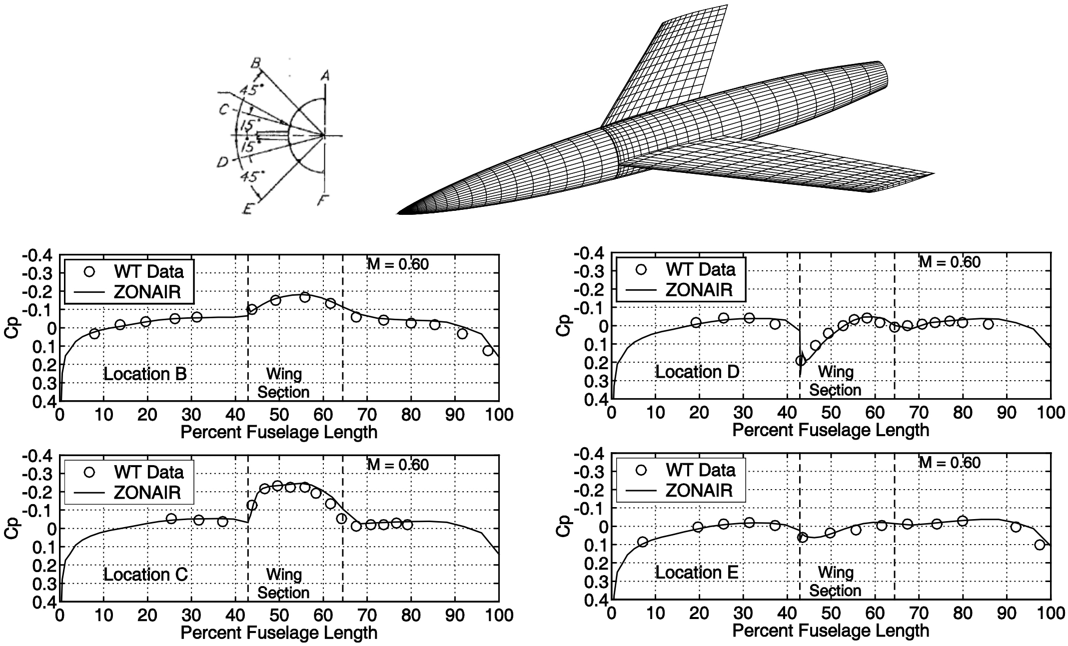
1.6 VALIDATION CASES FOR ZONAIR AERODYNAMICS

In what follows, some validation cases for ZONAIR aerodynamics ranging from subsonic to hypersonic as well as multi-body interference, wave drag predictions, ground effects, aeroheating analysis and wake relaxation are shown.

Subsonic Aerodynamics

NACA RM L51F07 wing-body configuration at M = 0.6, α = 4°

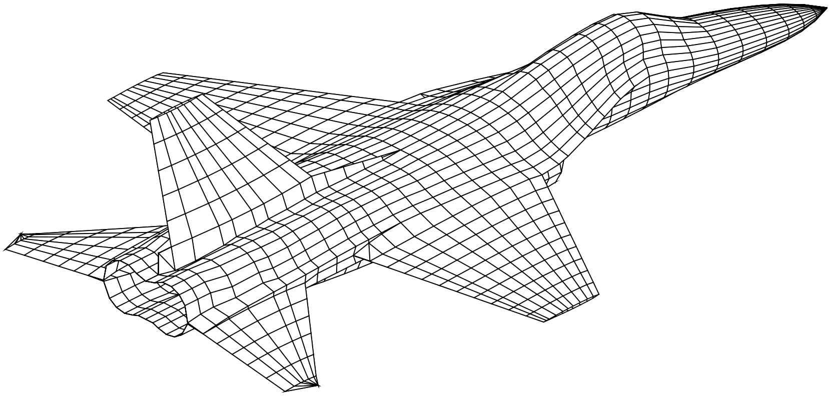
- Pressures along the body show strong wing-body interference.
- Good correlation with the wind-tunnel measurements.



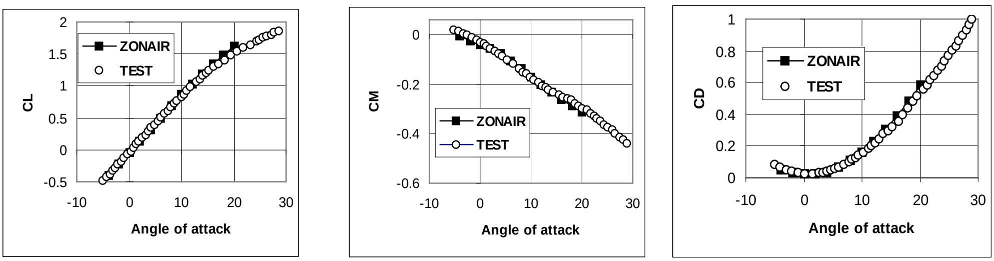
Supersonic Aerodynamics

Force and moment coefficients of Generic Advanced Fighter at M = 1.2 and 2.0

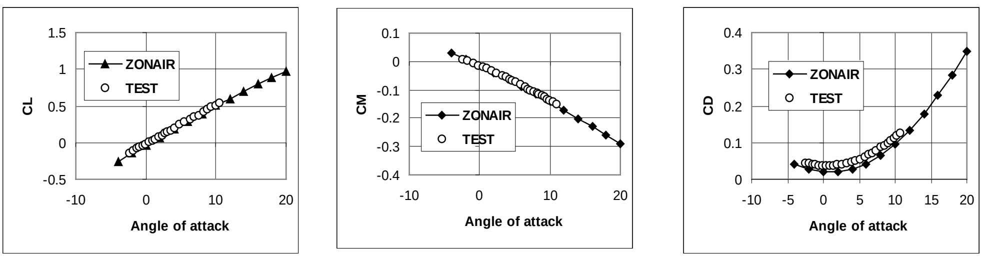
- Whole aircraft with tip missile configuration shows the capability of ZONAIR for accurate supersonic aerodynamics on complex geometry.
- CPU time is only 25 minutes on a 550 MHz PC computer.



M=1.2



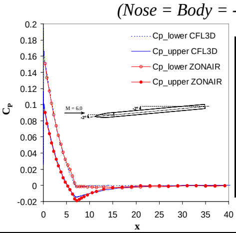
M=2.0



Hypersonic Aerodynamics

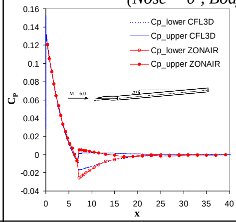
- Equivalent Mach number transformation to circumvent the super inclined panel problem.
- Local pulsating body analogy for flow rotationality effects.
- Good agreement between ZONAIR and CFL3D on the CKEM body at various bent-nose angles at M = 6.0.

Undeflected Case, Body & Nose at the same AOA
(Nose = Body = -2º, at M = 6.0)



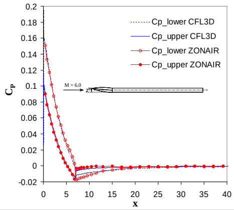
	CFL3D	ZONAIR
C_L	-0.118	-0.1125
C_m	-0.0549	-0.05588
C_D	0.0465	0.050
C_h	-0.00612	-0.00668

Positive 2º Deflection between Body & Nose
(Nose = 0º, Body = -2º, at M = 6.0)



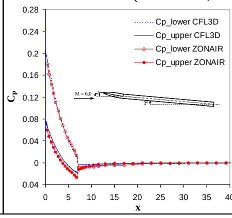
	CFL3D	ZONAIR
C_L	-0.076	-0.0712
C_m	-0.02552	-0.02776
C_D	0.0553	0.049
C_h	3.76e-7	0

Positive 2º Deflection between Body & Nose
(Nose = 2º, Body = 0º, at M = 6.0)



	CFL3D	ZONAIR
C_L	0.0437	0.0408
C_m	0.0292	0.02806
C_D	0.0492	0.0493
C_h	0.00612	0.00668

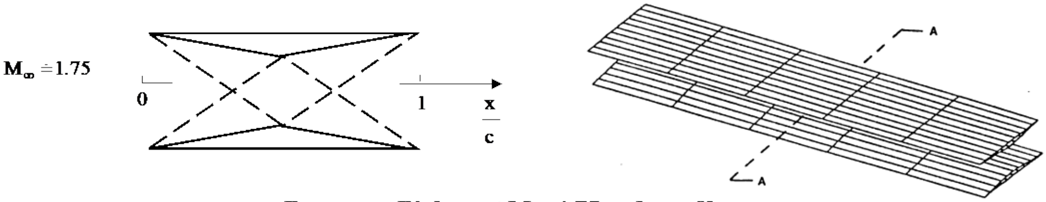
Positive 2º Deflection between Body & Nose
(Nose = 4º, Body = 2º, at M = 6.0)



	CFL3D	ZONAIR
C_L	0.1637	0.1517
C_m	0.0857	0.08388
C_D	0.0537	0.057
C_h	0.0123	0.0133

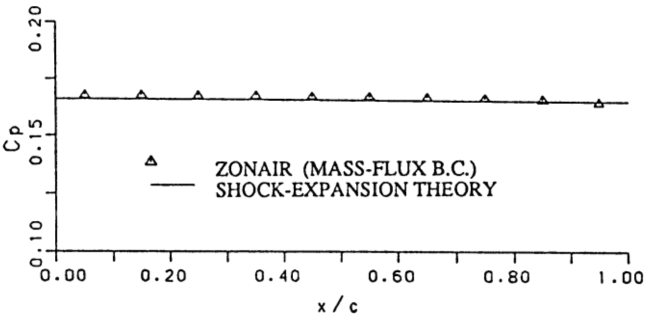
Multi-Body Interference

- Busemann Biplane at a design Mach number (M = 1.75 and α = 0°) where the shock-expansion theory predicts the nullification of wave drag due to the perfect cancellation of Mach waves.



Busemann Biplane at M = 1.75 and α = 0°

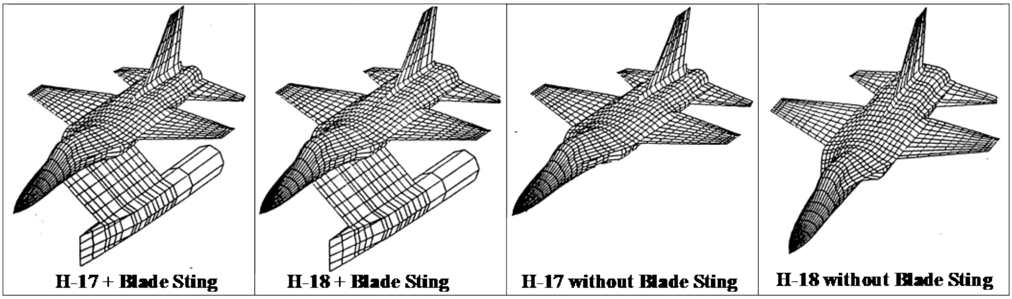
- Excellent agreement between ZONAIR and shock-expansion theory is obtained.



C_p on Busemann Biplane at M = 1.75 and α = 0°

Wave Drag Predictions

- The objective of the wind tunnel test is to determine the wave drag reduction of the GAF with a modified after body section (denoted as H-18) from the baseline GAF (denoted by H-17**).**
- Both wind tunnel models use an underbody "blade sting" for supplying the jet flow and have sealed inlets. The difference in measured drag between these two models is assumed to be caused by the afterbody modification.
- The purpose of this ZONAIR analysis is to validate this assumption by establishing four ZONAIR models; H-17 + blade sting, H-18 + blade sting, H-17 without blade sting, H-18 without blade sting



- Good agreement between ZONAIR and measured wave drag indicates that the blade sting effects on incremental wave drag measurements are small.

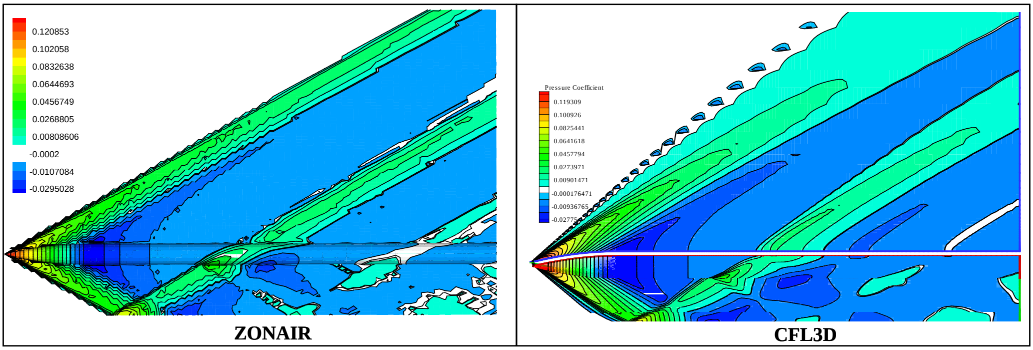
Blade Sting Effects on Wave Drag of GAF

M = 1.2	ZONAIR Wave Drag Predictions	Measured Drag
(H-17 + blade sting) – (H-18 + blade sting)	33 counts	31 counts
(H-17 without blade sting) – (H-18 without blade sting)	34 counts	N/A

Ground Effects

Compact Kinetic Energy Missile (CKEM) Flying 5 Inches Above the Ground at M = 2.0

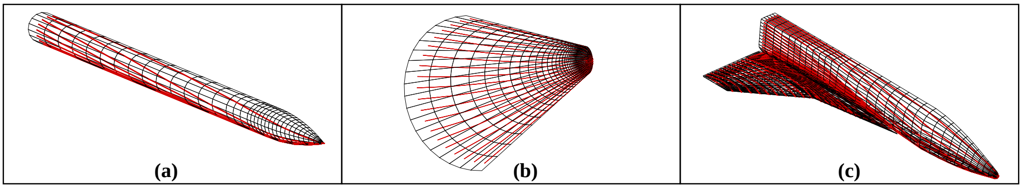
- Mirror-image approach where the ground is treated as a mid-plane between two mirror-image bodies.
- ZONAIR can compute flow field solutions for the visualization of the detailed flow field solutions.
- Good agreement of the pressure distribution on the body surface and in the flow field can be seen. For this case, ZONAIR takes about 10 minutes of CPU time on a 550 MHz PC computer whereas CFL3D takes about 10 hours.



Pressure Distribution of CKEM Flying 5 Inches Above the Ground at M = 2.0

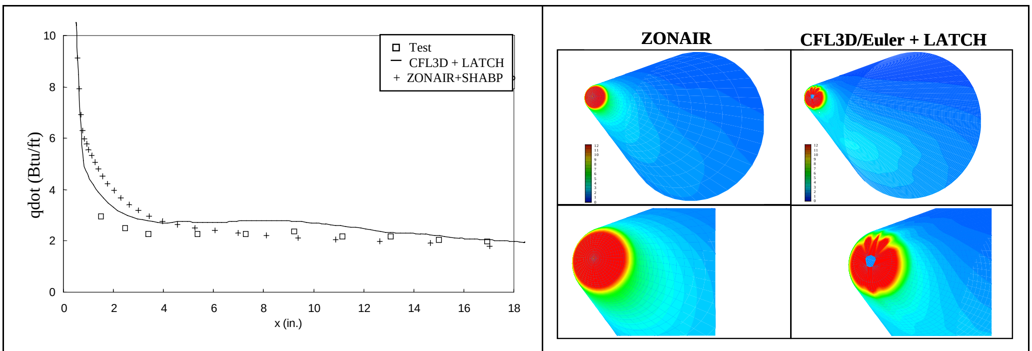
Aeroheating Analysis

- A finite-element-based streamline module called ZSTREAM that adopts the inviscid surface velocities generated by ZONAIR as input to yield high quality streamline solutions.



Streamline Results of (a) CKEM at M = 6.0 and α = 2º, (b) 15º Blunt Cone at M = 10.6 and α = 5º, (c) X-34 at M = 6 and α = 9º

- Once the streamlines are obtained, the aeroheating analysis can be performed along each streamline using a simple one-dimensional boundary layer method.
- The one-dimensional hypersonic boundary layer method is developed based on the similarity solutions of compressible (laminar/turbulent) boundary layer methodology of Eckert/Boeing, RhorMa, and the White-Christoph methods.

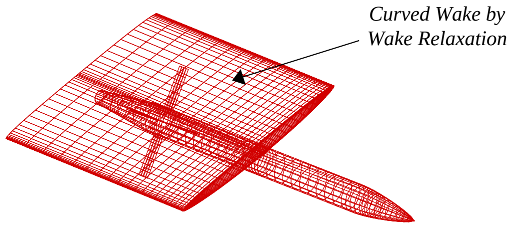


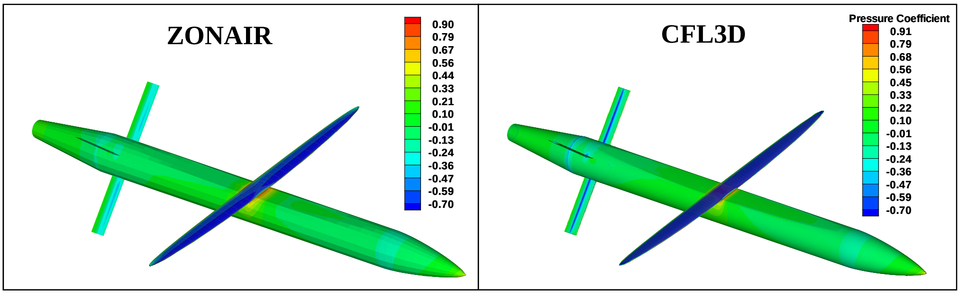
Laminar Heat Transfer Rates (Btu/ft^2 –s) on 15º Blunt Cone at $M_\infty = 10.6$, $\alpha = 5º$,
$p_\infty = 2.66$ lb/ft^2, $T_\infty = 89.971$ºR, $T_W = 540$ ºR

Wake Relaxation

Gun-launched projectile with oblique wing at M = 0.6, α = 4°

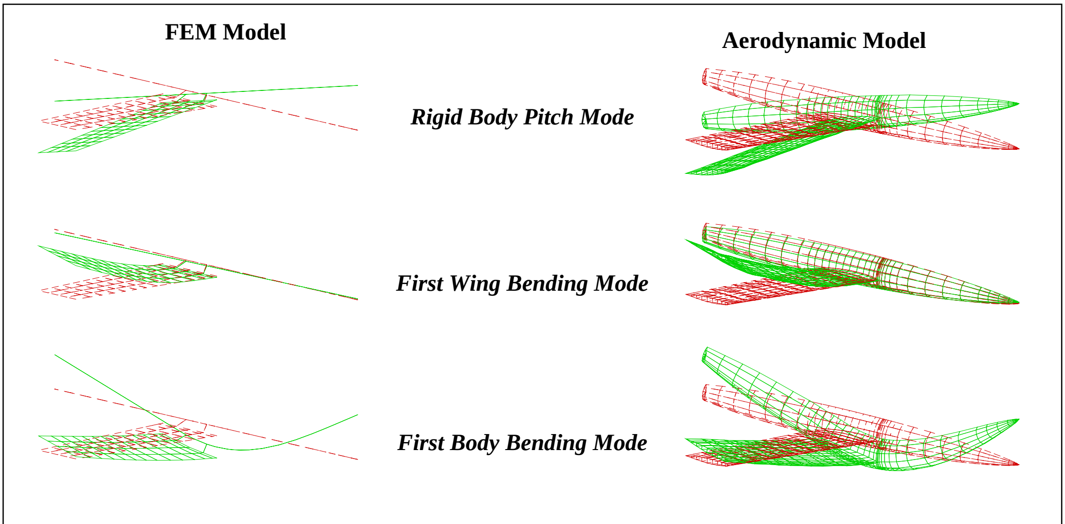
- Flat wake generated from wing cuts into body, which creates singularities in computations.
- Wake relaxation generates curved wake surface that removes the problem.





1.7 SPLINE MODULE

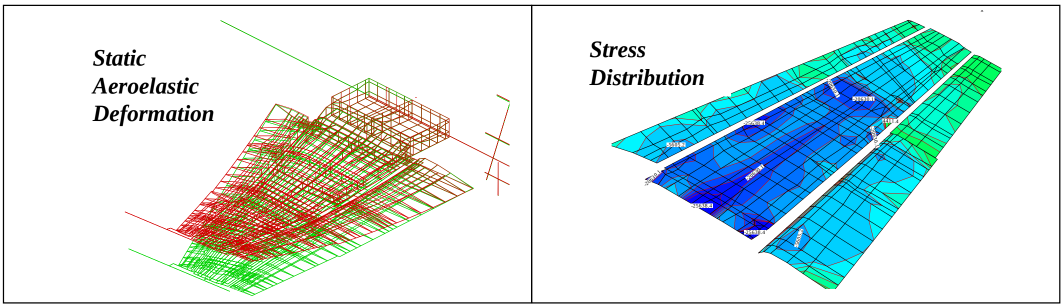
The 3D Spline module establishes the displacement/force transferal between the structural Finite Element Method (FEM) model and the ZONAIR aerodynamic model. It consists of four spline methods that jointly assemble a spline matrix. These four spline methods include: (a) Thin Plate Spline; (b) Infinite Plate Spline; (c) Beam Spline, and (d) Rigid Body Attachment methods. The spline matrix provides the x, y and z displacements and slopes in three dimensions at all aerodynamic grids.



NACA L51F07 Wing-Body Configuration with Three Structural Modes.

1.8 STATIC AEROELASTIC/TRIM MODULE

The Static Aeroelastic/Trim Module provides trim solutions and flexible loads.



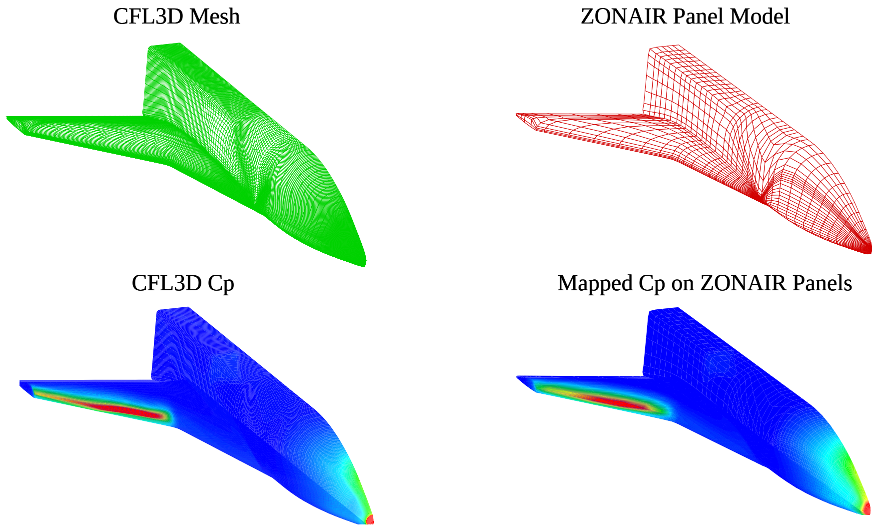
Main Features:

- It employs the modal approach for solving the trim system of the flexible aircraft. The modal approach formulates a reduced-order trim system that can be solved with much less computer time than the so-called *"direct method"*.
- It is capable of dealing with the determined trim system as well as the over-determined trim system (more unknowns than the trim equations). The solutions of the over-determined trim system are obtained by using an optimization technique, which minimizes a user-defined objective function while satisfying a set of constraint functions.
- For a symmetric configuration (symmetric about the x-z plane), it requires only the modeling of one half of the configuration even for the asymmetric flight conditions.
- It generates the flight loads on both sides of the configuration in terms of forces and moments at the structural finite element grid points in terms of NASTRAN FORCE and MOMENT bulk data cards for subsequent detailed stress analysis.

1.9 PRESSURE MAPPING FROM CFD MESH TO ZONAIR PANELS

Main Features:

- It interpolates the surface pressure coefficient from the CFD surface mesh onto the ZONAIR panels and use this pressure to generate the rigid loads for trim analysis.
- ZONAIR can further transfer this rigid load from the ZONAIR panel to the structure finite element grid points using the spline module.
- It also interpolates the surface velocities that are used for the streamline calculation for aeroheating analysis.
- Shown below is the comparison of Cp between the CFD results and the interpolated ZONAIR results on X-34 at M = 10, α=5°.



1.10 AIC CORRECTION MODULE FOR ACCURATE FLEXIBLE LOADS GENERATION

Main Features:

- The AIC correction module computes an AIC weighting matrix to modify the ZONAIR computed AIC matrix for accurate flexible loads generation.
- It adopts the force/moment correction method by Giesing et al. and the downwash correction method by Pitt and Goodman.
- The AIC weighting matrix generated by the force/moment correction method is computed by matching the wind-tunnel measured section loads.
- The AIC weighting matrix generated by the downwash correction method is computed by matching the surface pressures that are either measured by wind-tunnel test or compute by CFD.
- The corrected AIC matrix can be used to provide flexible loads due to structural deformation for trim analysis.

Chapter 2

HOW TO RUN ZONAIR

The ZONAIR software system is available for both the workstation (UNIX operating system) and the personal computer (Windows/DOS) platforms. The execution of ZONAIR (after proper installation of the code [See Installation Notes for instructions]) is described as follows:

UNIX

In the directory where the input file and the structural Finite Element Method (FEM) output file (the free vibration solutions of the FEM model) reside, type the following command:

zonair <inputfilename> <outputfilename>

where <outputfilename> is optional. An example is shown as follows:

```
zonair  myjob.inp  myjob.out
```

All output files will be placed in the same directory where the job was submitted after the program terminates. See Section 2.6 *The ZONAIR Script File* for a detailed description of this process that takes place during code execution.

Windows/DOS

1. Open a MS-DOS command prompt window (under Start / Programs / MS-DOS Prompt).

2. In the directory where the input file and the FEM output file reside, type the following command:

   zonair <inputfilename> <outputfilename>

   where <outputfilename> is optional. An example is shown as follows:

   ```
   zonair  myjob.xxx  myjob.out
   ```

   All output files will be placed in the same directory where the job was submitted after the program terminates. See Section 2.6 *The ZONAIR Script File* for a detailed description of this process that takes place during code execution.

2.1 INPUT AND OUTPUT FILES OF ZONAIR

Figure 2.1 shows the ZONAIR software system file processing that occurs during program execution. Four files are required to run the code, namely; the input file which contains the executive control, case control and Bulk Data Sections that describe the aerodynamic model, flight conditions, etc.; the structural Finite Element Method (FEM) output file containing the structure natural frequencies and mode shapes; DIRNAME.FIX which contains the pathname where the ZONAIR run-time database files are to be located; LICENSE.DAT which contains the user authorization codes required to run the ZONAIR program; and ZONAIR.DBS which contains permanent database information.

A minimum of two output files are generated for each ZONAIR run. These are the output file of the job and the logfile which contains the elapsed and step CPU times for each module call during the execution of ZONAIR. Additional output plot files can be generated through bulk data input requests (see Section 2.4 *ZONAIR Output Files*).

Additional details relating to these files and details on execution of the ZONAIR software system are described in the following sections.

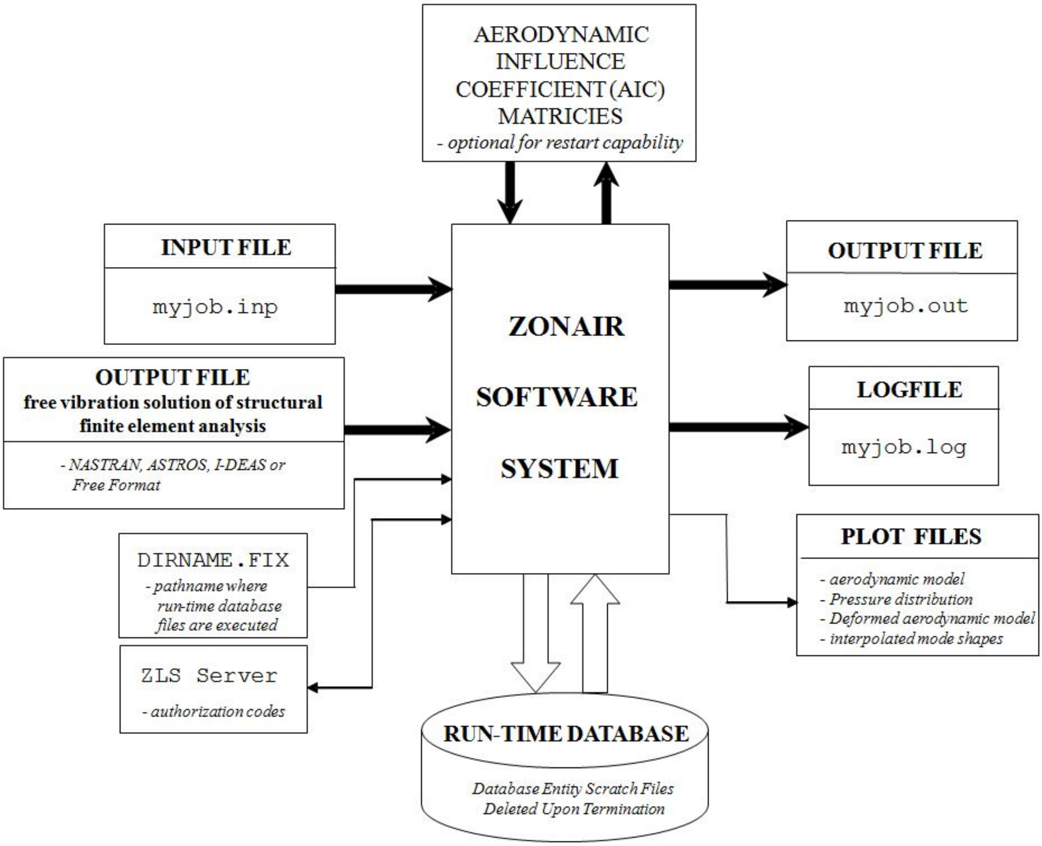


Figure 2.1 The ZONAIR Software System File Processing

2.2 INPUT FILES

The ZONAIR input file is made up of three sections that describe the aeroelastic problem to be analyzed. These are the following:

1. Executive Control Section
2. Case Control Section
3. Bulk Data Section

Figure 2.2 shows the ZONAIR input data structure format.

LEADING COMMENTS (INITIATED WITH A $) ARE ALLOWED

Executive Control Section

```
ASSIGN  FEM = <filename>, FORM = <form>, BOUNDARY = <type>, PRINT = <print>
DIAG <values>
CEND
```

Case Control Section

```
TITLE = <title>
ECHO = <sort/nosort>
SUBCASE = <number>
   SUBTITLE = <subtitle>
   LABEL = <label>
   AERO = <number>
      .
      .
      .
BEGIN BULK
```

Bulk Data Section

```
$       ACSID   XZSYM   FLIP    FMMUNIT FMLUNIT REFC    REFB    REFS    $
AEROZ   0       YES     NO      SLIN    IN      100.0   200.    10500.
+AERO
$       REFX    REFY    REFZ
+AERO   33.333  0.      0.
      .
      .
      .
ENDDATA
```

Figure 2.2 ZONAIR Input Data Structure Format

Executive Control Section

The Executive Control Section must be the first section of any ZONAIR input deck. The `ASSIGN` and `CEND` are required delimiters. The keyword `ASSIGN` triggers the input file processing performed by the software. This section contains information such as the filename of the structural finite element method (FEM) output to be read in, type of analysis to be performed (i.e., symmetric, anti-symmetric boundary condition, etc.), and print options. Finally, diagnostic routines, useful in programming in the ZONAIR environment, are specified in this section *(See Chapter 3 for details of the Executive Control Section).*

Case Control Section

The Case Control Section, which must be the second section of any ZONAIR input deck, is used to define the disciplines to be performed. Each case is defined by a subcase that lists flutter disciplines to be performed for that particular subcase. A title for the entire input deck and subtitles/labels for each subcase are defined in this section. The `BEGIN BULK` statement designates the end of the Case Control Section. *(See Chapter 3 for details of the Executive Control Section).*

Bulk Data Section

The last section of any ZONAIR input deck is the Bulk Data Section. The `BEGIN BULK` and `ENDDATA` are required delimiters. This section provides the complete engineering data required to perform the disciplines specified in the Case Control Section. This includes the geometry of the aerodynamic model, spline instructions for displacement and force transferal between the structural finite element grid points and the aerodynamic boxes, flight conditions, and other parameters such as reference density, lengths, etc. *(See Chapter 4 for details of the Bulk Data Section).*

2.3 RUN-TIME DATABASE

A ZONAIR run-time database is generated for each job that is submitted under the ZONAIR script file. The database contains relational, unstructured and matrix entities (stored in separate scratch files) that are created by ZONAIR during execution of the software. The location of the run-time database is dependent on the pathname specified in the 'DIRNAME.FIX' file that is stored in the ZONAIR home directory. Temporary database folders under this pathname are created for each job and are removed upon normal termination of the ZONAIR script file. The 'DIRNAME.FIX' file is setup during initial installation of the ZONAIR software and can be modified by the user to change the location where the ZONAIR database folders are executed.

Note: The location specified by 'DIRNAME.FIX' should be a very large scratch space with sufficient size to accommodate all jobs submitted under the ZONAIR script file. There is no rule of thumb for how large this space should be since the capability of ZONAIR, in terms of the size of the input model, is only limited by the memory and disk space of the hardware.

2.4 OUTPUT FILES

Output File

A minimum of two output files are generated for a given ZONAIR job. The first output file contains the standard output from ZONAIR program. The name of the output file will either be the name provided to the ZONAIR script file or will be the input filename with an extension of '.out'. For example,

```
zonair  testcase.inp
```

would generate an output filename of `testcase.out`, while

```
zonair  testcase.inp  job1.txt
```

would generate an output filename of `job1.txt`.

The output file contains information such as sorted bulk data input, interpolated modes on aerodynamic boxes, steady pressure results, stability derivatives, etc.

Logfile

The second output file is a logfile that contains the run-times of the ZONAIR engineering module calls. A sample of this output is shown in Figure 2.3. The logfile provides the elapsed time, Central Processing Unit (CPU) time and step CPU time for all module calls made during execution of ZONAIR. The logfile name will always be the input filename with an extension of '`.log`.' For example,

```
zonair  testcase.inp  job1.txt
```

would generate a logfile filename of `testcase.log`.

The logfile information is very useful in instances where the program terminates due to input errors. Although error messages are generated and printed in the output file, the specific module in which the program terminated can be ascertained. It is also useful to see the relative CPU costs of each phase of execution. Typically, the Aerodynamic Influence Coefficient (AIC) matrices generation phase, printed in the logfile as:

```
'GENAIC MODULE:  GENERATES ALL AIC MATRICES'
```

requires the most CPU time.

The output format for times are [hours : minutes : seconds . hundredths of a second] .

```
                          *  *  *  Z O N A I R   L O G F I L E  *  *  *

  ELASPED     TOTAL                                                                    STEP
   TIME        CPU                                                                     CPU
 ---------  -----------                                                             -----------

 000:00:00  000:00:00.0    *** BEGIN ZONAIR ***
 000:00:00  000:00:00.0     INIT MODULE: INITIALIZATION                                000:00:00.0
 000:00:00  000:00:00.0     CNTL MODULE: PROCESS CASE CONTROL                          000:00:00.0
 000:00:07  000:00:07.6     IFP MODULE: INPUT FILE PROCESSOR                           000:00:07.5
 000:00:17  000:00:17.1     GEOMETRY MODULE : ZONAIR MODEL GEOMETRY PROCESSOR          000:00:09.5
 000:00:22  000:00:22.1     CONMOD  MODULE: CONTROL MODES                              000:00:04.9
 000:00:22  000:00:22.6     GENDYN MODULE: STRUCTURAL DYNAMIC MATRICIES                000:00:00.4
 000:16:05  000:16:05.4     GENAIC MODULE: GENERATES ALL AIC MATRICES                  000:15:42.8
 000:16:05  000:16:05.4         SUBCASE NO.        1                                   000:00:00.0
 000:16:26  000:16:26.5     SOLVEM MODULE: SOLVE U,V,W AND CP                          000:00:21.1
 000:16:30  000:16:30.0     FORMOM MODULE: FORCE & MOMENT COEFFICIENTS                 000:00:03.4
 000:16:30  000:16:30.0     FIELDM MODULE: COMPUTES FLOW POINT SOLUTIONS               000:00:00.0
 000:16:30  000:16:30.0     *** END ZONAIR ***                                         000:00:00.0
```

Figure 2.3 ZONAIR Logfile Containing the Execution Summary

Note that both the <u>logfile and output file are overwritten</u> upon resubmission of a ZONAIR job with the same input filename which are located within the same directory where the logfile and output already reside. <u>Therefore, the user is cautioned to rename these files in the event they should be permanently saved</u>.

One exception to the output file being overwritten is if an output filename <u>is specified</u> when submitting a ZONAIR job that already exists. For example, if the file `testcase.out` exists in the current directory and a ZONAIR job is requested as follows:

```
zonair  testcase.inp  testcase.out
```

then the script file will prompt the user if the output file should be overwritten.

<u>Plot Files</u>

ZONAIR provides a number of output plot files that can be viewed by several plotting programs. Filenames for all output plot files are specified via the bulk data entries **PLTAERO**, **PLTCP**, **PLTMODE**, **PLTSURF**, and **PLTTRIM**. Table 2.1 lists the output plot file capability of ZONAIR.

Table 2.1 ZONAIR Output Plot File Capability

Category	Associated Bulk Data Card	Description	Software Compatibility
Aerodynamic Model	**PLTAERO**	Generates an ASCII text file for plotting the aerodynamic model.	- PATRAN - TECPLOT - I-DEAS - FEMAP - ANSYS - NASTRAN

Aerodynamic Pressure Coefficients	**PLTCP**	Generates an ASCII text file for plotting the unsteady pressure coefficients.	- PATRAN - TECPLOT - I-DEAS - FEMAP - ANSYS - NASTRAN - PEGASUS
Interpolated Structural Modes	**PLTMODE**	Generates an ASCII text file for plotting the interpolated structural mode on the aerodynamic model.	- PATRAN - TECPLOT - I-DEAS - FEMAP - ANSYS - NASTRAN
Control Surface Deflection	**PLTSURF**	ASCII text file generation for plotting the aerodynamic control surface.	- PATRAN - TECPLOT - I-DEAS - FEMAP - ANSYS - NASTRAN
Static Aeroelastic / Trim Analysis Results	**PLTTRIM**	Generates an ASCII text file for the post-processing of the static aeroelastic/trim analysis.	- PATRAN - TECPLOT - I-DEAS - FEMAP - ANSYS - NASTRAN - PEGASUS

2.5 ZONAIR RESTART CAPABILITY

The ZONAIR software system has an optional restart capability that reads the saved Aerodynamic Influence Coefficient (AIC) matrices generated during previous runs. The AIC file is generated by specifying the SAVE option in the **MACH** bulk data card (see **MACH** bulk data card in Section 4). The AIC file is saved in the same directory as the input and output decks, and accordingly, must be located in the same directory as the input deck during a restart run.

Since the generation of the AIC matrices almost always requires the longest time to complete any ZONAIR job, the restart feature provides tremendous savings in CPU time associated with the re-running of jobs. This feature is very useful when the changes are made to the flight conditions (α, β, p, q, r), the structural model, spline input or the static aeroelastic/trim solution (e.g., if solution is desired for a different density/altitude). However, in cases where changes to the aerodynamic model or input parameters in the **MACH** bulk data card are required, the AIC matrices must be recomputed.

2.6 ZONAIR SCRIPT FILE

The ZONAIR script file is used to submit jobs to be run by the ZONAIR software system and is located in the ZONAIR home directory. Multiple jobs can be submitted at one time on both UNIX and PC systems. This script file can be executed from any directory on the host system with the appropriate environment variables set. The environment variables are normally set-up automatically during installation of the ZONAIR software system, but can be set-up manually (see Installation Notes for details on how to adjust environment variables).

Two versions of the ZONAIR script file are available. The first, developed for the UNIX environment, is written in the C shell scripting language. The second, developed for the PC environment, is written in FORTRAN and is provided in executable format.

The following two sections provide instructions on submitting multiple ZONAIR jobs and step-by-step descriptions on the steps taken by UNIX and PC versions of the ZONAIR script file.

<u>UNIX</u>

Multiple jobs can be submitted in the UNIX environment (submitting multiple jobs is optional, not a requirement). Simply initiate the ZONAIR script file multiple times in succession. For example, to submit two jobs called `test1.inp` and `test2.inp` , type the following at the command prompt:

`zonair  test1.inp` and press the return key

followed by

`zonair  test2.inp` and press the return key

Two jobs will be submitted each with a unique process id (type `ps –a` to see a listing of all running jobs on the system).

Multiple jobs can be submitted from either the same directory or different directories. Associated output files will be placed in the directories from which the input jobs were submitted. Any AIC files to be read in for a restart run process must also be located in the directory from which the input job is submitted. At the end of each batch job process, the script file will notify the user of job termination by a *beep* sound.

As a final note, the input/output decks are in ASCII text format and can be viewed and/or modified with any editor on the host system (such as the ‘vi’ editor).

<u>- UNIX Script File Process</u>

1. Acquire the input filename from standard input.
2. Check if input file exists locally.
3. Acquire the output filename, if specified in the command line.
4. Establish an output filename (if not found in step #3) and a logfile filename.

5. Check the run-time database directory path specified in file 'DIRNAME.FIX' located in the ZONAIR home directory.
6. Establish a run-time database folder (i.e., directory) using the current process id as an extension. For example: ZONAIR0001.
7. Copy the complete pathname (pathname specified in DIRNAME.FIX along with the current run-time database folder name) to file 'DIRNAME.TMP'. This temporary file is read by the ZONAIR software system to know where the database files of the current job are to be executed.
8. Execute the ZONAIR software system using the input/output filenames.
9. Copy the logfile from the run-time database folder to the local directory.
10. Delete the database folder and scratch files.
11. Notify user of job termination by a *beep* sound.

Windows/DOS

Multiple jobs can be submitted in the PC environment (submitting multiple jobs is optional, not a requirement). The exception to this case would be if the host system is operating under MS-DOS and does not utilize the Windows operating system (Win 95/98/NT). In this situation, only one job can be submitted at a time which will tie up the machine until the job terminates (unless the user can utilize multiple command interpreters with the option to toggle between them). For a system with Windows installed, multiple jobs can be submitted by opening up multiple MS-DOS command prompt windows and submitting one job per Window. For example, to submit two jobs in Windows 95/98/NT called `test1.inp` and `test2.inp`, perform the following:

1. From the [Start] menu select [Programs/MS-DOS Prompt]. Note: The MS-DOS window can be maximized or minimized. Also Note: Terminating an MS-DOS window during execution of a job will terminate that ZONAIR job!

2. Change the directory to where the input deck resides.

3. Type in the following at the command prompt.

   `zonair  test1.inp` *and press the return key*

4. Open a second MS-DOS window as described in step #1 above.

5. Repeat step #2 from above.

6. Type in the following at the command prompt.

   `zonair  test2.inp` *and press the return key*

Two jobs will be submitted each with a unique folder designation (e.g., ZONAIR001) and will be located in the run-time database directory specified by the pathname in file 'DIRNAME.FIX'.

Multiple jobs can be submitted from either the same directory or different directories. Associated output files will be placed in the directories from which the input jobs were submitted. Any AIC files to be read in for a restart run process must also be located in the directory from which the input job is submitted. At the end of each batch job process, the script file will notify the user of job termination by a *beep* sound.

As a final note, the input/output decks are in ASCII text format and can be viewed and/or modified with any editor on the host system (such as the DOS editor – initiated in a MS-DOS Window by ‘edit’).

- PC Script File Process

This is identical to the *UNIX Script File Process* described earlier, except step #6, as follows:

6. Establish a run-time database folder (i.e., directory) using the first available (i.e., lowest number) folder to obtain a new folder extension. For example, if two jobs were already submitted that occupy folders ZONAIR001 and ZONAIR004 and a third job is to be submitted, then a folder name of ZONAIR002 would be used. Note that up to 999 jobs can be submitted at one time on the PC system.

Command Line Options

To view the available script file command line options, please use the `-help` switch, e.g.
`zonair -help`

Run-time Database Directory

The ZONAIR software system run-time database directory location is specified in the file ‘DIRNAME.FIX’ which is set-up upon installation of the software. Folders (i.e., directories) are set-up under this location for each job submitted via the ZONAIR script file (as described earlier in this section).

Upon normal termination of a job, the run-time database folder is deleted, except under the following conditions:

- if the computer is shut down or if power failure occurs during execution of a job.
- if a ZONAIR script file job is terminated by the user (e.g., by closing the MS-DOS prompt window) or is terminated by some other means (e.g., by the Windows operating system).

In such situations, the run-time database folders are left in the run-time database directory and can occupy tremendous amounts of disk space. Therefore the user should manually remove any run-time database folders of jobs that are no longer running.

2.7 THE ZONA LICENSE SERVER (ZLS)

The ZONA License Server (ZLS) has been developed by ZONA Technology, Inc. (ZONA) to act as the security license server for ZONA's software products. The ZLS operates with the Sentinel Protection Installer™ SuperPro hardware key that is developed by SafeNet (http://www.safenet-inc.com). The ZLS is described in detail in the ZLS User’s Manual that is installed with the ZLS software.

ZONAIR 4.1 is a "network ready" version of ZONAIR that requires the ZLS to be installed. During each ZONAIR execution, a token is "checked out" from the server and "checked back in" to the server when the job terminates.

There are two types of ZONAIR installations that can be made.

1. Node-Locked:
   The ZLS is installed on the same machine where ZONAIR is installed. If ZONAIR runs on a stand-alone machine, both ZONAIR and ZLS must be installed as node-locked.

2. Floating License:
   ZONAIR and the ZLS are installed on separate machines connected on a network.

Note that, if desired, tokens managed by the node-locked ZLS can also be checked out by ZONAIR jobs executed from any machines that can access the node-locked machine running the ZLS.

2.7.1 THE JAVA ENVIRONMENT

Java JRE 1.3.1 (or later versions) is required to run both the ZLS and ZONAIR.

For Windows, UNIX or Linux platforms, download and installation instructions can be found from the Internet. ZONA can provide this download/installation information if requested.

2.7.2 SERVER INSTALLATION AND OPERATIONS

For details regarding the ZLS installation and operation, please refer to Section 3 of the ZLS User's Manual.

2.7.3 ENVIRONMENT VARIABLES

To run ZONAIR, the following environment variables are required.

1. [PATH] variable needs to include ZONAIR home directory, which is specified at installation.
2. [ZONAIREXE] is set to the ZONAIR home directory location. It should end with \ for Windows and end with / for UNIX and Linux.
3. [ZLS_ZONAIR] is set to the IP of the machine hosting ZLS. If ZONAIR is run on the same machine that hosts the ZLS (i.e., a node-locked setup), the value of ZLS_ZONAIR should be set to `localhost`.
4. [ZLS_SERVER] is set to the ZLS home directory for node-locked installations.

2.7.4 THE ZONA LICENSE MONITOR

The ZONA License Monitor is a Windows program that provides a convenient interface for ZLS operations, including the ability to Start or Stop the ZLS, to load a new license file, and to view the status of the current token usage (i.e., what's checked-out). The ZONA License Monitor is only available on the machine hosting the ZLS. In the case of a node-locked installation of ZONAIR, both the ZLS and the ZONA License Monitor will exist on the same machine. For details on usage of the ZONA License Monitor, please refer to Section 6 of ZLS User's Manual.

2.7.5 LOCKED TOKENS AND THE CLEANUP UTILITY

ZONAIR is designed to operate in the following way. When a ZONAIR job is submitted, the ZLS is contacted for checkout of a token. With a successful checkout (i.e., tokens available for the requested modules in the ZONAIR job), a token file is saved under [ZLS\log] directory, the ZLS adjusts the token count, and then the ZONAIR job proceeds. After the ZONAIR job is finished, the ZLS is contacted for a check-in. With a successful check-in, the token file is deleted, and the ZLS adjusts the token count accordingly.

In the event of an abnormal ZONAIR termination (e.g., a power failure during a job) token(s) can become locked. To release locked token(s), a cleanup utility is provided. The utility program `zonair_cleanup.exe` (or `zonair_cleanup` for Unix or Linux) can be found in the ZONAIR home directory under the [ZLS\log] directory. To run the cleanup utility, open a command prompt window (UNIX and Linux) or an MS-DOS prompt window (Windows); change the directory to *ZONAIR home directory*\ZLS\log and type **`zonair_cleanup`**. When executing `zonair_cleanup`, if a locked-token is found, you will be prompted whether you wish to release the token back to the ZLS.

Token file names are in the format of log-nnn-DD-MMM-YY-hh-mm-ss (e.g., log-001-14-MAY-09-17-22-14). The time stamp in the log file name shows submission time of ZONAIR job and nnn indicates its tmp directory. Therefore, token file names can be used to judge if corresponding tokens should be freed while running `zonair_cleanup`.

Instead of using cleanup utility to release locked token(s), re-starting the ZLS will also free up locked token(s). However, doing this will also release the token(s) that might be checked out by other job(s), and **all on-going job(s) will terminate due to ZLS restart**. Therefore, it is strongly recommended to check if there is any job running before re-starting the ZLS by either (1) Clicking on the 'List Current Jobs' button within the ZONA License Monitor Windows program (see Section 6.1 of the ZLS User's Manual), or (2) Executing a '`java zls_serverwhatsrunning`' from a prompt in an MS-DOS or command window (see Section 5.4 of the ZLS User's Manual). Both (1) and (2) will show information related to any on-going job executions.

If ZLS is re-started for any reason, including a reboot of the computer, any remaining token files found in the [ZLS\log] folder under the ZONAIR home directory can be deleted before any new ZONAIR job(s) are submitted. These old token files are no longer useful since the ZLS record is cleared upon the ZLS re-start.

2.7.6 HEARTBEAT

During execution of ZONAIR, heartbeat signals are continuously sent back and forth between ZONAIR and the ZLS. Failure in receiving a heartbeat signal by a ZONAIR job will result in termination of that ZONAIR job. To avoid such a termination, the ZLS needs to be up and running all the times during the execution of ZONAIR job(s) and the network connection between the machines running ZONAIR and hosting the ZLS must be operational.

2.7.7 ZLS ERROR CODES

The following is a list of the ZLS status and error codes (last one or last three digits) that are reported in the ZONAIR output file or are displayed on the screen in the event of an error during submission and execution of a ZONAIR job. If the encountered error cannot be resolved, please contact ZONA's technical support staff for assistance. Section 7.1 of ZONA License Server User's Manual documents the error codes in more detail.

ZLS STATUS/ERROR CODES RELATED TO ZONAIR:

0 - Success status: the operation succeeded with no warnings.

Related to direct interaction with zls_server:
101 - Exception occurred at opening socket. Don't know about host: provided_zlsIP.
102 - Exception occurred at opening socket. Couldn't get I/O connecting to: provided_zlsIP.
103 - Exception occurred at fillarray.
104 - Exception occurred at readLine. Be aware zls_server might be forced down.

Related to license file:
201 - License has expired.
202 - License product name check failed at reading license.

Related to software product operation:
601 - Needed module was not found in license.
602 - Needed module was not available.
603 - CheckoutID was not found in the record.
604 - Module inconsistency was found in the license.
605 - Token count inconsistency was found in the license.

Chapter 3

EXECUTIVE CONTROL AND CASE CONTROL SECTIONS

The Executive Control Section must be located at the beginning of the input file. Its major functions are:

- to define the filename that contains the free vibration output from the structural finite element methods for static aeroelastic analysis
- to allow direct matrix input
- to turn on diagnostic routines

The Case Control Section must be located after the Executive Control Section and before the Bulk Data Section. Its major functions are:

- to input title cards that describe the ZONAIR analysis
- to select the disciplines (aerodynamic analysis, aeroheating analysis, trim analysis, …etc) for the analysis

A typical example of the Executive Control and Case Control Sections is shown as follows:

```
$ Begin Executive Control Section
ASSIGN FEM = demo1.f06, FORM = MSC, BOUND = SYM, PRINT = 1
ASSIGN FEM = demo2.f06, FORM = MSC, BOUND = ANTI
ASSIGN MATRIX = demo1.mgh, MNAME = AMGH
ASSIGN MATRIX = demo1.kgh, MNAME = AKGH
SOL 1
DIAG 1, 3
CEND
$ Begin Case Control Section
TITLE = DEMO WING-BODY CASE
ECHO = SORT
SUBCASE = 1
        SUBTITLE = Aerodynamic Analysis
        LABEL = at Mach 0.8
        AEROGEN = 10
SUBCASE = 2
        SUBTITLE = Aeroheating Analysis
        LABEL = at Mach 0.8
        THERMAL = 20
SUBCASE = 3
        SUBTITLE = Trim Analysis
        LABEL = at Mach 1.2
        TRIM = 30
BEGIN BULK
$ Begin Bulk Data Section
```

3.1 EXECUTIVE CONTROL SECTION

The Executive Control Section allows the following Executive Control Commands:

Command	Description	Remark
ASSIGN FEM =	Structural modal data importer.	Optional
ASSIGN MATRIX =	Direct matrix input by INPUTT4 format.	Optional
CEND	End of Executive Control Section.	Required
CPU	Defines the number of processors for parallel computation.	Optional
DIAG	Diagnostic output options.	Optional
DOUBLE	Convert the entire computation of the program from single precision to double precision on 32-bit computers.	Optional
MEMORY	Maximum memory in terms of megabytes that is allocable by ZONAIR from the heap space.	Optional
SOLUTION	Alter the solution sequence.	Optional
$	Comment statement.	Optional

All Executive Control Commands can be written either in lower case or upper case.

Each command must start from the first column and it must lie within 80 columns. For example:

```
ASSIGN FEM = demo1.f06, FORM = UAI, PRINT = -2
```

80 columns

As an added option, one and only one continuation line can be used when entering the '**ASSIGN FEM =**' and **'ASSIGN MATRIX ='** Executive Control Commands. The continuation line is active if the first line ends in a comma (,) as shown in the following example:

```
ASSIGN FEM = demo1.f06, FORM=MSC, BOUNDARY=SYM,
    PRINT=1, SUPORT =123
```

continuation line active if ending in (,)

CEND must be the last command in the Executive Control Section. Other commands can be located arbitrarily in the Executive Control Section.

'ASSIGN FEM =' Structural Modal Data Importer

Description: Assigns an external file that contains the free vibration solutions of the finite element model for static aeroelastic analysis by specifying the **SOL** Executive Control Command as **'SOL 1'**. It should be noted that the data entities created by the 'ASSIGN FEM=' executive control command can be saved using the **FEMSAVE** bulk data card.

Format:

ASSIGN FEM = ' a ', **FORM** = ' b ', **BOUNDARY** = ' c ', **PRINT** = n, **SUPORT** = m/L

Example 1:

```
ASSIGN FEM=demo1.f06, FORM=MSC, BOUNDARY=SYM, PRINT=1, SUPORT=123
```

Example 2:

```
ASSIGN FEM=/export/home/ZONAIR/demo2.f06, BOUNDARY=ANTI,
SUPORT=-246/3000
```

Describer	Meaning
`FEM = ' a '`	FEM indicates that ' a ' is the filename of the external file that contains the free vibration solution of the structural finite element model. ' a ' is a character string specifying the name of the external file. (Required) - UNIX systems are case sensitive. Therefore, lower/upper case characters must identically match the name of the file. - DOS and WINDOWS systems are not case sensitive (see Remarks 1 and 2).
`FORM = ' b '`	FORM indicates the name of the structural finite element code that generates the output file ' a ' by a free vibration analysis where ' b ' is a character string specifying the name of the structural finite element code. (Optional) Seven options are available for ' b ' : Data of the free vibration solution is: ' MSC ' generated by MSC.NASTRAN (see Remark 3) ' NE ' generated by NE/NASTRAN (see Remark 3) ' ASTROS ' generated by ASTROS (see Remark 4) ' IDEAS ' generated by I-DEAS (see Remark 5) ' ELFINI ' generated by ELFINI (see Remark 6) 'GENESIS' generated by GENESIS 'ABAQUS' generated by ABAQUS 'ALTAIR' generated by ALTAIR's RADIOSS (see Remark 7) ' FREE ' stored according to the input instruction described in Remark 8 'ACQUIRE' Retrieves the free vibration solution from the file

	'a' that must match the file name specified in the **FEMSAVE** bulk data card. If no FORM is specified in the "**ASSIGN FEM =**" command, 'MSC' is used as default. <u>Note</u>: For NASTRAN-type of finite element code, the scalar points (**SPOINT**) will be internally expanded from one degree of freedom to six..
`BOUNDARY = 'c'`	BOUNDARY indicates the boundary condition of the structural finite element model. (Optional) ' c ' is a character string that has 3 options: ' SYM ' for symmetric boundary condition ' ANTI ' for anti-symmetric boundary condition ' ASYM ' for asymmetric boundary condition If no BOUNDARY is specified, ' SYM ' is used as default (see Remark 9).
`SUPORT = m/L`	Optional input to specify the degrees of freedom of the rigid body modes of the structural finite element model. "`m`" is an integer representing the component numbers of the rigid body degrees of freedom. It contains any unique combination of the integer 1 through 6 with no embedded blanks, where 1, 2 and 3 represent the translational rigid body modes along the x, y and z axes of the finite element basic coordinates, respectively. 4, 5 and 6 are the rotation rigid body modes about the x, y and z axes, respectively. "`m`" can also be a negative integer that activates the program to perform the following tasks: - Replaces the imported rigid body modes by the program-computed rigid body modes. - Forces the natural frequency and the generalized stiffness of the rigid body modes to be zero. The "negative `m`" option is useful for the cases where the structural finite element analysis fails to provide well-behaved rigid body modes or zero rigid body natural frequency. "/L" is optional where L is an integer representing the identification number of a grid point in the structural finite element model where the rigid body modes are referred to. Note that there is a slash ("/") that separates m and L. If no "/L" is specified, the program will search for a grid point in the structural finite element model that can be best referred to by the rigid body modes. For NASTRAN type of finite element codes, "`m`" should be the R-set degrees of freedom (please see MSC.NASTRAN User's Manual for the definition of the R-set degrees of freedom) and L is the grid

	identification number that are specified in the NASTRAN **SUPORT** bulk data card. However, if the displacement of the grid point specified in the NASTRAN SUPORT bulk data card is defined in a local coordinate system, the user must transform the component numbers in the NASTRAN SUPORT bulk data card from the local coordinate system to the basic coordinate system. *Note that the spelling of SUPORT contains only one P.* (Optional, default = 0) (See Remark 10)
`PRINT = n`	Print options to the standard output file; where n is an integer. (Optional) n = 0 no printout of the imported structural free vibration solution | n | ≥ 1 print out the structural grid point locations in the aerodynamic coordinate system n ≥ 2 print out the modal data (mode shapes) at the structural grid points in the aerodynamic coordinate system n ≤ -2 print out the interpolated modal data at the control points of the aerodynamic boxes in the aerodynamic coordinate system n = 3 print all of the above If no PRINT is specified, n = 0 is used as a default.

Remarks:

Remark 1 of **'ASSIGN FEM=':**

At least one **'ASSIGN FEM='** Executive Control Command must exist in the Executive Control Section. If the user wishes to perform the aeroelastic analysis for both symmetric and anti-symmetric boundary conditions of the structural finite element model, two **'ASSIGN FEM='** Executive Control Commands can be specified, one with BOUNDARY = SYM and the other with BOUNDARY = ANTI. For example:

```
ASSIGN FEM = demo1.f06, FORM = MSC, BOUNDARY = SYM

ASSIGN FEM = demo2.f06, FORM = MSC, BOUNDARY = ANTI
```

However, no more than two **'ASSIGN FEM='** Executive Control Commands can be specified. Furthermore, if both symmetric and anti-symmetric boundary conditions are specified, the number of structural grid points and their locations must be identical between these two finite element models.

Remark 2 of **'ASSIGN FEM=':**

ZONAIR reads the file 'a' to obtain the free vibration solutions computed by the structural finite element code 'b'. Specifically, ZONAIR searches for the following data in the file 'a':

- the structural grid point locations of the finite element model. These grid point locations and their identification numbers are used for spline.
- the coordinate transformations that relate the local or global coordinates to the basic coordinates. These coordinate transformations are used to transform the structural grid point locations from the local coordinates to the basic coordinates as well as the modal data from the global coordinates to the basic coordinates (for the definition of local, global and basic coordinates, please see a NASTRAN User's Manual).
- the natural frequencies, the generalized masses, the generalized stiffness and the mode shapes.

<u>Remark 3</u> of **'ASSIGN FEM=':**

For MSC.NASTRAN, UAI/NASTRAN, CSA/NASTRAN or NE/NASTRAN, the following two commands must exist in the case control deck of the NASTRAN input (as well as output) file that generates the NASTRAN solution output file 'a'.

```
ECHO  =  SORT
DISP  =  ALL
```

Please see a NASTRAN User's Manual for a description of these two commands.

The user must ensure that the structural finite element analysis is a free vibration analysis (or normal modes analysis). For MSC.NASTRAN, the solution sequence:

```
SOL      103
```

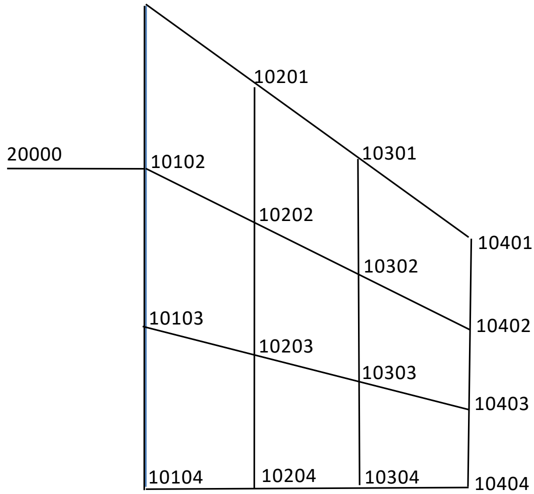
must be selected. In addition, the solution set eigenvector output, SVECTOR = ALL <u>must not be</u> selected.

<u>Remark 4</u> of '**ASSIGN FEM=**':

A single continuation line can be used in the **'ASSIGN FEM='** Executive Control Command if the first line ends in a comma (,)

MSC.NASTRAN Example

The following figure shows a plate type of finite element model:



The MSC.NASTRAN output file for normal modes analysis of the above model is listed as follows:

```
0        N A S T R A N    E X E C U T I V E    C O N T R O L    E C H O
0

     SOL 103
     CEND
0
0                                         C A S E    C O N T R O L    D E C K    E C H O
                 CARD
                 COUNT
                  1        ECHO=SORTED
                  2        DISP = ALL
                  3        METHOD = 20
                  4        SPC = 10
                  5        BEGIN BULK
0                              INPUT BULK DATA CARD COUNT =      43
0
0                                                  S O R T E D    B U L K    D A T A    E C H O
                 CARD
                 COUNT         .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
                    1-         ASET1   3       10101   THRU    10104
                    2-         ASET1   3       10201   THRU    10204
                    3-         ASET1   3       10301   THRU    10304
                    4-         ASET1   3       10401   THRU    10404
                    5-         CBAR    1010    1010    10102   20000   10101
                    6-         CQUAD4  1001    1000    10101   10102   10202   10201
                    7-         CQUAD4  1002    1000    10102   10103   10203   10202
                    8-         CQUAD4  1003    1000    10103   10104   10204   10203
                    9-         CQUAD4  1004    1000    10201   10202   10302   10301
                   10-         CQUAD4  1005    1000    10202   10203   10303   10302
                   11-         CQUAD4  1006    1000    10203   10204   10304   10303
                   12-         CQUAD4  1007    1000    10301   10302   10402   10401
                   13-         CQUAD4  1008    1000    10302   10303   10403   10402
                   14-         CQUAD4  1009    1000    10303   10304   10404   10403
                   15-         EIGRL   20                                      5
                   16-         GRID    10101           0.0     30.000  0.0
                   17-         GRID    10102           33.333  30.000  0.0
                   18-         GRID    10103           66.667  30.000  0.0
                   19-         GRID    10104           100.000 30.000  0.0
                   20-         GRID    10201           16.667  53.333  0.0
                   21-         GRID    10202           44.444  53.333  0.0
                   22-         GRID    10203           72.222  53.333  0.0
                   23-         GRID    10204           100.000 53.333  0.0
                   24-         GRID    10301           33.333  76.667  0.0
                   25-         GRID    10302           55.555  76.667  0.0
                   26-         GRID    10303           77.778  76.667  0.0
                   27-         GRID    10304           100.000 76.667  0.0
                   28-         GRID    10401           50.000  100.000 0.0
                   29-         GRID    10402           66.667  100.000 0.0
                   30-         GRID    10403           83.333  100.000 0.0
                   31-         GRID    10404           100.000 100.000 0.0
                   32-         GRID    20000           33.333  0.0     0.0
                   33-         MAT1    1100    1.E+07          .3      .1
                   34-         PARAM   COUPMASS1
                   35-         PARAM   WTMASS  .00259
```

```
                  36-        PBAR    1010    1100    100.    .1E+04  .1E+04  .05E+04
                  37-        PSHELL  1000    1100    1.5     1100
                  38-        SPC1    10      126     10101   THRU    10104
                  39-        SPC1    10      126     10201   THRU    10204
                  40-        SPC1    10      126     10301   THRU    10304
                  41-        SPC1    10      126     10401   THRU    10404
                  42-        SPC1    10      123456  20000
                             ENDDATA
0                       TOTAL COUNT=       43

                          E I G E N V A L U E   A N A L Y S I S   S U M M A R Y   (READ MODULE)


                                     BLOCK SIZE USED ......................7

                                     NUMBER OF DECOMPOSITIONS .............1

                                     NUMBER OF ROOTS FOUND ................5

                                     NUMBER OF SOLVES REQUIRED ............5


                                                 R E A L   E I G E N V A L U E S
   MODE    EXTRACTION      EIGENVALUE            RADIANS             CYCLES            GENERALIZED         GENERALIZED
    NO.       ORDER                                                                       MASS              STIFFNESS
        1         1        8.399865E+02        2.898252E+01        4.612711E+00        1.000000E+00        8.399865E+02
        2         2        5.401589E+03        7.349551E+01        1.169717E+01        1.000000E+00        5.401589E+03
        3         3        4.316370E+04        2.077587E+02        3.306583E+01        1.000000E+00        4.316370E+04
        4         4        7.341672E+04        2.709552E+02        4.312386E+01        1.000000E+00        7.341672E+04
        5         5        2.008154E+05        4.481243E+02        7.132120E+01        1.000000E+00        2.008154E+05

      EIGENVALUE =  8.399865E+02
      CYCLES =  4.612711E+00        R E A L   E I G E N V E C T O R   N O .          1

      POINT ID.   TYPE          T1             T2             T3             R1             R2             R3
         10101      G      0.0            0.0            2.438916E-01  -1.046505E-03   1.388628E-02   0.0
         10102      G      0.0            0.0           -2.682208E-03  -1.641355E-04   6.512418E-04   0.0
         10103      G      0.0            0.0           -2.536763E-01  -1.233849E-02   1.385677E-02   0.0
         10104      G      0.0            0.0           -7.429644E-01  -1.128285E-02   1.528565E-02   0.0
         10201      G      0.0            0.0            4.281797E-02  -2.549300E-03   4.682182E-03   0.0
         10202      G      0.0            0.0           -2.088563E-01  -1.018326E-02   1.336013E-02   0.0
         10203      G      0.0            0.0           -6.013343E-01  -1.044415E-02   1.434578E-02   0.0
         10204      G      0.0            0.0           -1.016269E+00  -1.194192E-02   1.532579E-02   0.0
         10301      G      0.0            0.0           -2.736918E-01  -9.773146E-03   1.539033E-02   0.0
         10302      G      0.0            0.0           -6.082150E-01  -1.032532E-02   1.458461E-02   0.0
         10303      G      0.0            0.0           -9.465001E-01  -1.173877E-02   1.546269E-02   0.0
         10304      G      0.0            0.0           -1.292082E+00  -1.146654E-02   1.546714E-02   0.0
         10401      G      0.0            0.0           -7.746809E-01  -1.083210E-02   1.543930E-02   0.0
         10402      G      0.0            0.0           -1.037815E+00  -1.164881E-02   1.600222E-02   0.0
         10403      G      0.0            0.0           -1.304427E+00  -1.135552E-02   1.564861E-02   0.0
         10404      G      0.0            0.0           -1.566373E+00  -1.190655E-02   1.563803E-02   0.0
         20000      G      0.0            0.0            0.0            0.0            0.0            0.0

      EIGENVALUE =  5.401589E+03
      CYCLES =  1.169717E+01        R E A L   E I G E N V E C T O R   N O .          2

      POINT ID.   TYPE          T1             T2             T3             R1             R2             R3
         10101          G      0.0            0.0           -2.248838E-01  -2.775307E-02  -1.129584E-02   0.0
         10102          G      0.0            0.0           -5.626384E-03  -3.665544E-04  -1.306792E-03   0.0
         10103          G      0.0            0.0            7.584442E-01  -2.015278E-02  -4.288727E-02   0.0
         10104          G      0.0            0.0            2.027624E+00  -3.048569E-02  -3.250301E-02   0.0
         10201          G      0.0            0.0           -6.131099E-01  -1.869456E-02  -7.974025E-03   0.0
         10202          G      0.0            0.0           -2.231425E-01  -2.759980E-02  -1.968281E-02   0.0
         10203          G      0.0            0.0            4.212290E-01  -2.518181E-02  -2.596193E-02   0.0
         10204          G      0.0            0.0            1.302277E+00  -3.147953E-02  -3.677993E-02   0.0
         10301          G      0.0            0.0           -1.083220E+00  -3.588441E-02  -1.368388E-02   0.0
         10302          G      0.0            0.0           -6.909589E-01  -3.148519E-02  -2.168402E-02   0.0
         10303          G      0.0            0.0           -1.315537E-01  -3.430069E-02  -2.810665E-02   0.0
         10304          G      0.0            0.0            5.153657E-01  -3.505625E-02  -2.956726E-02   0.0
         10401          G      0.0            0.0           -1.624408E+00  -3.543852E-02  -2.199665E-02   0.0
         10402          G      0.0            0.0           -1.240496E+00  -3.705165E-02  -2.421410E-02   0.0
         10403          G      0.0            0.0           -8.081899E-01  -3.638719E-02  -2.723050E-02   0.0
         10404          G      0.0            0.0           -3.356609E-01  -3.727286E-02  -2.898597E-02   0.0
         20000          G      0.0            0.0            0.0            0.0            0.0            0.0

      EIGENVALUE =  4.316370E+04
      CYCLES =  3.306583E+01        R E A L   E I G E N V E C T O R   N O .          3

      POINT ID.   TYPE          T1             T2             T3             R1             R2             R3
         10101      G      0.0            0.0            8.585293E-01   4.772991E-02   4.532157E-02   0.0
         10102      G      0.0            0.0            4.092312E-02   2.285311E-03  -1.063501E-03   0.0
         10103      G      0.0            0.0            6.611228E-01  -3.340588E-04  -2.785009E-02   0.0
         10104      G      0.0            0.0            1.358505E+00  -4.635419E-02  -1.239622E-02   0.0
         10201      G      0.0            0.0            1.117747E+00   2.147846E-02   3.023199E-02   0.0
         10202      G      0.0            0.0            5.920185E-01   3.574188E-02   3.084039E-03   0.0
         10203      G      0.0            0.0            5.350678E-01  -2.010099E-02   7.068093E-03   0.0
         10204      G      0.0            0.0            2.898809E-01  -4.816738E-02   1.145165E-02   0.0
         10301      G      0.0            0.0            1.326068E+00   2.839814E-02   1.657062E-02   0.0
         10302      G      0.0            0.0            6.829033E-01  -9.244961E-03   3.839550E-02   0.0
         10303      G      0.0            0.0           -1.475777E-01  -2.670205E-02   3.879387E-02   0.0
         10304      G      0.0            0.0           -9.657666E-01  -5.703675E-02   3.529658E-02   0.0
         10401      G      0.0            0.0            7.903178E-01  -1.441457E-02   6.219073E-02   0.0
         10402      G      0.0            0.0           -2.571835E-01  -2.155319E-02   6.048384E-02   0.0
         10403      G      0.0            0.0           -1.253393E+00  -4.181003E-02   5.970822E-02   0.0
```

```
     10404     G      0.0            0.0           -2.218969E+00  -4.735287E-02   5.613626E-02   0.0
     20000     G      0.0            0.0            0.0            0.0            0.0            0.0

      EIGENVALUE =  7.341672E+04
      CYCLES =  4.312386E+01        R E A L   E I G E N V E C T O R   N O .         4

  POINT ID.   TYPE          T1             T2             T3             R1             R2             R3
     10101     G      0.0            0.0           -4.123309E+00   2.694899E-04  -2.266406E-01   0.0
     10102     G      0.0            0.0           -2.318701E-02  -1.243020E-03  -5.314526E-03   0.0
     10103     G      0.0            0.0            4.520594E-01  -6.215813E-03  -2.121695E-02   0.0
     10104     G      0.0            0.0            2.440502E-01  -3.207996E-02   3.096157E-02   0.0
     10201     G      0.0            0.0           -1.283839E+00   3.459100E-02  -6.163387E-02   0.0
     10202     G      0.0            0.0            1.576902E-01   9.684119E-04  -3.170266E-02   0.0
     10203     G      0.0            0.0            2.870014E-01  -6.443665E-03   2.288025E-02   0.0
     10204     G      0.0            0.0           -4.325946E-01  -2.493853E-02   2.622103E-02   0.0
     10301     G      0.0            0.0            2.637444E-01   3.015133E-02  -2.357039E-02   0.0
     10302     G      0.0            0.0            4.917885E-01   1.411954E-02   9.793158E-03   0.0
     10303     G      0.0            0.0            9.593081E-03  -4.840639E-03   3.343225E-02   0.0
     10304     G      0.0            0.0           -9.164144E-01  -1.701009E-02   4.736346E-02   0.0
     10401     G      0.0            0.0            9.870760E-01   2.619092E-02   2.147435E-02   0.0
     10402     G      0.0            0.0            5.199889E-01   9.901542E-03   3.957807E-02   0.0
     10403     G      0.0            0.0           -2.610622E-01   8.370100E-04   5.313112E-02   0.0
     10404     G      0.0            0.0           -1.179375E+00  -7.177794E-03   5.455842E-02   0.0
     20000     G      0.0            0.0            0.0            0.0            0.0            0.0

      EIGENVALUE =  2.008154E+05
      CYCLES =  7.132120E+01        R E A L   E I G E N V E C T O R   N O .         5

  POINT ID.   TYPE          T1             T2             T3             R1             R2             R3
     10101     G      0.0            0.0            1.976632E+00  -9.472703E-02   1.147041E-01   0.0
     10102     G      0.0            0.0           -2.276870E-02  -1.390012E-03   9.441336E-04   0.0
     10103     G      0.0            0.0            8.776556E-01  -7.974713E-02  -5.213426E-02   0.0
     10104     G      0.0            0.0            2.455836E+00  -1.372054E-01  -3.867267E-02   0.0
     10201     G      0.0            0.0           -7.512134E-01  -4.105826E-02  -3.071724E-03   0.0
     10202     G      0.0            0.0           -6.829810E-01  -3.796132E-02  -3.375415E-03   0.0
     10203     G      0.0            0.0           -5.347021E-01  -3.837091E-02  -6.255790E-03   0.0
     10204     G      0.0            0.0           -5.127236E-01  -9.846668E-02   7.154678E-03   0.0
     10301     G      0.0            0.0           -7.428587E-01   2.160513E-02  -2.462126E-02   0.0
     10302     G      0.0            0.0           -3.308228E-01   6.036545E-02  -1.134401E-02   0.0
     10303     G      0.0            0.0           -4.807106E-01   4.840772E-02   2.519936E-02   0.0
     10304     G      0.0            0.0           -1.450914E+00   2.149668E-02   6.291359E-02   0.0
     10401     G      0.0            0.0            1.687299E+00   1.180740E-01  -3.960162E-02   0.0
     10402     G      0.0            0.0            1.979366E+00   1.149720E-01   8.102916E-03   0.0
     10403     G      0.0            0.0            1.461685E+00   1.163374E-01   5.380255E-02   0.0
     10404     G      0.0            0.0            3.300396E-01   1.111649E-01   8.177724E-02   0.0
     20000     G      0.0            0.0            0.0            0.0            0.0            0.0
```

Remark 5 of **'ASSIGN FEM=':**

If FORM = ASTROS, the following three commands must exist in the solution control section of the input (as well as output) file that generates the ASTROS solution output file 'a':

MODES
PRINT (MODES = ALL), DISP = ALL, ROOT = ALL
BEGIN BULK (SORT)

Please see the ASTROS User's Manual for a description of the above commands.

A sample output file of ASTROS free vibration analysis is shown below:

```
                    *****  ASTROS RESOURCE COMMANDS ECHO  *****

             *...10...**...20...**...30...**...40...**...50...**...60...**...70...**...80...*

             ASSIGN RUNDB=DEMO,NEW,PASSWORD=DEMO,REALLOC

             *...10...**...20...**...30...**...40...**...50...**...60...**...70...**...80...*
                         S O L U T I O N   C O N T R O L   S U M M A R Y

           ANALYZE
             BOUNDARY METHOD=20,REDUCE=30 ,SPC=10
               LABEL = DEMO CASE
              MODES
             PRINT (MODES=ALL) DISP=ALL,ROOT=ALL
           END

                           S O R T E D   B U L K   D A T A   E C H O
```

```
CARD
COUNT        *...1..**...2..**...3..**...4..**...5..**...6..**...7..**...8..**...9..**..10..*
    1 -      ASET1   30      3       10201   THRU    10204
    2 -      ASET1   30      3       10101   THRU    10104
    3 -      ASET1   30      3       10401   THRU    10404
    4 -      ASET1   30      3       10301   THRU    10304
    5 -      CBAR    1010    1010    10102   20000   10101
    6 -      CONVERT MASS     .00259
    7 -      CQUAD4  1001    1000    10101   10102   10202   10201
    8 -      CQUAD4  1002    1000    10102   10103   10203   10202
    9 -      CQUAD4  1003    1000    10103   10104   10204   10203
   10 -      CQUAD4  1004    1000    10201   10202   10302   10301
   11 -      CQUAD4  1005    1000    10202   10203   10303   10302
   12 -      CQUAD4  1006    1000    10203   10204   10304   10303
   13 -      CQUAD4  1007    1000    10301   10302   10402   10401
   14 -      CQUAD4  1008    1000    10302   10303   10403   10402
   15 -      CQUAD4  1009    1000    10303   10304   10404   10403
   16 -      EIGR    20      MGIV            500.0           5                       +ABC
   17 -      +ABC    MAX
   18 -      GRID    10101           0.0     30.000  0.0
   19 -      GRID    10102           33.333  30.000  0.0
   20 -      GRID    10103           66.667  30.000  0.0
   21 -      GRID    10104           100.000 30.000  0.0
   22 -      GRID    10201           16.667  53.333  0.0
   23 -      GRID    10202           44.444  53.333  0.0
   24 -      GRID    10203           72.222  53.333  0.0
   25 -      GRID    10204           100.000 53.333  0.0
   26 -      GRID    10301           33.333  76.667  0.0
   27 -      GRID    10302           55.555  76.667  0.0
   28 -      GRID    10303           77.778  76.667  0.0
   29 -      GRID    10304           100.000 76.667  0.0
   30 -      GRID    10401           50.000  100.000 0.0
   31 -      GRID    10402           66.667  100.000 0.0
   32 -      GRID    10403           83.333  100.000 0.0
   33 -      GRID    10404           100.000 100.000 0.0
   34 -      GRID    20000           33.333  0.0     0.0
   35 -      MAT1    1100    1.E+07          .3      .1
   36 -      PBAR    1010    1100    100.    .1E+04  .1E+04  .05E+04
   37 -      PSHELL  1000    1100    1.5     1100
   38 -      SPC     10      20000   123456
   39 -      SPC1    10      126     10101   THRU    10104
   40 -      SPC1    10      126     10201   THRU    10204
   41 -      SPC1    10      126     10301   THRU    10304
   42 -      SPC1    10      126     10401   THRU    10404
   43 -      ENDDATA
```

S U M M A R Y   O F   R E A L   E I G E N   A N A L Y S I S

16 EIGENVALUES AND 5 EIGENVECTORS EXTRACTED USING METHOD MGIVENS

MAXIMUM OFF DIAGONAL MASS TERM IS 1.890771509E-15 AT ROW 5 AND COLUMN 2

MODE	EXTRACTION ORDER	EIGENVALUE (RAD/S)**2	FREQUENCY (RAD/S)	FREQUENCY (HZ)	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	7.85673E+02	2.80299E+01	4.46109E+00	4.36633E-01	3.43051E+02
2	2	4.40079E+03	6.63384E+01	1.05581E+01	3.02067E-01	1.32933E+03
3	3	3.41514E+04	1.84801E+02	2.94120E+01	2.70232E-01	9.22883E+03
4	4	4.18786E+04	2.04643E+02	3.25699E+01	9.05048E-02	3.79021E+03
5	5	9.88844E+04	3.14459E+02	5.00477E+01	4.82244E-01	4.76864E+04
6	6	1.33059E+05	3.64773E+02	5.80554E+01	0.00000E+00	0.00000E+00
7	7	1.86616E+05	4.31991E+02	6.87535E+01	0.00000E+00	0.00000E+00
8	8	3.81747E+05	6.17857E+02	9.83350E+01	0.00000E+00	0.00000E+00
9	9	3.88298E+05	6.23135E+02	9.91751E+01	0.00000E+00	0.00000E+00
10	10	6.67839E+05	8.17214E+02	1.30064E+02	0.00000E+00	0.00000E+00
11	11	8.58100E+05	9.26337E+02	1.47431E+02	0.00000E+00	0.00000E+00
12	12	1.03264E+06	1.01619E+03	1.61732E+02	0.00000E+00	0.00000E+00
13	13	1.17125E+06	1.08224E+03	1.72245E+02	0.00000E+00	0.00000E+00
14	14	1.76139E+06	1.32717E+03	2.11226E+02	0.00000E+00	0.00000E+00
15	15	2.78933E+06	1.67013E+03	2.65809E+02	0.00000E+00	0.00000E+00
16	16	4.13498E+06	2.03347E+03	3.23636E+02	0.00000E+00	0.00000E+00

```
1                                                                                  ASTROS VERSION 21.2 B04/10/09   P.    8
                                                                                      FINAL ANALYSIS SEGMENT
 DEMO CASE                                                                       MODES ANALYSIS: BOUNDARY 1, MODE 1
```

R E A L   E I G E N V E C T O R   F O R   M O D E   1

```
EIGENVALUE       =     7.85673E+02  (RAD/S)**2
CYCLIC FREQUENCY =     4.46109E+00  HZ
```

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
10101	G	0.00000E+00	0.00000E+00	-1.57724E-01	4.74973E-04	-9.04594E-03	0.00000E+00
10102	G	0.00000E+00	0.00000E+00	1.65129E-03	1.01365E-04	-4.18610E-04	0.00000E+00
10103	G	0.00000E+00	0.00000E+00	1.60828E-01	7.84750E-03	-8.90299E-03	0.00000E+00
10104	G	0.00000E+00	0.00000E+00	4.75673E-01	7.20763E-03	-9.88694E-03	0.00000E+00
10201	G	0.00000E+00	0.00000E+00	-3.11719E-02	1.54758E-03	-3.01484E-03	0.00000E+00
10202	G	0.00000E+00	0.00000E+00	1.30878E-01	6.42130E-03	-8.59521E-03	0.00000E+00
10203	G	0.00000E+00	0.00000E+00	3.82162E-01	6.65170E-03	-9.26838E-03	0.00000E+00
10204	G	0.00000E+00	0.00000E+00	6.49799E-01	7.61182E-03	-9.90462E-03	0.00000E+00
10301	G	0.00000E+00	0.00000E+00	1.69017E-01	6.16125E-03	-9.91356E-03	0.00000E+00

10302	G	0.00000E+00	0.00000E+00	3.84447E-01	6.54387E-03	-9.40881E-03	0.00000E+00
10303	G	0.00000E+00	0.00000E+00	6.02194E-01	7.47848E-03	-9.98555E-03	0.00000E+00
10304	G	0.00000E+00	0.00000E+00	8.25272E-01	7.31122E-03	-1.00018E-02	0.00000E+00
10401	G	0.00000E+00	0.00000E+00	4.88816E-01	6.88055E-03	-9.98074E-03	0.00000E+00
10402	G	0.00000E+00	0.00000E+00	6.58736E-01	7.41750E-03	-1.03422E-02	0.00000E+00
10403	G	0.00000E+00	0.00000E+00	8.30776E-01	7.23585E-03	-1.01161E-02	0.00000E+00
10404	G	0.00000E+00	0.00000E+00	1.00000E+00	7.59407E-03	-1.01071E-02	0.00000E+00
20000	G	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

1 ASTROS VERSION 21.2 B04/10/09 P. 9
FINAL ANALYSIS SEGMENT
DEMO CASE MODES ANALYSIS: BOUNDARY 1, MODE 2

R E A L   E I G E N V E C T O R   F O R   M O D E   2

EIGENVALUE = 4.40079E+03 (RAD/S)**2
CYCLIC FREQUENCY = 1.05581E+01 HZ

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
10101	G	0.00000E+00	0.00000E+00	-9.99443E-02	-1.37041E-02	-5.07218E-03	0.00000E+00
10102	G	0.00000E+00	0.00000E+00	-2.77751E-03	-1.81102E-04	-6.32624E-04	0.00000E+00
10103	G	0.00000E+00	0.00000E+00	3.69295E-01	-9.94513E-03	-2.12634E-02	0.00000E+00
10104	G	0.00000E+00	0.00000E+00	1.00000E+00	-1.52928E-02	-1.62984E-02	0.00000E+00
10201	G	0.00000E+00	0.00000E+00	-2.96668E-01	-9.29880E-03	-3.80525E-03	0.00000E+00
10202	G	0.00000E+00	0.00000E+00	-1.10681E-01	-1.36695E-02	-9.48454E-03	0.00000E+00
10203	G	0.00000E+00	0.00000E+00	2.01263E-01	-1.24942E-02	-1.27435E-02	0.00000E+00
10204	G	0.00000E+00	0.00000E+00	6.35580E-01	-1.58076E-02	-1.82668E-02	0.00000E+00
10301	G	0.00000E+00	0.00000E+00	-5.32187E-01	-1.78486E-02	-6.38841E-03	0.00000E+00
10302	G	0.00000E+00	0.00000E+00	-3.44961E-01	-1.56378E-02	-1.04377E-02	0.00000E+00
10303	G	0.00000E+00	0.00000E+00	-7.43806E-02	-1.71329E-02	-1.37092E-02	0.00000E+00
10304	G	0.00000E+00	0.00000E+00	2.41691E-01	-1.75982E-02	-1.45025E-02	0.00000E+00
10401	G	0.00000E+00	0.00000E+00	-8.07570E-01	-1.76693E-02	-1.05283E-02	0.00000E+00
10402	G	0.00000E+00	0.00000E+00	-6.22996E-01	-1.85493E-02	-1.16236E-02	0.00000E+00
10403	G	0.00000E+00	0.00000E+00	-4.14728E-01	-1.82571E-02	-1.31904E-02	0.00000E+00
10404	G	0.00000E+00	0.00000E+00	-1.85288E-01	-1.87568E-02	-1.41208E-02	0.00000E+00
20000	G	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

1 ASTROS VERSION 21.2 B04/10/09 P. 10
FINAL ANALYSIS SEGMENT
DEMO CASE MODES ANALYSIS: BOUNDARY 1, MODE 3

R E A L   E I G E N V E C T O R   F O R   M O D E   3

EIGENVALUE = 3.41514E+04 (RAD/S)**2
CYCLIC FREQUENCY = 2.94120E+01 HZ

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
10101	G	0.00000E+00	0.00000E+00	-1.75601E-01	-2.32465E-02	-9.02655E-03	0.00000E+00
10102	G	0.00000E+00	0.00000E+00	-1.71048E-02	-9.66031E-04	6.84568E-04	0.00000E+00
10103	G	0.00000E+00	0.00000E+00	-2.88296E-01	-1.42254E-03	1.34849E-02	0.00000E+00
10104	G	0.00000E+00	0.00000E+00	-6.34242E-01	2.18125E-02	6.83909E-03	0.00000E+00
10201	G	0.00000E+00	0.00000E+00	-4.50809E-01	-1.25424E-02	-1.14398E-02	0.00000E+00
10202	G	0.00000E+00	0.00000E+00	-2.79537E-01	-1.80782E-02	2.91873E-04	0.00000E+00
10203	G	0.00000E+00	0.00000E+00	-2.61509E-01	7.86821E-03	-3.22475E-03	0.00000E+00
10204	G	0.00000E+00	0.00000E+00	-1.33835E-01	2.23012E-02	-6.19697E-03	0.00000E+00
10301	G	0.00000E+00	0.00000E+00	-6.44802E-01	-1.60531E-02	-5.98641E-03	0.00000E+00
10302	G	0.00000E+00	0.00000E+00	-3.71222E-01	2.48809E-03	-1.76481E-02	0.00000E+00
10303	G	0.00000E+00	0.00000E+00	2.27884E-02	1.12650E-02	-1.89721E-02	0.00000E+00
10304	G	0.00000E+00	0.00000E+00	4.31970E-01	2.59648E-02	-1.80001E-02	0.00000E+00
10401	G	0.00000E+00	0.00000E+00	-4.65978E-01	4.68261E-03	-2.96838E-02	0.00000E+00
10402	G	0.00000E+00	0.00000E+00	3.61408E-02	9.01868E-03	-2.95462E-02	0.00000E+00
10403	G	0.00000E+00	0.00000E+00	5.21803E-01	1.88400E-02	-2.95140E-02	0.00000E+00
10404	G	0.00000E+00	0.00000E+00	1.00000E+00	2.15487E-02	-2.79225E-02	0.00000E+00
20000	G	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00

1 ASTROS VERSION 21.2 B04/10/09 P. 11
FINAL ANALYSIS SEGMENT
DEMO CASE MODES ANALYSIS: BOUNDARY 1, MODE 4

R E A L   E I G E N V E C T O R   F O R   M O D E   4

EIGENVALUE = 4.18786E+04 (RAD/S)**2
CYCLIC FREQUENCY = 3.25699E+01 HZ

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
10101	G	0.00000E+00	0.00000E+00	1.00000E+00	-2.01715E-03	5.64829E-02	0.00000E+00
10102	G	0.00000E+00	0.00000E+00	4.92003E-03	2.67899E-04	1.21958E-03	0.00000E+00
10103	G	0.00000E+00	0.00000E+00	-7.22189E-02	8.02059E-04	3.34307E-03	0.00000E+00
10104	G	0.00000E+00	0.00000E+00	1.42218E-02	4.72348E-03	-8.03788E-03	0.00000E+00
10201	G	0.00000E+00	0.00000E+00	2.91175E-01	-7.87643E-03	1.41986E-02	0.00000E+00
10202	G	0.00000E+00	0.00000E+00	-2.42111E-02	8.48906E-04	6.83955E-03	0.00000E+00
10203	G	0.00000E+00	0.00000E+00	-4.72883E-02	7.89466E-04	-5.12644E-03	0.00000E+00
10204	G	0.00000E+00	0.00000E+00	1.03009E-01	2.83089E-03	-5.22758E-03	0.00000E+00
10301	G	0.00000E+00	0.00000E+00	-1.28856E-02	-4.00481E-03	4.67938E-03	0.00000E+00
10302	G	0.00000E+00	0.00000E+00	-6.90750E-02	-1.66587E-03	-9.81907E-04	0.00000E+00
10303	G	0.00000E+00	0.00000E+00	-2.46962E-04	9.49519E-04	-5.16162E-03	0.00000E+00
10304	G	0.00000E+00	0.00000E+00	1.50640E-01	1.48197E-03	-7.97554E-03	0.00000E+00
10401	G	0.00000E+00	0.00000E+00	-1.25005E-01	-3.45775E-03	-2.60315E-03	0.00000E+00
10402	G	0.00000E+00	0.00000E+00	-6.85205E-02	-9.94270E-04	-5.30369E-03	0.00000E+00

```
          10403        G      0.00000E+00   0.00000E+00   3.93305E-02  -3.41754E-04  -7.56189E-03   0.00000E+00
          10404        G      0.00000E+00   0.00000E+00   1.70948E-01   5.85900E-04  -7.80940E-03   0.00000E+00
          20000        G      0.00000E+00   0.00000E+00   0.00000E+00   0.00000E+00   0.00000E+00   0.00000E+00

1                                                                              ASTROS VERSION 21.2 B04/10/09   P.   12
                                                                                   FINAL ANALYSIS SEGMENT
 DEMO CASE                                                             MODES ANALYSIS: BOUNDARY 1, MODE 5


                                R E A L   E I G E N V E C T O R   F O R   M O D E   5

         EIGENVALUE       =     9.88844E+04  (RAD/S)**2
         CYCLIC FREQUENCY =     5.00477E+01  HZ

         POINT ID.   TYPE          T1            T2            T3            R1            R2            R3
          10101        G      0.00000E+00   0.00000E+00   7.30464E-01  -6.58403E-02   4.60747E-02   0.00000E+00
          10102        G      0.00000E+00   0.00000E+00  -1.01415E-02  -6.32742E-04  -6.43032E-04   0.00000E+00
          10103        G      0.00000E+00   0.00000E+00   5.49054E-01  -3.57703E-02  -3.07092E-02   0.00000E+00
          10104        G      0.00000E+00   0.00000E+00   1.00000E+00  -7.20460E-02   2.40956E-03   0.00000E+00
          10201        G      0.00000E+00   0.00000E+00  -6.66242E-01  -2.65721E-02  -1.53368E-02   0.00000E+00
          10202        G      0.00000E+00   0.00000E+00  -2.27467E-01  -1.97661E-02  -1.47552E-02   0.00000E+00
          10203        G      0.00000E+00   0.00000E+00  -7.48511E-02  -1.81559E-02   5.30764E-03   0.00000E+00
          10204        G      0.00000E+00   0.00000E+00  -4.51465E-01  -4.65767E-02   2.02751E-02   0.00000E+00
          10301        G      0.00000E+00   0.00000E+00  -4.88703E-01   9.74488E-03  -2.84319E-02   0.00000E+00
          10302        G      0.00000E+00   0.00000E+00  -4.13593E-02   2.35718E-02  -1.00285E-02   0.00000E+00
          10303        G      0.00000E+00   0.00000E+00  -1.31374E-01   1.94000E-02   1.94331E-02   0.00000E+00
          10304        G      0.00000E+00   0.00000E+00  -8.59769E-01   1.16691E-02   4.44581E-02   0.00000E+00
          10401        G      0.00000E+00   0.00000E+00   7.68068E-01   5.36557E-02  -2.24129E-02   0.00000E+00
          10402        G      0.00000E+00   0.00000E+00   9.32998E-01   5.02390E-02   4.81151E-03   0.00000E+00
          10403        G      0.00000E+00   0.00000E+00   6.32223E-01   5.15985E-02   3.23634E-02   0.00000E+00
          10404        G      0.00000E+00   0.00000E+00  -4.26008E-02   5.12637E-02   4.69097E-02   0.00000E+00
          20000        G      0.00000E+00   0.00000E+00   0.00000E+00   0.00000E+00   0.00000E+00   0.00000E+00
```

<u>Remark 6</u> of **'ASSIGN FEM=':**

If FORM = IDEAS, the structural grids and modal results are read in from I-DEAS universal files. ZONAIR supports both the older and newer versions of I-DEAS output formats. The following table lists allowable data sets for modal data input to ZONAIR.

Data Set No.	Description
781 and/or 2411	Nodes (i.e. GRID points)
55 and/or 2414	Eigenvector information including frequency and modal mass (i.e. structure mode shapes)
18 and/or 2420	Coordinate systems

Data sets other than those in the table above may appear in the universal file and are ignored. ZONAIR output plot files in universal file format are also supported which can be directly viewed by I-DEAS. Please see the PLTxxxx bulk data cards in Chapter 4 for descriptions.

A sample output file of the universal file format is shown below:

```
-1

2420

         8

Demo

         1         0         8

CS1

  1.0000000000000000D+000  0.0000000000000000D+000  0.0000000000000000D+000
  0.0000000000000000D+000  1.0000000000000000D+000  0.0000000000000000D+000
  0.0000000000000000D+000  0.0000000000000000D+000  1.0000000000000000D+000
  0.0000000000000000D+000  0.0000000000000000D+000  0.0000000000000000D+000
```

```
       111         0         8
CS111
  9.9999999999999989D-001  0.0000000000000000D+000  0.0000000000000000D+000
  0.0000000000000000D+000  0.0000000000000000D+000 -1.0000000000000000D+000
  0.0000000000000000D+000  1.0000000000000000D+000  0.0000000000000000D+000
  0.0000000000000000D+000  0.0000000000000000D+000  0.0000000000000000D+000
    -1
-1
  2411
     10101         1         1         1
   3.0000000000000000D+01   0.0000000000000000D+00   0.0000000000000000D+00 10102         1         1         1
   3.0000000000000000D+01   3.3333000183105467D+01   0.0000000000000000D+00 10103         1         1         1
   3.0000000000000000D+01   6.6666999816894527D+01   0.0000000000000000D+0010104         1         1         1
   3.0000000000000000D+01   1.0000000000000000D+02   0.0000000000000000D+0010201         1         1         1
   5.3333000183105472D+01   1.6666999816894532D+01   0.0000000000000000D+0010202         1         1         1
   5.3333000183105472D+01   4.4444000244140626D+01   0.0000000000000000D+0010203         1         1         1
   5.3333000183105472D+01   7.2222000122070308D+01   0.0000000000000000D+00
     10204         1         1         1
   5.3333000183105472D+01   1.0000000000000000D+02   0.0000000000000000D+00
     10301         1         1         1
   7.6666999816894527D+01   3.3333000183105467D+01   0.0000000000000000D+00
     10302         1         1         1
   7.6666999816894527D+01   5.5555000305175781D+01   0.0000000000000000D+00
     10303         1         1         1
   7.6666999816894527D+01   7.7777999877929691D+01   0.0000000000000000D+00
     10304         1         1         1
   7.6666999816894527D+01   1.0000000000000000D+02   0.0000000000000000D+00
     10401         1         1         1
   1.0000000000000000D+02   5.0000000000000000D+01   0.0000000000000000D+00
     10402         1         1         1
   1.0000000000000000D+02   6.6666999816894527D+01   0.0000000000000000D+00
     10403         1         1         1
   1.0000000000000000D+02   8.3333000183105490D+01   0.0000000000000000D+00
     10404         1       111         1
   1.0000000000000000D+02   1.0000000000000000D+02   0.0000000000000000D+00
     20000         1         1         1
   0.0000000000000000D+00   3.3333000183105467D+01   0.0000000000000000D+00
    -1
-1
  2414
         1
B.C. 0,MODE 1, DISPLACEMENT_1
         1
NONE
OUGV1    : REAL MODE SHAPE
ANALYSIS DATE 07/27/99
REAL EIGENVALUE SOLUTION
MODE SHAPE         1 : FREQUENCY (HERTZ) 4.61271E+000
         1         2         3         8         2         6
       -11         0         1         0         1         1         0         0
      1500         0
  0.00000E+00  4.61271E+00  0.00000E+00  1.00000E+00  0.00000E+00  0.00000E+00
  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  10101
  0.00000E+00  0.00000E+00  2.43892E-01 -1.38863E-02  1.04650E-03  0.00000E+0010102
  0.00000E+00  0.00000E+00 -2.68221E-03 -6.51242E-04  1.64135E-04  0.00000E+0010103
  0.00000E+00  0.00000E+00 -2.53676E-01 -1.38568E-02  1.23385E-02  0.00000E+0010104
  0.00000E+00  0.00000E+00 -7.42964E-01 -1.52856E-02  1.12829E-02  0.00000E+0010201
  0.00000E+00  0.00000E+00  4.28180E-02 -4.68218E-03  2.54930E-03  0.00000E+0010202
  0.00000E+00  0.00000E+00 -2.08856E-01 -1.33601E-02  1.01833E-02  0.00000E+0010203
  0.00000E+00  0.00000E+00 -6.01334E-01 -1.43458E-02  1.04441E-02  0.00000E+0010204
  0.00000E+00  0.00000E+00 -1.01627E+00 -1.53258E-02  1.19419E-02  0.00000E+0010301
  0.00000E+00  0.00000E+00 -2.73692E-01 -1.53903E-02  9.77315E-03  0.00000E+0010302
  0.00000E+00  0.00000E+00 -6.08215E-01 -1.45846E-02  1.03253E-02  0.00000E+0010303
  0.00000E+00  0.00000E+00 -9.46500E-01 -1.54627E-02  1.17388E-02  0.00000E+0010304
  0.00000E+00  0.00000E+00 -1.29208E+00 -1.54671E-02  1.14665E-02  0.00000E+0010401
  0.00000E+00  0.00000E+00 -7.74681E-01 -1.54393E-02  1.08321E-02  0.00000E+0010402
  0.00000E+00  0.00000E+00 -1.03781E+00 -1.60022E-02  1.16488E-02  0.00000E+0010403
  0.00000E+00  0.00000E+00 -1.30443E+00 -1.56486E-02  1.13555E-02  0.00000E+00 10404
  0.00000E+00  0.00000E+00 -1.56637E+00 -1.56380E-02  1.19065E-02  0.00000E+00 20000
  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
    -1
```

Remark 7 of **'ASSIGN FEM=':**

Radioss/OptiStruct can output the modal solution in the ZONAIR's ASSIGN FEM= 'FREE' format. To generate these output from Radioss/OptiStruct requires the following additional line be included in the Radioss/OptiStruct input deck:

PARAM,ZONAIR,YES

The output eigenmode data are then output from Radioss/OptiStruct to an ASCII text file named

```
<input data file name>.zonair
```

The G-set mass matrix can also be output by Radioss/OptiStruct in the DMIG format. The DMIG can then simply be pasted into a ZONAIR input deck to perform analyses that require the mass matrix (e.g., a Trim run to include inertial effects).

The output DMIG file (containing the MGG data) is named

```
<input data file name>_<DMIG matrix name>.pch
```

where <DMIG matrix name> can be defined using the following card in output control:

```
DMIGNAME=<DMIG matrix name>  (Default is AX)
```

Radioss can directly process NASTRAN bulk data cards. Therefore, most NASTRAN input files (e.g., those from MSC.Nastran, NX.Nastran, etc.) can be run directly by Radioss. Note that Radioss only supports the Lanczos eigenvalue solver, so EIGRL needs to be used when defining METHOD in the case control.

Remark 8 of **'ASSIGN FEM=':**

ZONAIR supports the ELFINI neutral output file to acquire the free vibration solutions. Since ELFINI always outputs the free vibration solutions in SI (Standard International) format (metric - Length = meters, Mass = kilograms) the structural model and aerodynamic model may be in different unit systems for this option only. ***Again, different units between the structural and aerodynamic models is only allowed for this type of input*** (FORM=ELFINI). To convert the ELFINI metric units to the aerodynamic model units requires specifying the FMMUNIT and FMLUNIT entries of the **AEROZ** bulk data card to reflect the units of the aerodynamic model. The program will then convert the ELFINI free vibration solutions to match the units of the aerodynamic model. If the aerodynamic model is also in SI units, then the FMMUNIT and FMLUNIT entries should be set to KG and M, respectively.

A sample of the ELFINI neutral file is shown as follows:

```
HEADER=MODEL

 RELEASE=   1
 NAME=      E767
 DATE=30/10/96 AT=10.49.10

  TITLE
   NO TITLE
  END TITLE

 END HEADER

CONTENT

 DEGREE     NBDOF=   30

 K-MATRIX   NBMATRIX=    1

 M-MATRIX   NBMATRIX=    1
```

```
 MONVAL     NBMON= 3177
 END CONTENT

UNIT
 SYSTEM= ISO
 END UNIT

DEGREE
 END DEGREE

K-MATRIX
 DOF=    1
    0.1230923559613264D+04    0.3686414966027151D-04    0.2419062914082075D-03
    0.6983785713017072D-04    -.2023261010701697D-04    0.7831696499717704D-04
    -.2457474668222889D-03    0.1130354829300728D-03    0.4604977332201705D-04
    -.1091649015086483D-03    -.3635281838273271D-04    -.9274910202744236D-04
    0.1309670841427416D-03    0.4488872714871719D-04    -.2327751708509681D-04
    -.7472762150226767D-04    0.4713285201889093D-04    0.3429857074005640D-04
    -.5447145357492463D-06    0.3868854191317292D-05    -.3624751739196352D-04
    0.8176428928352975D-05    -.1887274213933592D-05    0.1598938947169428D-05
    -.1808144454036312D-05    0.1165396547550420D-05    -.3689883842386831D-04
    -.2884186353798238D-04    0.8310472989868395D-05    -.3608598589997129D-05
 DOF=    2
    0.3686414966027151D-04    0.1358544160900551D+05    0.4296049769816649D-03
    0.1628147041567078D-03    -.5617118452227373D-04    0.1914983001579172D-03
.
M-MATRIX

 DOF=    1

    0.5497212390994216D+00    -.9446850040509963D-14    -.4294748421913158D-14
    0.9254207643250023D-15    -.1457946990131992D-14    0.1109663982879969D-14
    -.6852211940217012D-14    0.6256388636327603D-15    -.1378020961229076D-15
    0.1480555993560104D-14    0.7164950056870456D-15    0.2515687853345272D-15
    -.3575698764857194D-15    -.1365281585702371D-14    0.1470923534883928D-15
    0.4089610594615323D-15    -.1493488492598782D-15    0.1576836534608606D-16
    -.4511975103434207D-16    -.2422683635736750D-16    0.3794707603699266D-17
    -.3460616633478488D-16    0.3662570463927595D-17    0.2534322578184867D-16
    0.1245350190700635D-17    0.3208899617378191D-16    0.3016114918583113D-16
    0.1008308020411519D-16    -.9849299110673004D-17    0.8090181085815273D-16
 DOF=    2
    -.9446850040509963D-14    0.1517800567316923D+01    -.1020468025402302D-14
    -.2718403166413960D-14    -.1067939139898222D-16    0.6759217887003857D-14

MONVAL=     1
 TITLE
KIND=DISP    ;NAME=                ;UNIT=M         ;
SELECT=WING;NODE=        2;TYPE=TX;COORD.=0.2940557999999999D+00 0.0000000000000
000D+00 0.9113519999999997D-01 M;
  END TITLE
    -.6270452321170384D-04    -.3770965314259045D-03    0.1681525813481753D-02
    -.7268882809304363D-03    0.8641032168708783D-03    -.5617263119365574D-02
    -.4243476398549203D-03    0.1115622083120243D-01    -.2398198156757896D-02
    0.3264161266023014D-02    -.1459664532940326D-01    -.1179512947055147D-01
    0.6565833985373308D-02    -.1217856158745318D-01    -.7468784150169609D-02
    0.4677584975980958D-02    -.2097598934419818D-01    -.4019675274132945D-02
    0.5269019719698231D-03    -.2955775293472249D-02    0.7297341338640479D-03
    -.7193417522388700D-03    -.5516094061587379D-03    -.1730473266346012D-02
    -.1565697075052970D-03    -.9836643468589825D-04    0.3743652572097349D-02
    -.9436596571633759D-03    0.1392135637645999D-03    -.1182337803036962D-03
 END MONVAL

MONVAL=     2
 TITLE
KIND=DISP    ;NAME=                ;UNIT=M         ;
SELECT=WING;NODE=        2;TYPE=TY;COORD.=0.2940557999999999D+00 0.0000000000000
000D+00 0.9113519999999997D-01 M;
  END TITLE
    -.6631092559614345D-04    0.2057090096506267D-02    -.6501226652201383D-02
    0.2216313171525446D-02    -.4468904163869089D-02    0.3136186294985838D-01
```

Remark 9 of **'ASSIGN FEM=':**

If FORM = FREE, it is assumed that the free vibration solution of the finite element model is obtained by some other structural finite element code. In this case, it is the user's responsibility to set up the modal data in file 'a' according to the following data format:

There are four input card sets required to construct the file 'a'. Each card set may contain one or a group of input cards.

Card Set 1	**NGRID, NMODE** (Free Format)
NGRID NMODE	Number of structural grid points of the finite element model (Integer > 0) Number of structural modes (Integer > 0)
Example	17 5

Card Set 2	**ID, x, y, z** (Free Format)
ID X, y, z	Identification number of the structural grid points (Integer > 0) x, y and z locations of the grid points (Real)
Example	100 1.0 3.0 0.0

Repeat card set 2, **NGRID** times for all structural grid points.

Card Set 3	**FREQ, GENM** (Free Format)
FREQ GENM	Natural frequency of the mode (rad/sec) (Real) Generalized mass of the modes (Real)
Example	38.23 0.032

Card Set 4	**ID, T_1, T_2, T_3, R_1, R_2, R_3** (Free Format)
ID T_1, T_2, T_3 R_1, R_2, R_3	Identification number of the structural grid point; must exist in card set 2 (Integer > 0) Translational modal displacement in x, y and z directions (Real) Rotational modal displacement about x, y and z directions (Real)
Example	100 0.0 0.0 3.3 2.1 0.5 4.0

Repeat card set 4 **NGRID** times for the modal displacement at all grid points.

Go back to card set 3. Repeat this process **NMODE** times for all modes.

Comment cards may be used in a modal data file with FORM = FREE format and must be initiated with a "$" in the first column.
An example for FORM = FREE, is shown as follows:

```
$  EXAMPLE CASE WITH FORM = FREE
17   5
    10101        0.0000    30.0000  0.0000
    10102       33.3330    30.0000  0.0000
    10103       66.6670    30.0000  0.0000
    10104      100.0000    30.0000  0.0000
    10201       16.6670    53.3330  0.0000
    10202       44.4440    53.3330  0.0000
```

```
    10203        72.2220   53.3330  0.0000
    10204       100.0000   53.3330  0.0000
    10301        33.3330   76.6670  0.0000
    10302        55.5550   76.6670  0.0000
    10303        77.7780   76.6670  0.0000
    10304       100.0000   76.6670  0.0000
    10401        50.0000  100.0000  0.0000
    10402       66.6670   100.0000  0.0000
    10403        83.3330  100.0000  0.0000
    10404       100.0000  100.0000  0.0000
    20000        33.3330    0.0000  0.0000
$ MODE 1
0.28983E+02  0.10000E+01
   10101             0.00000E+00   0.00000E+00    0.24389E+00  -0.10465E-02   0.13886E-01   0.00000E+00
   10102             0.00000E+00   0.00000E+00   -0.26822E-02  -0.16414E-03   0.65124E-03   0.00000E+00
   10103             0.00000E+00   0.00000E+00   -0.25368E+00  -0.12338E-01   0.13857E-01   0.00000E+00
   10104             0.00000E+00   0.00000E+00   -0.74296E+00  -0.11283E-01   0.15286E-01   0.00000E+00
   10201             0.00000E+00   0.00000E+00    0.42818E-01  -0.25493E-02   0.46822E-02   0.00000E+00
   10202             0.00000E+00   0.00000E+00   -0.20886E+00  -0.10183E-01   0.13360E-01   0.00000E+00
   10203             0.00000E+00   0.00000E+00   -0.60133E+00  -0.10444E-01   0.14346E-01   0.00000E+00
   10204             0.00000E+00   0.00000E+00   -0.10163E+01  -0.11942E-01   0.15326E-01   0.00000E+00
   10301             0.00000E+00   0.00000E+00   -0.27369E+00  -0.97731E-02   0.15390E-01   0.00000E+00
   10302             0.00000E+00   0.00000E+00   -0.60821E+00  -0.10325E-01   0.14585E-01   0.00000E+00
   10303             0.00000E+00   0.00000E+00   -0.94650E+00  -0.11739E-01   0.15463E-01   0.00000E+00
   10304             0.00000E+00   0.00000E+00   -0.12921E+01  -0.11467E-01   0.15467E-01   0.00000E+00
   10401             0.00000E+00   0.00000E+00   -0.77468E+00  -0.10832E-01   0.15439E-01   0.00000E+00
   10402             0.00000E+00   0.00000E+00   -0.10378E+01  -0.11649E-01   0.16002E-01   0.00000E+00
   10403             0.00000E+00   0.00000E+00   -0.13044E+01  -0.11356E-01   0.15649E-01   0.00000E+00
   10404             0.00000E+00   0.00000E+00   -0.15664E+01  -0.11907E-01   0.15638E-01   0.00000E+00
   20000             0.00000E+00   0.00000E+00    0.00000E+00   0.00000E+00   0.00000E+00   0.00000E+00
$ MODE 2
 0.73496E+02  0.10000E+01
   10101             0.00000E+00   0.00000E+00  -0.22488E+00  -0.27753E-01  -0.11296E-01   0.00000E+00
   10102             0.00000E+00   0.00000E+00  -0.56264E-02  -0.36655E-03  -0.13068E-02   0.00000E+00
   10103             0.00000E+00   0.00000E+00   0.75844E+00  -0.20153E-01  -0.42887E-01   0.00000E+00
   10104             0.00000E+00   0.00000E+00   0.20276E+01  -0.30486E-01  -0.32503E-01   0.00000E+00
   10201             0.00000E+00   0.00000E+00  -0.61311E+00  -0.18695E-01  -0.79740E-02   0.00000E+00
   10202             0.00000E+00   0.00000E+00  -0.22314E+00  -0.27600E-01  -0.19683E-01   0.00000E+00
   10203             0.00000E+00   0.00000E+00   0.42123E+00  -0.25182E-01  -0.25962E-01   0.00000E+00
   10204             0.00000E+00   0.00000E+00   0.13023E+01  -0.31480E-01  -0.36780E-01   0.00000E+00
   10301             0.00000E+00   0.00000E+00  -0.10832E+01  -0.35884E-01  -0.13684E-01   0.00000E+00
   10302             0.00000E+00   0.00000E+00  -0.69096E+00  -0.31485E-01  -0.21684E-01   0.00000E+00
   10303             0.00000E+00   0.00000E+00  -0.13155E+00  -0.34301E-01  -0.28107E-01   0.00000E+00
   10304             0.00000E+00   0.00000E+00   0.51537E+00  -0.35056E-01  -0.29567E-01   0.00000E+00
   10401             0.00000E+00   0.00000E+00  -0.16244E+01  -0.35439E-01  -0.21997E-01   0.00000E+00
   10402             0.00000E+00   0.00000E+00  -0.12405E+01  -0.37052E-01  -0.24214E-01   0.00000E+00
   10403             0.00000E+00   0.00000E+00  -0.80819E+00  -0.36387E-01  -0.27230E-01   0.00000E+00
   10404             0.00000E+00   0.00000E+00  -0.33566E+00  -0.37273E-01  -0.28986E-01   0.00000E+00
   20000             0.00000E+00   0.00000E+00   0.00000E+00   0.00000E+00   0.00000E+00   0.00000E+00
$ MODE 3
 0.20776E+03  0.10000E+01
   10101             0.00000E+00   0.00000E+00    0.85853E+00   0.47730E-01   0.45322E-01   0.00000E+00
   10102             0.00000E+00   0.00000E+00    0.40923E-01   0.22853E-02  -0.10635E-02   0.00000E+00
   10103             0.00000E+00   0.00000E+00    0.66112E+00  -0.33406E-03  -0.27850E-01   0.00000E+00
   10104             0.00000E+00   0.00000E+00    0.13585E+01  -0.46354E-01  -0.12396E-01   0.00000E+00
   10201             0.00000E+00   0.00000E+00    0.11177E+01   0.21478E-01   0.30232E-01   0.00000E+00
   10202             0.00000E+00   0.00000E+00    0.59202E+00   0.35742E-01   0.30840E-02   0.00000E+00
   10203             0.00000E+00   0.00000E+00    0.53507E+00  -0.20101E-01   0.70681E-02   0.00000E+00
   10204             0.00000E+00   0.00000E+00    0.28988E+00  -0.48167E-01   0.11452E-01   0.00000E+00
   10301             0.00000E+00   0.00000E+00    0.13261E+01   0.28398E-01   0.16571E-01   0.00000E+00
   10302             0.00000E+00   0.00000E+00    0.68290E+00  -0.92450E-02   0.38396E-01   0.00000E+00
   10303             0.00000E+00   0.00000E+00   -0.14758E+00  -0.26702E-01   0.38794E-01   0.00000E+00
   10304             0.00000E+00   0.00000E+00   -0.96577E+00  -0.57037E-01   0.35297E-01   0.00000E+00
   10401             0.00000E+00   0.00000E+00    0.79032E+00  -0.14415E-01   0.62191E-01   0.00000E+00
   10402             0.00000E+00   0.00000E+00   -0.25718E+00  -0.21553E-01   0.60484E-01   0.00000E+00
   10403             0.00000E+00   0.00000E+00   -0.12534E+01  -0.41810E-01   0.59708E-01   0.00000E+00
   10404             0.00000E+00   0.00000E+00   -0.22190E+01  -0.47353E-01   0.56136E-01   0.00000E+00
   20000             0.00000E+00   0.00000E+00    0.00000E+00   0.00000E+00   0.00000E+00   0.00000E+00
$ MODE 4
 0.27096E+03  0.10000E+01
   10101             0.00000E+00   0.00000E+00   -0.41233E+01   0.26949E-03  -0.22664E+00   0.00000E+00
   10102             0.00000E+00   0.00000E+00   -0.23187E-01  -0.12430E-02  -0.53145E-02   0.00000E+00
   10103             0.00000E+00   0.00000E+00    0.45206E+00  -0.62158E-02  -0.21217E-01   0.00000E+00
   10104             0.00000E+00   0.00000E+00    0.24405E+00  -0.32080E-01   0.30962E-01   0.00000E+00
   10201             0.00000E+00   0.00000E+00   -0.12838E+01   0.34591E-01  -0.61634E-01   0.00000E+00
   10202             0.00000E+00   0.00000E+00    0.15769E+00   0.96841E-03  -0.31703E-01   0.00000E+00
   10203             0.00000E+00   0.00000E+00    0.28700E+00  -0.64437E-02   0.22880E-01   0.00000E+00
   10204             0.00000E+00   0.00000E+00   -0.43259E+00  -0.24939E-01   0.26221E-01   0.00000E+00
   10301             0.00000E+00   0.00000E+00    0.26374E+00   0.30151E-01  -0.23570E-01   0.00000E+00
   10302             0.00000E+00   0.00000E+00    0.49179E+00   0.14120E-01   0.97932E-02   0.00000E+00
   10303             0.00000E+00   0.00000E+00    0.95931E-02  -0.48406E-02   0.33432E-01   0.00000E+00
   10304             0.00000E+00   0.00000E+00   -0.91641E+00  -0.17010E-01   0.47363E-01   0.00000E+00
   10401             0.00000E+00   0.00000E+00    0.98708E+00   0.26191E-01   0.21474E-01   0.00000E+00
   10402             0.00000E+00   0.00000E+00    0.51999E+00   0.99015E-02   0.39578E-01   0.00000E+00
   10403             0.00000E+00   0.00000E+00   -0.26106E+00   0.83701E-03   0.53131E-01   0.00000E+00
   10404             0.00000E+00   0.00000E+00   -0.11794E+01  -0.71778E-02   0.54558E-01   0.00000E+00
   20000             0.00000E+00   0.00000E+00    0.00000E+00   0.00000E+00   0.00000E+00   0.00000E+00
```

```
$ MODE 5
 0.44812E+03  0.10000E+01
   10101             0.00000E+00    0.00000E+00     0.19766E+01   -0.94727E-01    0.11470E+00    0.00000E+00
   10102             0.00000E+00    0.00000E+00    -0.22769E-01   -0.13900E-02    0.94413E-03    0.00000E+00
   10103             0.00000E+00    0.00000E+00     0.87766E+00   -0.79747E-01   -0.52134E-01    0.00000E+00
   10104             0.00000E+00    0.00000E+00     0.24558E+01   -0.13721E+00   -0.38673E-01    0.00000E+00
   10201             0.00000E+00    0.00000E+00    -0.75121E+00   -0.41058E-01   -0.30717E-02    0.00000E+00
   10202             0.00000E+00    0.00000E+00    -0.68298E+00   -0.37961E-01   -0.33754E-02    0.00000E+00
   10203             0.00000E+00    0.00000E+00    -0.53470E+00   -0.38371E-01   -0.62558E-02    0.00000E+00
   10204             0.00000E+00    0.00000E+00    -0.51272E+00   -0.98467E-01    0.71547E-02    0.00000E+00
   10301             0.00000E+00    0.00000E+00    -0.74286E+00    0.21605E-01   -0.24621E-01    0.00000E+00
   10302             0.00000E+00    0.00000E+00    -0.33082E+00    0.60365E-01   -0.11344E-01    0.00000E+00
   10303             0.00000E+00    0.00000E+00    -0.48071E+00    0.48408E-01    0.25199E-01    0.00000E+00
   10304             0.00000E+00    0.00000E+00    -0.14509E+01    0.21497E-01    0.62914E-01    0.00000E+00
   10401             0.00000E+00    0.00000E+00     0.16873E+01    0.11807E+00   -0.39602E-01    0.00000E+00
   10402             0.00000E+00    0.00000E+00     0.19794E+01    0.11497E+00    0.81029E-02    0.00000E+00
   10403             0.00000E+00    0.00000E+00     0.14617E+01    0.11634E+00    0.53803E-01    0.00000E+00
   10404             0.00000E+00    0.00000E+00     0.33004E+00    0.11116E+00    0.81777E-01    0.00000E+00
   20000             0.00000E+00    0.00000E+00     0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
```

Remark 10 of **'ASSIGN FEM=':**

Since the geometry of an aircraft is usually symmetric about a vertical plane passing through the centerline of the fuselage, only half of the aircraft is required to be modeled structurally (as well as aerodynamically). The symmetric modes and anti-symmetric modes of the aircraft structure can be obtained by imposing the so-called 'symmetric boundary condition' and 'anti-symmetric boundary condition', respectively, at the structural grid points along the centerline plane of the fuselage. Each boundary condition gives different natural frequencies and mode shapes.

For symmetric and anti-symmetric boundary conditions, it is usually required to perform the aeroelastic analysis separately. But this is not the case for ZONAIR. ZONAIR can compute the Aerodynamic Influence Coefficient (AIC) matrices for both boundary conditions simultaneously without costing significant additional computer time. Therefore, it is more efficient when both symmetric and anti-symmetric free vibration solutions are included with one ZONAIR analysis.

Remark 11 of **'ASSIGN FEM=':**

If the SUPORT entry is activated, the program will transform the rigid body modes computed by the finite element analysis from the generalized coordinates to the body axis coordinates but leaves the elastic modes unaltered. In the body axis coordinates, all translational rigid body modes have a value of one in their respective translational degrees of freedom and zero in other degrees of freedom. Whereas all rotational rigid body modes have a unit rotation angle about their respective rotation degrees of freedom whose rotation center is located at REFX, REFY, and REFZ (specified by the **AEROZ** bulk data card). Consequently, the generalized mass matrix associated with the rigid body modes are also transformed into the body axis coordinates. This normally gives a non-diagonal generalized mass matrix that, in fact, contains the physical mass properties of the structure. Note that if only one half of the configuration is modeled (XZSYM = "YES" in the **AEROZ** bulk data card), these mass properties are only one half of the mass and mass moment of inertia of the whole configuration.

Note that to compute the distributed inertial loads of a free-free structure for trim analysis requires activating the SUPORT entry. Otherwise, the program assumes that the structure is restrained and ignores the distributed inertial load effects.

‘ASSIGN MATRIX=’ Direct Matrix Input by INPUTT4 Format

Description: Assign an external file that contains the ASCII or binary data of a matrix for direct matrix input. The format of the external file is the same as the INPUTT4 format of NASTRAN (see INPUTT4 or OUTPUT4 module description of MSC.NASTRAN DMAP Module Dictionary).

Format:

ASSIGN MATRIX = ' a ', **FORM** = ' b ', **MNAME** = ' c ', **PRINT** = n

Note that a single continuous line can be used if the first line ends in a comma (,).

Example 1:

```
ASSIGN MATRIX = demo1.mgh, MNAME=SMGH, FORM=FORMAT, PRINT = 1
```

Example 2:

```
ASSIGN MATRIX = /export/home/zonair/demo2.mgh,
FORM = UNFORMAT
```

Describer	Meaning
MATRIX = ' a '	MATRIX indicates that ' a ' is the filename of the external file that contains the data of a matrix for direct matrix input. ' a ' represents a character string specifying the name of the external file. (Required)
FORM = ' b '	FORM indicates the format of the data on the external file. (Optional) (default = FORMAT) ' b ' = FORMAT for non-sparse and ASCII with 5E16.9 format. ' b ' = FORMAT23 for non-sparse and ASCII with 3D23.16 format. ' b ' = UNFORMAT for binary format. ' b ' = SFORMAT for sparse and ASCII format. Note that 'b'=FORMAT can read in both sparse and non-sparse with both 5E16.9 and 3D23.16 formats. By default, the program will store the matrix internally as a sparse matrix. For large full matrices this can considerably decrease run-time performance. To force the program to store the matrix as a non-sparse full matrix internally, prepend 'R' (Regular) to the FORM option: 'b' = RFORMAT for OUTPUT4 ASCII non-sparse format file stored as a full matrix. 'b' = RUNFORM for OUTPUT4 binary non-sparse format file stored as a full matrix.
MNAME = ' c '	MNAME indicates that ' c ' is the name of the matrix (up to 8 characters). The matrix on the external file ' a ' is read in and written on the runtime database as a matrix entity with name = ' c '. If MNAME is not specified, the name of the matrix specified in the header record of the INPUTT4 format is used as the name of the matrix. (Optional)

PRINT = n	Print option to the output file; where n is an integer. n = 0 no printout of matrix. $n \neq 0$ print out the matrix. If no PRINT is specified, n = 0 is used as a default. (Optional)

'ASSIGN MATRIX=' is an optional Executive Control Command for direct matrix input, because trim and transient response analysis may require some additional structural matrices from the finite element analysis. These matrices can be exported from FEM analysis and imported into ZONAIR using the **'ASSIGN MATRIX='** Executive Control Command. (See remark 1 for those structural matrices). The format of the matrix data stored on the external file is very similar to that of the INPUTT4 (or OUTPUT4) module of NASTRAN.

To output the matrix such as G-set mass (MGG) or stiffness (KGG) matrix from NASTRAN, one can use the following ALTER statements in the NASTRAN input file:

For ASCII and non-sparse matrix:

```
ASSIGN OUTPUT4='ha144ds.mgg' UNIT=13 FORM=FORMATTED
ASSIGN OUTPUT4='ha144ds.kgg' UNIT=14 FORM=FORMATTED
COMPILE SEMODES SOUIN=MSCSOU LIST NOREF $
ALTER 'STRAIN ENERGY' $
MATGEN EQEXINS/INTEXT/9//LUSETS $
OUTPUT4 MGG//-1/13///16 $
OUTPUT4 KGG//-1/14///16 $
ENDALTER
```

For ASCII and sparse matrix:

```
ASSIGN OUTPUT4='ha144ds.sparse.ascii.mgg' unit=29 form=formatted
ASSIGN OUTPUT4='ha144ds.sparse.ascii.kgg' unit=30 form=formatted
COMPILE SEMODES SOUIN=MSCSOU LIST NOREF $
ALTER 'STRAIN ENERGY' $
MATGEN EQEXINS/INTEXT/9//LUSETS $
OUTPUT4 MGG//-1/-29///16 $
OUTPUT4 KGG//-1/-30///16 $
ENDALTER
```

For binary and non-sparse matrix:

```
ASSIGN OUTPUT4='ha144ds.sparse.bin.mgg' unit=35 form=unformatted
ASSIGN OUTPUT4='ha144ds.sparse.bin.kgg' unit=36 form=unformatted
COMPILE SEMODES SOUIN=MSCSOU LIST NOREF $
ALTER 'STRAIN ENERGY' $
MATGEN EQEXINS/INTEXT/9//LUSETS $
OUTPUT4 MGG//-1/-35///16 $
OUTPUT4 KGG//-1/-36///16 $
ENDALTER
```

For binary and sparse matrix:

```
ASSIGN OUTPUT4='ha144ds.sparse.bin.bigmat.mgg' unit=37 form=unformatted
ASSIGN OUTPUT4='ha144ds.sparse.bin.bigmat.kgg' unit=38 form=unformatted
COMPILE SEMODES SOUIN=MSCSOU LIST NOREF $
ALTER 'STRAIN ENERGY' $
MATGEN EQEXINS/INTEXT/9//LUSETS $
OUTPUT4 MGG//-1/-37//TRUE/16 $
OUTPUT4 KGG//-1/-38//TRUE/16 $
ENDALTER
```

The options of format are presented as follows:

For Non-Sparse and ASCII Format (FORM = FORMAT)

Record 1	NCOL, NROW, NF, NTYPE, NAME (4I8, A8)	
	NCOL	Number of columns
	NROW	Number of rows
	NF	Form of matrix NF=2 General rectangular matrix NF=6 Symmetric matrix. Only the upper triangular part (including diagonals) is input.
	NTYPE	Type of matrix NTYPE=1 Real, single precision NTYPE=2 Real, double precision NTYPE=3 Complex, single precision NTYPE=4 Complex, double precision
	NAME	Character string up to 8 characters If no MNAME = ′c′ is specified, these characters are used as the name of the matrix.
Record 2	ICOL, IROW, NW (3I8)	
	ICOL	Column Number
	IROW	Row position of the first nonzero term
	NW	Number of words in the column. For a complex matrix, there are two words for each element of the matrix.
Record 3	A(J) , J = IROW, IROW + NW / NC - 1 (5E16.9) for FORM = FORMAT (3D23.16) for FORM = FORMAT23	

9	For	NTYPE=1: NC=1 and A is a real, single precision array NTYPE=2: NC=1 and A is a real, double precision array NTYPE=3: NC=2 and A is a complex, single precision array NTYPE=4: NC=2 and A is a complex, double precision array

Records 2 and 3 are repeated for each column.

Record 2 with the last column number plus +1 and at least one dummy value in Record 3 must also be added at the bottom of the file. Thus, there are a total of (NCOL + 1) numbers of Records 2 and 3 in the file.

An example is shown as follows:

```
    5     102       2       2MGH     1P,5E16.9
       1       3      99
 6.855846336E-03 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00-1.162878605E-02 0.000000000E+00-2.181833573E-03 0.000000000E+00
 0.000000000E+00 0.000000000E+00-5.625212629E-02 0.000000000E+00 0.000000000E+00
 0.000000000E+00 0.000000000E+00 0.000000000E+00-4.825029982E-02 0.000000000E+00
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00-6.989890183E-03
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
-6.215569848E-02 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00-1.509172999E-01 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00 0.000000000E+00-1.093032792E-01 0.000000000E+00 0.000000000E+00
 0.000000000E+00 0.000000000E+00 0.000000000E+00-3.930833207E-02 0.000000000E+00
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00-1.210470133E-01
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
-1.884292515E-01 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00-1.173323700E-01 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00 0.000000000E+00-2.918305947E-02 0.000000000E+00 0.000000000E+00
 0.000000000E+00 0.000000000E+00 0.000000000E+00-7.453748578E-02 0.000000000E+00
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00-9.896419781E-02
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00 5.763368009E-02
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00-1.495288195E-04 0.000000000E+00 1.115356274E-03
       2       3      99
-1.847709670E-02 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00-1.297997974E-03 0.000000000E+00-4.428561904E-03 0.000000000E+00
             ⋮
0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00 9.050600279E-03
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00-2.976067064E-04 0.000000000E+00 2.228496429E-03
       3       3      99
-5.003520334E-02 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00-6.703697305E-02 0.000000000E+00-3.474696162E-02 0.000000000E+00
             ⋮
0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00-6.193062631E-02
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00-2.439368145E-03 0.000000000E+00 1.811090503E-02
       4       3      99
-1.515793658E-01 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00-6.854211102E-02 0.000000000E+00-2.003283120E-02 0.000000000E+00
             ⋮
0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00 3.274867786E-02
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00-1.419543836E-03 0.000000000E+00 1.052054613E-02
       5       3      99
 4.641623764E-02 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00 8.665747224E-03 0.000000000E+00-1.854310840E-02 0.000000000E+00
             ⋮
0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00-2.731625756E-03
 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00 0.000000000E+00
 0.000000000E+00-1.271699994E-03 0.000000000E+00 9.484510803E-03
       6       1       1
 1.310664892E+00
```

For Sparse and ASCII Format (FORM = SFORMAT)

Record 1	NCOL, NROW, NF, NTYPE, NAME (4I8, A8)
	NCOL — Number of columns NROW — Number of rows NF — Form of matrix NF=2 General rectangular matrix NF=6 Symmetric matrix. Only the upper triangular part (including diagonals) is input. NTYPE — Type of matrix NTYPE=1 Real, single precision NTYPE=2 Real, double precision NTYPE=3 Complex, single precision NTYPE=4 Complex, double precision NAME — Character string up to 8 characters If no MNAME = ′c′ is specified, these characters are used as the name of the matrix.
Record 2	ICOL, IZERO, NW (3I8)
	ICOL — Column Number IZERO — Must be 0 NW — Number of words in the column. For a complex matrix, there are two values per row.
Record 3	IS (I8)
	IS = IROW + 65536 * (L + 1) where IROW is the row position of the first term in the string and L is the length of the string. For example, a string of six words beginning in row 4 has IS = 458756. L and IROW may be derived from IS by: L = INT (IS / 65536) – 1 IROW = IS – 65536 * (L + 1)
Record 4	A(J) , J = IROW, IROW + L / NC / ND - 1 (5E16.9)
	For NTYPE=1: NC=1, ND=1 and A is a real, single precision array

	NTYPE=2: NC=1, ND=2 and A is a real, double precision array NTYPE=3: NC=2, ND=1 and A is a complex, single precision array NTYPE=4: NC=2, ND=2 and A is a complex, double precision array

Records 3 and 4 are repeated for NW words.

Records 2, 3 and 4 are repeated for each column.

Record 2 with the last column number plus +1 and at least one dummy value in Records 3 and 4 must also be added at the bottom of the file. Thus, the total numbers of Record 2 in the file must be (NCOL + 1).

An example is shown as follows:

```
    5     102       2       2MGH     1P,5E16.9
       1       0      57
  196611
 6.855846336E-03
  196617
-1.162878605E-02
  196619
-2.181833573E-03
  196623
-5.625212629E-02
  196629
-4.825029982E-02
  196635
-6.989890183E-03
  196641
-6.215569848E-02
  196647
-1.509172999E-01
  196653
-1.093032792E-01
              :
  196677
-1.173323700E-01
  196683
-2.918305947E-02
  196689
-7.453748578E-02
  196695
-9.896419781E-02
  196700
 5.763368009E-02
  196707
-1.495288195E-04
  196709
 1.115356274E-03
       2       0      57
  196611
-1.847709670E-02
  196617
-1.297997974E-03
  196619
              :
-2.976067064E-04
  196709
 2.228496429E-03
       3       0      57
  196611
```

```
-5.003520334E-02
  196617
-6.703697305E-02
  196619
             ⋮
-2.439368145E-03
  196709
 1.811090503E-02
       4       0      57
  196611
-1.515793658E-01
  196617
-6.854211102E-02
  196619
             ⋮
-1.419543836E-03
  196709
 1.052054613E-02
       5       0      57
  196611
 4.641623764E-02
  196617
 8.665747224E-03
  196619
             ⋮
-1.271699994E-03
  196709
 9.484510803E-03
       6       1       1
 1.026752114E+00
```

For Non-Sparse and Binary Format (FORM = UNFORMAT)

Record 1			
Word Numbers	Type	NCOL, NROW, NF, NTYPE, WORD1, WORD2 (4I8, A8)	
1	Integer	NCOL	Number of columns
2	Integer	NROW	Number of rows
3	Integer	NF	Form of matrix NF=2 General rectangular matrix NF=6 Symmetric matrix. Only the upper triangular (including diagonals) is inputted.
4	Integer	NTYPE	Type of matrix NTYPE=1 Real, single precision NTYPE=2 Real, double precision NTYPE=3 Complex, single precision NTYPE=4 Complex, double precision
5 and 6	Character	WORD1, WORD2	Character string up to 8 characters Two character string. Each has 4 characters. If no MNAME = ′c′ is specified, these characters are used as the name of the matrix.

<table>
<tr><td>Record
2</td><td colspan="3"></td></tr>
<tr><td>Word
Number</td><td>Type</td><td colspan="2">ICOL, IROW, NW, A(J) , J = IROW, IROW + NW / NC / ND - 1</td></tr>
<tr><td>1

2

3

NW</td><td>Integer

Integer

Integer

Real or
Complex,
Single or
Double
Precision</td><td>ICOL

IROW

NW

A</td><td>Column number

Row position of first nonzero term

Number of words in the column
For:
NTYPE = 1: NC = 1, ND = 1 and A is a real, single precision array
NTYPE = 2: NC = 1, ND = 2 and A is a real, double precision array
NTYPE = 3: NC = 2, ND = 1 and A is a complex, single precision array
NTYPE = 4: NC = 2, ND = 2 and A is a complex, double precision array</td></tr>
</table>

Record 2 is repeated for each column.

At the end of the file, Record 2 with the last column number plus +1 and at least one dummy value in A must be included. Thus, the total number of Record 2 in the file is NCOL + 1.

Remarks:

Remark 1 of **'ASSIGN MATRIX='**

A single continuation line can be used in the **'ASSIGN MATRIX='** executive command control if the first line ends in a comma (,)

CEND — The End of Executive Control Section

Description: Designates the end of the Executive Control Section.

Format:

CEND

Example:

```
CEND
```

Remarks:

CEND must exist at the end the Executive Control Section.

CPU

Number of Processors

Description: Defines the number of processors for parallel computation using OpenMP

Format:

CPU N

Example:

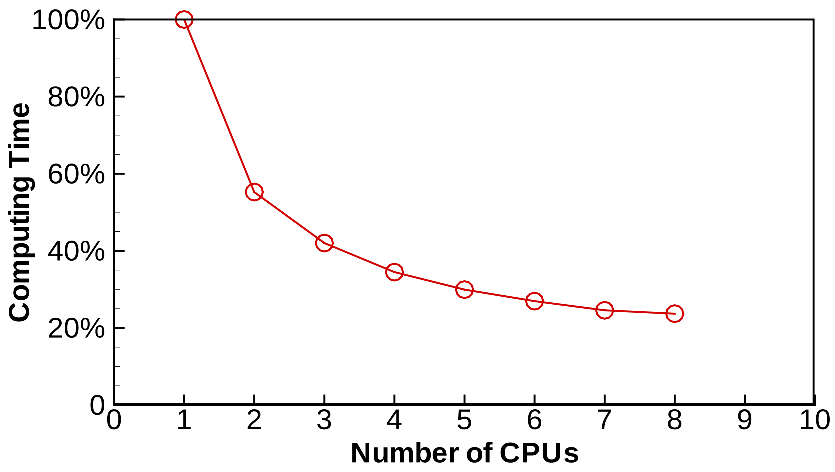
```
CPU 3
```

Describer	Meaning
N	Number of processors.

Remarks:

1. The **CPU** Executive Control Command is optional where N = 1 is the default value.

2. The following figure shows a typical savings of computational time v.s. number of processors.



DESSEN

Geometry Parameter Linking

Description: Activates the linking of a set of dependent geometry parameters.

Format:

DESSEN N

Example:

```
DESSEN 100
```

Describer	Meaning
N	Integer refers to a **DESSEN** bulk data card in the bulk data card section. (Default N=0)

Remarks:

1. The **DESSEN** Executive Control Command activates the linking of a set of geometry parameters by referring to a **DESSEN** bulk data card. If no **DESSEN** Executive Control Command is specified, then the **DESSEN** bulk data card is not activated.

DIAG

Diagnostic Output Options

Description: Request diagnostic output on special options.

Format:

DIAG $K_1, K_2, \ldots, K_i$

Example 1:

```
DIAG  1
```

Example 2:

```
DIAG  1, 3
```

Describer	Meaning
K_i	A list separated by commas of desired diagnostic.

Remarks:

1. The **DIAG** command is optional.

2. Multiple **DIAG** commands are allowed.

3. The following are the possible values for K_i and their corresponding actions.

   K = 1 Turn on the dynamic memory allocation debugger.
   K = 2 Print out the dynamic memory allocation history.
   This will generate massive output due to the large number of memory calls.
   K = 3 Turn on the database file manager debugger.

DOUBLE

Convert from Single Precision to Double Precision Computation

Description: Convert the entire computation of the program from single precision to double precision on 32-bit computers.

Format:

DOUBLE

Example 1:

```
DOUBLE
```

Remarks:

1. The **DOUBLE** command is optional.

2. This command also converts all matrix entities stored on the runtime database from single precision to double precision. Note that the specification of the **DOUBLE** Executive Control Command is highly recommended in the case where the stiffness matrix such as the KGG matrix (KGG matrix is defined as the G-set stiffness matrix) is imported by the **'ASSIGN MATRIX='** Executive Control Command or the **DMI/DMIG** bulk data card. This is because the KGG matrix normally requires high precision to store it. On a 32 bit computer, the single precision computation (without the **DOUBLE** Executive Control Command) involving the KGG matrix will yield large errors due to the truncation error.

MEMORY **Allocable Maximum Memory**

Description: Defines the maximum memory in terms of megabytes (MB) that is allocable by ZONAIR from the computers heap space memory.

Format:

MEMORY nMB

Example:

```
MEMORY 32MB
```

Remarks:

1. The **MEMORY** command is optional. If no **MEMORY** command is specified, the default value is 1,600 megabytes (1,600MB) for 32-bit executable code or 8,000 megabytes (8,000MB) for 64-bit executable code.

2. nMB represents an integer followed by the characters ‘MB’.

3. ZONAIR dynamically allocates memory within the computers heap space memory for matrix operations. For large matrices, ZONAIR will occupy a large portion of the heap space for in-core matrix operations. This may degrade the performance of other jobs that are simultaneously running on the computer. To circumvent this problem, it is recommended that the **MEMORY** command be used to define the maximum allocable memory by ZONAIR so that the out-of-core matrix operations are employed for large size problems. In this case, the rest of the computers heap space can be reserved for other jobs.

SOLUTION — Alter the Solution Sequence

Description: Specifies the solution sequence.

Format:

SOLUTION n

Example:

```
SOL -1
```

Remarks:

1. The **SOLUTION** command is optional (default is 0).
2. A blank space must exist between the character string SOLUTION and the negative integer.
3. n denotes an integer. Currently, only three options are available:

SOL 0	No structural FEM result is imported. All results are computed for the "rigid" aerodynamic configuration
SOL 1	Structural FEM results are imported by the **'ASSIGN FEM='** Executive Control Command. This allows the flexible aerodynamic loads to be computed.
SOL -1	Stops the program execution after the aerodynamic geometry module is computed. This gives the user the option to verify the aerodynamic panel model before computing the aerodynamic solutions.

$ Comment Statement

Description: Used to insert comments into the Executive Control Section.

Format:

$ followed by any characters up to column 80.

Example:

```
$   This is a test case.
```

Remarks:

1. $ must appear in the first column.
2. This command can be repeatedly used anywhere in the Executive Control Section.

3.2 CASE CONTROL SECTION

The Case Control Section allows the following Case Control Commands:

Command	Description	Remarks
AEROGEN	Invokes the aerodynamic analysis.	Optional
BEGIN BULK	To end the Case Control Section and also to indicate the beginning of the Bulk Data Section.	Required
ECHO	Controls echo (printout) of the Bulk Data Section.	Optional
FLEXLD	Refers to an identification number of the **FLEXLD** bulk data card for flexible loads analysis.	Optional
GENBASE	Generates an Aerodynamic Database.	Optional
JIGCP	Corrects the pressure distribution from the cruise shape to the jig shape.	Optional
JIGSHP	Determines the jig shape.	Optional
LABEL	Provides additional description of the subcase by a character string (up to 56 characters).	Optional
SUBCASE	Delimits and identifies a subcase section.	Required
SUBTITLE	Defines a subtitle of each subcase section by a character string (up to 56 characters).	Optional
TITLE	Describes the job by a character string (up to 56 characters).	Optional
THERMAL	Invokes the aeroheating analysis.	Optional
TRIM	Invokes the static aeroelastic/trim analysis discipline.	Optional
WT1CFD	Refers to a **WT1CFD** bulk data card to perform AIC correction	Optional
$	Comment statement.	Optional

- All Case Control Commands can be written either in lower case or upper case.
- The Case Control Section may contain many subcases. Each subcase is initiated by the command **SUBCASE**.
- Within each subcase, only one discipline among can be selected.
- **TITLE** and **ECHO** must appear before the subcase section.
- **SUBTITLE** and **LABEL** must appear within the subcase section.

AEROGEN **Invokes the Aerodynamic Analysis Discipline**

Description: Invokes the aerodynamic analysis discipline by pointing to an identification number of the **AEROGEN** bulk data card.

Format:

AEROGEN = n

Example:

```
AEROGEN = 100
```

Remarks:

1. **AEROGEN** Case Control Command must appear within a subcase section, i.e., between two **SUBCASE** Case Control Commands.

2. The integer n is the identification number of the **AEROGEN** bulk data card (Integer > 0). This **AEROGEN** bulk data card must exist in the Bulk Data Section.

3. **AEROGEN** and n must be separated by an equal sign (' = ').

BEGIN BULK — The End of the Case Control Section

Description: To signify the end of the Case Control Section and the beginning of the Bulk Data Section.

Format:

BEGIN BULK

Example:

```
BEGIN BULK
```

Remarks:

BEGIN BULK must be located at the end of the Case Control Section.

ECHO

Controls Echo of the Bulk Data Section

Description: Controls the echo (printout) of the Bulk Data Section.

Format:

$$\textbf{ECHO} = \left\{ \begin{array}{c} \text{NONE} \\ \text{SORT} \\ \text{NOSORT} \end{array} \right\}$$

Example:

```
ECHO  =  NOSORT
```

Remarks:

1. **ECHO** = NONE — no print.
   ECHO = SORT — print out bulk data input cards in alphanumeric order.
   ECHO = NOSORT — print out the unsorted bulk data input cards.

2. If no **ECHO** is specified, **ECHO** = NONE is used.

3. **ECHO** must appear before any **SUBCASE** Case Control Command.

4. No more than one **ECHO** is allowed.

5. The equal sign (' = ') is required.

FLEXLD **Invokes the Flexible Loads Analysis**

Description: Invokes the aerodynamic analysis on flexible aircraft by referring to an identification number of the **FLEXLD** bulk data card. The Executive Control Commands: **'ASSIGN FEM='** and **'SOL 1'** are required to import the structural finite element solution and to activate of spline module, respectively.

Format:

FLEXLD = n

Example:

```
FLEXLD = 100
```

Remarks:

1. **FLEXLD** Case Control Command must appear within a subcase section; i.e., between two **SUBCASE** Case Control Commands.

2. The integer *n* is the identification number a **FLEXLD** bulk data card (Integer > 0). This **FLEXLD** bulk data card must exist in the Bulk Data Section.

3. FLEXLD and *n* must be separated by an equal sign ("=").

GENBASE — Generates an Aerodynamic Database

Description: Generates an aerodynamic database by referring to a **GENBASE** bulk data card.

Format:

GENBASE = N

Example:

```
GENBASE = 100
```

Remarks:

1. The **GENBASE** Case Control Command must appear within a subcase section; i.e., between two subcase control commands.

2. The integer N is the identification number of a **GENBASE** bulk data card (Integer > 0). This **GENBASE** bulk data card refers to a number of **AEROGEN** bulk data cards whose computed aerodynamic force and moment coefficients are exported to an external file.

3. GENBASE and N must be separated by an equals sign (“=”).

JIGCP

Invoke the JIGCP Module

Description: Invoke the JIGCP module to correct the pressure coefficients on the cruise shape to those on the jig shape.

Format:

JIGCP = n

Example:

```
JIGCP = 100
```

Remarks:

1. The **JIGCP** case control command must appear within a subcase section, i.e., between two **SUBCASE** control commands.

2. The integer n refers to the identification number of a **JIGCP** bulk data card.

3. To activate the **JIGCP** module, the "**SOLUTION 1**" and "**ASSIGN FEM=**" executive control commands must be specified. In addition, the SPLINE module must be activated.

JIGSHP

Invoke the JIGSHP Module

Description: Invoke the JIGSHP module to determine the jig shape.

Format:

JIGSHP = n

Example:

```
JIGSHP = 100
```

Remarks:

1. The **JIGSHP** case control command must appear within a subcase section, i.e., between two **SUBCASE** control commands.

2. The integer n refers to the identification number of a **JIGSHP** bulk data card.

3. To activate the **JIGSHP** module, the "**SOLUTION 1**" and "**ASSIGN FEM=**" executive control commands must be specified. In addition, the SPLINE module must be activated.

LABEL

Provides Additional Description of a Subcase

Description: Provides additional description of a subcase by a character string up to 56 characters in length.

Format:

LABEL = ' A '

Example:

```
LABEL =  This is a test case.
```

Remarks:

1. The **LABEL** Case Control Command must appear within a subcase section.

2. ' A ' represents a character string up to 56 characters in length that allows for additional description of the subcase within which the **LABEL** Case Control Command is located.

3. Within each subcase section, only one **LABEL** Case Control Command is allowed.

4. If no **LABEL** exists in a subcase section, then the character string ' A ' is blank.

SUBCASE **Delimits and Identify a Subcase Section**

Description: To start a subcase section and assign an identification number to the subcase.

Format:

SUBCASE = n

Example:

```
SUBCASE = 2
```

Remarks:

1. The Case Control Section can contain many subcase sections. Each subcase section must be started by a **SUBCASE** = n Case Control Command.

2. ‘n’ is an integer that assigns an identification number to the subcase section. Among all **SUBCASE** Case Control Commands n must be unique.

3. Within each subcase section, only one discipline (e.g., **AEROGEN, TRIM** and **THERMAL** Case Control Commands) is allowed.

4. **SUBTITLE** and **LABEL** Case Control Commands must be located within each subcase section.

SUBTITLE

Defines a Subtitle of Each Subcase Section

Description: Defines a subtitle of each subcase section by a character string up to 56 characters in length.

Format:

SUBTITLE = ' A '

Example:

```
SUBTITLE = TRIM Analysis at M = 0.8
```

Remarks:

1. The **SUBTITLE** Case Control Command must appear within a subcase section.
2. ' A ' represents a character string up to 56 characters in length that allows for additional description of the subcase section.
3. Within each subcase section, only one **SUBTITLE** Case Control Command is allowed.
4. If no **SUBTITLE** exists in a subcase section, then the character string ' A ' is blank.

THERMAL — Invokes the Aeroheating Analysis Discipline

Description: Invokes the aeroheating analysis discipline by pointing to an identification number of the **THERMAL** bulk data card.

Format:

THERMAL = n

Example:

```
THERMAL = 100
```

Remarks:

1. **THERMAL** Case Control Command must appear within a subcase section, i.e., between two **SUBCASE** Case Control Commands.

2. The integer n is the identification number of the **THERMAL** bulk data card (Integer > 0). This **THERMAL** bulk data card must exist in the Bulk Data Section.

3. **THERMAL** and n must be separated by an equal sign ('=').

TITLE

Title of the Job

Description: Provides the title of the job by a character string up to 56 characters in length.

Format:

TITLE = ' A '

Example:

```
TITLE = ZONAIR Analysis of a Demo Case
```

Remarks:

1. Only one **TITLE** Case Control Command is allowed in the entire Case Control Section. **TITLE** must appear before the **SUBCASE** Case Control Command.

2. ' A ' represents a character string up to 56 characters in length to provide the title of the job.

3. If no **TITLE** exists in a subcase section, then the character string ' A ' is blank.

TRIM

Invokes the Static Aeroelastic/Trim Analysis Discipline

Description: Invokes the static aeroelastic/trim analysis discipline by referring to an identification number of the **TRIM** bulk data card. If “SOL 1” is specified in the Executive Control Section, both trim results on the “rigid” and “flexible” configurations are computed.

Format:

TRIM = n

Example:

```
TRIM = 103
```

Remarks:

1. The **TRIM** Case Control Command must appear within a subcase section, i.e., between two **SUBCASE** Case Control Commands.

2. The integer n is the identification number of the **TRIM** bulk data card (Integer > 0). This **TRIM** bulk data card must exist in the Bulk Data Section.

3. **TRIM** and n must be separated by an equal sign (' = ').

4. For a symmetric trim system (trim system involving only the longitudinal degrees of freedom) with structural flexibility, the free vibration solution of the finite element model with symmetric boundary condition must be imported by the **‘ASSIGN FEM=’** Executive Control Command with BOUNDARY = ‘SYM’. For an anti-symmetric trim system (trim system involving only the lateral degrees of freedom), the free vibration solution of the finite element model with anti-symmetric boundary condition must be imported by the **‘ASSIGN FEM=’** Executive Control Command with BOUNDARY = ‘ANTI’. For an asymmetric trim system (trim system involving both the longitudinal and the lateral degrees of freedom), both free vibration solutions must be imported. However, for an asymmetric configuration (entry XZSYM = “NO” in the **AEROZ** bulk data card), only one **‘ASSIGN FEM=’** Executive Control Command with BOUNDARY = ‘ASYM’ is required.

5. Computing the distributed inertial loads resulting from the trim system requires a matrix called ‘SMGH’ for symmetric (or asymmetric) structural boundary condition and a matrix called ‘AMGH’ for anti-symmetric structural boundary condition to be inputted by the **‘ASSIGN MATRIX=’** Executive Control Command.

These matrices are the product of the G-set mass matrix and the G-set modal matrix of the structural finite element model (G-set is defined as 6 × number of structural finite element grid points). The equations to obtain these matrices are shown as follows:

$$[SMGH] = [MGG][PHG]_s$$

$$[AMGH] = [MGG][PHG]_a$$

where

$[MGG]$ is the mass matrix of the G-set d.o.f.

$[PHG]_s$ is the symmetric modal matrix of the G-set d.o.f.

and

$[PHG]_a$ is the anti-symmetric modal matrix of the G-set d.o.f.

[*SMGH*] and [*AMGH*] are used to compute the so-called inertial coupling matrices between the structural modes and the control surface modes.

The following example shows the MSC.NASTRAN DMAP alter statements that generate these matrices by the NASTRAN/OUTPUT4 module.

Note: 'SMGH' or 'AMGH' is required only if the structural finite element contains rigid body degrees of freedom; i.e., the SUPORT entry in the '**ASSIGN FEM=**' Executive Control Command specifies a non-zero integer.

```
ASSIGN OUTPUT4='demo1.mgh',UNIT=12,FORM=FORMATTED
SOL 103
COMPILE SEMODES SOUIN=MSCSOU LIST NOREF  $
ALTER 'STRAIN ENGERGY'
MATGEN EQEXINS/INTEXT/9//LUSETS $ GENERATE EXTERNAL SEQUENCE MATRIX
MPYAD MGG,PHG,/MGHINT $ MGHINT IS THE MGH IN INTERNAL SEQUENCE
MPYAD INTEXT,MGHINT,/MGH/1 $ TRANSFORM MGHINT TO EXTERNAL SEQUENCE
OUTPUT4 MGH//-1/12/2 $ OUTPUT MGH TO UNIT=12 IN demo1.mgh
ENDALTER
CEND
```

Once the file ′demo1.mgh′ is generated by NASTRAN, it can be directly input into ZONAIR by the **'ASSIGN MATRIX='** Executive Control Command.

- The format for symmetric or asymmetric boundary condition is:
  ASSIGN MATRIX = ′demo1.mgh′, MNAME = ′SMGH′, FORM = ′FORMAT′

- The format for anti-symmetric boundary condition is:
  ASSIGN MATRIX = ′demo1.mgh′, MNAME = ′AMGH′, FORM = ′FORMAT′

Note that the name of the matrix is defined as ′MGH′ in the NASTRAN DMAP alter statements. However, in the **'ASSIGN MATRIX='** Executive Control Command for trim analysis, it is replaced by MNAME = ′SMGH′ for the symmetric boundary condition and MNAME = ′AMGH′ for the anti-symmetric boundary condition.

An alternative way to obtain the SMGH and/or AMGH matrices is to import the MGG matrix directly. This can be achieved by using the following Executive Control Command:

ASSIGN MATRIX = filename,   MNAME = 'MGG'

Once the MGG matrix is imported, ZONAIR will automatically compute the SMGH and/or AMGH matrices by multiplying the MGG matrix by the modal matrix.

The following example shows the MSC.NASTRAN DMAP alter statements that generate the MGG matrix:

```
ASSIGN OUTPUT4='demo1.mgg',UNIT=12,FORM=FORMATTED
SOL 103
COMPILE SEMODES SOUIN=MSCSOU LIST NOREF  $
ALTER 'STRAIN ENGERGY'
MATGEN EQEXINS/INTEXT/9//LUSETS $ GENERATE EXTERNAL SEQUENCE MATRIX
MPYAD INTEXT,MGG,/MGGT/1 $ TRANSFORM MGG TO EXTERNAL SEQUENCE
OUTPUT4 MGGT//-1/12/2 $ OUTPUT MGG TO UNIT=12 IN demo1.mgg
ENDALTER
CEND
```

WT1CFD

Perform AIC Correction

Description: Refers to a **WT1CFD** bulk data card to generate the corrected AIC matrix by the force correction method.

Format:

WT1CFD = n

Example:

```
WT1CFD = 100
```

Remarks:

1. The **WT1CFD** Case Control Command must appear within a subcase section, i.e., between two **SUBCASE** Case Control Commands.

2. The integer n is the identification number of a **WT1CFD** bulk data card (Integer > 0). This **WT1CFD** bulk data card must exist in the Bulk Data Section.

$ Comment Statement

Description: Used to insert comments into the Case Control Section.

Format:

$ followed by any characters up to column 80.

Example:

```
$  The next command is FLUTTER
```

Remarks:

1. **$** must appear in the first column.
2. This command can be repeatedly used anywhere in the Case Control Section.

Chapter 4

ZONAIR BULK DATA SECTION

The Bulk Data Section begins right after the **BEGIN BULK** Case Control Command and ends at a bulk data card **ENDDATA**. The Bulk Data Section contains bulk data cards that specify:

- the geometry of the aerodynamic model
- spline for displacement and force transferal between the structural finite element grid points and aerodynamic panels for static aeroelastic analysis
- the Mach numbers, aerodynamic methods and flight conditions for aerodynamic result generation
- disciplines (aerodynamic analysis, aeroheating analysis, trim analysis … etc.) to be analyzed
- other miscellaneous inputs

4.1 FORMAT OF BULK DATA CARDS

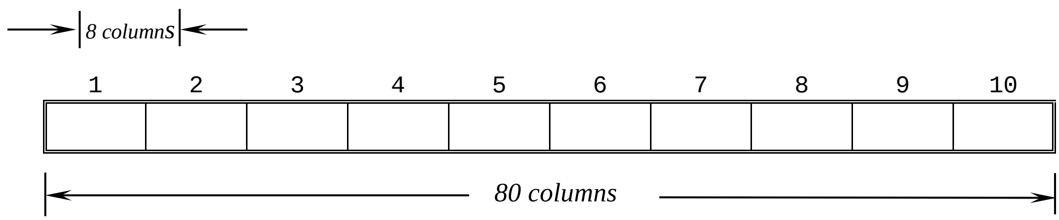
The format of bulk data cards is identical to that in NASTRAN except for the so-called 'Large Field Entry' (i.e., 16 characters wide) which is not allowed (for definition of 'Large Field Entry', please see a NASTRAN User's Manual).

The bulk data card contains ten fields per input data entry. The first field contains the character name of the bulk data card. Fields two through nine contain data input information for the bulk data entry. The tenth field never contains data – it is reserved for a continuation card, if applicable.

Two types of format are allowed for each bulk data card; the fixed format and free format.

Fixed Format

Fixed format separates a bulk data card into ten equal fields of eight columns each.



A typical bulk data card is shown as follows:

1	2	3	4	5	6	7	8	9	10
PANLST1	SETID	MACROID	BOX1	BOX2					

Name of the Bulk Data Card

entries

not used

Field 10 is used only for optional continuation

Example:

PANLST1	100	111	111	118					

The name of the bulk data card <u>must appear in the first field and start from the first column</u>. Three possible types of data can be specified for bulk data entries and are described as follows.

Integer	numerical value with no decimal point
Real	numerical value with a decimal point
Character	can be any alphanumeric string

Real numbers may be specified in various way. The following examples are all acceptable:

```
3.14       3.14E+00    .314+01
.314+1     .314E+1     31.4-01
```

The above example shows that each bulk data card allows 8 entries to be specified from field 2 to field 9. If there are more than 8 entries required for a bulk data card, the so-called "continuation label" is required in the tenth field and more than one input cards are needed. The additional input cards are called "continuation lines". A typical example of this kind of bulk data card is shown as follows:

AEFACT	SID	D1	D2	D3	D4	D5	D6	D7	CONT

"CONT" can be any alphanumeric string including blanks

CONT	D8	D9	etc.						

Example:

AEFACT	100	0.0	0.2	0.3	0.4	0.5	0.6	0.7	+A
+A	0.8	0.9							

There are several major differences between ZONAIR and NASTRAN regarding the treatment of continuation lines. <u>ZONAIR has the following restrictions</u>:

- The continuation lines must follow their associated bulk data card. No other bulk data cards can be inserted between continuation lines except a comment (**$**).
- If continuation label is blank, no other bulk data cards can be inserted between continuation lines including a comment (**$**).
- Duplicate continuation labels may be used. For example, the following bulk data cards with continuation lines are acceptable:

Example 1:

AEFACT	100	0.0	0.2	0.3	0.4	0.5	0.6	0.7	+A
+A	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	+A
A+	1.6								

Example 2:

AEFACT	100	0.0	0.2	0.3	0.4	0.5	0.6	0.7	+A
+A	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	+B
+B	1.6								

<u>Free Format</u>

In free format, the data entries must be separated by commas (separation by a blank is not allowed). The following shows the **AEFACT** bulk data card with one continuation line in free format:

Indicates an empty field; default value will be used.

AEFACT, 100, , 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, +A
+A, 0.8, 0.9

There are several rules for free format:

- Free format data must start in column 1.
- Each data entry (for all three types of data: integer, real and character) cannot exceed 8 columns.
- To skip one entry, use two commas in succession (and so on).
- Fixed format and free format can be mixed. For example, the following is acceptable:

AEFACT	100	0.0	0.2	0.3	0.4	0.5	0.6	0.7	+A

+A, 0.8, 0.9

4.2 BULK DATA CARDS SUMMARY AND INTERRELATIONSHIPS

This section contains a summary of all the bulk data cards in the ZONAIR system separated into logically related groups according to the ZONAIR engineering modules. These modules are shown in the Figure 4.1. Note that the SPLINE module is invoked only if the Executive Control Command **'SOLUTION 1'** is specified that activates the inclusion of structural flexibility effects for the trim analysis.

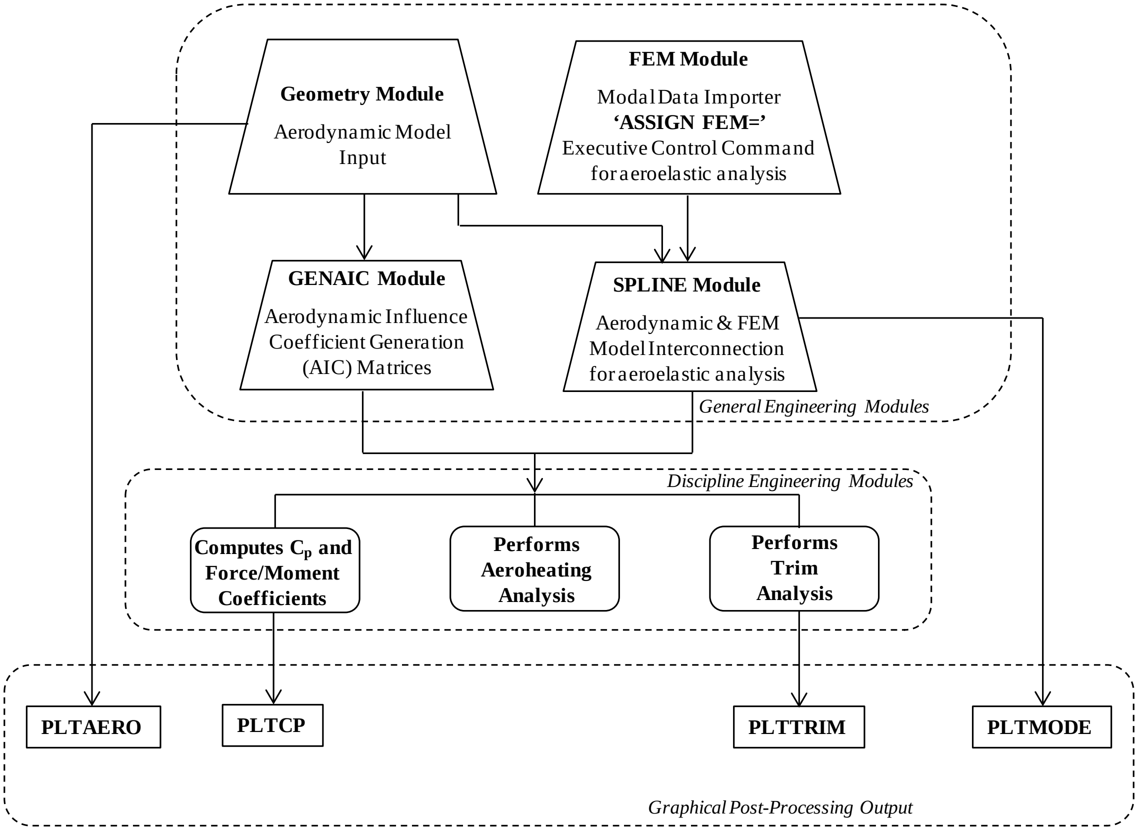


Figure 4.1 ZONAIR Engineering Module Diagram

4.2.1 AERODYNAMIC MODEL INPUT

The bulk data cards used to define the aerodynamic model are listed in the following table. If the user to convert aerodynamic model from half span to full span model, a standalone code half2full is provided in miscel folder that can automatically accomplish the task.

Name	Description	Remarks
ACOORD	Aerodynamic local coordinate system definition.	Optional
AEROZ	Basic aerodynamic reference parameters.	Required
AESLINK	Linking a set of **AESURFZ** bulk data card.	Optional
AESURFZ	Aerodynamic control surface definition.	Optional
AUTOBAR	Generates a set of CBAR.	Optional
AUTOROD	Generates a set of CROD.	Optional
AUTOTIP	Tip modeling of a thick-wing component.	Optional
AUTOVOR	Automatically generates a VORNET macroelement	Optional
BODY7	Aerodynamic body macroelement of a body-like component.	Optional
CAERO7	Aerodynamic thin-wing component geometry input.	Optional
CAEROCP	Apply a factor to the pressure coefficients on the CAERO7 macroelements.	Optional
CBAR	Wake element for flat wake surface by specifying two surface grid points.	Optional
CQUAD4	Quadrilateral aerodynamic surface panel.	Optional
CROD	Line Vortex element.	Optional
CSHEAR	Wake panel on the curved wake surface.	Optional
CTRIA3	Triangular aerodynamic surface panel.	Optional
EXTFILE	Defines a character string as the name of an external file.	Optional
FOILSEC	Defines an NACA-series type of airfoil section.	Optional
GRID	Location of a surface or a reference grid point.	Required for arbitrary panel model
JETFRC	Control force due to jet.	Optional
JOINTHK	Join Two THKWING's.	Optional

MATBODY	Aerodynamic component by grouping a set of CQUAD4/CTRIA3 panels.	Required if **CQUAD4/CTRIA3** bulk data card exists.
MATWAKE	Label of a curved wake surface.	Required if **CSHEAR** bulk data card exists.
PAFOIL7	Defines airfoil cross sections at the root and tip of a **CAERO7**.	Optional
PAFOIL8	Alternative form of the **PAFOIL7** bulk data card.	Optional
PSHEAR	Properties of the CSHEAR panels.	Required if **CSHEAR** bulk data card exists.
PSHELL	Properties of the CQUAD4/CTRIA3 panels.	Required if **CQUAD4/CTRIA3** exists.
PZTMODE	Control forces due to smart structural actuation.	Optional
RBAR	Combines two grid points into one point.	Optional
RBE2	Wake condition behind the thick-wing and body junction.	Optional
RELAXW	Wake relaxation.	Optional
SLICE	Slice a closed wing trailing edge.	Optional
THKWING	Aerodynamic thick-wing component.	Optional
VISCOUS	Defines the viscous parameters for computing the skin frictions.	Optional
VORNET	Macroelement for vortex roll-up model.	Optional
WAKENET	Wake macroelement for curved wake surface.	Optional

Figure 4.2 presents a flow chart showing the interrelationship of the bulk data cards for aerodynamic geometry input.

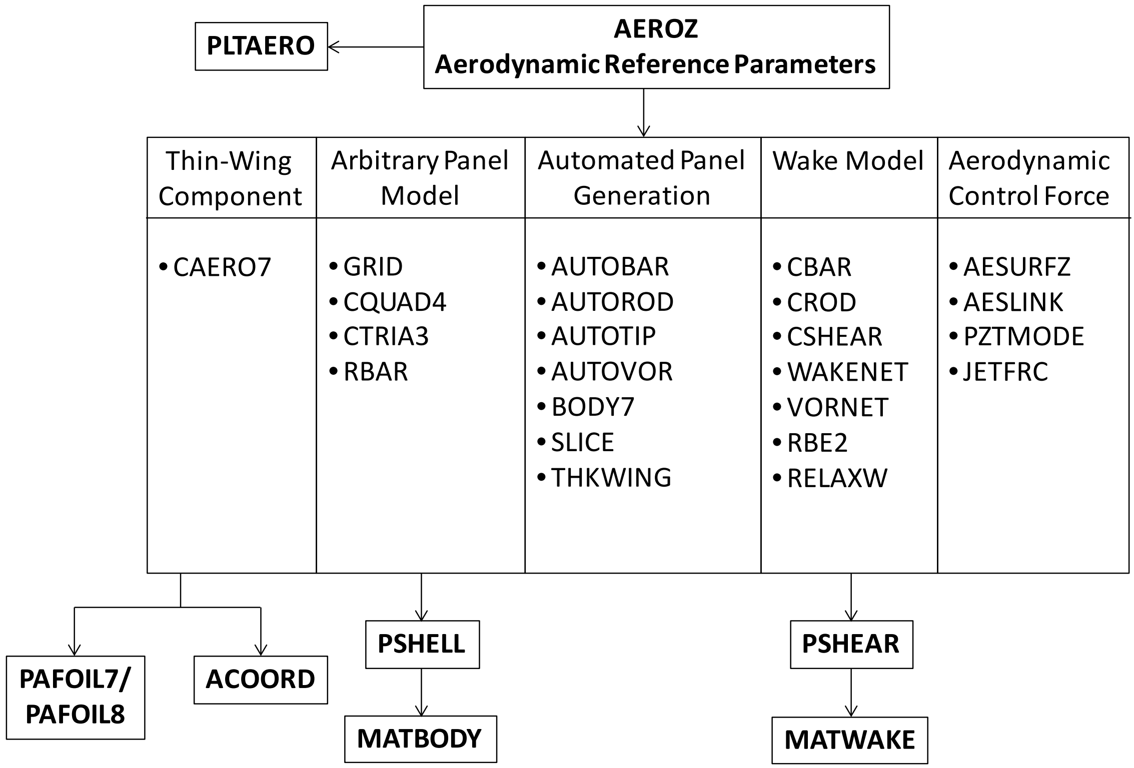


Figure 4.2 Bulk Data Interrelationship for Aerodynamic Geometry Input

4.2.2 SPLINE INPUT (SPLINE MODULE)

The SPLINE module is invoked only if the Executive Control Command **'SOLUTION 1'** is specified that activates the inclusion of structural flexibility effects for flexible aerodynamic analysis. In other words, all bulk data cards related to the SPLINE module are used only if the Executive Control Command **'SOLUTION 1'** is specified. The bulk data cards of Spline Input define the interconnection between the aerodynamic model and the structural finite element model for displacement and force transferal. Specifically, the spline input generates a spline matrix that "attaches" every aerodynamic panel to a set of structural finite element grid points. Here, the aerodynamic panels represent the discretized aerodynamic model that is defined by the aerodynamic geometry input. The structural finite element grid points are imported through the external file specified in the **'ASSIGN FEM='** Executive Control Command.

The following table presents the bulk data cards for the spline input:

Name	Description	Remarks
ATTACH	Defines a rigid body connection between aerodynamic panels and structural finite element grid points.	Optional
PANADD	Internally generates a **PANLST2** bulk data card by adding other **PANLST2/PANLST3** bulk data card together	Optional
PANLST1	Defines a set of aerodynamic panels (region defined by 2 aerodynamic panel identification numbers).	Optional
PANLST2	Defines a set of aerodynamic panels (region defined by individual aerodynamic panel identification numbers).	Optional
PANLST3	Defines a set of aerodynamic panels (region defined by the entry LABEL in the **CAERO7, BODY7,** or **MATBODY** bulk data card).	Optional, but all aerodynamic panel identification numbers must be uniquely and completely listed in **PANLST1**, **PANLST2** and/or **PANLST3**
PANRMV	Internally generates a **PANLST2** bulk data card by removing the panel identification numbers listed in a **PANLST2/PANLST3** bulk data card from those listed in other **PANLST2/PANLST3** bulk data cards	Optional
SET2	Defines the aerodynamic macroelements in term of spanwise and chordwise points (zone) for spline.	Optional
SPLINE0	Imposes zero-displacement condition on aerodynamic panels.	Optional
SPLINE1	Defines a surface spline method (Infinite Plate Spline method) for **CAERO7**.	Optional
SPLINE2	Defines a beam spline method for **CAERO7/BODY7/ CQUAD4/CTRIA3**.	Optional
SPLINE3	Defines a 3-D spline (Thin Plate Spline method) for **CAERO7** / **BODY7 /CQUAD4 / CTRIA3**.	Optional
SPLINEF	Spline matrix for force mapping.	Optional
SPLINEM	Saves or retrieves the spline matrix.	Optional

It should be noted that all identification numbers of the aerodynamic panels must be uniquely and completely specified in the **PANLST1**, **PANLST2** and/or **PANLST3** bulk data cards. Violation of this condition results in fatal errors as following:

```
FATAL ERROR: AERODYNAMIC PANEL WITH ID = ' xxxx ' IS NOT ATTACHED TO
FEM MODEL
```

⇒ This indicates that the aerodynamic panel with identification number = ' xxxx ' is not specified in the **PANLST1, PANLST2** and/or **PANLST3** bulk data cards.

```
FATAL ERROR: AERODYNAMIC PANEL WITH ID = ' xxxx ' = HAS BEEN SPLINED
MORE THAN ONCE
```

⇒ This indicates that the aerodynamic panel with identification number = ' xxxx ' is repetitively specified in the **PANLST1**, **PANLST2** and/or **PANLST3** bulk data cards.

Figure 4.3 depicts the interrelationships of the bulk data cards for spline:

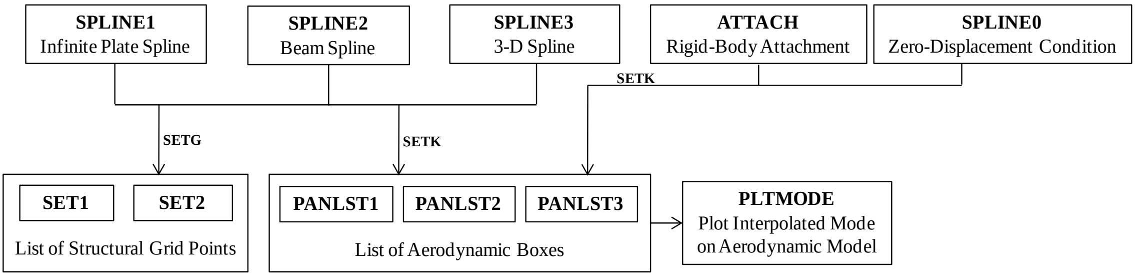


Figure 4.3 Bulk Data Interrelationship for Spline

4.2.3 AERODYNAMIC ANALYSIS FOR COMPUTING THE PRESSURE AND FORCE/MOMENT COEFFICIENTS

The bulk data cards for the aerodynamic analysis are listed as follows:

Name	Description	Remarks
AEROGEN	Defines the flight conditions.	Required
AJJSAV	Save or retrieve the aerodynamic influence coefficient matrix for stability derivatives.	Optional
CPFACT	Weighting Factor for Pressure Derivatives	Optional
CPSPLN	Maps the wind tunnel measured pressures onto ZONAIR aerodynamic panels by spline to replace ZONAIR computed pressures.	Optional

CPSPLNL	Maps the wind tunnel measured pressure coefficients onto ZONAIR aerodynamic panels by a linear spline method to replace the ZONAIR computed solution.	Optional
FLEXLD	Computes the aerodynamic pressure coefficients, forces and moments of a flexible aircraft.	Optional
FLOWPT	Aerodynamic solutions at flow field points.	Optional
GENBASE	Generates an aerodynamic database.	Optional
INPCFD	Imports the structured Computational Fluid Dynamics (CFD) solution and replaces that ZONAIR solution by the CFD solution.	Optional
INPCFD1	Imports the unstructured Computational Fluid Dynamics (CFD) solution and replaces that ZONAIR solution by the CFD solution.	Optional
INPDMI	Imports the user-supplied pressure coefficients via a direct matrix input to replace the pressure coefficient computed by ZONAIR.	Optional
JIGCP	Corrects the pressure distribution from the cruise shape to the jig shape.	Optional
JIGSHP	Determines the jig shape.	Optional
LESUCT	Activates the inclusion of additional lift due to vortex-up from wing leading edge	Optional
MACH	Generates Aerodynamic Influence Coefficient (AIC) matrix at a given Mach Number.	Required
MATCHLD	Corrects the pressure coefficient generated by the AEROGEN bulk data card to match a given set of sectional loads	Optional
OMITCFD	Defines the surface mesh index of a structured CFD mesh.	Optional
WT1AJJ	Corrects the AIC matrices by a force/moment correction matrix.	Optional
WT1CFD	Internally generates a **WT1AJJ** and a set of **WT1FRC** bulk data cards and executes the **WT1AJJ** bulk data card to generate the corrected AIC matrices.	Required if the **WT1CFD** case control command is specified
WT1FRC	Specifies a set of component forces and moments for generating the AIC weighting matrix.	Referred to by the **WT1AJJ** bulk data card
WT2AJJ	Corrects the AIC matrices by a downwash weighting matrix.	Optional

Figure 4.4 depicts the interrelationships of the bulk data card for aerodynamic analysis.

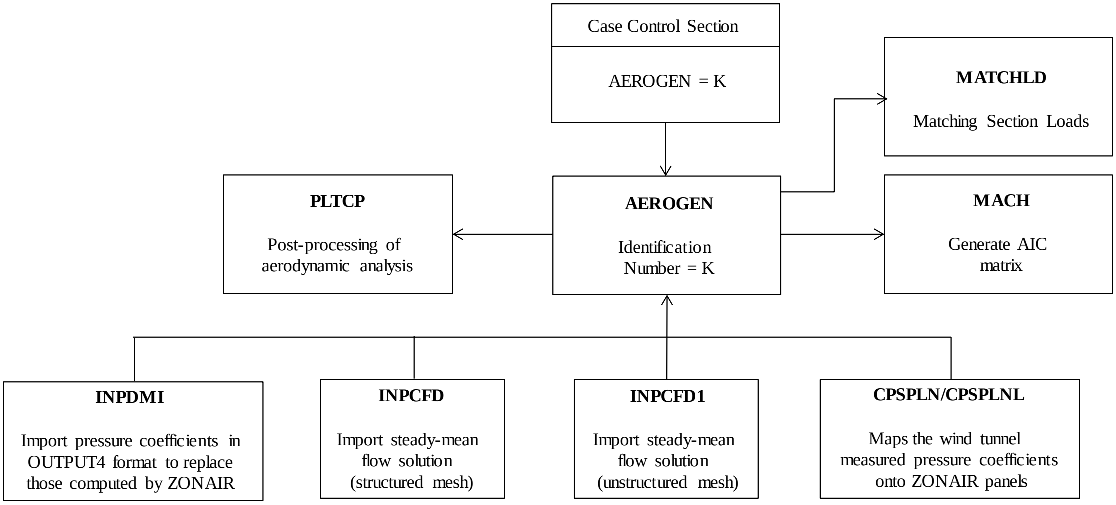


Figure 4.4 Bulk Data Interrelationship for Aerodynamic Analysis

The appearance of a **MACH** bulk data card in the Bulk Data Section "triggers" the computation of the AIC matrix even if this **MACH** bulk data card is not referred to by any other bulk data card. Note that the AIC matrix is only dependent on the Mach number and the aerodynamic panel model, it can be reused for different flight conditions (different α, β, p, q, r…etc.). Because the computation of the AIC matrix is time-consuming, a SAVE-RESTART capability is implemented in ZONAIR through the **MACH** bulk data card. The SAVE in the **MACH** bulk data card entry is used to specify whether to save the AIC matrix of the current run or the read from a previously saved AIC file (i.e., the restart process).

In the following conditions, the restart process becomes inapplicable, and a new AIC matrix must be computed (i.e., entry SAVE cannot be "ACQUIRE")

- Any change in the aerodynamic panel modeling
- Any change in the **MACH** bulk data card

4.2.4 AEROHEATING ANALYSIS

There is only one bulk data card called **THERMAL** required to perform the aeroheating analysis

Name	Description	Remarks
THERMAL	Performs the aeroheating analysis at a specified flight condition.	Required for aeroheating analysis

Figure 4.5 shows the interrelationship of the **THERMAL** bulk data card with other bulk data cards.

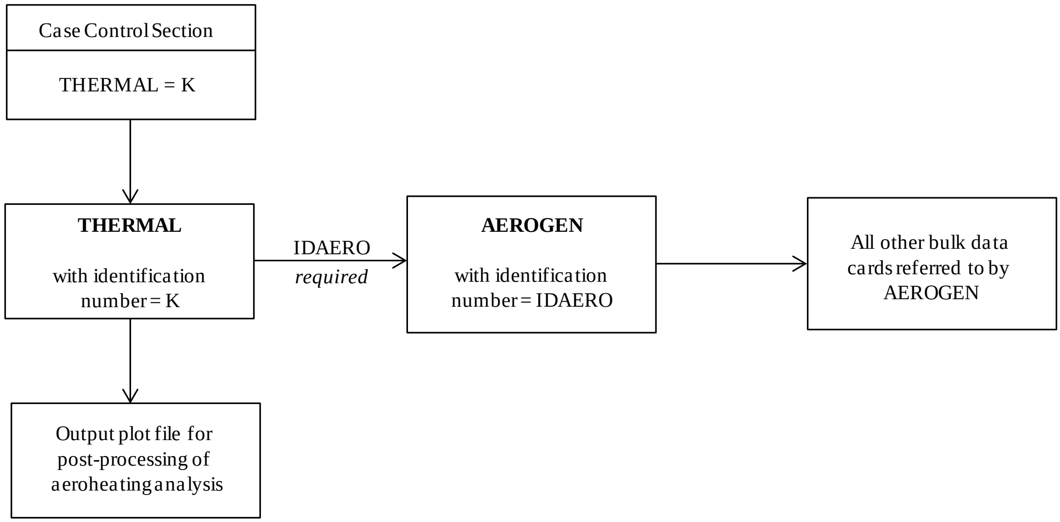


Figure 4.5 Bulk Data Interrelationship for Aeroheating Analysis

4.2.5 INPUT FOR STATIC AEROELASTIC/TRIM ANALYSIS (TRIM MODULE)

The function of the static aeroelastic/trim analysis is to solve the trim system and compute the flight loads. The solution of the trim system requires the balance of the inertial loads due to the accelerations of the trim degrees of freedom ($\ddot{X}$, $\ddot{Y}$, $\ddot{Z}$, $\dot{p}$, $\dot{q}$ and $\dot{r}$; see Figure 4.6) and the aerodynamic loads generated by the trim variables α, β, p, q, r, control surface deflections, …, etc.). It should be noted that the structural flexibility effects are included in the trim analysis only if the Executive Control Command **'SOLUTION 1'** is specified and the structural finite element modal solution is imported via the **'ASSIGN FEM='** Executive Control Command.

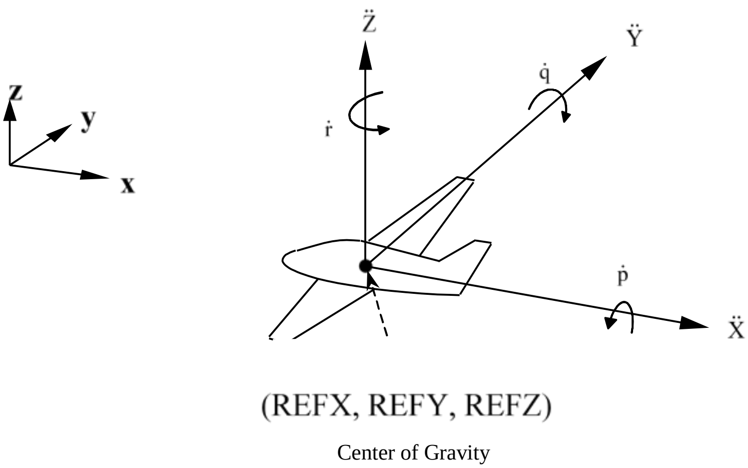


Figure 4.6 Definition of Trim Degrees of Freedom

There are several major differences between the ZONAIR solution technique and the NASTRAN solution technique in solving the trim system:

- ZONAIR employs the modal approach to solve the trim system of the flexible aircraft whereas NASTRAN uses the direct method that includes all structural degrees of freedom in the trim system. The modal approach assumes that the structural deformation $\{x\}$ can be approximated as:

  $$\{x\} = [PHG]\{q\}$$

  where $[PHG]$ is the modal matrix containing the lower order modes of the structural finite element model, and $\{\boldsymbol{q}\}$ are the generalized coordinates.

  Numerical experience shows that, for a complete aircraft structure, using the first fifty lower order modes for $[PHG]$ is sufficient to achieve a converged solution. The modal approach reduces the size of the trim system from over thousands degrees of freedom (for a complete aircraft structure, the number of degrees of freedom in the structural finite element model can easily be in the thousands) down to as low as fifty. Thus, the modal approach offers a solution technique that is much more efficient than the direct method.
- NASTRAN is only capable of solving the determined trim system (the number of unknowns equal to the number of trim degrees of freedom). In addition to the determined trim system, ZONAIR can also solve the over-determined trim system (i.e., where the number of unknowns is greater than the number of trim degrees of freedom) by using a feasible direction technique that minimizes a user-defined objective function while satisfying a set of constraint functions. The objective and constraint functions can be specified in terms of the so-called "trim functions" that include induced drag, component loads, element stresses, lower and upper limits of the trim variables, … etc.
- For the asymmetric flight condition, NASTRAN requires modeling of the whole aircraft both structurally and aerodynamically even if the configuration is symmetric about its mid-plane. By contrast, for a symmetric configuration ZONAIR only requires modeling of one half of the aircraft. ZONAIR superimposes the symmetric solutions and the anti-symmetric solutions to obtain the asymmetric solutions of the complete aircraft.

The bulk data cards for static aeroelastic/trim discipline are listed in the following table:

Name	Description	Remarks
TRIM	Defines the flight condition, rigid body mass matrix, trim degrees of freedom and trim variables to perform static aeroelastic/trim analysis.	Required, if the **TRIM** Case Control Command is selected in the Case Control Section.
TRIMADD	Defines a trim function as a function of other trim functions.	Optional
TRIMCON	Defines a set of constraint functions to be satisfied for solving the over-determined trim system.	Required only for the over-determined trim system.
TRIMFNC	Defines a trim function whose value is depended on the trim variables and trim degrees of freedom.	Required only for the over-determined trim system.

TRIMINP	Replaces the ZONAIR computed pressure derivatives with respect to the trim variable by user supplied values.	Optional
TRIMLNK	Defines a set of coefficient and trim variable identification number pairs for trim variable linking.	Optional
TRIMOBJ	Defines an objective function to be minimized for solving the over-determined trim system.	Required only for the over-determined trim system
TRIMSEN	Sensitivity analysis.	Optional
TRIMVAR	Defines a trim variable for the static aeroelastic/trim analysis.	Required if a **TRIM** bulk data card is active.

The interrelationship between the bulk data cards for static aeroelastic/trim analysis is depicted in Figure 4.7. In addition to the above listed bulk data cards, the **PLTTRIM** bulk data card (specified in Section 4.2.6) can be used to generate the plot files of the deformed aerodynamic model and steady pressure distributions. In addition, **PLTTRIM** can be used to generate a file that contains the flight loads in terms of NASTRAN **FORCE** and **MOMENT** bulk data cards at the structural finite element grid points. The user can insert this file back to the finite element model to perform a static analysis for detailed stress calculations.

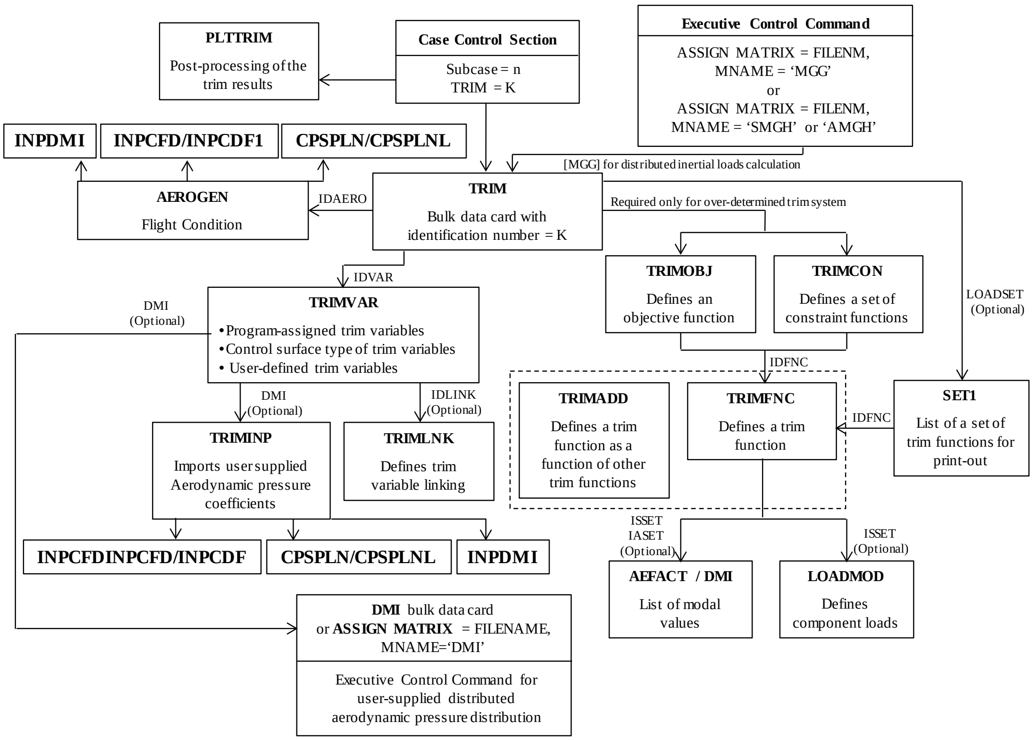


Figure 4.7 Bulk Data Interrelationship for Static Aeroelastic/Trim Analysis

It should be noted that, for a symmetric trim system (trim system involving only the longitudinal trim degrees of freedom; $\ddot{X}$, $\ddot{Z}$, and / or $\dot{q}$), the free vibration solution of the finite element model with symmetric boundary condition must be imported by the **'ASSIGN FEM='** Executive Control Command with BOUNDARY = 'SYM'. For an anti-symmetric trim system (trim system involving only the lateral trim degrees of freedom; $\ddot{Y}$, $\dot{p}$ and / or $\dot{r}$), the anti-symmetric free vibration solution must be imported by the **'ASSIGN FEM='** Executive Control Command with BOUNDARY = 'ANTI'. For the asymmetric trim system (involving both longitudinal and lateral trim degrees of freedom), both free vibration solutions must be imported. However, if the configuration is asymmetric about the x-z plane (XZSYM = 'NO' in the **AEROZ** bulk data card), only one free vibration solution with BOUNDARY = 'ASYM' is required.

In addition to the free vibration solutions, for computing the distributed inertial loads, the static aeroelastic/trim analysis also requires a matrix called [*SMGH*] for the symmetric trim system, a matrix called [*AMGH*] for the anti-symmetric trim system, and both for the asymmetric trim system that are imported by the **'ASSIGN MATRIX='** Executive Control Command. The distributed inertial loads exist only if the structural finite element model contains rigid body degrees of freedom (a non-zero integer specified by the SUPORT entry of the **'ASSIGN FEM='** Executive Control Command). The equation for computing the inertial loads of a symmetric trim system reads:

$$\{F_I\}_s = [MGG]\{\ddot{X}\}_s = [MGG][PHG]_s\{\ddot{u}_r\}_s = [SMGH]\{\ddot{u}_r\}_s$$

where

$\{F_I\}$	is the distributed inertial loads
$[MGG]$	is the mass matrix of the structural finite element model defined in the G-set d.o.f.
$[PHG]$	is the modal matrix of the free vibration solution that is imported by the **'ASSIGN FEM='** Executive Control Command
$\{\ddot{u}_r\}$	represents the accelerations of the trim degrees of freedom
$\{\ddot{X}\} = [PHG]\{\ddot{u}_r\}$	is the acceleration vector that is approximated by the modal approach in terms of the product of [*PHG*] and $\{\ddot{u}_r\}$
$[SMGH] = [MGG]\,[PHG]_s$	

and the subscript *s* denotes that the matrix/vector is for the symmetric structural modes.

Likewise, for the anti-symmetric trim system, it can be shown that the matrix [*AMGH*] is computed by:

$$[AMGH] = [MGG]\,[PHG]_a$$

where $[PHG]_a$ is the anti-symmetric modal matrix.

4.2.6 INPUT FOR PLOT FILE GENERATION

ZONAIR does not provide graphic capability. Instead, ZONAIR generates files that can be read by TECPLOT, FEMAP, PATRAN, or I-DEAS for post-processing. The bulk data cards shown in the following table can be specified to generate various output files.

Name	Description	Remarks
PLTAERO	Generates an ASCII text file for plotting the aerodynamic model.	Optional
PLTCP	Generates an ASCII text file for plotting the steady pressure coefficients.	Optional
PLTDCP	Generates an ASCII text file for plotting the derivative of pressure coefficients.	Optional
PLTMODE	Generates an ASCII text file for plotting the interpolated structural mode on the aerodynamic model.	Optional
PLTPANS	ASCII Text File Generation for Plotting Panel List and Structural Grid List	Optional
PLTSURF	ASCII text file generation for plotting the aerodynamic control surface.	Optional
PLTTRIM	Generates an ASCII text file for the post-processing of the static aeroelastic/trim analysis.	Optional

These bulk data cards are not referred to by other bulk data cards. Their appearance in the Bulk Data Section "triggers" the program to generate their associated output files.

4.2.7 ZONA's Design Variable Linking Scheme (ZLINK)

ZONA's Design Variable Linking Scheme (ZLINK) module is included within the ZONAIR software. This module is shared by many of ZONA's software (e.g., ZAERO and ZMORPH) and its bulk data input is, therefore, completely portable between the applications. This feature is very convenient, for example, when performing an optimization process where a specified set of design variables (e.g., those defining wing span, leading edge sweep angle, etc.) saved within a single file can be directly read in and used by all of these codes. Such an external file is included within each of these software bulk data input decks via the **INCLUDE** bulk data card. In this fashion, all of the standard input for these codes remains unchanged and only the single file containing the design variables is updated by the optimizer during each stage of the optimization process. Identical changes to the models of the different codes are then automatically handled by ZLINK within each of the applications.

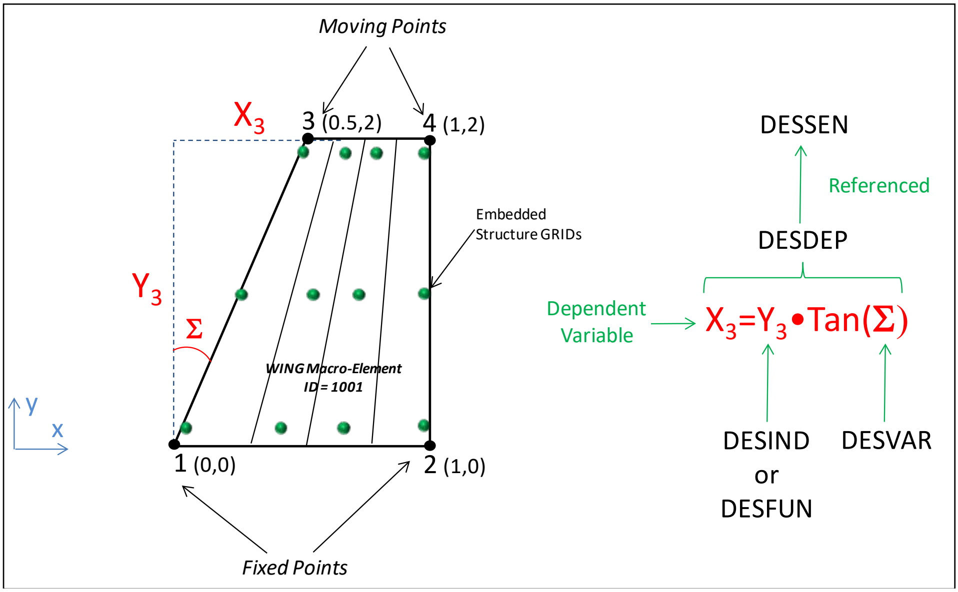
NOTE: ZLINK is used to describe, and is completely responsible for, the geometrical shape change (i.e., morph) that takes place. It allows for the input of design variables, independent and dependent variable definitions, and arbitrary general functions of virtually any complexity. ZLINK is very general and flexible in the sense that user input equations can be used to drive the morph. Based on final values computed for the dependent variables, the action of ZLINK is to internally modify existing bulk data input entries. ZONAIR bulk data cards whose entries are modified via ZLINK to establish a geometric perturbation are: **CAERO7**, **GRID**, **AEFACT**, **FOILSEC**, and **CORD2R**.

The five bulk data cards used to setup the ZLINK input are shown in the following table along with a description of each card. At a minimum, a single **DESDEP** and **DESSEN** bulk data card are required to execute a geometrical shape change within ZONAIR.

Bulk Data Card	Description	Remarks
DESDEP	Defines a dependent geometric parameter.	*Required*
DESFUN	Defines a function to link the dependent geometric parameters with the independent geometric parameters and the shape design variables.	*Optional*
DESIND	Defines an independent geometric parameter.	*Optional*
DESSEN	Activates the shape design variables.	*Required*
DESVAR	Defines a shape design variable.	*Optional*

The following figure demonstrates how these bulk data cards can be used to define a simple shape change. Suppose we have a planar wing with a swept leading edge defined by a **CAERO7** macro-element with the points 1-4 located as shown and that we wish to change the leading edge sweep angle to any value defined by a design variable. For this case, points 1 and 2 remain fixed and points 3 and 4 move relative to the input sweep angle. First, we define a design variable, say SIGMA, and set its value to 35 degrees via the following **DESVAR** bulk data card with ID=10:

DESVAR 10 SIGMA 35.0



Next, we need to define the coordinate Y3 to be able to evaluate the equation shown in the figure; namely,

$$X3 = Y3 \times tan(\Sigma)$$

There are two ways Y3 can be defined; explicitly as a value (of 2.0) via the **DESFUN** bulk data card as:

```
DESFUN  20
     (      2.0                              )
```

or by assigning an independent variable; such as the Y-value of point 3; where **CAERO7** with ID=1001 is the label of the wing macro-element:

```
DESIND  20      YTVAL   CAERO7  1001    YTL
```

A single **DESDEP** bulk data card is then used to alter the tip leading edge of the **CAERO7** macro-element X3 value:

```
DESDEP  10      SWEEP   CAERO7  1001    XTL     0
     1.0     20      TAN     0.01745 10
```

where XTL is the entry of the **CAERO7** bulk data card to be altered, 0 is the i-th index (as there is no repeating entry on the WING bulk data card), 20 is the ID of the **DESFUN** or **DESIND** bulk data card, and 10 is the ID of the **DESVAR** with LABEL=SIGMA bulk data card. The factor of 0.01745 is used to convert the degree input of SIGMA to radians.

Finally, referencing the **DESDEP** via a **DESSEN** card will trigger ZONAIR to perform modification of the aerodynamic model defined by the **DESDEP** card(s). Note that changing the value of SIGMA on the **DESVAR** card and re-running ZONAIR will generate a new aerodynamic model based on the newly updated **CAERO7** macro-element.

4.2.8 MISCELLANEOUS INPUT

Name	Description	Remarks
$	Used to insert comments into the Bulk Data Section.	Optional
AEFACT	Specifies a list of real numbers.	Optional
ALTER	Perform Matrix Operations.	Optional
CORD1C	Cylindrical coordinate system definition, Form 1.	Optional
CORD1R	Rectangular coordinate system definition, Form 1.	Optional
CORD1S	Spherical coordinate system definition, Form 1.	Optional
CORD2C	Cylindrical coordinate system definition, Form 2.	Optional
CORD2R	Rectangular coordinate system definition, Form 2.	Optional
CORD2S	Spherical coordinate system definition, Form 2.	Optional
DMI	Header of direct matrix input.	Optional
DMIG	Direct matrix input at structural finite element grid points.	Optional
DMIL	Defines the values of matrix elements by 16-column fields.	Optional
DMIS	Defines the values of the matrix elements by 8-column fields.	Optional
DYNSAVE	Save or retrieve data entities created by the GENDYN module.	Optional
ENDDATA	To signify the end of the Bulk Data Section.	Required
FEMSAVE	Save the structural Modal Solution	Optional
GRIDFRC	Defines a control force at a set of a structural finite element grid points.	Optional
INCLUDE	Inserts an external file into the Bulk Data Section.	Optional
LMDSAVE	Save or retrieve matrices created by the LOADMOD bulk data cards.	Optional
LOADMOD	Defines a load mode of a set of structural grid points for computing component loads.	Optional
OMITMOD	Delete structural modes.	Optional
OUTINP	Outputs a valid aerodynamic model to an ASCII file	Optional

OUTPUT4	Exports a matrix data entity in the OUTPUT4 format to a data file.	Optional
PARAM	Alters values for parameters used in the computation.	Optional
PCHFILE	Imports a NASTRAN Punch output file that contains the modal values of element forces, stresses, strains, etc.	Optional
SET1	Defines a list of identification numbers. If used for spline, it contains a list of identification numbers of structural finite element grid points.	Optional
SETADD	Defines a set of integers as a union integer set defined on the SET1 bulk data cards.	Optional

4.3 BULK DATA DESCRIPTIONS

This section contains a complete description of each ZONAIR bulk data card.

ACOORD **Aerodynamic Coordinate System**

Description: Defines a local coordinate system for an aerodynamic component referenced by the **BODY7** or **CAERO7** bulk data cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
ACCORD	ID	XORIGN	YORIGN	ZORIGN	DELTA	THETA			

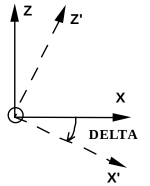
ACOORD	10	250.0	52.5	15.0	0.0	0.0			

Field	Contents
ID	Coordinate system identification number (Integer > 0)
XORIGN YORIGN ZORIGN	X , Y, and Z location of the component origin (Real)
DELTA	Pitch angle in degrees measured from the X-Z axes of the basic coordinate system to the X'-Z' axes of the component coordinate system, positive in direction shown (see Remark 4 figure). This parameter will not physically rotate the model. Its effects are introduced in the boundary condition. Therefore, **DELTA** must be a small value. (Real) (See Remark 4)
THETA	Roll angle in degrees measured from the Y-Z axes of the basic coordinate system to the Y'-Z' axes of the component coordinate system, positive in direction shown (see Remark 4 figure). Unlike **DELTA**, **THETA** will physically rotate the model. (Real)

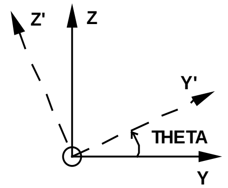
Remarks:

1. Coordinate system identification numbers (ID) on all **ACOORD** bulk data cards must be unique.
2. If **ACOORD** is referenced by a **BODY7** bulk data card, the X-axis of the coordinate system defines the centerline of the body.
3. All coordinate locations are with reference to the basic coordinate system. **ACOORD** defines a rectangular coordinate system whose X-axis must be parallel to the X-axis of the basic coordinate system.
4. Since most underwing stores have a small inclination angle to the free stream, **DELTA** can be used to provide a simpler means for defining this inclination.

Definition of Angle DELTA



Definition of Angle THETA



AEFACT — List of Real Numbers

Description: Used to specify lists of real numbers.

Format and Example:

1	2	3	4	5	6	7	8	9	10
AEFACT	SID	VALUE1	VALUE2	VALUE3	VALUE4	VALUE5	VALUE6	VALUE7	CONT
CONT	VALUE8	VALUE9	-etc-						

AEFACT	97	.3	.7	1.0					

Field	Contents
SID	Set identification number (Unique Integer > 0)
VALUEi	Number (Real)

Remarks:

1. Embedded blank fields are forbidden.

AEROGEN Computes Aerodynamic Results

Description: Computes aerodynamic pressure coefficients, forces and moments at a specified flight condition.

Format and Example:

1	2	3	4	5	6	7	8	9	10
AEROGEN	IDAERO	IDMACH	ALPHA	BETA	PRATE	QRATE	RRATE	STABDRV	CONT
CONT	$LABEL_1$	$VALUE_1$	$LABEL_2$	$VALUE_2$		etc			

AEROGEN	100	10	1.0	0.0	0.01	0.0	0.0	YES	+A
+A	RUDDER	1.0	ELEV	3.0	FLAP	-1.3			

Field	Contents
IDAERO	Identification number. Note that the local Mach number and pressure coefficient distribuation on the panel model can be displayed via the **PLTCP** bulk data card (Integer > 0) (See Remark 1)
IDMACH	Identification number of a **MACH** bulk data card for defining the Mach number (Integer > 0)
ALPHA	Angle of attack in degrees. (Real)
BETA	Side slip angle in degrees. (Real)
PRATE, QRATE, RRATE	Non-dimensional Roll, Pitch, and Yaw rates. (Real) (See Remark 2)
STABDRV	Character string either “YES” or “NO”. For STABDRV = “YES”, it triggers the program to generate the *AJJ*, *FJK*, and *DJK* matrices. Consequently, the aerodynamic stability derivatives are computed by the those matrices. (Character, Default = “NO”) (See Remark 3)
$LABEL_i$	Label of the control surfaces defined in the **AESURFZ**, **AESLINK**, **PZTMODE**, or **JETFRC** bulk data card. (Character)
$VALUE_i$	Command to the control surfaces. (Real) (See Remark 4)

Remarks:

1. The **AEROGEN** bulk data card is referred to by an **AEROGEN** Case Control Command that invokes the program to compute the aerodynamic pressure coefficients, forces and moments. It also can be referred to by a **TRIM**, **GENBASE**, or **FLEXLD** bulk data card to define the flight condition where the aerodynamic loads are computed.

   It should be noted that the rigid aerodynamic solution generated by the **AEROGEN** bulk data card can be replaced by the user supplied values using the **INPCFD**, **INPCFD1**, **INPDMI**, **CPSPLNL** or **CPSPLN** bulk data card with the same identification number as the entry IDAERO. This is to say that if any **INPCFD**, **INPCFD1**, **INPDMI**, **CPSPLNL** or **CPSPLN** bulk data card has the same identification number as the **AEROGEN** bulk data card, the **AEROGEN** bulk data card generated pressure distribution on the rigid aircraft is replaced by the user supplied data. If the **INPCFD/INPCFD1** bulk data card is used to replace the pressure distribution (Cp) computed by ZONAIR, a closest-point approach is employed to perform such a replacement by assuming that the ZONAIR panel model and CFD surface mesh share the same surface definition. For a control point on the panel model, the closest-point approach searches for the closest CFD grid then replaces the program computed Cp by that of CFD. It should be noticed that if the entry VALUE*i* is non-zero which implies that the CFD surface mesh contains a deflected control surface, ZONAIR will internally generate a panel model with the same control surface deflection so that the surfaces of ZONAIR and CFD can match with each other.

   In additional to the aerodynamic pressure coefficients, forces and moments, the **AEROGEN** bulk data card also computes the sectional loads defined by all the **LOADMOD** bulk data cards specified in the Bulk Data Section.

   To include the additional lift due to vortex-up using the Polhamus leading edge suction analogy, the user can specify the **LESUCT** bulk data card.

2. The non-dimensional roll, pitch, and yaw rates are defined as:

```
PRATE =  (roll rate)  *  (REFB/2.0)/V
QRATE =  (pitch rate) *  (REFC/2.0)/V
RRATE =  (yaw rate)   *  (REFB/2.0)/V
```

   where *V* is the free stream velocity, which is not required for input. The quantities REFB and REFC are the reference span and reference chord, respectively, specified in the **AEROZ** bulk data card with units specified in the FMLUNIT entry.

3. Computing aerodynamic stability derivatives requires the assembling of an aerodynamic Influence coefficient matrix, called the *AJJ*, *FJK*, and *DJK* matrices, that can be used to generate aerodynamic pressure derivatives with respect to rigid body modes, control surface modes and structural natural modes. These aerodynamic stability derivatives are the derivatives of the drag, side force, lift, roll moment, pitch moment and yaw moment with respect to α, β, p, q, r and the aerodynamic control surfaces (including all **AESURFZ**, **AESLINK**, **PZTMODE** and **JETFRC** bulk data cards). For static aeroelastic analysis (if "SOLUTION 1" executive control command is specified), the *AJJ*, *FJK*, and *DJK* matrices lead to the generalized aerodynamic force matrix with respect to the structural natural modes. If the **AEROGEN** bulk data card is referred to by the **TRIM** bulk data card, the *AJJ*, *FJK*, and *DJK* matrices are automatically generated even the entry STABDRV=”NO”

is specified. Since the computational time for generating those matrices may not be small, those matrices can be saved or retrieved using the **AJJSAV** bulk data card. It should be noticed that the actual names of those matrices are *AJJS000i*, *FJKS000i*, and *DJKS000i*, where *i* is the index of the **AEROGEN** bulk data cards existed in the input file. Please refer to the **OUTPUT4** bulk data card for the description of those matrix names.

The derivatives of the pressure coefficients with respect to α, β, p, q, r and the aerodynamic control surfaces can be displayed via the **PLTDCP** bulk data card.

4. For the **AESURFZ** or **AESLINK** bulk data card, VALUE_i is the deflection angle of the control surface in degrees. For the **PZTMODE** or **JETFRC** the unit of VALUE_i is defined by the user.

AEROZ **Model Physical Data**

Description: Defines the basic aerodynamic reference parameters.

Format and Example:

1	2	3	4	5	6	7	8	9	10
AEROZ	ACSID	XZSYM	FLIP	FMMUNIT	FMLUNIT	REFC	REFB	REFS	CONT
CONT	REFX	REFY	REFZ						

AEROZ	1	YES	NO	SLIN	IN	400.0	300	12000.	+AEROZ
+AEROZ	10.	0.	0.						

Field	Contents
ACSID	Identification number of a **CORD2R** bulk data card defining a coordinate system where x-axis is toward the pilot's face (from a pilot situated in the finite element model) and y-axis is on the pilot's right hand side. Used only if the Executive Control Command **'SOLUTION 1'** is specified. (Integer > 0 or Blank) (See Remark 2)
XZSYM	Character string, either "YES" or "NO"; = YES the aerodynamic model is symmetric about its x-z plane (this implies that only the half model on the right hand side is described), = NO both the right and left hand sides of the aircraft are modeled. (Character, Default = "YES") (See Remark 2)
FLIP	Character string, either "YES" or "NO"; = YES the structural model is on the left hand side of the pilot but aerodynamic model is on the right hand side. Used only if the Executive Control Command **'SOLUTION 1'** is specified. (Character, Default = "NO"). (See Remark 2)
FMMUNIT	**Not used.** Units of mass used in the structural finite element model. This parameter is automatically assigned by the program to be "LBF/" if English units are used or "N/" if metric units are used on the FMLUNIT entry. Note that if FMLUNIT is assigned to be "NONE", the program will automatically set FMMUNIT to "NONE".
FMLUNIT	Units of length used in the structural finite element model as well as all length dimensions involved in the aerodynamic model. Must be one of "IN", "FT", "M", "MM", "CM", "KM" or "NONE". (Character, Default = "NONE"). (See Remark 3)
REFC	Reference chord length. Units must be in FMLUNIT. (Real ≥ 0, Default = 1.0) (See Remark 4)
REFB	Reference span length. Units must be in FMLUNIT. (Real ≥ 0, Default = 1.0) (See Remark 4)

REFS	Reference area. Units must be in FMLUNIT**2. (Real ≥ 0, Default = 1.0) Note that the reference area should account for the area on both the right hand and the left sides of the configuration even if only a right hand side configuration is modeled, i.e. XZSYM = "YES." (See Remark 4)
REFX, REFY, REFZ	Location of aerodynamic moment center for computing aerodynamic force and moment coefficients due to rigid body motion. (Real) (See Remark 5)

Remarks:

1. This card must exist. Only one **AEROZ** is allowed.

2. ZONAIR assumes that the flow is in the positive x-direction in the basic coordinate system and that the aerodynamic model is on the right hand side of the x-z plane (i.e., positive y-direction). However, for the spline module that requires the perfect overlapping between the aerodynamic model and the structural, the structural model may be oriented in an arbitrary coordinate system. In this case, for the displacements and loads spline between the aerodynamic and structural models, the structural grid points will be transformed to the aerodynamic coordinate system according to **ACSID**. It is possible that the structural model may be located on the left hand side (i.e., negative y-axis) of the coordinate system **ACSID**. In this situation, the structural model can be flipped from the left to the right hand side by specifying **FLIP**=”YES”.

   For a symmetric model (about the x-z plane), ZONAIR generates the symmetric and anti-symmetric aerodynamic influence coefficient matrices simultaneously for all Mach numbers specified in the **MACH** bulk data card.

3. FMLUNIT is the length unit involved in the structural analysis. The unit of length of the aerodynamic model must also be in FMLUNIT. Thus, the units of length of structural and aerodynamic models must be the same. FMMUNIT, formerly required as input, is automatically set to be a consistent mass unit based on the input length unit. For example, if the length unit is meters, the mass unit will end up kilogram; if the length unit is inches, the mass unit will end up slinch, and so on. In other words, for any metric length unit input, a "N/" will automatically be applied for the mass unit and if English length unit is input, a "LBF/" will automatically be applied for the mass unit. This always ensures that consistent units are used.

5. The non-dimensional aerodynamic force and moment coefficients are defined as:

Lift Coefficient	$C_L = \dfrac{L}{q_\infty (REFS)}$	, L is the lift force
Drag Coefficient	$C_D = \dfrac{D}{q_\infty (REFS)}$	, D is the drag force
Pitch Moment Coefficient	$C_M = \dfrac{M}{q_\infty (REFS)(REFC)}$	, M is the pitch moment
Side Force Coefficient	$C_Y = \dfrac{Y}{q_\infty (REFS)}$	, Y is the side force
Roll Moment Coefficient	$C_\ell = \dfrac{\ell}{q_\infty (REFS)(REFB)}$	, ℓ is the roll moment

Yaw Moment Coefficient $C_n = \dfrac{N}{q_\infty (REFS)(REFB)}$, N is the yaw moment

Note that all forces and moments computed by the program account for those generated by both sides of the configuration, even if only a right hand side configuration is modeled. Therefore, REFS should account for the area on both sides of the configuration.

6. All aerodynamic moment coefficients as well as stability derivatives are computed using REFX, REFY and REFZ as the aerodynamic moment center.

AESLINK — Aerodynamic Control Surface Linking

Description: Defines an additional aerodynamic control surface by linking a set of **AESURFZ** bulk data cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
AESLINK	LABEL	TYPE	ACTID						CONT
CONT	COEFF1	AESURF1	COEFF2	AESURF2		-etc-			

AESLINK	AES1	SYM	100						+A
+A	1.0	AES2	0.5	AES3	0.3	AES4			

Field	Contents
LABEL	Unique alphanumeric string of up to eight characters used to define an additional aerodynamic control surface. (Character) (See Remark 1)
TYPE	Type of boundary condition. (Character) (See Remark 2) SYM symmetric ANTI anti-symmetric ASYM asymmetric
ACTID	Not Used
COEFFi	A list of coefficients to define the linear combination of a set of **AESURFZ** bulk data cards. (Real) (See Remark 3)
AESURFi	A list of LABEL entries defined in the **AESURFZ** bulk data cards. (Character)

Remarks:

1. **AESLINK** provides a means to handle more than one aerodynamic control surface that is driven by one actuator or one control input command. Among all **AESLINK**, **AESURFZ**, **PZTMODE**, **GRIDFRC**, and **JETFRC**, no duplicated LABEL is allowed.

2. TYPE must match the TYPE entry defined in the **AESURFZ** bulk data cards that are specified in the AESURFi list.

3. The resulting aerodynamic forces/moments of **AESLINK** is:

$$\phi_L = \sum_i Coeffi \;\; \phi_i$$

where ϕ_L is the aerodynamic forces/moments of **AESLINK**

ϕ_i is the aerodynamic forces/moments of the i^{th} **AESURFZ**.

AESURFZ **Control Surface Definition**

Description: Specifies an aerodynamic control surface.

Format and Example:

1	2	3	4	5	6	7	8	9	10
AESURFZ	LABEL	TYPE	CID	SETK	SETG	ACTID			
AESURFZ	RUDDER	ASYM	1	10					

Field	Contents
LABEL	Unique alphanumeric string of up to eight characters used to identify the control surface (Character) (See Remark 2)
TYPE	Type of surface (Character) SYM symmetric surface ANTI anti-symmetric surface ASYM asymmetric surface
CID	The absolute value of CID is the identification number of a rectangular coordinate system (**CORD2R** bulk data card). For CDI ≥ 0; Y-axis of this coordinate system defines the hinge line of the control surface. For CID < 0, the Z-axis of the coordinate system defines the hinge line of the control surface. (Integer or blank) (See Remark 3)
SETK	Identification number of **PANLST1**, **PANLST2** or **PANLST3** bulk data card used to identify the aerodynamic panel ID's of the control surface (Integer > 0).
SETG	Not used.
ACTID	Not used.

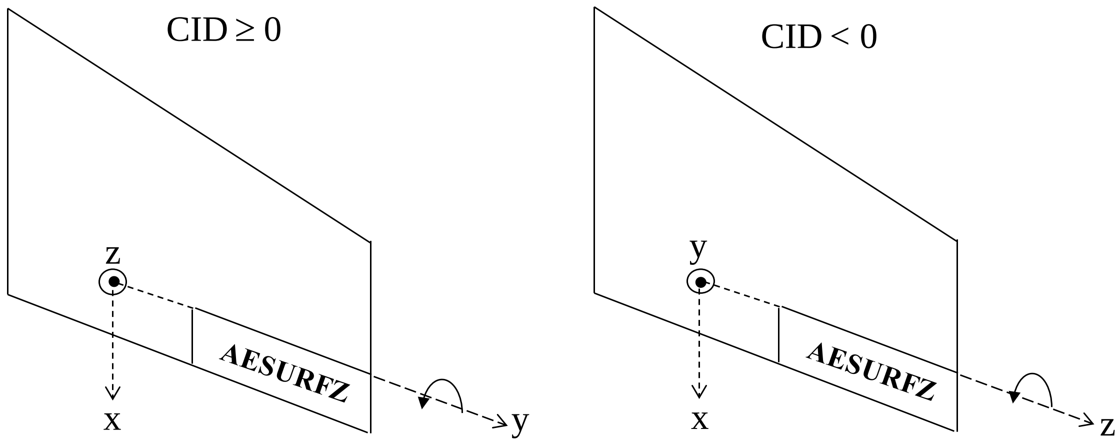
Remarks:

1. The existence of an **AESURFZ** bulk data card "triggers" the program to generate the aerodynamic forces and moments due to the control surface deflection. The user can activate the **PLTSURF** bulk data card to view the deflected control surface.

2. The **LABEL** is arbitrary, but all labels must be unique.

3. The y-axis or z-axis of the rectangular coordinate system should pass through the hinge line of the control surface. The rotation about the y-axis or z-axis by the right hand rule defines the direction

of the control surface deflection. For instance, the figure shown below indicates that the positive deflection of the control surface is deflecting downward.



If CID = 0, then the y-axis of the basic coordinates is used to define the hinge line location.

Note that if the control surface consists of CQUAD4/CTRIA3 panels (not the CAERO7 panels), the x-axis of the rectangular coordinates must be towards downstream so that the X-Y plane (if CID > 0) or the X-Z plane (if CID < 0) defines the mean plane of the control surface.

AJJSAV **Save or Retrieve the Aerodynamic Influence Coefficient Matrix for Stability Derivatives**

Description: Save or retrieve the Aerodynamic Influence Coefficient (AIC) matrix associated with an **AEROGEN** bulk data card for aerodynamic stability derivatives or flexible loads generation.

Format and Example:

1	2	3	4	5	6	7	8	9	10
AJJSAV	IDAERO	SAVE	FILENM						

AJJSAV	10	ACQU	FAIC.dat						

Field	Contents
IDAERO	An integer that matches the IDAERO entry of the **AEROGEN** bulk data card whose generated *AJJ*, F*JK*, and *DJK* matrices are to be saved or retrieved. (Integer > 0) (See Remark 1)
SAVE	Save the *AJJ*, F*JK*, and *DJK* matrices generated by the **AEROGEN** bulk data card with identification number being equal to IDAERO to file "FILENM" or retrieve *AJJ*, F*JK*, and *DJK* matrices from "FILENM" (Characters or blank) SAVE = SAVE: saves the AIC data SAVE = ACQUIRE: retrieves an existing file containing the AIC data. Otherwise: do not save or retrieve data
FILENM	File name (up to 16 Characters) to specify the file name on which the AIC data is saved or retrieved (Character or Blank) (See Remark 2)

Remarks:

1. To compute the aerodynamic stability derivatives or the flexible loads, it is required to generate three matrices namely, *AJJ*, *FJK* and *DJK* shown as follows

$$\left\{C_{p_f}\right\} = \left[[AJJ]^T [FJK]^T - [DJK]^T\right]\{W\}$$

where $\{W\}$ is a mode vector that can be the rigid body pitch mode, rigid body yaw mode, control surface kinematic mode or the the structural mode shapes. C_{p_f} is the pressure coefficient derivative with respect to $\{W\}$.

The actual names of *AJJ*, *FJK* and *DJK* are indexed according to the ascending order of the **AEROGEN** bulk data cards. The actual matrix names of those matrices are documented in the **OUTPUT4** bulk data card.

It should be noted that the generation of *AJJ*, *FJK* and *DJK* matrices may be computationally costly. Therefore, it is recommended to save these matrices and then retrieve them for different trim analysis.

2. If SAVE = “SAVE”, the AIC matrices will be saved on an unformatted data file with file name = “FILENM” as the archival data entity. If SAVE = “ACQUIRE”, the AIC matrices will be retrieved from the data file with the name “FILENM”. In this case, a large amount of computing time can be saved.

3. If the bulk data cards **WT1AJJ/WT2AJJ/WT1CFD** are applied to correct the *AJJ*, *FJK* and *DJK* matrices based on test data, those corrected matrices can be outputted by three **OUTPUT4** bulk data cards. For the restart run, these matrices can be retrieved using “**ASSIGN MATRIX**= “executive control commands. This is to say that the **AJJSAV** bulk data card only saves the uncorrected *AJJ*, *FJK* and DJK matrices (before **WT1AJJ/WT2AJJ/WT1CFD** are applied).

ALTER

Perform Matrix Operation

Description: Performs matrix operations without modifying the program.

Format and Example:

1	2	3	4	5	6	7	8	9	10
ALTER	STEP	MODULE	RESULT	OPERATOR	COEFFA	MATRIXA	SYMBOL	MATRIXB	
ALTER	3	FEM	SMHH	TRNS	1.0	SPHI	*	MGH	

Field	Contents
STEP	Index of operation sequence (Integer > 0) (See Remark 1)
MODULE	Character either "FEM", "SPLINE", or "GENAIC" to specify the module after which the matrix operations are performed (Character) (See Remark 2)
RESULT	Character string defining the name of the resulting matrix from the matrix operation (Character)
OPERATOR	Character string either "INV", "TRNS", "PRINT", "GTOA", "ATOG", "COLGTOA", "COLATOG", "ROWGTOA", "ROWATOG" or blank that defines a matrix operation for the matrix "MATRIXA" (Character, Default = Blank) (See Remark 3)

where

"INV" = Invert [(COEFFA)[MATRIXA]]
"DEL" = delete matrix [MATRIXA].
"TRNS" = Transposed [(COEFFA)[MATRIXA]]
"PRINT" = Print out the matrix [RESULT]
"GTOA" = Reduce rows and columns of [MATRIXA] from g-set to a-set or remove the rows amd columns associated with the SPOINT/EPOINT
"ATOG" = Expand rows and columns of [MATRIXA] from a-set to g-set.
The elements in the expanded submatrices are zero.
"COLGTOA" = Reduce the columns of [MATRIXA] from g-set to a-set
"COLATOG" = Expand the columns of [MATRIXA] from a-set to g-set
"ROWGTOA" = Reduce the rows of [MATRIXA] from g-set to a-set
"ROWATOG" = Expand the rows of [MATRIXA] from a-set to g-set

	Note:	g-set is 6× (number of structural grid points of the FEM model) a-set is 6× (number of structural grid points defined by the DISP = n **NASTRAN** Executive Control Command, or the grid point defined by the **FEMASET** bulk data card) See **'ASSIGN FEM ='** Executive Control Command for the description of g-set and a-set

COEFFA — A real multiplication factor for matrix "MATRIXA" (Real, Default = 1.0)

MATRIXA — Character string that is the name of the matrix "MATRIXA" (Character) (See Remark 4)

SYMBOL — Character string either "+", "-", "*", "//" or blank where

"+"	represents addition
"-"	represents subtraction
"*"	represents multiplication
"//"	represents appending

(Character)

MATRIXB — Character string represents the name of the matrix "MATRIXB". Used only if SYMBOL is not blank (Character)

Remarks:

1. The **ALTER** bulk data cards provide means to perform certain matrix operations without modifying the program source code. These matrix operations are executed before the program invokes any disciplines (flutter, ASE, trim or dynamic loads analysis). Note that the **ALTER** bulk data card is not referred to by any other bulk data cards. Its existence in the Bulk Data Section "triggers" the program to perform the matrix operations. Multiple **ALTER** bulk data cards can be specified where the execution sequence of the matrix operation defined by each **ALTER** bulk data card is performed according to the ascending order of the entry STEP.

2. The execution of these **ALTER** bulk data cards are performed after the computation of the engineering module that is specified by the MODULE entry is completed where

   MODULE = "FEM": The Matrices exist on the run-time database include those imported by **DMI** and **DMIG** bulk data cards, **'ASSIGN FEM='** and **'ASSIGN MATRIX='** Executive Control Commands.

   MODULE = "SPLINE": The execution of these **ALTER** bulk data card after the computation of the SPLINE module is completed. The matrices exist on the run-time database include the SPLINE matrix (called UGTKG) and those of the control surface modes and **LOADMOD** (generated by **LOADMOD** bulk data card).

   MODULE = "UAIC": After the computation of the GENAIC module (aerodynamic matrix generation) is completed. The matrices exist on the run-time database include the generalized aerodynamic force matrices of the FEM mode, and control surfaces.

3. The resulting matrix is computed based on the following equation

   [RESULT] = [“OPERATR” [(COEFFA) [MATRIXA]]] “SYMBOL” [MATRIXB]

   For example,

   [SMHH] = [TRNS [(2.0) [SPHI]]] * [MGH]

4. The matrix [MATRIXA] (and [MATRIXB] if SYMBOL $\neq$ blank) must already exist on the run-time database. Note that if the matrix [RESULT] exists on the run-time database, it will be replaced by the resulting new matrix.

5. The following are examples of the applications using the **ALTER** bulk data cards to add mass to the generalized mass matrix such as

   $$[SMHH] = [SMHH] + [SPHI]^T [DELTAM] [SPHI]$$

   where [SMHH] is the symmetric generalized mass matrix
   [SPHI] is the symmetric modal matrix
   - Note that [SMHH] and [SPHI] are imported by the **‘ASSIGN FEM=’** Executive Control Command.

   [DALTAM] contains the mass in the g-set d.o.f. that is to be added into the generalized mass matrix. Note that DELTAM can be defined by the **DMIG** bulk data card.

   The following three **ALTER** bulk data cards can be used to perform the above task.

ALTER	1	FEM	TMP	TRNS	1.0	SPHI		DELTA	

ALTER	2	FEM	TMP		1.0	TMP		SPHI	

ALTER	3	FEM	SMHH		1.0	SMHH		TMP	

ATTACH

Aerodynamic Panel-To-Structural Grid Spline Attachment

Description: Defines aerodynamic panel(s) to be attached to a reference structural grid for splining. The **ATTACH** bulk data card is activated only if **'SOLUTION 1'** Executive Control Command is specified.

Format and Example:

1	2	3	4	5	6	7	8	9	10
ATTACH	EID	MODEL	SETK	REFGRID					
ATTACH	1	WING	10	3					

Field	Contents
EID	Element identification number (Integer > 0) (See Remark 2)
MODEL	NOT USED
SETK	Identification number of **PANLST1, PANLST2** or **PANLST3** bulk data card used to identify the aerodynamic panel ID's (Integer > 0)
REFGRID	Reference structural grid point identification number (Integer > 0) (See Remark 3)

Remarks:

1. **ATTACH** is used only for computing the flexible loads. For an aerodynamic component not represented in the structural model, **ATTACH** is used to translate the displacements and loads between a structural grid point and the aerodynamic component.

   A typical example is an underwing store that is modeled structurally by a concentrated mass at a single structural grid point. In this case, the respective aerodynamic model of the underwing store will be splined to this single structural grid point by **ATTACH**. The resulting motion on the aerodynamic panels will be a rigid body motion that follows the motion of this single structural grid point.

2. **EID** is used only for error messages.

3. The translational and rotational degrees of freedom at the reference grid point define a rigid body type of motion of the aerodynamic component.

AUTOBAR — Generates a Set of CBAR

Description: Automatically generates a set of CBAR elements between two surface grid points.

Format and Example:

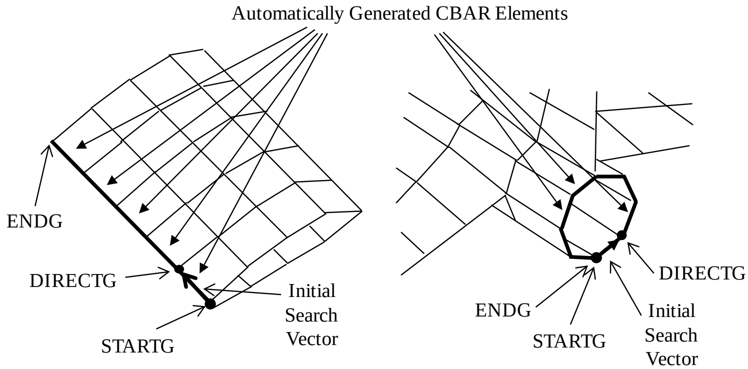
1	2	3	4	5	6	7	8	9	10
AUTOBAR	EID	STARTG	ENDG	DIRECTG					

AUTOBAR	100	31	31	40					

Field	Contents
EID	Unique identification number. (Integer > 0) (See Remark 1)
STARTG	Identification number of a surface grid point at which the automatically generated CBAR elements start. (Integer > 0)
ENDG	Identification number of a surface grid point at which the automatically generated CBAR elements end.
DIRECTG	Optional Input. DIRECTG is the identification number of a surface grid point to define the initial search vector. (Integer ≥ 0) (See Remark 2)

Remarks:

1. The **AUTOBAR** bulk data card automatically generates a set of CBAR elements between the grid points STARTG and ENDG.



2. The initial search vector is from the grid point STARTG to the grid point ENDG. The initial search vector directs the search procedure to find all grid points between STARTG and ENDG.

AUTOROD — Generates a Set of CROD

Description: Automatically generates a set of CROD elements between two surface grid points.

Format and Example:

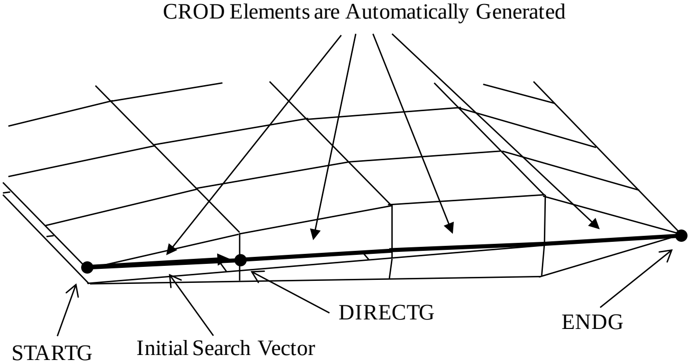
1	2	3	4	5	6	7	8	9	10
AUTOROD	EID	STARTG	ENDG	DIRECTG					

AUTOROD	100	30	51	0					

Field	Contents
EID	Unique identification number. (Integer > 0) (See Remark 1)
STARTG	Identification number of a surface grid point that is located at the trailing edge of the wing tip. (Integer > 0)
ENDG	Identification number of a surface grid point that is located at the leading edge of the wing tip.
DIRECTG	Optional Input. DIRECTG is the identification number of a surface grid point to define the initial search vector. (Integer ≥ 0) (See Remark 2)

Remarks:

1. The **AUTOROD** bulk data card automatically generates a set of CROD elements between the grid points STARTG and ENDG.



2. The initial search vector is from the grid point STARTG to the grid point ENDG. The initial search vector directs the search procedure to find all grid points between STARTG and ENDG.

AUTOTIP — Tip Modeling of a Thick-Wing Component

Description: Defines an aerodynamic macroelement for the modeling of the tip of a thick-wing component.

Format and Example:

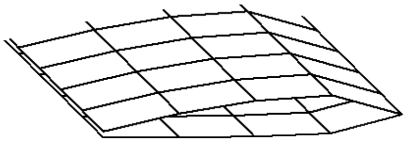
1	2	3	4	5	6	7	8	9	10
AUTOTIP	EID	GRIDS	PANELS	RODS	PSHELL	TIPGRID	UPSET1	LOWSET1	CONT
CONT	CIRCLE	NLINE							

AUTOTIP	10	101	301	1	10	1001	20	0	+AUTO
+AUTO	CIRCLE	3							

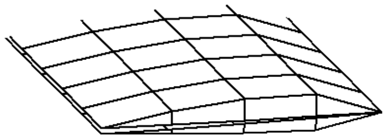
Field	Contents
EID	Unique identification number. (Integer ≠ 0) (See Remark 1)
GRIDS	Starting identification number of those internally generated grid points. (Integer > 0) (See Remark 2)
PANELS	Starting identification number of those internally generated CQUAD4/CTRIA3 elements. (Integer > 0) (See Remark 3)
RODS	Starting identification number of those internally generated CROD elements. (Integer ≥ 0) (See Remark 4)
PSHELL	Identification number of a **PSHELL** bulk data card. (Integer > 0)
TIPGRID	Identification number of a surface grid point that is located at the leading edge of the wing tip. (Integer > 0) (See Remark 5)
UPSET1	Identification number of a **SET1** bulk data card that lists a set of identification numbers of surface grid points that are located along the upper surface of the wing tip. (Integer ≥ 0) (See Remark 6)
LOWSET1	Identification number of a **SET1** bulk data card that lists a set of identification numbers of surface grid points that are located along the lower surface of the wing tip. (Integer ≥ 0) (See Remark 7)
CIRCLE	Character string either “FLAT” or “CIRCLE”. For CIRCLE=”FLAT”, The panels on the wing tip are flat panels. For CIRCLE=”CIRCLE”, the panels on the wing tip are around a half circle (Character, default=’FLAT’) (See Remark 8)
NLINE	Number of lines of grid are created internally to connect the panels on the wing tip. For CIRCLE=”FLAT”, NLINE is fixed to be one. For CIRCLE=”CIRCLE”, NLINE=3 is recommended. (Integer>0, default=1).

Remarks:

1. The purpose of the **AUTOTIP** bulk data card is to automatically generate a set of surface grid points, CQUAD4/CTRIA3 element and CROD element for the modeling of the tip of a thick-wing component. See the example below.

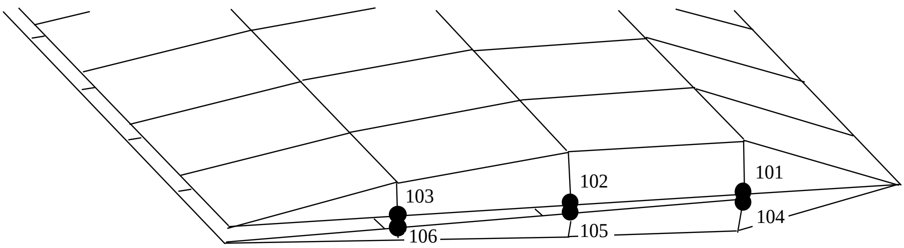


Thick wing without tip modeling



Thick wing with the **AUTOTIP** bulk data card

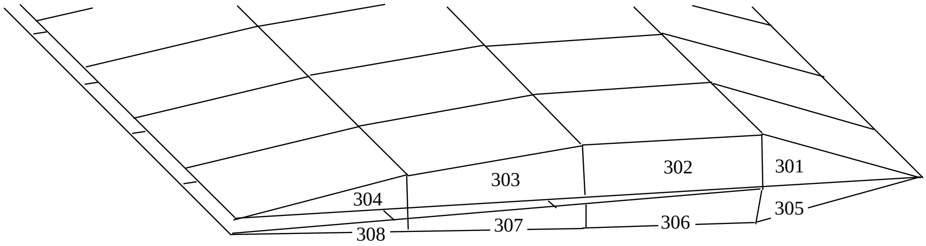
2. The **AUTOTIP** bulk data card automatically generates two sets of surface grid points. The location of these surface grid points is the average of the location of those grid points listed in the **SET1** bulk data cards with identification numbers being equal to UPSET1 and LOWSET1. The identification numbers of those automatically generated surface grid points start from GRIDS.



In the example shown above, six surface grid points are generated by the **AUTOTIP** bulk data card. If GRIDS = 101, the identification numbers of those grid points are 101, 102, 103, 104, 105, and 106 where grid points 101, 102 and 103 are used to connect the upper part of the CQUAD4/CTRIAS elements and grid points 104, 105 and 106 connect the lower part of the CQUAD4/CTRIA3 elements.

However, if EID < 0, only one set of surface grid points is generated and the upper and lower parts of the CQUAD4/CTRIA3 elements share the same set of grid points. In addition, no CROD element is generated.

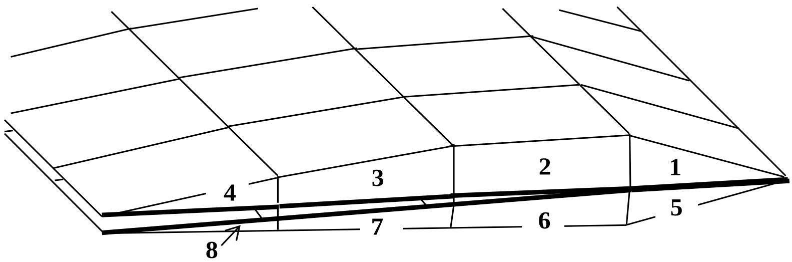
3. The **AUTOTIP** bulk data card automatically generated two sets of CQUAD4/CTRIA3 elements, one connects to those surface grid points along the upper surface at the wing tip and the other one connects the lower surface. The identification numbers of these automatically generated CQUAD4/CTRIA3 elements start from PANELS.



In the example shown above, eight CQUAD4/CTRIA3 elements are automatically generated by the **AUTOTIP** bulk data card. If PANELS = 301, the identification numbers of those CQUAD4/CTRIA3 elements are 301~308 where elements 301~304 are connected to the upper grid points and the elements 305~308 to the lower grid points.

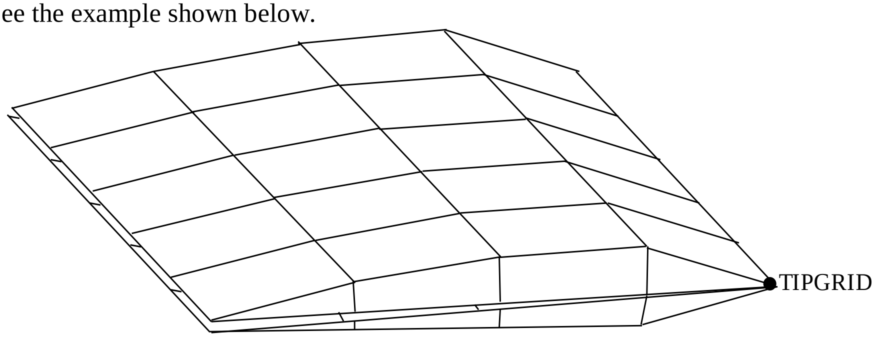
Note that the out-normal vector of those CQUAD4/CTRIA3 elements is defined by the right hand rule from TIPGRID to the grid on the upper surface and then to the grid on the lower surface.

4. The **AUTOTIP** bulk data card automatically generates two sets of CROD elements, one is connected by those internally generated upper grid points and the other one is connected by the lower grid points. The identification numbers of those internally generated CROD elements start from RODS.

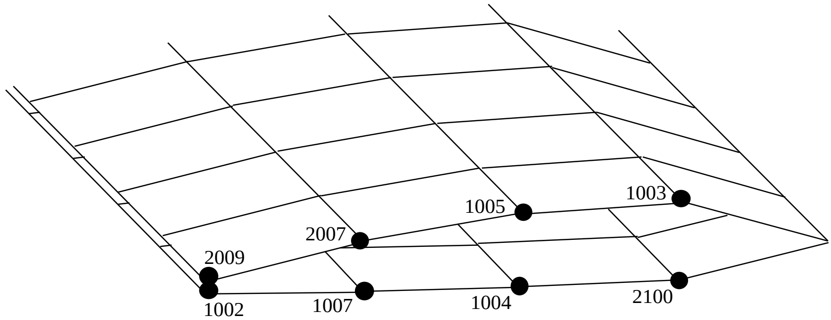


In the example shown above, eight CROD elements are automatically generated by the **AUTOTIP** bulk data card. If RODS = 1, the identification numbers of those CROD elements are 1~8 where CROD 1~4 are connected by the upper grid points and 5~8 by the lower grid points. This generation of CROD element can be deactivated by specifying RODS=0.

5. TIPGRID must be an existing surface grid points which is located at the leading edge of the wing tip. See the example shown below.

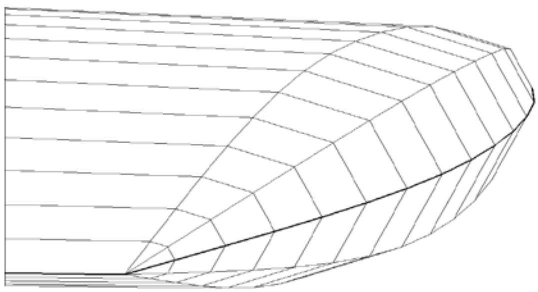


6. In the example shown below, the surface grid points located along the upper surface of the wing tip are 1003, 1005, 2007, and 2009 whereas the surface grid points located along the lower surface are 2100, 1004, 1007, and 1002. Note that the surface grid point TIPGRID must be excluded from the lists. In addition the x locations of those grid points must be in the ascending order, i.e. from upstream to downstream.



7. For a symmetric aerodynamic model (XZSYM = "YES" in the **AEROZ** bulk data card), only modeling half of the configuration is required even for a vertical tail whose mean plane is located on the X-Z plane. This is to say that because of the absence of the left-hand-side surface of the vertical tail surface, it is not required to generate the CQUAD4/CTRIA3 and CROD elements in the left hand side of the model. In this case UPSET1 = 0 or LOWSET1=0 is required where the specification of UPSET1 = 0 or LOWSET1 = 0 determines the normal vector of those CQUAD4/CTRIA3 on the right hand side of the model. (See Remark 3)

8. The figure below shows an example for CIRCLE="CIRCLE" and NLINE=3. It should be noticed that the vertical panels created by CIRLCE="FLAT" may induce very high flow velocity on the wing tip panels. This is because as the flow rolling up from the wing lower surface to the wing tip panels, the flow can experience a 90-degree sharpe turn which induces a unrealistic high velocity. By specifying CIRCLE="CIRCLE", a round tip-panel model can be created to mitigate such a high flow velocity problem.



AUTOVOR

Automatically Generates a VORNET Macroelement

Description: Automatically generates a **VORNET** bulk data card to model a vortex roll-up sheet for nonlinear lift at high angles of attack.

Format and Example:

1	2	3	4	5	6	7	8	9	10
AUTOVOR	EID	LABEL	TIPGRID	ANGLE	CANT	ROOLUP	NFED	CBAR	CONT
CONT	GRID1	GRID2	GRID3	...	-etc-	...			

AUTOVOR	100	ROLLUP	101	10.1	30.0	CIRCLE	3	NO	+A
+A	AUTO	100	-200						

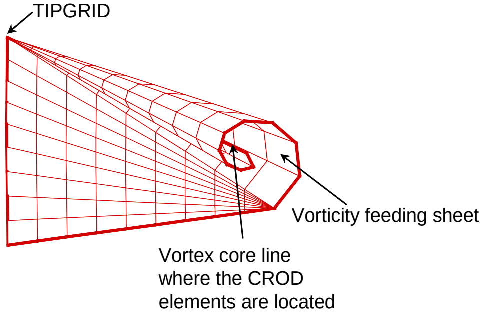
Field	Contents
EID	Unique identification number. (Integer > 0) (See Remark 1)
LABEL	An arbitrary character string used to define a label for the vortex roll-up surface. (Character)
TIPGRID	Identification number of a surface grid point where the roll-up vortex starts. Note that TIPGRID can be a negative integer. This gives the generation of the roll-up vortex sheet by following the left hand rule about the vortex line. Otherwise, it follows the right hand rule. (Integer $\neq 0$)
ANGLE	An angle in degrees to define the location of the vortex core line where the CROD elements are located. This angle is defined by the angle between the vortex core and the x-axis. Based on numerical experience, this angle should be half of the angle of attack specified in the **AEROGEN** bulk data card. (Real > 0.0)
CANT	A cant angle in degrees between the vector from the surface grid to the vortex core and the z-axis. (Real)
ROLLUP	Character string "LINE" or "CIRCLE" to define the shape of the roll-up vortex line. (Character, Default = "CIRCLE")
NFED	Number of vortices feeding points along each vortex roll-up line. (Integer > 0) (See Remark 2)
CBAR	Character string either "YES" or "NO". For CBAR = "YES", a set of CBAR elements are automatically generated and attached to the last vortex roll-up line. See description of Remark 4 of the **VORNET** bulk data card. (Character, Default = "YES")

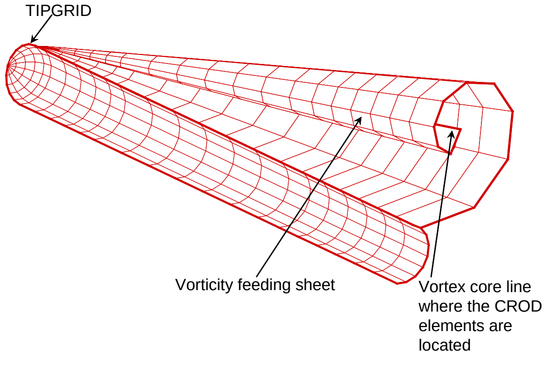
GRID*i* If $GRID_1$ is an integer, GRID*i* is a list of the identification numbers of the surface grid points that are in the downstream of the grid point TIPGRID. Thus, the vortex roll-up sheet starts from TIPGRID and progresses along GRID*i*. Therefore, x-location of GRID*i* must be in the ascending order. The program will slice those panels along GRID*i* into two sets of panels and internally adds another set of grid points. In fact, GRID*i* are the entry GRIDU*i* and those internally generated grid points are the entry GRIDL*i* of the **VORNET** bulk data card. Note that the last GRID*i* can be a negative integer. In this case, the last GRID*i* will not be sliced into two grid points.

If $GRID_1$ is the character string "AUTO", all downstream grid points from TIPGRID to the end of the body or the trailing edge of the wing can be automatically identified by the program. Thus, all the rest of GRID*i* is not required for input. However, if $GRID_2 \neq 0$, then it is the identification number of a surface grid that is used to define an initial search vector for the identification of the downstream grid points. This vector starts from TIPGRID and towards $GRID_2$. If $GRID_2 = 0$, the x-axis is used as the initial search vector. If $GRID_3 \neq 0$, it is the identification number of a surface grid point at which the vortex roll-up sheet ends. If $GRID_3 = 0$, the vortex roll-up sheet automatically ends at the end of a body or the trailing edge of a wing. Note that $GRID_3$ can be a negative integer. In this case, the search vector does not slice the grid point with ID = $GRID_3$ into two grid points. (Integer or Character) (see Remark 3)

Remarks:

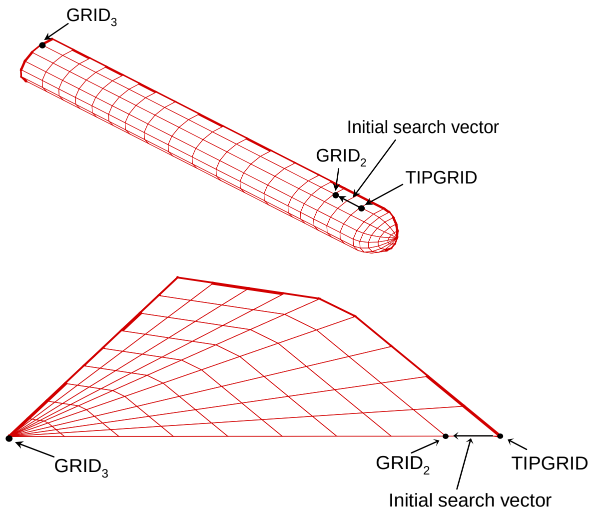
1. The **AUTOVOR** bulk data card internally generates a **VORNET** bulk data card by automatically setting up all entries in the **VORNET** bulk data card. The identification number of this internally generated **VORNET** bulk data card is EID. The objective of the **VORNET** bulk data card is to model a vortex roll-up sheet on the wing leading edge or top of the body. See figures below.





2. A set of reference grid points (PS> 0 in the **GRID** bulk data card) are internally generated and located along the vortex core line. These reference grid points are the entry IDSET*i* in the **VORNET** bulk data card. See the remarks of the **VORNET** bulk data card for the description of ROLLUP and NFED.
3. The initial vector is shown in the figure below. The search vector slices the surface grid into two sets of surface grid points from TIPGRID to the end of the body or trailing edge of the wing. These two set of surface grid points are the input to the entries GRIDU*i* and GRIDL*i* of the **VORNET**

bulk data card. Note that if $GRID_3 < 0$, the program automatically sets GRIDU*i* = GRIDL*i*, where *i* is the index of the end point with ID = ABS ($GRID_3$).



BODY7 Aerodynamic Body Component

Description: Defines an aerodynamic body macroelement of a body-like component.

Format and Example:

1	2	3	4	5	6	7	8	9	10
BODY7	BID	LABEL	ACOORD	NAXIS	NRAD	NOSERAD	IAXIS	CBAR	CONT
CONT	ITYPE1	X1	CAM1	YR1	ZR1	IDY1	IDZ1		CONT
CONT	ITYPE2	X2	CAM2	YR2	ZR2	IDY2	IDZ2		CONT
CONT	ITYPE2	X3	CAM3	YR3	ZR3	IDY3	IDZ3	-etc-	

BODY7	4	BODY	2	8	4	0.1	3	NO	+BC
+BC	1	0.0	0.0	0.0					+EF
+EF	1	1.0	0.0	0.5					+HI
+HI	3	2.0				103	104		

Field	Contents
BID	Identification number. (Integer > 0) (See Remark 1)
LABEL	An arbitrary character string (up to 8 characters) used to define the body. (Character)
ACOORD	Identification number of **ACOORD** bulk data card (specifying body center line location and orientation). (Integer ≥ 0 or Blank, Default = 0) (See Remark 2)
NAXIS	Number of axial stations. (i.e., divisions) of the body. (Integer ≥ 2)
NRAD	Number of circumferential points of the body. (Integer ≥ 3) (See Remark 3)
NOSERAD	Nose radius of blunt body. NOSERAD is active only if Hypersonic Aerodynamic Method is used. (Real ≥ 0.0) (See Remark 4)
IAXIS	The index of the axial station where the blunt nose ends. (Integer > 1). IAXID is active only if for hypersonic aerodynamic analysis. (See remark 4)
CBAR	Character String either "YES" or "NO". For CBAR = "YES", a set of CBAR elements will be automatically generated to model the wake that is shaded from the body. (character)(See Remark 5)
ITYPEi	Type of input used to define the circumferential panel cuts; = 1 body of revolution, = 2 elliptical body, = 3 arbitrary body (Integer 1, 2, or 3). (See Remark 6)
Xi	x-location of the axial station; Xi must be in ascending order. (i.e., Xi+1 > Xi) (Real)
CAMi	Body camber at the Xi axial station. (Real)
YRi	Body cross-sectional radius if ITYPEi = 1 or the semi-axis length of the elliptical body parallel to the y-axis if ITYPEi = 2 (Real). Note that YR_1 must be 0.0.
ZRi	The semi-axis length of the elliptical body parallel to the z-axis (Real). Note that ZR_1 must be 0.0.

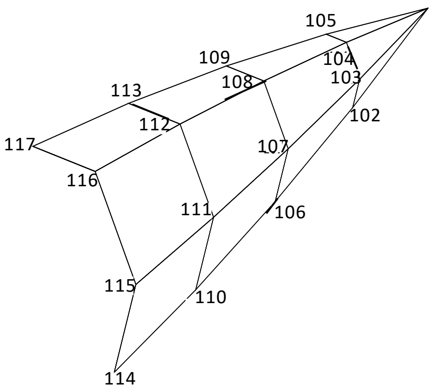
IDYi	Identification number of **AEFACT** bulk data card that specifies NRAD number of the y coordinate locations of the circumferential points at the Xi axial station (Integer > 0). Note that at X_1 the **AEFACT** bulk data card must contain only one y coordinate location to represent the body nose.
IDZi	Identification number of **AEFACT** bulk data card that specifies NRAD number of the z coordinate locations of the circumferential points at the Xi axial station (Integer > 0). Note that at X_1 the AEFACT bulk data card must contain only one z coordinate location to represent the body nose. (See Remark 7)

Remarks:

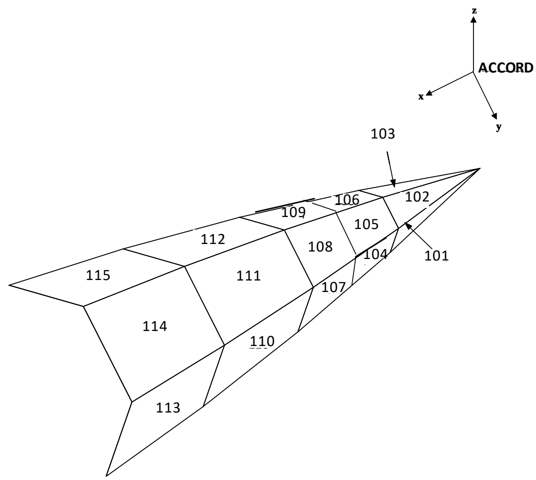
1. The **BODY7** bulk data card triggers the program to generate a set of CQUAD4 and CTRIA3 panels and a set of grid points. The identification numbers of these panels and grids are numbered sequentially beginning with BID. For instance, if BID=101, then the identification numbers of the CTRIA3/CQUAD4 panels and grids are 101, 102, etc.

2. The X-axis specified by the **ACOORD** bulk data card defines the centerline of the body macroelement. If ACOORD entry is zero, the X-axis of the basic coordinate system is used.

3. The number of aerodynamic grids and panels generated by each segment is 1+(NAXIS-1) × NRAD and (NAXIS-1) × (NRAD-1) respectively; therefore, there are 1+ (NAXIS) × $NRAD_i$ and ($NAXIS_i$-1) × ($NRAD_i$-1) number of grids and panels, respectively, for each **BODY7** bulk data card. For instance, if BID=101, NAXIS=5, and NRAD=4, the grid and panel identification number are shown below.

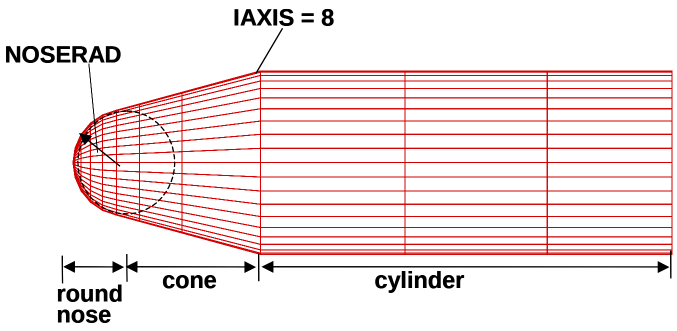


Grid Identification Numbers

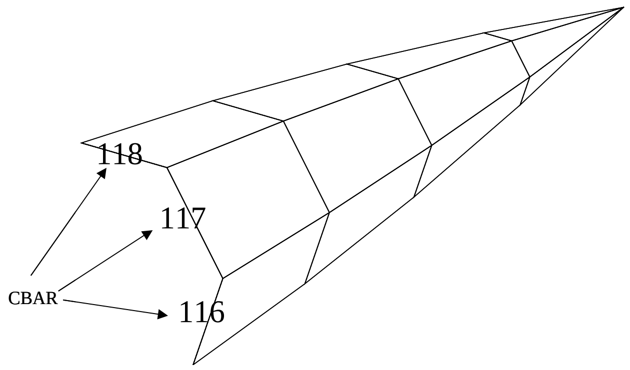


Panel Identification Numbers

4. For a blunt-nose body in hypersonic flow, the local Mach number at the nose often becomes subsonic which needs special treatment. The following figure shows a body that consists of a round nose, a cone and a cylinder. For this type of body, IAXIS should be the axial station where the cone ends. In other words, IAXIS covers both the round nose and the cone. For the following figure, IAXIS = 8.



5. (NRAD-1) number of CBAR elements are generated which are connected by those grid points located at the last axial stations (NAXIS). The identification numbers of those CBAR elements begin with BID + (NAXIS-1) $\times$ (NRAD-1). See figure below for example.

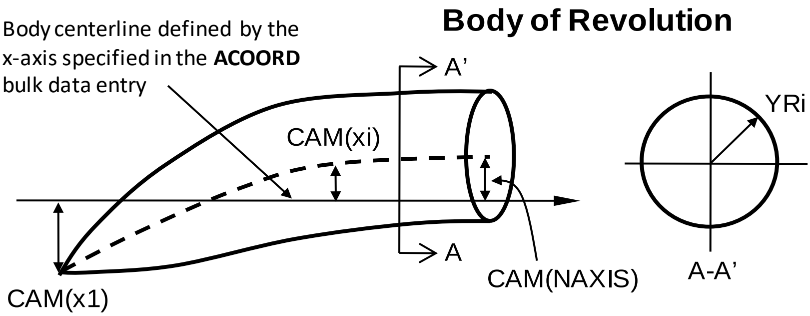


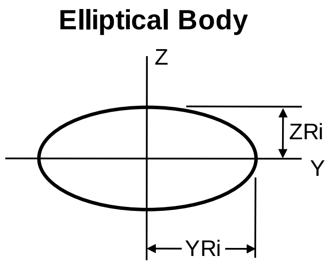
6. There are three methods to define the circumferential points at a given axial station:

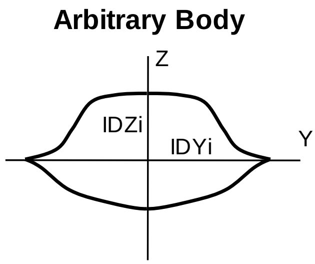
   1) Body of Revolution (using ITYPEi = 1, and Xi, CAMi, YRi entries)

   2) Elliptical Body (using ITYPEi = 2, and Xi, YRi, ZRi entries)

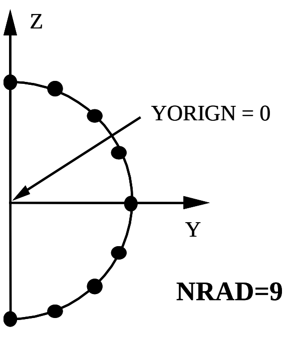
   3) Arbitrary Body (using ITYPEi = 3, and Xi, IDYi, IDZi entries)

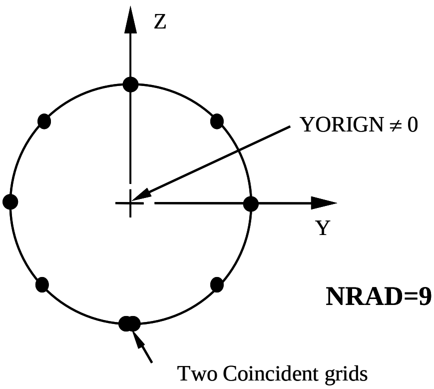






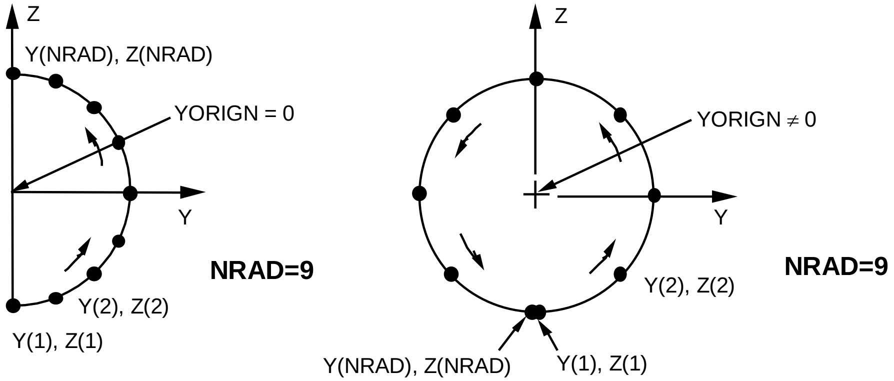
For a <u>body of revolution</u> or <u>elliptical body</u>, the number of circumferential points are divided evenly for the body. If YORIGN defined in the **ACOORD** bulk data card to which the body refers is zero and the XZSYM entry of the **AEROZ** bulk data card is YES, only half of the body (on the positive Y side) is generated. Conversely, if YORIGN is not zero and the XZSYM entry of the **AEROZ** bulk data card is YES, the points must be distributed over the entire circumference of the body (e.g., an underwing store). For this case, the first and last points are coincident points. (See figures below) However, if the XZSYM entry of the **AEROZ** bulk data card is NO, then the entire body must be input (i.e., all circumferential points defined), regardless of the value of YORIGN.





For an <u>arbitrary body,</u> the circumferential points must be entered in a counterclockwise direction (as viewed along the negative x-axis) looking at the y-z plane (in local body coordinates). If

YORIGN defined in the **ACOORD** bulk data card to which the body refers is zero and the XZSYM entry of the **AEROZ** bulk data card is YES, only half of the body (on the positive y side) is generated. Conversely, if YORIGN is not zero and the XZSYM entry of the **AEROZ** bulk data card is YES, the points input must be distributed over the entire circumference of the body. For both of these cases, the y values listed in the **AEFACT** bulk data card must start with zero and end with zero. (See the following figures) However, if the XZSYM entry of the **AEROZ** bulk data card is NO, then the entire body must be input (i.e., all circumferential points defined), regardless of the value of YORIGN.



7. ITYPEi through IDZi entries must be repeated for each axial station of the body (i.e., NAXIS times), therefore, CAMi, YRi, ZRi, IDYi and IDZi represent the circumferential points at Xi.

CAERO7 Aerodynamic Thin-Wing Component

Description: Defines an aerodynamic wing macroelement of a thin-wing component.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CAERO7	WID	LABEL	ACOORD	NSPAN	NCHORD	LSPAN	PAFOIL7	FRICT	CONT
CONT	XRL	YRL	ZRL	RCH	ATTR	LRCHD	RWAKE		CONT
CONT	XTL	YTL	ZTL	TCH	ATTT	LTCHD	TWAKE		

CAERO7	101	WING	8	5	4	20	0	0	+BC
+BC	0.0	0.0	0.0	1.0	YES	4	3		+EF
+EF	0.0	1.0	0.0	1.0	NO	0	0		

Field	Contents
WID	Identification number (Integer > 0) (See Remark 1)
LABEL	An arbitrary character string (up to 8 characters) used to define the thin-wing component (Character)
ACOORD	Identification number of **ACOORD** (specifying a local coordinate system and orientation) bulk data card (Integer ≥ 0 or blank, Default = 0) (See Remark 2)
NSPAN	Number of spanwise divisions of the thin-wing component (Integer ≥ 2)
NCHORD	Number of chordwise divisions of the thin-wing component (Integer ≥ 2)
LSPAN	Identification number of **AEFACT** bulk data card used to specify the spanwise divisions of the thin-wing component in percentage of the wing span. The number of values listed in **AEFACT** must be NSPAN and must start with 0.0 and end with 100.0. If LSPAN = 0, then NSPAN evenly distributed spanwise divisions are used. (Integer ≥ 0) (See Remark 3)
PAFOIL7	Identification number of a **PAFOIL7/PAFOIL8** bulk data card to specify sectional airfoil coordinates. If **PAFOIL7** = 0, it is assumed that the **CAERO7** wing component is a flat plate. (Integer ≥ 0)
FRICT	Component form drag factor for computing the skin friction drag on this **CAERO7**. Active on if the **VISCOUS** bulk data card is referred to by the **MACH** bulk data card. (Real>0.0, default=1.0) (see Remark 4)

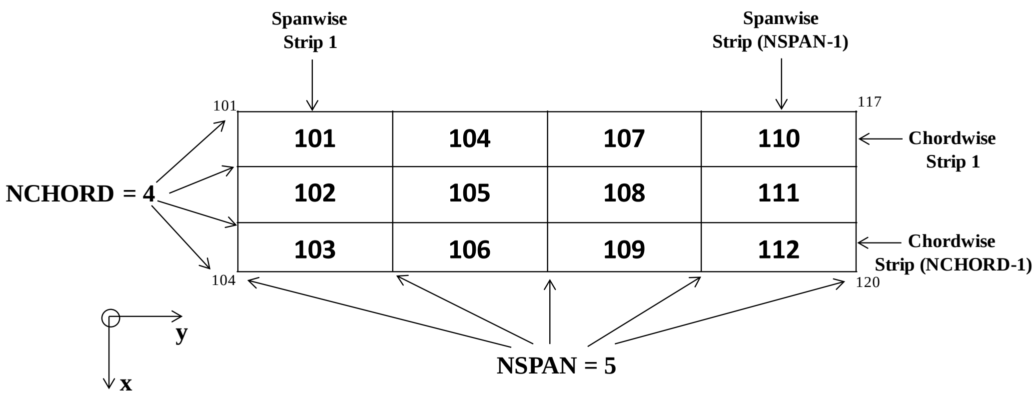
XRL YRL ZRL	X, Y, and Z location of the root chord leading edge (Real)
RCH	Length of the root chord. (Real)
ATTR	Character string either “YES” or "NO”. For ATTR = “YES”, the root of the thin-wing component is attached to is a body component (represented by **CQUAD4, CTRIA3** or **BODY7** bulk data cards). (Character) (Default = "NO")
LRCHD	For ATTR = “NO”; LRCHD is the identification number of an **AEFACT** bulk data card used to specify the root chord divisions of the wing component in percentage of the root chord. The number of values listed in **AEFACT** must be NCHORD and must start with 0.0 and end with 100.0. If LRCHD = 0, then NCHORD evenly distributed chordwise divisions for the root is used. (Integer ≥ 0) For ATTR = “YES”; LRCHD is the identification number of a **SET1** bulk data card that lists NCHORD identification number of the surface grid points (**GRID** bulk data card with entry PS = 0 or Blank). (Integer > 0) Note that LRCHD can also be a character string = “AUTO” that triggers the program to automatically search for the surface grid points located along the wing-body junction (Default = “AUTO”) (See Remark 5)
RWAKE	Identification number of a **SET1** bulk data card that lists a set of identification numbers of the surface grid points. These grid points are located behind the root of the thin-wing component where the wake from the wing root is attached. (Integer ≥ 0) Note that the RWAKE can also be a character string = “AUTO” that triggers the program to automatically search for the surface grid points located behind the root of the thin-wing component. (Default = “AUTO) (See Remark 6)
XTL YTL ZTL	X, Y, and Z location of the tip chord leading edge (Real) (See Remark 7)
TCH	Length of the tip chord. (Real)
ATTT	Same as ATTR but for the tip of the thin-wing component. (Character)
LTCHD	Same as LRCHD but for the tip of the thin-wing component. (Integer ≥ 0)
TWAKE	Same as RWAKE but for the tip of the thin-wing component. (Integer ≥ 0)

Remarks:

1. CAERO7 represents a thin-wing component where a sheet of vortex and source singularities is distributed on the main plane of the thin-wing. The vortex singularity models the lifting effects and source singularity models the thickness effects of the thin-wing component.

2. All coordinate locations defined above in XRL, YRL, ZRL, XTL, YTL**,** and ZTL are in the local wing coordinate system defined by the **ACOORD** bulk data card.

3. The number of spanwise and chordwise divisions of the thin-wing component includes the end points; therefore, there will be NSPAN-1 spanwise strips, NCHORD-1 chordwise strips, NSPAN × NCHORD aerodynamic grids and (NSPAN-1) × (NCHORD-1) aerodynamic panels generated by each **CAERO7** bulk data card. Among all aerodynamic grids and panels (of the **CAERO7**, **BODY7**, **CTRIA3**, and **CQUAD4** bulk data cards) no duplicate identification number is allowed. The following figure demonstrates the numbering scheme. In the example given below, a **CAERO7** has WID = 101, NSPAN = 5 and NCHORD = 4. There are (5-1) × (4-1) = 12 aerodynamic panels and 5 × 4 = 20 aerodynamic grid points generated for this lifting surface. Wing panels are numbered starting with the wing id of 101 and ending at 112. Wing aerodynamic grid points are numbered starting with the wing id of 101 and ending at 120. A duplicate identification number (i.e., aerodynamic panel(s) and aerodynamic grid point(s)) would occur, for example, if another thin-wing component were defined with a wing id of say 112, since there would be two aerodynamic panels with id's of 112 and duplicate aerodynamic grids of 112, 113, etc. Therefore, for this case, the next closest wing id (WID) or grid id (BID) that could be used is 121.

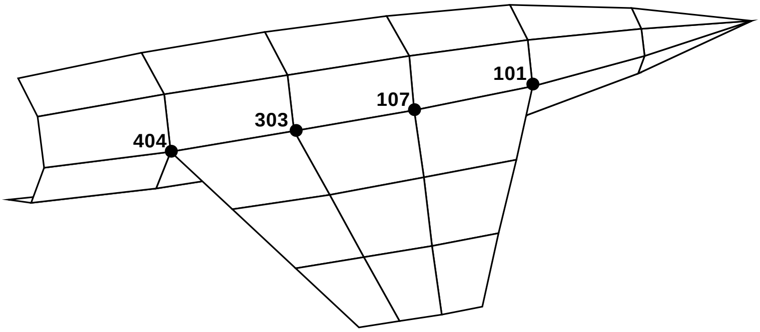


4. The user should calculate FRICT according to the following equation:

$$FRICT = \left[1 + \frac{0.6}{(x/c)_{\max}}\left(\frac{t}{c}\right) + 100.\left(\frac{t}{c}\right)^4\right]\left[1.34\left(COS\Lambda_{\max}\right)^{0.28}\right]$$

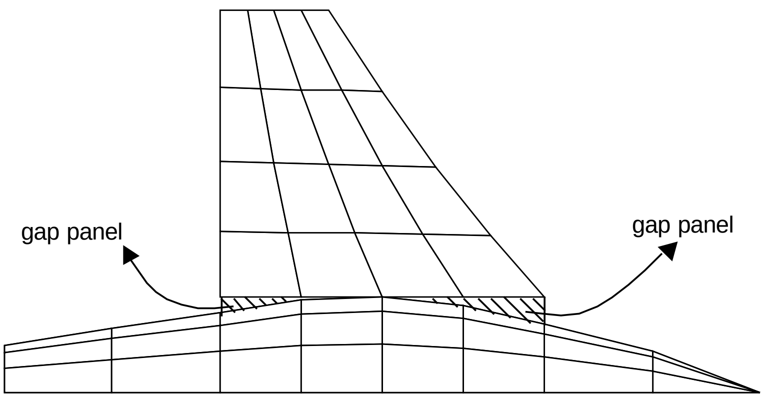
Where $(x/c)_{max}$ is the the chordwise location of the airfoil maximum thickness point. $\left(\frac{t}{c}\right)$ is the maximum airfoil thickness normalized by the wing chord length. Λ_{max} is the sweep angle of the wing of the maximum-thickness line.

5. The set of identification numbers of the **GRID** bulk data card is to ensure a perfect match of the thin-wing panels to the CTRIA3/CQUAD4 panels at the wing-body junction so that the line vortex emanating from the wing root can be cancelled by the doublet singularity of the body panels (CTRIA3 or CQUAD4 panels). For instance, the configuration illustrated below shows that the identification numbers of the **GRID** bulk data card are 101, 107, 303, and 404.



Note that if LRCHD = "AUTO", the number of surface grid points located along the wing-body junction must be equal to NCHORD. Otherwise, a fatal error occurs.

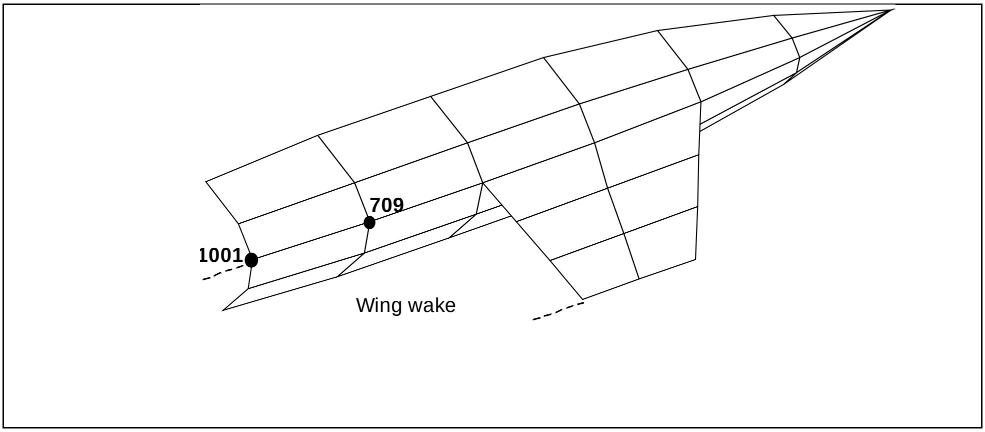
For a body with non-constant cross section at the wing-body junction, there exists a gap between the wing root and body. In this situation, the program will automatically create "gap panels" to fill in these gaps. The vortex strength of the gap panel is the same as its adjacent wing panel at the root so that no additional unknowns are introduced into the problem.



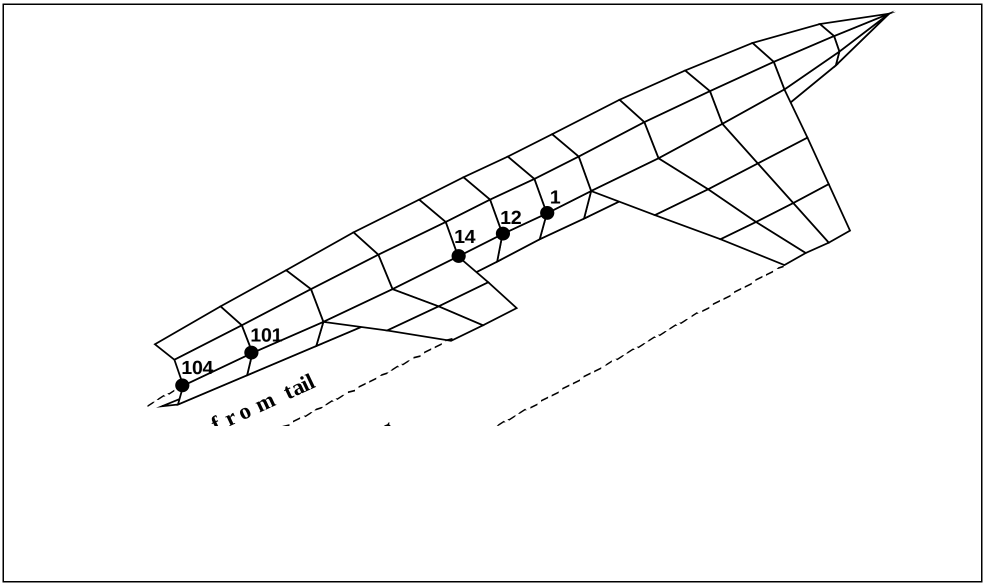
It should be noted that the leading and trailing edges of gap panels must be parallel to the y-z pane of the aerodynamic coordinate system. Otherwise, the aerodynamic influence coefficients from those gap panels may create large error. For a wing root attached to *n* number of GRID points, denoted as $GRID_i$, $i=1,2,..n$, using the following equations to determine the entry RCH and the values listed in the **AEFACT** bulk data card referred to the entry LRCHD is highly recommended:

RCH = x location of $GRID_n$ - x location of $GRID_1$
$AEFACT_i$ = (x location of $GRID_i$ – x location of $GRID_1$)/RCH×100.0%

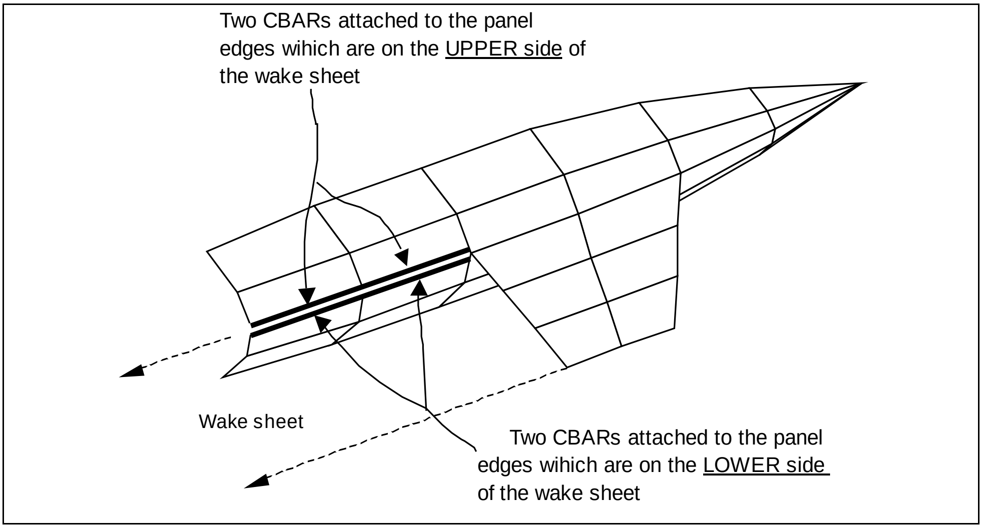
6. Since the wake shed from the thin-wing trailing edge creates a potential jump across the wake sheet, any body grids located on the plane of the wake sheet will experience the same potential jump. This is to say that the doublet distribution is continuous over the body surface except at these grid points. In the following figures, there are two grid points on the body located on the plane of the wake sheet. Therefore, the identification numbers of the grid listed in the **SET1** bulk data card are 709 and 1001.



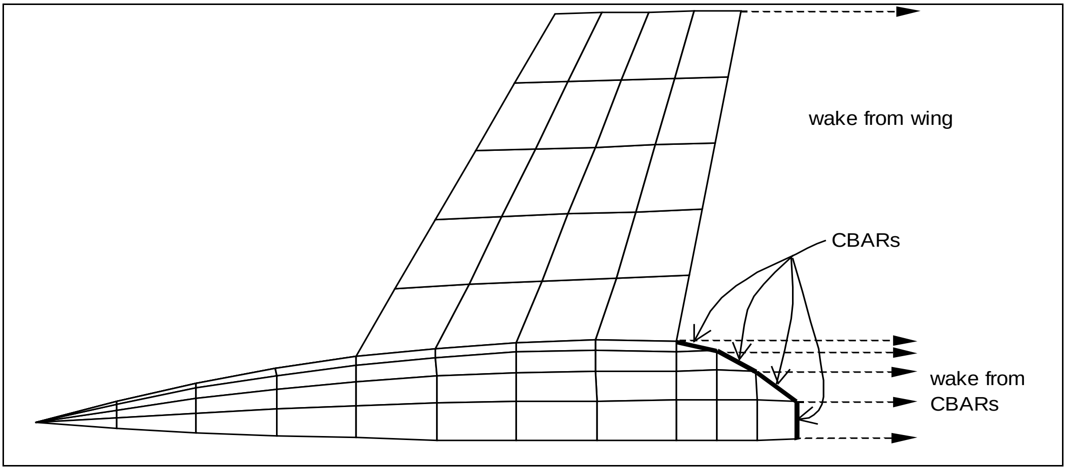
For a coplanar wing-tail configuration, only the grid points between the trailing edge of the wing and the leading edge of the tail (included) are listed in the **SET1** bulk data card. For instance, for the configuration shown below, there are three grid points namely 1, 12, 14 are listed in the **SET1** bulk data card for the wing wake. For the tail wake, the grid points listed in the **SET1** bulk data card are 101, 104.



Noted that once RWAKE (or TWAKE) is activated, the program will internally generate two sets of CBAR elements, one set is attached to CQUAD4/CTRIA3 panels located on the upper side of the wake sheet and the other set on the lower side of the wake sheet. In the following figures, there are four CBAR elements (two on the upper side and two on the lower side) are generated by the program.



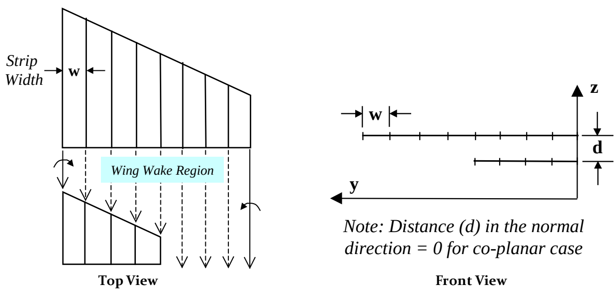
These CBAR's generate wake sheets that extend to infinity ensuring that the gap between the root of the wing wake and the body is filled up by the wake sheets.



Note that these internally generated CBAR elements can be individually removed. This is done by specifying negative identification numbers of two consecutive grids that are listed in the **SET1** bulk data card (including the trailing edge grid referred to by the LRCHD/LTCHD entry). This internally generated CBAR element between these two grids will be consequently removed by the program.

7. XRL, YRL, ZRL, XTL, YTL, and ZTL implicitly define the normal vector of the CAERO7 macroelement. This normal vector is computed by the cross product between the vector from leading to trailing edge and the vector from (XRL, YRL, ZRL) to (XTL, YTL, ZTL). Noted the upper surface of the CAERO7 macroelement is also defined by this normal vector. <u>For a left hand side thin wing and if the root of the wing (XRL, YRL,ZRL) is attached to a body, the normal vector is toward lower side of the wing. In this case, the camber of the airfoil section specified by the **PAFOIL7/PAFOIL8** bulk data card associated with this thin wing must be reversed.</u>

8. For a coplanar wing-tail configuration and both wing and tail are modeled by CAERO7 macroelements, the spanwise cuts between the wing and tail must be aligned (see Figure below). If a gap (**d** shown in fiure below) exists between the wing and tail and the gap is smaller than the width of the panel strip (**w** shown in Figure below) of the wing, this modeling restriction still holds. Note that if the wing is modeled by thick wing (**GRID**, **CQUAD4**,.etc), this modeling restriction can be relaxed.



CAEROCP

Apply a factor to the pressure coefficients on the CAERO7 macroelements

Description: Apply a factor to the pressure coefficients on the upper and lower surface of a **CAERO7** macroelements.

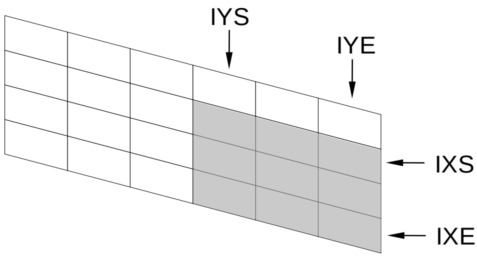
Format and Example:

1	2	3	4	5	6	7	8	9	10
CAEROCP	IDAERO	IDWING	IYS	IYE	IXS	IXE	CPU	CPL	
CAEROCP	101	20	4	6	2	4	0.3	0.3	

Field	Contents
IDAERO	Identification number of an **AEROGEN** bulk data card whose generated pressure coefficients on CAERO7 macroelements are multiplied by a factor. (Integer > 0) (See Remark 1)
IDWING	Identification number of a **CAERO7** bulk data card. (Integer > 0)
IYS	The starting strip index. (Integer > 0)
IYE	The ending strip index. (Integer > 0)
IXS	The starting chordwise panel index. (Integer > 0)
IXE	The ending chordwise panel index. (Integer > 0) (See Remark 2)
CPU	A factor applied to the upper surface pressure coefficients. (Real, default=1.0)
CPL	A factor applied to the lower surface pressure coefficients. (Real, default=1.0)

Remarks:

1. Multiple **CAEROCP** bulk data cards can be specified to apply factors to various CAERO7 macroelements.
2. Only the pressure coefficients on those within IYS, IYE, IXS, and IXE are multiplied by the factor specified in the CPU and CPL entries.


IYS
IYE
IXS
IXE

CBAR

Wake Element

Description: Defines a flat wake surface by specifying two surface grid points.

Format and Example:

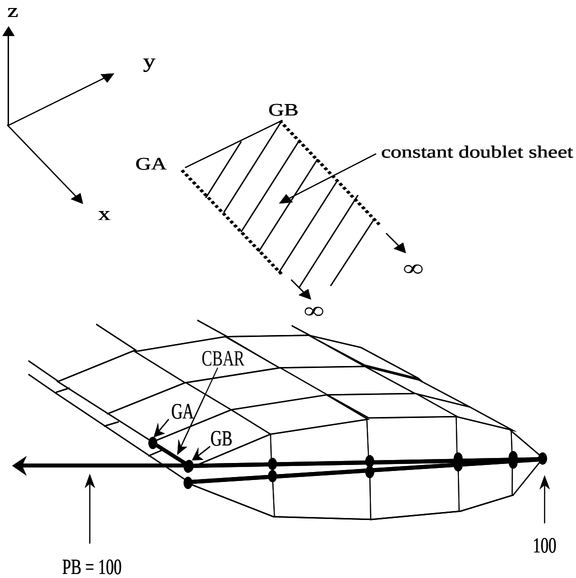
1	2	3	4	5	6	7	8	9	10
CBAR	EID	PBAR	GA	GB	X1	X2	X3		CONT
CONT	PA	PB							

CBAR		2	101	131					+C
+C	0	100							

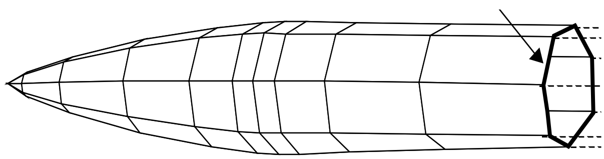
Field	Contents
EID	Identification number. (Integer > 0) (See Remark 1)
PBAR	Not used.
GA, GB	Identification numbers of two **GRID** bulk data cards. GA and GB must be the surface grid points (PS = 0 in the **GRID** bulk data card). (Integer > 0) (See Remark 2)
X1, X2, X3	Not used.
PA, PB	Flags for infinite vortex line at points GA and GB, respectively (Integer ≥ 0, Default = 0) (See Remark 3). If PA (or PB) ≠ 0, PA represents a surface grid ID at which this infinite vortex line originates, i.e. the grid point at the leading edge of the wing tip. See the figure below.

Remarks:

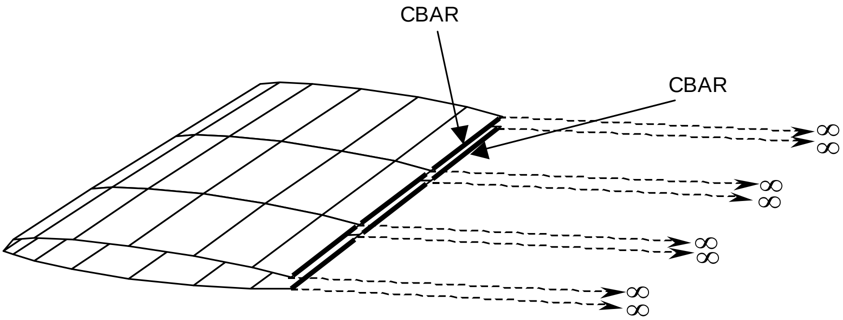
1. CBAR is to generate a sheet of constant doublet by sweeping the segment defined by the two grid points along the x-direction to infinity (See Figure Below). It is usually placed at the trailing edge of the thick-wing model and at the rear edge of the body.



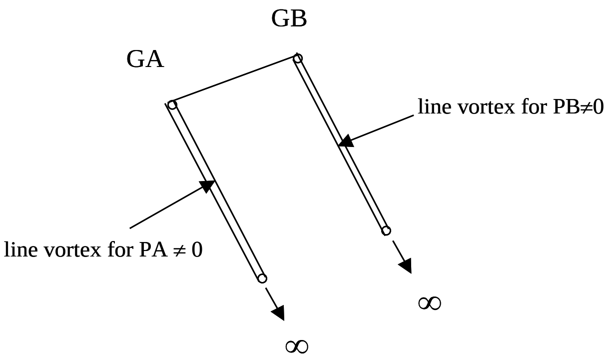
2. For a truncated-end body, the CBAR's must be attached to the trailing edge of all panels at the end of the body.



To model a thick wing type body, two grid points that have the same X,Y, and Z locations must be specified at the trailing edge of the body. Two CBAR's are attached to the upper and lower side of the trailing edge. In this way, the potential jump of the wake effect can be represented by the potential difference between these two wake sheets.



3. For PA ≠ 0 (or PB ≠ 0), program will automatically generate a line vortex starting from grid point GA or (GB) and extending to infinity.



CORD1C

Cylindrical Coordinate System Definition, Form 1

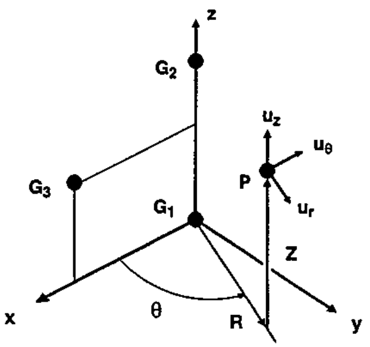
Description: Defines a cylindrical coordinate system by reference to three grid points. These points must be defined in coordinate systems whose definition does not involve the coordinate system being defined. The first point is the origin, the second lies on the z-axis and the third lies in the plane of the azimuthal origin.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CORD1C	CID	G1	G2	G3	CID	G1	G2	G3	

CORD1C	3	16	32	19					

Field	Contents
CID	Coordinate system identification number. (Integer > 0)
G_i	Grid point identification number. G_i can be either a surface grid or a reference grid. (Integer > 0; $G1 \neq G2 \neq G3$)



Remarks:

1. Coordinate system identification numbers on all **CORD1R**, **CORD1C**, **CORD1S**, **CORD2R**, **CORD2C**, and **CORD2S** entries must be unique.

2. The three points G1, G2 and G3 must be noncollinear.

3. The location of a grid point (P in the sketch) in this coordinate system is given by (R, θ, Z) where θ is measured in degrees.

4. The displacement coordinate directions at P are dependent on the location of P as shown above by (u_r, u_θ, u_z).

5. Points on the z-axis may not have their displacement directions defined in this coordinate system since an ambiguity results.

6. One or two coordinate systems may be defined on a single entry.

CORD1R Rectangular Coordinate System Definition, Form 1

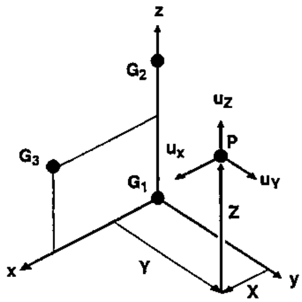
Description: Defines a rectangular coordinate system by reference to three grid points. These points must be defined in coordinate systems whose definition does not involve the coordinate system defined. The first point is the origin, the second lies on the z-axis and the third lies in the plane of the x-z plane.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CORD1R	CID	G1	G2	G3	CID	G1	G2	G3	

CORD1R	3	16	32	19					

Field	Contents
CID	Coordinate system identification number (Integer > 0)
G_i	Grid point identification number. G_i can be either a surface grid or a reference grid. (Integer > 0; G1 ≠ G2 ≠ G3)



Remarks:

1. Coordinate system identification numbers on all **CORD1R**, **CORD1C**, **CORD1S**, **CORD2R**, **CORD2C**, and **CORD2S** entries must be unique.

2. The three points G1, G2 and G3 must be noncollinear.

3. The location of a grid point (P in the sketch) in this coordinate system is given by (X, Y, Z) where θ is measured in degrees.

4. The displacement coordinate directions at P are shown above by (u_x, u_y, u_z).

5. One or two coordinate systems may be defined on a single entry.

CORD1S

Spherical Coordinate System Definition, Form 1

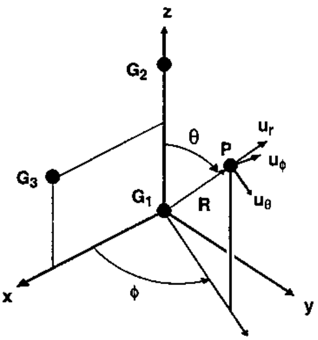
Description: Defines a spherical coordinate system by reference to three grid points. These points must be defined in coordinate systems whose definition does not involve the coordinate system defined. The first point is the origin, the second lies on the z-axis and the third lies in the plane of the azimuthal origin.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CORD1S	CID	G1	G2	G3	CID	G1	G2	G3	

CORD1S	1	16	32	19					

Field	Contents
CID	Coordinate system identification number. (Integer > 0)
G_i	Grid point identification number. G_i can be either a surface grid or a reference grid. (Integer > 0; $G1 \neq G2 \neq G3$)



Remarks:

1. Coordinate system identification numbers on all **CORD1R**, **CORD1C**, **CORD1S**, **CORD2R**, **CORD2C**, and **CORD2S** entries must be unique.

2. The three points G1, G2 and G3 must be noncollinear.

3. The location of a grid point (P in the sketch) in this coordinate system is given by (R, θ, ϕ) where θ and ϕ are measured in degrees.

4. The displacement coordinate directions at P are dependent on the locations of P as shown above by (u_r, u_θ, u_ϕ).

5. Points on the polar axis may not have their displacement direction defined in this coordinate system since an ambiguity results.

6. One or two coordinate systems may be defined on a single entry.

CORD2C — Cylindrical Coordinate System Definition, Form 2

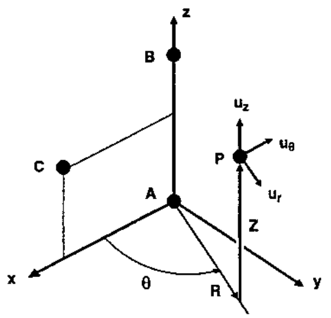
Description: Defines a cylindrical coordinate system by reference to the coordinates of three grid points. The first point defines the origin. The second point defines the direction of the z-axis. The third lies in the plane of the azimuthal origin. The reference coordinate system must be independently defined.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CORD2C	CID	RID	A1	A2	A3	B1	B2	B3	CONT
CONT	C1	C2	C3						

CORD2C	3	17	-2.9	1.0	0.0	3.6	0.0	1.0	+23
+23	5.2	1.0	-2.9						

Field	Contents
CID	Coordinate system identification number (Integer > 0)
RID	Reference to a coordinate system which is defined independently of new coordinate system (Integer ≥ 0, or blank)
Ai, Bi, Ci	Coordinates of three points in coordinate system defined by RID (Real)



Remarks:

1. A continuation entry must be present.

2. The three points (A1, A2, A3), (B1, B2, B3), (C1, C2, C3) must be unique and noncollinear. Noncollinearity is checked by the geometry processor.

3. Coordinate system identification numbers on all **CORD1R**, **CORD1C**, **CORD1S**, **CORD2R**, **CORD2C**, and **CORD2S** entries must all be unique.

4. An RID of zero references the basic coordinate system.

5. The location of a grid point (P in the sketch) in this coordinate system is given by (R, θ, Z) where θ is measured in degrees.

6. The displacement coordinate directions at P are dependent on the location of P as shown above by (u_r, u_θ, u_z).

7. Points on the z-axis may not have their displacement directions defined in this coordinate system since an ambiguity results.

CORD2R Rectangular Coordinate System Definition, Form 2

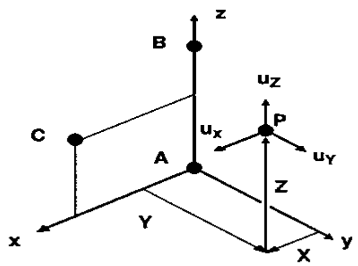
<u>Description:</u> Defines a rectangular coordinate system by reference to coordinates of three points. The first point defines the origin. The second point defines the direction of the z-axis. The third point defines a vector, which with the z-axis, defines the x-z plane. The reference coordinate system must be independently defined.

<u>Format and Example:</u>

1	2	3	4	5	6	7	8	9	10
CORD2R	CID	RID	A1	A2	A3	B1	B2	B3	CONT
CONT	C1	C2	C3						

CORD2R	3	17	-2.9	1.0	0.0	3.6	0.0	1.0	+23
+23	5.2	1.0	-2.9						

Field	Contents
CID	Coordinate system identification number (Integer > 0)
RID	Reference to a coordinate system which is defined independently of new coordinate system (Integer ≥ 0, or Blank)
Ai, Bi, Ci	Coordinates of three points in coordinate system defined by RID (Real)



<u>Remarks:</u>

1. A continuation entry must be present.

2. The three points (A1, A2, A3), (B1, B2, B3), (C1, C2, C3) must be unique and noncollinear. Noncollinearity is checked by the geometry processor.

3. Coordinate system identification numbers on all **CORD1R**, **CORD1C**, **CORD1S**, **CORD2R**, **CORD2C**, and **CORD2S** entries must all be unique.

4. An RID of zero references the basic coordinate system.

5. The location of a grid point (P in the sketch) in this coordinate system is given by (X, Y, Z).

6. The displacement coordinate directions at P are dependent on the location of P as shown above by (u_x, u_y, u_z).

CORD2S Spherical Coordinate System Definition, Form 2

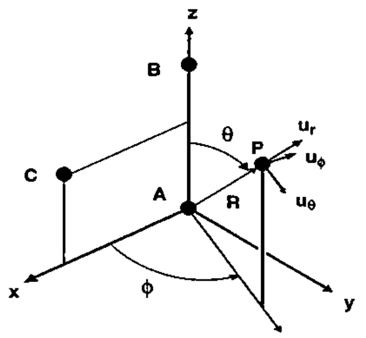
Description: Defines a spherical coordinate system by reference to coordinates of three points. The first point defines the origin. The second point defines the direction of the z-axis. The third lies in the plane of the azimuthal origin. The reference coordinate system must be independently defined.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CORD2S	CID	RID	A1	A2	A3	B1	B2	B3	CONT
CONT	C1	C2	C3						

CORD2S	3	17	-2.9	1.0	0.0	3.6	0.0	1.0	+23
+23	5.2	1.0	-2.9						

Field	Contents
CID	Coordinate system identification number. (Integer > 0)
RID	Reference to a coordinate system which is defined independently of new coordinate system. (Integer ≥ 0, or Blank)
Ai, Bi, Ci	Coordinates of three points in coordinate system defined by RID. (Real)



Remarks:

1. A continuation entry must be present.

2. The three points (A1, A2, A3), (B1, B2, B3), (C1, C2, C3) must be unique and noncollinear.

3. Coordinate system identification numbers on all **CORD1R**, **CORD1C**, **CORD1S**, **CORD2R**, **CORD2C**, and **CORD2S** entries must all be unique.

4. An RID of zero references the basic coordinate system.

5. The location of a grid point (P in the sketch) in this coordinate system is given by (R, θ, ϕ), where θ and ϕ are measured in degrees.

6. The displacement coordinate directions at P are shown above by (u_r, u_θ, u_ϕ).

7. Points on the polar axis may not have their displacement directions defined in this coordinate system since an ambiguity results.

CPFACT **Weighting Factor for Pressure Derivatives**

Description: Multiplies the computed aerodynamic pressures derivatives by a weighting factor. The **CPFACT** bulk data card is active only if "SOLUTION 1" executive control command is specified.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CPFACT	EID	IDMK	SYM	KINDEX	TYPE	LABEL	REAL		CONT
CONT	PANLST1	PANLST2	PANLST3	…		-etc-			

CPFACT	100	90	SYM	ALL	FEM	ALL	1.0		+CP1
+CP1	301	701							

Field	Contents
EID	**CPFACT** identification number. (Integer > 0) (See Remark 2)
IDMK	Identification number of **AEROGEN** bulk data card with entry STABDRV= "YES" being specified die to which the generated aerodynamic pressure derivatives are multiplied by a weighting factor. (Integer > 0)
SYM	Symmetric condition of the aerodynamic pressures derivatives generated by the **AEROGEN** bulk data card. (Character) SYM = 'SYM' for symmetric condition SYM = 'ANTI' for antisymmetric condition SYM = 'ASYM' for asymmetric condition
KINDEX	Not used.
TYPE	Character string to specify the type of the modes associated with the aerodynamic pressures derivatives (default="ALL"). TYPE = 'FEM' The structural finite element modes that are imported by the '**ASSIGN FEM='** Executive Control Command. TYPE = 'AESURFZ' The control surface modes that are defined by the **AESURFZ, AESLINK, PZTMODE,** or **GRIDFRC** bulk data. TYPE = 'RIGID' For rigid body modes (used only for trim analysis). TYPE = 'ALL' For all the above modes.
LABEL	Defines the index of the modes (default="ALL"). For TYPE = 'FEM' If LABEL is an integer, LABEL represents the index of the structural finite element modes. (Integer > 0) If LABEL = "ALL", it implies that all structural finite element modes are included. (Character)

For TYPE = 'AESURFZ' LABEL represents the LABEL entry of the **AESURFZ, AESLINK** or **PZTMODE** bulk data cards. (Character) If LABEL = "ALL", this implies that all control surface modes are included. (Character)

For TYPE = 'RIGID' LABEL is a character string and must be one of the following:

For SYM= "SYM":

LABEL = "PITCH" represents the pitching mode.

For SYM = "ANTI":

LABEL = "YAW" represents the yawing mode, and

For SYM = "ASYM":

LABEL can be one of the character string, "PITCH", or "YAW"

It should be noticed that the pressure derivatives of "PITCH" is used by the **TRIMVAR** bulk data card with LABEL = ALPHA and the "YAW" for LABEL = "BETA" for the trim analysis.

REAL Weighting factor. (Real)

PANLSTi List of identification numbers of the **PANLST1**, **PANLST2** and/or **PANLST3** bulk data cards. The aerodynamic pressures derivatives on the aerodynamic boxes that are listed in the **PANLSTi** bulk data cards are multiplied by the weighting factor. (Integer) (See Remark 3)

Remarks:

1. It is often that the users need to modify the aerodynamic pressures derivatives in a certain region of the aerodynamic model and consequently change the generalized aerodynamic forces for better aeroelastic predictions. For instance, the inviscid aerodynamic methods may overestimate the hinge moments of the control surface modes. To reduce the computed hinge moment, the users can apply a factor to the aerodynamic pressures derivatives with respect the control surface mode on the aerodynamic boxes of the control surfaces. In addition, the pressure derivatives of those panels on the inlet face can be zero-out using the **CPFACT** bulk data card.

2. EID is not referred to by any other bulk data card. The existence of each **CPFACT** in the Bulk Data Section "triggers" the multiplication procedure of the aerodynamic pressures derivatives by the weighting factors. EID is used for error message output only.

3. The aerodynamic pressures derivatives of the aerodynamic boxes that are not listed in the **PANLSTi** bulk data cards will not be altered. It should be noticed that for the panels on the lower surface of the CAERO7 macroelement, their identification numbers listed in the **PANLSTi** bulk data card are the same as those on the upper surface but with a negative sign.

CPSPLN **Wind Tunnel Measured Pressure**

Description: Maps the wind tunnel measured pressure coefficients onto ZONAIR aerodynamic panels by spline to replace the ZONAIR computed solution.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CPSPLN	IDAERO	SCALE	IDCOR	FILEWT		FORM	PLTFILE		CONT
CONT	$METHOD_1$	CP_1	$SETK_1$	$SETG_1$	DZ_1	EPS_1	$PROJ_i$	$EXTFILE_i$	CONT
CONT	---	etc	---						

CPSPLN	-100	12.0	3	WTCP.DAT		TECPLOT	WTCP.PLT		+C
+C	TPS		10	20	0.1	0.0001			+C
+C	BEAM	50	60	70					

Field	Contents
IDAERO	If IDAERO is a positive integer, it refers to the identification number of an **AEROGEN** bulk data card. The pressure coefficients on the rigid aircraft at the flight condition defined by the **AEROGEN** bulk data card with ID = IDAERO computed by the program are replaced by the wind tunnel measured pressure coefficients. If IDAERO is a negative integer, it is referred to by a **TRIMINP** or **WT1CFD** bulk data card. Note that the **CPSPLN** bulk data card is processed after the **INPCFD**/**INPCFD1** bulk data card being processed. To rapidly verify the interpolated pressure coefficient, it is recommended that the **PARAM** bulk data card with entry NAME="BYPASS" be used. (Integer ≠ 0) (See Remark 1)
SCALE	A scale factor applying to the *x*, *y*, and *z* where the wind tunnel measured pressures are located. (Real > 0.0, default = 1.0)
IDCOR	Identification number of a **CORD2R** bulk data card defining a coordinate system in which the wind tunnel model is located. Note that IDCOR can be a negative integer. This negative sign implies that the wind tunnel model is located on the negative y-axis. (Integer) (See Remark 2)
FILEWT	File name to specify an ASCII file where the wind tunnel measured pressure coefficients are stored. If the first character of FILEWT starts with a dollar sign “$”, the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. The feature allows for filenames up to 56 characters to be input. (Character ≠ blank) (See Remark 3)

FORM	The format of the output plot file "PLTFILE": FORM = "TECPLOT" for generating a TECPLOT file FORM = "PATRAN" for generating a PATRAN neutral file FORM = "IDEAS" for generating an I-DEAS universal file FORM = "FEMAP" for generating a FEMAP neutral file FORM = "ANSYS" for generating an ANSYS supported neutral file FORM = "NASTRAN" for generating a NASTRAN bulk data deck (Character, default = "TECPLOT") (See Remark 4)
PLTFILE	File name to store the wind tunnel measurement locations and the ZONAIR aerodynamic panel model together to verify the overlapping between these two models. If the first character of PLTFILE starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. The feature allows for filenames up to 56 characters to be input. (Character or blank)
$METHOD_i$	Character string either "IPS", "TPS" or "BEAM" to indicate a spline method for interpolating the wind tunnel measured pressure coefficient onto the ZONAIR panels. For $METHOD_i$ = IPS, the infinite spline method similar to the **SPLINE1** bulk data card is used. For $METHOD_i$ = TPS, the thin plate method similar to the **SPLINE3** bulk data card. For $METHOD_i$ = BEAM, the beam spline method similar to the **SPLINE2** bulk data card is used. (Character) (See Remark 5)
CP_i	Identification number of a **CORD2R** bulk data card to define a local coordinate system. For $METHOD_i$ = IPS, the x-y plane of the local coordinate system in the coordinate system (aerodynamic coordinate system) specified by the IDCOR entry is the spline plane for the infinite spline method. For $METHOD_i$ = TPS, CP_i is not used. For $METHOD_i$ = BEAM, the y-axis of the local coordinate system is the spline axis of the beam spline method. (Integer)
$SETK_i$	Identification number of a **PANLST2** or **PANLST3** bulk data card to list the identification numbers of the aerodynamic panels for pressure spline. Note that the **PANLST1** bulk data card is not allowed. (Integer > 0) (See remark 6)
$SETG_i$	Identification number of a **SET1** bulk data card to list the identification numbers of the wind tunnel pressure points from which the wind tunnel measured coefficients are mapped to those ZONAIR panels listed in $SETK_i$. (Integer > 0)
DZ_i	Linear attachment flexibility for least square approximation. (Real $\geq$ 0.0).(See Remark 7)

EPS$_i$ — Multiplication factor to obtain a small tolerance to detect any duplicated location of structural grid points. The tolerance is computed by EPS*REFC, where REFC is the reference chord defined in the **AEROZ** bulk data card. (Real ≥ 0.0, Default = 0.00001)

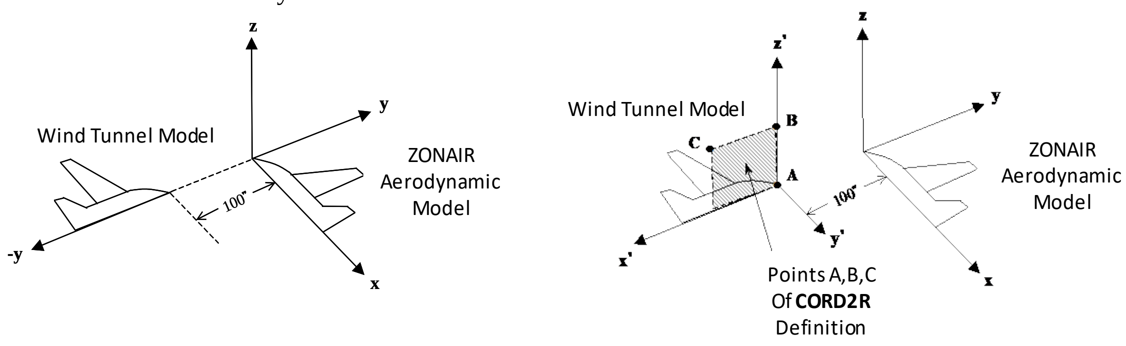
PROJ$_i$ — Character string either "YES" or "NO". If PROJ = "YES", the aerodynamic panels and the wind tunnel pressure points are projected on the x-y plane defined by the entry Cp$_i$. Note that PROJ is active only for method = "IPS". (Character, default = "YES").

EXTFILE$_i$ — Identification number of an **EXTFILE** bulk data card to specify the file name that stores the aerodynamic panels listed in SETK$_i$ and the wind tunnel pressure points listed in SETG$_i$. This output file allows the user to verify the input data for the pressure spline. (Integer ≥ 0).

Remarks:

1. The **CPSPLN** bulk data card replaces the ZONAIR computed pressure coefficients on the rigid aircraft by the wind tunnel measured pressure coefficients. These pressure coefficients are treated as the rigid loads for computing the flexible loads due to the static aeroelastic effects by the **TRIM** and **FLEXLD** bulk data cards. Note that if any ZONAIR panels are not involved in the **CPSPLN** bulk data card, the ZONAIR computed pressure coefficients will be used for those panels.

2. Because the wind tunnel model may be oriented in an arbitrary fashion with respect to the aerodynamic model, it is required to transform the wind tunnel model so that the wind tunnel model and the ZONAIR aerodynamic model overlap with each other. This can be achieved by introducing a **CORD2R** bulk data card with identification number = IDCOR that defines a coordinate system where the wind tunnel model is located. In the following figure, the X'-Y'-Z' system is the local coordinates defined by a **CORD2R** bulk data card whereas X-Y-Z is the aerodynamic coordinates of the ZONAIR aerodynamic model.



In the example, the nose of the fuselage of the wind tunnel model is located at x=z=0 and y = -100 (with respect to the ZONAIR aerodynamic model) whereas that of the ZONAIR aerodynamic model at x=y=z=0. To transform the wind tunnel model, it is required to specify a **CORD2R** bulk data card such as

CORD2R	50		0.0	-100.0	0.0	0.0	-100.0	1.0	+C
+C	0.0	-101.0	1.0						

In addition, because the above figure shows that the wind tunnel model is located in the negative y' axis, the entry IDCOR must be a negative integer (in this case, IDCOR = -50) to "flip" the wind tunnel model from the negative y-axis to the positive y-axis.

3. The wind tunnel data is stored in the free format. If there are *n* numbers of wind tunnel measured pressure coefficients, the format of the wind tunnel data is shown as follows:

   ID_1, X_1, Y_1, Z_1, CP_1
   ID_2, X_2, Y_2, Z_2, CP_2
   .
   .
   .
   .
   ID_n, X_n, Y_n, Z_n, CP_n

   where ID_i is the identification number of the wind tunnel pressure that is referred to by the entry $SETG_i$. Among all ID_i, no duplicate ID is allowed (Integer > 0).
   X_i, Y_i, and Z_i are the location of the *i*th wind tunnel pressure. (Real)

   CP_i is the *i*th measured pressure coefficient. (Real)
   Note that command cards may be used that must be initiated with a "$" in the first column. An example of the file is shown as follows:

```
$ CP ON WING UPPER SURFACE
     101    3.8066    2.1429    0.1530   -0.0474
      91   33.9695   19.2857   -0.1750   -0.0149
............ ...................................
........... ....................................
.......... .....................................
    1008   33.0853   23.5714   -0.3074   -0.0941
$ CP ON WING LOWER SURFACE
     100   37.6840   23.5714   -0.1642   -0.0125
     200   39.9833   23.5714   -0.0559    0.0428
......... ......................................
........ .......................................
....... ........................................
      98   43.5455   27.8571   -0.0522    0.0549
```

4. TECPLOT, FEMAP and I-DEAS are commercially available graphical software programs. I-DEAS universal file output are data sets 781 and 780 for aerodynamic grids and aerodynamic boxes, respectively. PATRAN is the pres- and post-processor of NASTRAN. FEMAP neutral file outputs

are Data Blocks 403 and 404 for aerodynamic grids and aerodynamic boxes, respectively. Structural grid points are displayed as points through DATA Block 570. The ANSYS output is a FEMAP neutral file that can be read in by an ANSYS neutral file translator developed by PADT Inc.

5. For the use of IPS, TPS and BEAM methods; please see Modeling Guidelines of SPLINE described in Chapter 6.

6. For lower surface panels generated by the **CAERO7** bulk data card, their identification numbers listed in the **PANLST2** bulk data card are the same as those of the upper surface panels except with a negative sign.

7. Because the structural deformation is usually smooth, using the linear attachment flexibility is not recommended for interpolating the structural deformation. This is not the case for pressure interpolation. Pressure distribution especially around the wing leading edge varies rapidly. Without the linear attachment flexibility, the interpolated pressure distribution may have "over-shot' and may be physically unrealistic. The least square approximation using the linear attachment flexibility can smoothen the interpolated pressure.

CPSPLNL **Wind Tunnel Measured Pressure**

Description: Maps the wind tunnel measured pressure coefficients onto ZONAIR aerodynamic panels by a linear spline method to replace the ZONAIR computed solution.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CPSPLNL	IDAERO	SCALE	IDCOR	FILEWT		FORM	PLTFILE		CONT
CONT	$METHOD_1$	CP_1	$SETK_1$	$SETGR_1$	$SETGL_1$	$NPOINT_1$	DZ_i	EPS_i	CONT
CONT	---	etc	---						

CPSPLNL	-100	12.0	3	WTCP.DAT		TECPLOT	WTCP.PLT		+C
+C	TPS	2	10	20	30	5	1000.		+C
+C	IPS	50	60	70	80	3	0.0		

Field	Contents
IDAERO	If IDAERO is a positive integer, it refers to the identification number of an **AEROGEN** bulk data card. The pressure coefficients on the rigid aircraft at the flight condition defined by the **AEROGEN** bulk data card with ID = IDAERO computed by the program are replaced by the wind tunnel measured pressure coefficients. If IDAERO is a negative integer, it is referred to by a **TRIMINP** or **WT1CFD** bulk data card. Note that the **CPSPLNL** bulk data card is processed after the **CPSPLN** bulk data card is processed. To rapidly verify the interpolated pressure coefficient, it is recommended that the **PARAM** bulk data card with entry NAME="BYPASS" be used. (Integer ≠ 0) (See Remark 1)
SCALE	A scale factor applying to the *x*, *y*, and *z* where the wind tunnel measured pressures are located. (Real > 0.0, default = 1.0)
IDCOR	Identification number of a **CORD2R** bulk data card defining a coordinate system in which the wind tunnel model is located. Note that IDCOR can be a negative integer. This negative sign implies that the wind tunnel model is located on the negative y-axis. (Integer) (See Remark 2)
FILEWT	File name to specify an ASCII file where the wind tunnel measured pressure coefficients are stored. If the first character of FILEWT starts with a dollar sign “$”, the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. The feature allows for filenames up to 56 characters to be input. (Character ≠ blank) (See Remark 3)

FORM	The format of the output plot file "PLTFILE": FORM = "TECPLOT" for generating a TECPLOT file FORM = "PATRAN" for generating a PATRAN neutral file FORM = "IDEAS" for generating an I-DEAS universal file FORM = "FEMAP" for generating a FEMAP neutral file FORM = "ANSYS" for generating an ANSYS supported neutral file FORM = "NASTRAN" for generating a NASTRAN bulk data deck (Character, default = "TECPLOT") (See Remark 4)
PLTFILE	File name to store the wind tunnel measurement locations and the ZONAIR aerodynamic panel model together to verify the overlapping between these two models. If the first character of PLTFILE starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. The feature allows for filenames up to 56 characters to be input. (Character or blank)
$METHOD_i$	Character string either "IPS" or "TPS" to indicate a spline method for interpolating the wind tunnel measured pressure coefficient onto the ZONAIR panels. For $METHOD_i$ = IPS, the infinite spline method similar to the **SPLINE1** bulk data card is used. For $METHOD_i$ = TPS, the thin plate method similar to the **SPLINE3** bulk data card.
CP_i	For $METHOD_i$ = IPS, the x-y plane of the local coordinate system in the coordinate system (aerodynamic coordinate system) defined by the **CORD2R** bulk data card referred to by the IDCOR entry is the spline plane for the infinite spline method. For $METHOD_i$ = TPS, Since the TPS method does not require a spline plane, CP_i has a completely different meaning. If CP_i=0, the x locations of those wind tunnel points listed in SETGR; and SEGRL; entries are sorted into the ascending order. If CP_i=1, the y locations are sorted and if CP_i=2, the z locations are sorted into the ascending order. (Integer $\geq$ 0) (See remark 5)
$SETK_i$	Identification number of a **PANLST2** or **PANLST3** bulk data card to list the identification numbers of the aerodynamic panels for pressure spline. Note that the **PANLST1** bulk data card is not allowed. (Integer > 0) (See remark 6)
$SETGR_i$	Identification number of a **SET1/SETADD** bulk data card to list the identification numbers of the wind tunnel pressure points along the right hand side of those ZONAIR panels listed in the **PANLST2/PANLST3** with identification number being equal to $SETK_i$. (Integer > 0)
$SETGL_i$	Same as $SETGR_i$ except for the left hand side. Note that the number of pressure points listed in $SETGL_i$ must be the same as that in $SETGR_i$. (Integer > 0)

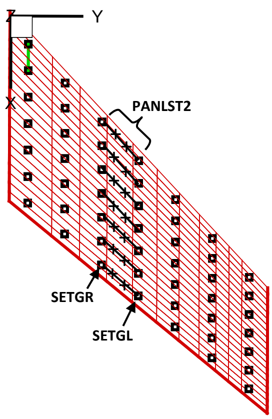
NPOINTi The number of points between two pressure points, listed in $SETGR_i$ and $SETGL_i$ are created internally by the linear interpolation. (Integer > 1, default = 3)

DZ_i Linear attachment flexibility for least square approximation. (Real ≥ 0.0).(See Remark 7)

EPS_i Multiplication factor to obtain a small tolerance to detect any duplicated location of wind tunnel pressure points. The tolerance is computed by EPS*REFC, where REFC is the reference chord defined in the **AEROZ** bulk data card. (Real ≥ 0.0, Default = 0.00001)

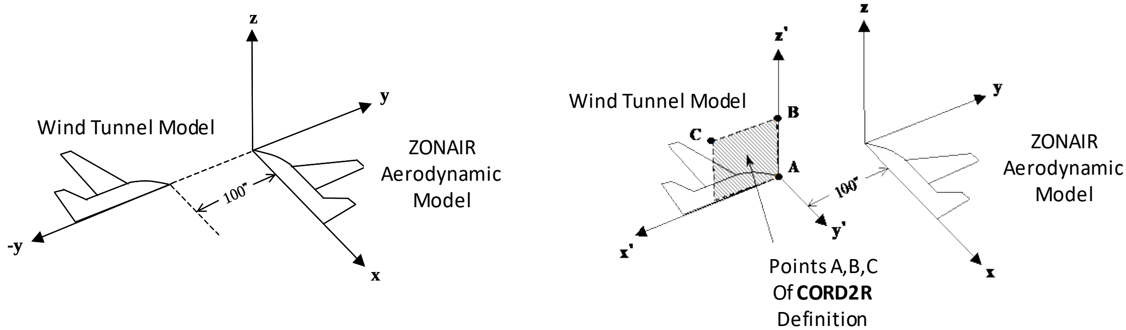
Remarks:

1. The **CPSPLNL** bulk data card uses two columns of wind tunnel pressure points to interpolate the pressure coefficients at those points to the ZONAIR panels between those two columns. For instance, shown in the figure below, the two columns shown by the black square symbols are the wind tunnel pressure locations specified by $SETGR_i$ and $SETGL_i$, respectively. The ZONAIR panels on which the pressure coefficients are interpolated from those two columns of wind tunnel pressure locations are listed in the entry $SETK_i$. In order to ensure that the linear interpolation takes place for the pressure interpolation, the program internally creates extra points between the right hand side (RHS) and left hand side (LHS) pressure points. The number of extra points is defined by the entry $NPOINT_i$. (NPOINT=2 is shown in the figure below). The locations and pressure coefficients at those extra points are linearly interpolated from the RHS and LHS pressure points. These extra points and those listed in the RHS and LHS columns together are used for interpolation either by the infinite plate spline (IPS) or thin plate spline (TPS) method.



2. Because the wind tunnel model may be oriented in an arbitrary fashion with respect to the aerodynamic model, it is required to transform the wind tunnel model so that the wind tunnel model and the ZONAIR aerodynamic model overlap with each other. This can be achieved by introducing a **CORD2R** bulk data card with identification number = IDCOR that defines a coordinate system where the wind tunnel model is located. In the following figure, the X'-Y'-Z' system is the local

coordinates defined by a **CORD2R** bulk data card whereas X-Y-Z is the aerodynamic coordinates of the ZONAIR aerodynamic model.



In the example, the nose of the fuselage of the wind tunnel model is located at x=z=0 and y = -100 (with respect to the ZONAIR aerodynamic model) whereas that of the ZONAIR aerodynamic model at x=y=z=0. To transform the wind tunnel model, it is required to specify a **CORD2R** bulk data card such as

CORD2R	50		0.0	-100.0	0.0	0.0	-100.0	1.0	+C
+C	0.0	-101.0	1.0						

In addition, because the above figure shows that the wind tunnel model is located in the negative y' axis, the entry IDCOR must be a negative integer (in this case, IDCOR = -50) to "flip" the wind tunnel model from the negative y-axis to the positive y-axis.

3. The wind tunnel data is stored in the free format. If there are *n* numbers of wind tunnel measured pressure coefficients, the format of the wind tunnel data is shown as follows:

ID_1, X_1, Y_1, Z_1, CP_1
ID_2, X_2, Y_2, Z_2, CP_2
.
.
.
.
ID_n, X_n, Y_n, Z_n, CP_n

where ID_i is the identification number of the wind tunnel pressure that is referred to by the entry $SETG_i$. Among all ID_i, no duplicate ID is allowed (Integer > 0).
X_i, Y_i, and Z_i are the location of the *i*th wind tunnel pressure. (Real)

CP_i is the *i*th measured pressure coefficient. (Real)

Note that command cards may be used that must be initiated with a “$” in the first column. An example of the file is shown as follows:

```
$ CP ON WING UPPER SURFACE
     101    3.8066    2.1429    0.1530   -0.0474
      91   33.9695   19.2857   -0.1750   -0.0149
............ ..................................
........... ...................................
.......... ....................................
    1008   33.0853   23.5714   -0.3074   -0.0941
$ CP ON WING LOWER SURFACE
     100   37.6840   23.5714   -0.1642   -0.0125
     200   39.9833   23.5714   -0.0559    0.0428
......... .....................................
........ ......................................
....... .......................................
      98   43.5455   27.8571   -0.0522    0.0549
```

4. TECPLOT, FEMAP and I-DEAS are commercially available graphical software programs. I-DEAS universal file output are data sets 781 and 780 for aerodynamic grids and aerodynamic boxes, respectively. PATRAN is the pres- and post-processor of NASTRAN. FEMAP neutral file outputs are Data Blocks 403 and 404 for aerodynamic grids and aerodynamic boxes, respectively. Structural grid points are displayed as points through DATA Block 570. The ANSYS output is a FEMAP neutral file that can be read in by an ANSYS neutral file translator developed by PADT Inc.

5. In order to create those extra points, the locations of the pressure points must be in the ascending order either according to the x, y, or z locations. For $METHOD_i$ = IPS, the program automatically sorts the x locations of those RHS and LHS columns of pressure points. For $METHOD_i$ = TPS, the user must decide to use x, y, or z locations for sorting. For instance, if the pressure points are around the leading edge of the wing located on the x-y plane, $CP_i = 2$ should be used to sort the z locations.

6. For lower surface panels generated by the **CAERO7** bulk data card, their identification numbers listed in the **PANLST2** bulk data card are the same as those of the upper surface panels except with a negative sign.

7. Because the structural deformation is usually smooth, using the linear attachment flexibility is not recommended for interpolating the structural deformation. This is not the case for pressure interpolation. Pressure distribution especially around the wing leading edge varies rapidly. Without the linear attachment flexibility, the interpolated pressure distribution may have "over-shot' and may be physically unrealistic. The least square approximation using the linear attachment flexibility can smoothen the interpolated pressure.

CQUAD4 Quadrilateral Aerodynamic Panel

Description: Defines a quadrilateral aerodynamic surface panel by four surface grid points.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CQUAD4	EID	PID	G1	G2	G3	G4			

CQUAD4	10	1	3	6	8	101			

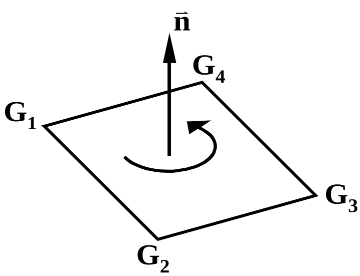
Field	Contents
EID	Unique panel identification number (Integer > 0) (See Remark 1)
PID	Identification number of a **PSHELL** bulk data card (Integer > 0) (See Remark 2)
G1, G2, G3, G4	Identification numbers of connected grid points (**GRID** bulk data cards) G_i must be the surface grid (PS = 0 in the **GRID** bulk data card) (Unique, Integer > 0) (See Remark 3)

Remarks:

1. Among all **CQUAD4, CTRIA3, CAERO7**, and **BODY7** bulk data cards, EID must be unique.

2. The **PSHELL** bulk data card must exist.

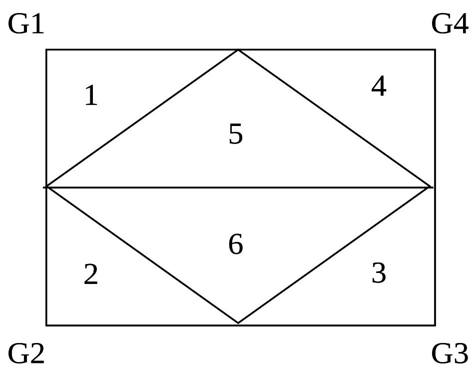
3. The sequence of the four corner grid points defines the out-normal vector of the panel. See figure below:



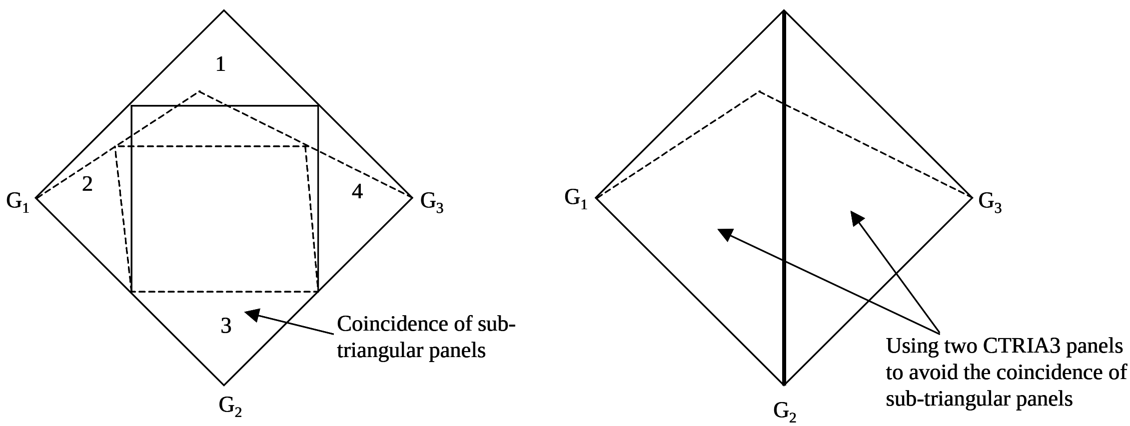
The user must ensure the out-normal vector is toward “outside” the aerodynamic model. Incorrect out-normal vector will definitely lead to wrong results.

Note:

- The program subdivides each CQUAD4 panel into six sub-triangular panels show below.



- Two CQUAD4 sharing three grid points will give a coincidence of the sub-triangular panels and lead to a singular matrix. In the following figure, two CQUAD4 share the same three grid points G_1, G_2, and G_3. In this case, one can see that the third sub-triangular panels of the upper and lower CQUAD4 panels coincide with each other. To avoid such a coincidence one can use two CTRIA3 panels instead of one CQUAD4 panel.



CROD Line Vortex Element

Description: Defines a line vortex element by two surface grid points.

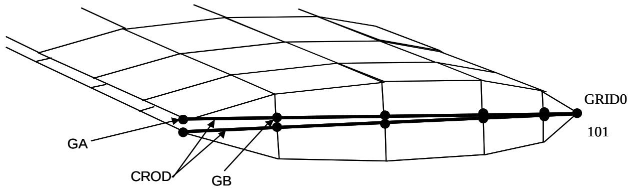
Format and Example:

1	2	3	4	5	6	7	8	9	10
CROD	EID	GRID0	GA	GB					
CROD	1	101	141	105					

Field	Contents
EID	Identification number. (Integer > 0) (See Remark 1)
GRID0	A surface grid ID at which this line vortex element originates. (Integer > 0)
GA, GB	Identification numbers of two **GRID** bulk data cards. GA and GB must be the surface grid points (PS = 0 in the **GRID** bulk data card) (Integer > 0)

Remarks:

1. The line vortex element is usually placed along the tip of a thick-wing component to simulate the tip vortex effects.



2. The CROD generated an inviscid vortex flow at which the induced velocity is infinite at the center of the vortex core. This may create numerical problems if a receiving point exactly aligns with the line of the CROD. To circumvent this problem, the user may select the viscous vortex core model by specifying the **VISCOUS** bulk data card.

CSHEAR

Wake Panel

Description: Defines a wake panel on the curved wake surface.

Format and Example:

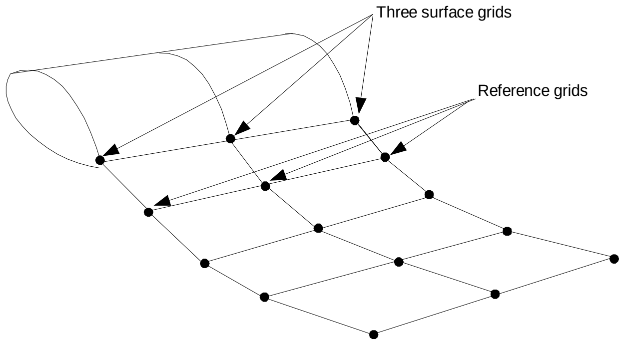
1	2	3	4	5	6	7	8	9	10
CSHEAR	EID	PID	G1	G2	G3	G4	CROD	CBAR	

CSHEAR	10	20	101	131	140	160	13	2	

Field	Contents
EID	Unique identification number. (Integer > 0) (See Remark 1)
PID	Identification number of a **PSHEAR** bulk data card. (Integer > 0) (See Remark 2)
G1, G2, G3, and G4	Identification numbers of the surface grid or reference grid points that connect the CSHEAR panel. (Integer > 0) (See Remark 3)
CROD	Indices of the four side edges of the CSHEAR panel along which CROD elements are attached. (Integer or Blank)
CBAR	Same as CROD but for the CBAR elements. (Integer of Blank) (See Remark 4)

Remarks:

1. To model a curved wake surface shed from a body or thick wing component, the user can discretize the curved wake surface by reference grids (defined by the **GRID** bulk data card with entry PS≠0) and connect these reference grids by the CSHEAR panels. In the following example, the curved wake surface that is attached to the three surface grids is discretize by 3 × 4 reference grids.

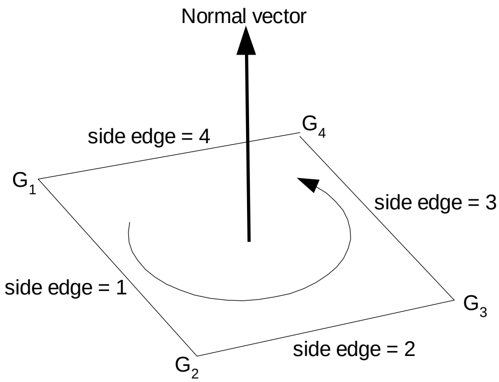


These 3 × 4 reference grids and 3 surface grids are connected by 2 × 4 CSHEAR panels. A sheet of doublet singularity is placed on each CSHEAR panel to model the vorticity shed from the three surface grids.

2. The **PSHEAR** bulk data card must exist to impose the constant potential condition on the CSHEAR panels.

3. For those CSHEAR panels immediately behind the surface grids, two of G1, G2, G3, and G4 must be the surface grids and the other two are the reference grids. The rest of the CSHEAR panels are connected by the reference grids. Note that for triangular CSHEAR panel, G3=G4 must be specified.

4. The indices of the four side edges are shown in the following figure where the first side edge is connected by G_1 and G_2, the second by G_2 and G_3, the third by G_3 and G_4 and the fourth by G_4 and G_1.



The CROD entry (or the CBAR entry for the CBAR element) can be an integer of any combination by 1, 2, 3, or 4. For instance, CROD = 134 implies that three CROD elements are placed along the first, third and fourth side edges.

CTRIA3 — Triangular Aerodynamic Panel

Description: Defines a triangular aerodynamic surface panel by three surface grid points.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CTRIA3	EID	PID	G1	G2	G3				

CTRIA3	100	1	4	7	8				

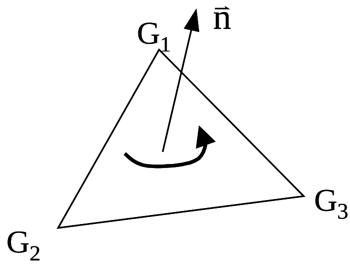
Field	Contents
EID	Unique element identification number. (Integer > 0)
PID	Identification number of a **PSHELL** bulk data card. (Integer > 0) (See Remark 2)
G1, G2, G3	Identification numbers of connected grid points (**GRID** bulk data cards) G_i must be the surface grid points (PS = 0 in the **GRID** bulk data card). (Unique, Integer > 0) (See Remark 3)

Remarks:

1. Among all **CQUAD4**, **CTRIA3**, **CAERO7**, and **BODY7** bulk data cards, EID must be unique.

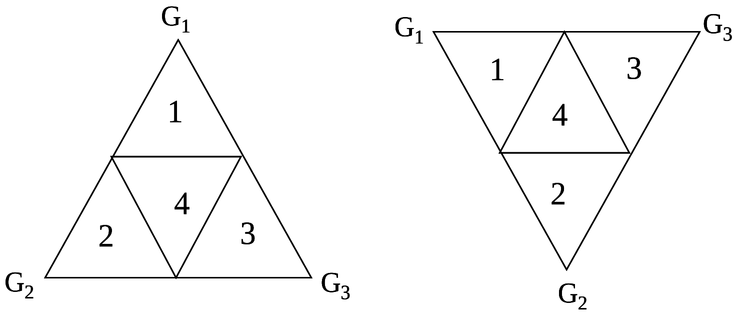
2. The **PSHELL** bulk data card must exist.

3. The sequence of the three corner grid points defines the out-normal vector of the panel as shown below.



The user must ensure the the out-normal vector is toward "outside" the aerodynamic model. Incorrect out-normal vector will definitely lead to wrong results.

Note that the program subdivides each CTRIA3 panel into four sub-triangular panels shown below.


G_1
1
4
2
3
G_2
G_3
G_1
G_3
1
3
4
2
G_2

DESDEP — Dependent Geometry Parameter

Description: Defines a dependent geometry parameter. This function is defined by the following equation where *DESDEP* represents the resulting value of the **DESDEP** bulk data card.

$$DESDEP = \sum_{i=1}^{n} A_i \cdot IDPRMA_i \cdot FUN_i \left(B_i \cdot IDPRMB_i \cdot \oplus_i \; C_i \cdot IDPRMC_i \right)$$

Format and Example:

1	2	3	4	5	6	7	8	9	10
DESDEP	IDDEP	LABEL	BULK	ID	ENTRY	ITH			CONT
CONT	A_1	$IDPRMA_1$	FUN_1	B_1	$IDPRMB_1$	$SYMBOL_1$	C_1	$IDPRMC_1$	CONT
CONT	A_2	$IDPRMA_2$	FUN_2	B_2	$IDPRMB_2$	$SYMBOL_2$	C_2	$IDPRMC_2$	CONT
CONT	-etc-	…	…	-etc-	…	…	…	-etc-	

DESDEP	100	SWEEP	WING	200	XTL	1			+D1
+D1	1.0	100	ATAN	-1.0	110	/	2.0	120	+D2
+D2	1.0	130	*	3.0	140				

Field	Contents
IDDEP	Identification number that is referred to by a **DESSEN** bulk data card. (Integer > 0) (See Remark 1)
LABEL	Any character string (up to 8 characters) with no embedded blanks to define the label of the dependent geometry parameter. (Character)
BULK	The name of a bulk data card that contains the dependent geometry input. (Character) (See Remark 2)
ID	Identification number of the bulk data card specified in the entry BULK. If the bulk data card referenced by BULK is identified by a label rather than an integer, then ID must be input as the label. (Integer or Character)
ENTRY	The name of the entry of the bulk data card specified in the entry BULK. The value of this entry is the dependent geometry parameter that is subjected to the change by the shape design variable. (Character)
ITH	For open-ended bulk data cards, there can be multiple entries of ENTRY (i.e., when the bulk data entry name is subscripted with an "i"). ITH indicates which "i-th"entry is selected as the dependent geometry parameter. For any ENTRY that does not have a subscript i, ITH should be set to 0 (Integer ≥ 0, Default = 1) (See Remark 3)
A_i	A real coefficient involved in the above equation (Real, Default = 1.0)
$IDPRMA_i$	Identification number of a **DESVAR**, **DESIND** or **DESFUN** bulk data card whose resulting value is plugged into the above equation. If $IDPRMA_i$=0, the resulting value is 1.0 (Integer ≥ 0)

FUN_i	Character string to define a function involved in the above equation. (Character) FUN_i = SIN — the function is Sine FUN_i = COS — the function is Cosine FUN_i = TAN — the function is Tangent FUN_i = ASIN — the function is Arcsine FUN_i = ACOS — the function is Arccosine FUN_i = ATAN — the function is Arctan FUN_i = SQRT — the function is a Square Root FUN_i = LOG — the function is a Natural Logarithm FUN_i = LOG10 — the function is a Logarithm of base 10 FUN_i = EXP — the function is an Exponential FUN_i = ABS — the function is the Absolute Value FUN_i = * — the function is Multiplication FUN_i = / — the function is Division FUN_i = UNIT — the resulting function is 1.0 and the remaining entries Bi, IDPRMB Ci, and IDPRMCi are not used.
B_i	A real coefficient shown in the above equation (Real, Default = 1.0)
$IDPRMB_i$	Same as IDPRMAi except the resulting value is plugged into its position shown in the above equation. (Integer ≥ 0)
$SYMBOL_i$	Character string representing the symbol $\oplus$ in the above equation. (Character, Default = +) $SYMBOL_i$ = + results in $(B_i \cdot IDPRMB_i) + (C_i \cdot IDPRMC_i)$ $SYMBOL_i$ = - results in $(B_i \cdot IDPRMB_i) - (C_i \cdot IDPRMC_i)$ $SYMBOL_i$ = * results in $(B_i \cdot IDPRMB_i) * (C_i \cdot IDPRMC_i)$ $SYMBOL_i$ = / results in $(B_i \cdot IDPRMB_i) / (C_i \cdot IDPRMC_i)$
C_i	A real coefficient shown in the above equation (Real)
$IDPRMC_i$	Same as $IDPRMA_i$ except its resulting value is plugged into its position shown in the above equation. (Integer ≥ 0)

<u>Remarks:</u>

1. The **DESDEP** bulk data card defines a dependent geometry parameter whose value depends on the value of the shape design variable. The **DESDEP** bulk data card refers to an ENTRY in a bulk data card that is associated with the geometry input of the box model. The value of this ENTRY is calculated by the equation shown above that is a function of the bulk data card(s) **DESFUN, DESIND** or **DESVAR**. Note that only those **DESDEP** bulk data cards referenced in the **DESSEN** bulk data card are active (i.e., those not referenced by any DESSEN have no effect).

2. The entries BULK, ID, ENTRY, and ITH jointly define a <u>dependent</u> geometry parameter whose value is subjected to the change by the shape design variable being specified (typically by a **DESVAR** bulk data card).

3. The following example shows what the ITH value would be for an open-ended bulk data card.

```
SEGMESH 2001     10      11
        1       10.0    0.0     15.0   to change any real value on this line, ITH = 1
        1       20.0    0.0     15.0   to change any real value on this line, ITH = 2
        1       30.0    0.0     15.0   to change any real value on this line, ITH = 3
        1       40.0    0.0     15.0   to change any real value on this line, ITH = 4
                                       and so on...
```

To change an entry for a <u>non</u>-open-ended bulk data card, ITH should be set to 0.

to change any of these example entries, ITH = 0

```
CORD2R  101             0.0     0.0     0.0     0.0     0.0     1.0
        0.0     1.0     1.0
```

DESFUN

Variable Linking Function

Description: Defines a function to link the dependent geometry parameter with the independent geometry parameters and the shape design variables.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DESFUN	IDPRM	FUN							CONT
CONT	$OPEN_1$	A_1	$IDVARA_1$	B_1	$IDVARB_1$	C_1	$CLOSE_1$	E_1	CONT
CONT	$OPEN_2$	A_2	$IDVARA_2$	B_2	$IDVARB_2$	C_2	$CLOSE_2$	E_2	CONT
CONT				…	etc	…			

DESFUN	100	SIN							+D1
+D1	(	2.0	10	1.0	20	2.0			+D2
+D2	+	3.0	0		0		)	2.0	+D3
+D3	/(	1.0	10	2.0	0				+D4
+D4	-	1.0	0		30	3.0	)	3.0	

Field	Contents
IDPRM	Unique identification number that is referred to by a **DESDEP** bulk data card. Among all **DESFUN**, **DESIND,** and **DESVAR** bulk data cards, no duplicate identification number is allowed. (Integer > 0) (See Remark 1)
FUN	Character string to define a function. (Character, Default = blank) FUN = SIN — the function is Sine FUN = COS — the function is Cosine FUN = TAN — the function is Tangent FUN = ASIN — the function is Arcsine FUN = ACOS — the function is Arccosine FUN = ATAN — the function is Arctan FUN = SQRT — the function is a Square Root FUN = LOG — the function is a Natural Logarithm FUN = LOG10 — the function is a Logarithm of base 10 FUN = EXP — the function is an Exponential FUN = ABS — the function is the Absolute Value FUN = blank — no function is applied
$OPEN_i$	For $OPEN_1$, $OPEN_1$ must be one of "(", "((", "(((", "((((", "(((((", "((((((", or "(((((((". For $OPEN_i$ where i > 1, the first character in $OPEN_i$ must be either "+", "-", "*", or "/". The rest of the characters must be one of "(", "((", "(((", "((((", "(((((", "((((((", "(((((((" or blank. (Character)
A_i	A real coefficient. (Real, Default = 1.0)

$IDVARA_i$	Identification number of a **DESVAR**, **DESIND** or another **DESFUN** bulk data card whose resulting value is used to in the function. If $IDVARA_i = 0$, the value is assumed to be 1.0. (Integer ≥ 0) (See Remark 2)
B_i	A Real coefficient that is the exponent of $IDVARA_i$, i.e. $\left(\mathrm{IDVARA}_i\right)^{B_i}$. (Real, Default = 1.0)
$IDVARB_i$	Same as $IDVAR_i$ except defining the second value in the function. (Integer ≥ 0)
C_i	Same as B_i except for $\left(\mathrm{IDVARB}_i\right)^{C_i}$.
$CLOSE_i$	Character string either ")", "))", ")))", "))))", ")))))", "))))))", ")))))))" or blank. (Character)
E_i	A real coefficient that is the exponent of the function that is enclosed by a pair of open parenthesis ("(") and a closed parenthesis (")"). (Real, Default =1.0)

Remarks:

1. The **DESFUN** bulk data card defined an algebraic equation whose resulting value is a function of the shape design variables (defined by the **DESVAR** bulk data card) and the independent geometry parameters (defined by the **DESIND** bulk data card). The **DESFUN** bulk data card is referred to by a **DESDEP** bulk data card to link the dependent geometry parameter with the shape design variable and the independent geometry parameter. This algebraic equation is defined as:

$$F = FUN\left[\sum_{i=1}^{n}\left(OPEN_i\right)A_i\cdot\left(IDVARA_i\right)^{B_i}\cdot\left(IDVARB_i\right)^{C_i}\left(CLOSE_i\right)^{E_i}\right]$$

2. The **DESFUN** bulk data card can be used to define any algebraic equation as a function of $IDVARA_i$ and $IDVARB_i$.

   For example, let x be the value of a shape design variable being defined by the **DESVAR** bulk data card with ID = 10 and y be the value of an independent geometry parameter being defined by the **DESIND** bulk data card with ID = 20, if the algebraic equation is:

$$F = \frac{\left(\left(3.14x^2+1.4xy^3\right)+\sqrt{\left(x^2+x+1.0\right)^2+\sqrt{1000.0+2y^2+x}}\right)}{\left(10.0xy+\left(x+10.\right)y+x^3\right)^{3.2}}$$

   the corresponding **DESFUN** bulk data card is:

DESFUN	1								+D1
+D1	((	3.14	10	2.0	0				+D2
+D2	+	1.4	10	1.0	20	3.0	)	1.0	+D3
+D3	+((	1.0	10	2.0	0			1.0	+D4
+D4	+	1.0	10	1.0	0			1.0	+D5
+D5	+	1.0	0	0.0	0	0.0	)	2.0	+D6

+D6	+(	1000.0	0	0.0	0	0.0			+D7
+D7	+	2.0	20	2.0	0	0.0			+D8
+D8	+	1.0	10	1.0			)	0.5	+D9
+D9	+	0.0	0				)	0.5	+D10
+D10	+						)	1.0	+D11
+D11	/(	10.0	10	1.0	20	1.0			+D12
+D12	+(	1.0	10	1.0					+D13
+D13	+	10.0	0	1.0			)		+D14
+D14	*	1.0	20						+D15
+D15	+	1.0	10	3.0			)	3.2	

DESIND — Independent Geometry Parameter

Description: Defines an independent geometry parameter whose value is used to calculate the value of a dependent geometry parameter.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DESIND	IDGEO	LABEL	BULK	ID	ENTRY	ITH			

DESIND	100	LE	SEGMESH	10	X	50			

Field	Contents
IDGEO	Unique identification number that is referred to by a **DESFUN** or **DESDEP** bulk data card. Among all **DESIND**, **DEFUN** and **DESVAR** bulk data cards, no duplicate identification number is allowed. (Integer > 0) (See Remark 1)
LABEL	Any character string to define the label of the independent geometry parameter (Character)
BULK	The name of a bulk data card that is associated with the geometry input of the aerodynamic model. (Character) (See Remark 2)
ID	Identification number of the bulk data card specified in the entry BULK. If the bulk data card **BULK** is identified by label, ID is a character string that is used to refer to this bulk data card. (Integer or Character)
ENTRY	The name of the entry of the bulk data card specified by the entry BULK. The value of this entry is the independent geometry parameter that is involved in the equation defined in the **DESFUN** bulk data card. (Character)
ITH	For an open-ended bulk data card, there could be multiple entries of ENTRY; ITH indicates which entry is selected as the independent geometry parameter. (Integer ≥ 0, Default = 1)

Remarks:

1. The **DESIND** bulk data card defines an independent geometry parameter whose value is independent of the shape design variable and is only used to calculate the value of the dependent geometry parameter. The **DESIND** bulk data card refers to an ENTRY in a bulk data card that is associated with the geometry input of the aerodynamic model.

2. The entries BULK, ID, ENTRY, and ITH jointly define an independent geometry parameter whose value is used to calculate the value of a dependent geometry parameter via the **DESFUN** bulk data card.

DESSEN Linking Dependent Geometry Parameters

Description: Links a set of dependent geometry parameters by shape design variables.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DESSEN	IDSEN	FILENM							CONT
CONT	$IDDEP_1$	$IDDEP_2$	…	etc	…				

DESSEN	10								+D
+D	101	201	301						

Field	Contents
IDSEN	Identification number that is referred to by a **DESSEN** Executive Control Command. (Integer > 0) (See Remark 1)
FILENM	A filename that stores those bulk data cards whose input entries are changed by the **DESDEP** bulk data card. The user can replace those bulk data cards in the input deck by those stored in FILENM to obtain an updated model. (Character or Blank)
$IDDEP_i$	Identification number of a **DESDEP** bulk data card whose defined dependent geometry parameter is perturbed by the shape design variable. (Integer > 0) (See Remark 2)

Remarks:

1. Because only one **DESSEN** Executive Control Command is allowed to be specified in the Executive Control Section, one job only computes the sensitivity of one shape design variable.

2. Among all **DESDEP** bulk data cards in the input file, only those listed in the **DESSEN** bulk data card are activated.

DESVAR

Shape Design Variable

Description: Defines a shape design variable.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DESVAR	IDVAR	LABEL	BASE						

DESVAR	10	SWEEP	30.0						

Field	Contents
IDVAR	Unique identification number. Among all **DESVAR, DESFUN,** and **DESIND** bulk data cards, no duplicate identification number are allowed. (Integer > 0) (See Remark 1)
LABEL	Any character string to define the label of the shape design variable. (Character)
BASE	Baseline value of the shape design variable. (Real) (See Remark 2)

Remarks:

1. The shape design variable may not be an input entry of those bulk data cards for defining the geometry of the aerodynamic model. It is a shape design variable defined by the user and is controlled by the optimizer. If the value of the shape design variable is updated by the optimizer, all dependent geometry parameters being defined by the **DESDEP** bulk data cards listed in the **DESSEN** bulk data card are changed accordingly.

2. BASE is used to compute the sensitivity of the aerodynamic surface mesh using the Complex Variable Differentiation (CVD) technique. Note that the BASE must be properly calculated for input so that all dependent geometry parameters that are a function of the shape design variable matches with their corresponding value specified in their associated bulk data card.

DMI

Header of Direct Matrix Input

Description: Defines the header information of **DMIS** or **DMIL** bulk data cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DMI	NAME	ZERO	FORM	TIN	TOUT	LARGE	M	N	

DMI	BBB	0	2	1		DMIS	7	2	

Field	Contents
NAME	Name of the matrix (Character) (See Remark 1)
ZERO	Must be an integer “0”.
FORM	Form of matrix, as follows: (Integer) 2 = General rectangular matrix 6 = Symmetric matrix
TIN	Type of matrix being inputted, as follows: (Integer) 1 = Real, single precision (one field used/element) 2 = Real, double precision (one field used/element) 3 = Complex, single precision (two fields used/element) 4 = Complex, double precision (two fields used/element)
TOUT	Not used.
LARGE	Character string either = “DMIL” or “DMIS”. (Character) (See Remark 2) LARGE = “DMIL”, the element of the matrix is defined by the **DMIL** bulk data card LARGE = “DMIS”, the element of the matrix is defined by the **DMIS** bulk data card
M	Number of columns in NAME. (Integer > 0)
N	Number of columns in NAME. (Integer > 0)

Remarks:

1. The name of the matrix cannot be the same as the name of any data entities existed on the runtime database.
2. **DMIL** bulk data card is the large field matrix input if high precision is required for defining the numerical values of the matrix elements. Otherwise, use **DMIS** bulk data card.

DMIG

Direct Matrix Input at Structural Finite Element Grid Points

Description: Defines structure-related direct input matrices with terms located by specifying the identification numbers of the structural Finite Element Method (FEM) grid points and their component values.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DMIG	NAME	PREC	FORM						CONT
CONT	GCOL	CCOL	GROW	CROW	x_{ij}		y_{ij}		CONT
CONT	GCOL	CCOL	GROW	CROW	x_{ij}		y_{ij}		

DMIG	MASS1	RSP	SYM						+A
+A	1001	4	2001	2	1.25E+05				+B
+B	1001	4	3001	3	2.7E+04		-etc-		

Field	Contents
NAME	Character string to define the name of the matrix. (Character) (See Remark 1)
PREC	The precision of the matrix. Any one of the following character string: RSP, RDP, CSP or CDP. (Character) (See Remark 2)
FORM	Character string either REC or SYM. (Character) (See Remark 3)
GCOL	Identification number of a grid point in the structural finite element model for column index. (Integer > 0) (See Remark 4)
CCOL	Component number for GCOL. 1 ≤ CCOL ≤ 6. (Integer > 0)
GROW	Identification number of a grid point in the structural finite element model for row index. (Integer > 0) (See Remark 5)
CROW	Component number for GROW. 1 ≤ CROW ≤ 6. (Integer > 0)
x_{ij}, y_{ij}	Matrix terms. x_{ij} is real part for real or complex matrix. y_{ij} is the imaginary part for complex matrix. y_{ij} is not used for real matrix. Noted that x_{ij} and y_{ij} occupy 2 fields for each input value. (Real) (See Remark 6)

Remarks

1. **DMIG** creates a matrix with entity name = NAME. The size of matrix is *g-set* by *g-set* where *g-set* is 6 × (number of structural grid points). This matrix can be used to specify an elementary mass or stiffness matrix of an element in the structural finite element model as a design variable for sensitivity analysis.

2 RSP = Real Single Precision, RDP = Real Double Precision, CSP = Complex Single Precision and CDP = Complex Double Precision.

3. REC = Rectangular matrix. SYM = Symmetric matrix. Note that if FORM = SYM, only the upper triangular part of the matrix (including the diagonal) is allowed for input.

4. GCOL and CCOL define the column index. The column index can be calculated by $6 \times n$ + CCOL, where n is the number of structural grid points whose identification numbers are smaller than GCOL.

5. GROW and CROW define the row index of the matrix. The row index can be calculated by $6 \times n$ + CROW, where n is the number of structural grid points whose identification numbers are smaller than GROW.

6. The column index and row index can uniquely define the location of x_{ij} (and y_{ij} for complex matrix) in the matrix. All terms in the matrix that are not specified in the **DMIG** bulk data card will be zero. The mass unit and the length unit involved in the terms must be consistent with the FMMUNIT and FMLUNIT entries defined in the **AEROZ** bulk data card.

DMIL — Matrix Element Value Definition by Large Fields (16-Column Fields)

Description: Defines the values of matrix elements by 16-column fields. **DMIL** is referred to by **DMI** bulk data cards.

Format and Example:

1	2 3	4 5	6 7	8 9	10
DMIL	NAME	J	I1	A(I1, J)	CONT
CONT	…	-etc-	I2	A(I2, J)	CONT
CONT	…	-etc-			

DMIL	BBB	1	1	1.0	+D1
+D1	4.0	8.0	2.0	7	+D2
+D2	9.0				

Field	Contents
NAME	Name of the matrix. NAME must be the same as the entry NAME of the **DMI** bulk data card. (Character)
J	Column number of NAME. (Integer > 0)
I1, I2, etc.	Row number of NAME, which indicates the beginning of a group of nonzero elements in the column. (Integer > 0)
A(Ix, J)	Real part of element (see TIN of **DMI** bulk data card). (Real)
B(Ix, J)	Imaginary part of element (see TIN of **DMI** bulk data card). (Real)

Remarks:

1. **DMIL** is referred by the **DMI** bulk data card with entry LARGE = ′**DMIL**′. The size and type of the matrix is defined in the **DMI** bulk data card.

2. The matrix elements is shown as follows:

$$[\,\text{NAME}\,] = \begin{bmatrix} A(1,1) & A(1,2) & \cdots & A(1,N) \\ A(2,1) & A(2,2) & \cdots & A(2,N) \\ \vdots & \vdots & & \vdots \\ A(M,1) & A(M,2) & \cdots & A(M,N) \end{bmatrix}$$

where M is the number of rows and N is the number of columns. M and N are defined in the **DMI** bulk data card.

3. For symmetric matrix, only the input of the upper triangular part (including the diagonals) is allowed, i.e. $I \leq J$.

4. Only nonzero terms need to be entered. Therefore, I1, I2, etc. are the row locations of the first nonzero element in the J^{th} column.

5. Complex input must have both the real and imaginary parts entered if either part is nonzero; i.e., the zero component must be inputted explicitly.

<u>Example of a Complex Matrix:</u>

DMIL	QQQ	1	1	4.0	+Q1
+Q1	2.0	5.0	0.0	4	+Q2
+Q2	6.0	6.0			
DMIL	QQQ	2	2	7.0	+Q3
+Q3	7.0	4	4.0	4.0	

$$[QQQ] = \begin{bmatrix} 4.0+2.0i & 0.0+0.0i \\ 5.0+0.0i & 7.0+7.0i \\ 0.0+0.0i & 0.0+0.0i \\ 6.0+6.0i & 4.0+4.0i \end{bmatrix}$$

6. **DMIL** can be repeatedly specified for each column of the matrix. For columns that are not referred to by the **DMIL** bulk data card, null columns are assumed.

DMIS

Matrix Element Value Definition by 8-Column Fields

Description: Defines the values of the matrix elements by 8-column fields. **DMIS** is referred to by **DMI** bulk data cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DMIS	NAME	J	I1	A(I1,J)	A(I1+1,J)	…	-etc-	I2	CONT
CONT	A(I2,J)	…	-etc-						

DMIS	BBB	1	1	1.0	4.0	8.0	2.0	7	+D1
+D1	9.0								

Field	Contents
NAME	Name of the matrix. NAME must be the same as the entry NAME of the **DMI** bulk data card. (Character)
J	Column number of NAME. (Integer > 0)
I1, I2, etc.	Row number of NAME, which indicates the beginning of a group of nonzero elements in the column. (Integer > 0)
A(Ix, J)	Real part of element (see TIN of **DMI** bulk data card). (Real)
B(Ix, J)	Imaginary part of element (see TIN of **DMI** bulk data card). (Real)

Remarks:

1. **DMIS** is referred to by the **DMI** bulk data card with entry LARGE = ′**DMIS**′. The size and type of the matrix is defined in the **DMI** bulk data card.

2 The locations of the matrix elements is shown as follows:

$$[\ \mathrm{NAME}\ ] = \begin{bmatrix} A(1,1) & A(1,2) & \cdots & A(1,N) \\ A(2,1) & A(2,2) & \cdots & A(2,N) \\ \vdots & \vdots & & \vdots \\ A(M,1) & A(M,2) & \cdots & A(M,N) \end{bmatrix}$$

where M is the number of rows and N is the number of columns. M and N are defined in the **DMI** bulk data card.

3. For symmetric matrix, only the input of the upper triangular part (including the diagonals) is allowed, i.e. $I \le J$.

4. Only nonzero terms need to be entered. Therefore, I1, I2, etc. are the row locations of the first nonzero element in the J^{th} column.

5. Complex input must have both the real and imaginary parts entered if either part is nonzero; i.e., the zero components must be inputted explicitly.

Example of a Complex Matrix:

DMIS	QQQ	1	1	4.0	2.0	5.0	0.0	4	
	6.0	6.0							
DMIS	QQQ	2	2	7.0	7.0	4	4.0	4.0	

$$[QQQ] = \begin{bmatrix} 4.0 + 2.0i & 0.0 + 0.0i \\ 5.0 + 0.0i & 7.0 + 7.0i \\ 0.0 + 0.0i & 0.0 + 0.0i \\ 6.0 + 6.0i & 4.0 + 4.0i \end{bmatrix}$$

6. **DMIS** can be repeatedly specified for each column of the matrix. For columns that are not referred to by the **DMIS** bulk data card, null columns are assumed.

DYNSAVE

Save or Retrieve Data Entities Created by GENDYN Module

Description: Save or retrieve data entities created by the GENDYN module.

Format and Example:

1	2	3	4	5	6	7	8	9	10
DYNSAVE	SAVE	FILENM							
DYNSAVE	ACQUIRE	GENDYN.DAT							

Field	Contents
SAVE	Character string either "SAVE" or "AQUIRE". For SAVE = "SAVE", the data entities created by the GENDYN module are saved in an external file. For SAVE = "ACQUIRE", those data entieites are retrieved. In this case, the **PLTMODE** bulk data card is not processed. (Character) (See Remark 1)
FILENM	Unformatted file name to store the data entities created by the GENDYN module. If the first character of FILENM starts with a dollar sign “$”, the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character)

Remarks:

1. For a large structural model, the computational time of the GENDYN module could be long. The data entities created by the GENDYN module include the mode shape matrix with the rigid body modes (due to entry SUPORT in the "**ASSIGN FEM**" executive control command), the updated generalized mass and stiffness matrices, etc.

EXTFILE External File

Description: Defines a character string as the name of an external file.

Format and Example:

1	2	3	4	5	6	7	8	9	10
EXTFILE	ID	FILENM							
EXTFILE	100	/ZONAIR/TestCases/flutter/case1/ext.dat							

Field	Contents
ID	Unique identification number. (Integer > 0) (See Remark 1)
FILENM	This feature allows for filenames up to 56 characters with no embedded blanks to be input. Note that unlike all other bulk data cards where any characters are converted to upper case, these characters will not be converted to upper case. This feature is important for the UNIX system because it is case sensitive.

Remarks:

1. The **EXTFILE** bulk data card is referred to by other bulk data cards that require external file for input or output. Whenever an external file name is needed in a bulk data card for input or output, rather than directly specifying a character string for the file name, the user can specify a character string started with a dollar sign “$” and followed by an integer; for instance $101. This integer is used to refer to the identification number of the **EXTFILE** bulk data card where the actual file name is specified by FILENM.

2. **EXTFILE** can be used to enforce the reading of file names in LOWER CASE if needed. File name case sensitivity can be an issue for the UNIX operating systems. In this situation, **EXTFILE** can be used to circumvent this problem.

FEMSAVE — Save the Structural Modal Solution

Description: Saves the structural modal solution that is imported by the **'ASSIGN FEM='** executive control command.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FEMSAVE	BOUND	FILENM							

FEMSAVE	ANTI	FEMSOL.DAT							

Field	Contents
BOUND	Character string either 'SYM', 'ANTI' or 'ASYM' that matches with the entry BOUNDARY of the 'ASSIGN FEM=' executive control command. (Character)
FILENM	The name of the file that stores the data entities generated by the **'ASSIGN FEM='** executive control command. If the first character of FILENM starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character ≠ Blank) (See Remark 1)

Remarks:

1. For a large size of structural finite element model, extracting the structural grids, eigenvalues and eigenvectors from the output file of the finite element solver could be time consuming. Time can be saved on future runs by using the **FEMSAVE** bulk data card to save the structural modal solution, then specifying the entry FORM = "ACQUIRE" in the **'ASSIGN FEM='** executive control command to retrieve the modal solution.

FLEXLD

Aerodynamic Analysis of Flexible Aircraft

Description: Computes the aerodynamic pressure coefficients, forces and moments of a flexible aircraft.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FLEXLD	IDFLEX	IDAERO	Q	FORM	FILENM		OUTPUT4		
FLEXLD	100	110	3.20	FEMAP	FLEX.PLT		FLEXCP.DAT		

Field	Contents
IDFLEX	Identification number that is referred to by a **FLEXLD** Case Control Command. (Integer > 0) (See Remark 1)
IDAERO	Identification number of an **AEROGEN** bulk data card. (Integer > 0) (See Remark 2)
Q	The absolute value of Q is the dynamic pressure for computing the flexible aerodynamic loads. Note that Q can be a negative value. In this case, the follower force effects are taken into account. (Real) (See Remark 3)
FORM	Character string to define the format of the output file “FILENM”. (Character) FORM = “TECPLOT” for generating the TECPLOT file FORM = “PATRAN” for generating the PATRAN neutral/results file FORM = “IDEAS” for generating an I-DEAS universal file FORM = “FEMAP” for generating a FEMAP neutral file FORM = “ANSYS” for generating an ANSYS supported neutral file FORM = “ABAQUS” for generating an ABAQUS supported file FORM = “NASTRAN” for generating a NASTRAN bulk data deck.
FILENM	Character string to define an output file name where the deformed aerodynamic model and the pressure coefficients including structural flexibility effects are stored. If the first character of FILENM starts with a dollar sign “$” rest of the character must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character, or blank)
OUTPUT4	Character string to define an output file name where the flexiblized aerodynamic pressure coefficients on the panel model are stored in the OUTPUT4 format. If the first character of FILENM starts with a dollar sign “$” rest of the character must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character, or blank) (See Remark 4)

Remarks:

1. The **FLEXLD** bulk data card is referred to by a **FLEXLD** Case Control Command. To include the structural flexibility effects, it is required to specify the Executive Control Commands **'ASSIGN FEM='** and **'SOLUTION 1'** in the Executive Control Section.

2. The aerodynamic pressure coefficients computed by the **AEROGEN** bulk data card is used as the aerodynamic loads on the rigid aircraft. The **FLEXLD** bulk data card "flexiblizes" these rigid aerodynamic loads by including the structural flexibility effects.

3. The units of the dynamic pressure must be consistent with the mass and length units defined in the **AEROZ** bulk data card.

4. This OUTPUT4 matrix can be imported back to ZONAIR using the **INPDMI** bulk data card.

FLOWPT Aerodynamic Solutions at Flowfield Points

Description: Defines a set of points in the flowfield where the aerodynamic solutions are calculated.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FLOWPT	IDFLOW	IDAERO	FORM	INPFILE		OUTFILE			
FLOWPT	100	10	P3D	INP.DAT		OUT.DAT			

Field	Contents
IDFLOW	Identification number. (Integer > 0) (See Remark 1)
IDAERO	Identification number of an **AEROGEN** bulk data card. (Integer > 0) (See Remark 2)
FORM	FORM indicates the format of the flowfield point mesh on the external file. (Character, Optional) (Default = TECPLOT)
	P3D: Mesh is in the formatted PLOT3D format without IBLANK.
	IP3D: Mesh is in the formatted PLOT3D format with IBLANK.
	UP3D: Mesh is in the unformatted PLOT3D format without IBLANK and in single precision.
	UDP3D: Mesh is in the unformatted PLOT3D format without IBLANK and in double precision.
	IUP3D: Same as UP3D but with IBLANK.
	IUDP3D: Same as UDP3D but with IBLANK (See Remark 3).
	NASTRAN: Mesh is in the NASTRAN format (See Remark 4).
	FREE: Mesh is in the free format (See Remark 5).
	TECPLOT: Mesh is in the TECPLOT format (See Remark 6).
INPFILE	The name of the input file where the flowfield point mesh is stored. (Character)
OUTFILE	The name of an output file where the aerodynamic solutions are stored. Note that the format of the output data is also stored according to the entry FORM.

Remarks:

1. The **FLOWPT** bulk data card is not referred to by any other bulk data cards. Its existence in the Bulk Data Section “triggers” the program to generate aerodynamic solution at flowfield points.

2. The flowfield solutions are computed based on the flight condition specified by the **AEROGEN** bulk data card with identification number = IDAERO

3. For the PLOT3D formatted file, all data are written in the free format. For the PLOT3D unformatted file, all data are stored in the binary format.

Card Set 1	**BLK**
NBLK	Number of blocks of the mesh (Integer > 0)
Example	2

Card Set 2	**(IMAX(L), JMAX(L), KMAX(L), L=1, NBLK)**
IMAX(L), JMAX(L), KMAX(L)	IMAX, JMAX and KMAX are the number of grid points along the I, J and K directions of each block, respectively. (Integer > 0)

L=1

Card Set 3	**(x(i,j,k), I=1, IMAX(L), j=1, JMAX(L), k=1, KMAX(L)), (y(i,j,k), I=1, IMAX(L), j=1, JMAX(L), k=1, KMAX(L)), (z(i,j,k), I=1, IMAX(L), j=1, JMAX(L), k=1, KMAX(L))**
x(i,j,k), y(i,j,k), and z(i,j,k)	x(i,j,k), y(i,j,k) and z(i,j,k) are the x, y and z locations of the grid points (Real). For FORM = UDP3D or IUDP3D, x, y and z are in the double precision

Omit Card Set 4 for FORM = 'P3D', 'UP3D' or 'UDP3D'.

Card Set 4	**(IBLANK(i,j,k), i=1, IMAX(L), j=1, JMAX(L), k=1, KMAX(L))**
IBLANK (i,j,k)	IBLANK (i,j,k) are the indices of each grid point for blanking (Integer)

Repeat Card Set 3 and Card Set 4 NBLK times.

L= L+1

For output, five variables namely ρ, ρU, ρV, ρW and E are stored in the output file OUTFILE. Where ρ is the density, U, V and W are the velocities and E is the energy. Note that these five variables are computed based on the assumption that P_∞ = 1/1.4, where P_∞ is the freestream pressure.

4. For FORM = NASTRAN, the flowfield point mesh is an unstructured grid and in the NASTRAN bulk data card format called "GRID". File INPFILE can contain other **NASTRAN** bulk data cards but only the input card starts with "GRID" is read in.

Format:

1	2	3	4	5	6	7	8	9	10
GRID	ID		X	Y	Z				

Example:

GRID	101		1.0	0.0	3.0				

Field	Content
ID	Unique Identification number of the grid (Integer > 0)
x, y, z	Location of the flowfield point (Real)

For output, the **NASTRAN TEMP** bulk data cards are used to store the aerodynamic solutions; U, V, W, C_p, and Mach numbers.

5. For FORM = FREE, the flowfield point mesh is an unstructured mesh and its grid points are listed in a free format according to the following input instruction.

Card Set 1	**NGRID (Free Format)**
NGRID	Number of grid points (Integer > 0)

Card Set 2	**x, y, z (Free Format)**
x, y, z	Location of the flowfield point

Repeat Card Set 2 NGRID times.

Comment card may be used and must be initiated with a "$" in the first column.

6. For FORM = "TECPLOT", the TECPLOT format is used to define the flowfield point mesh. Multiple zones are allowed and the mesh can be either "POINT" or "FEPOINT". For output, the aerodynamic solutions U, V, W, C_p, and Mach numbers are stored at each point.

FOILSEC

NACA Airfoil Section

Description: Defines an NACA-series type of airfoil section.

Format and Example:

1	2	3	4	5	6	7	8	9	10
FOILSEC	ID								CONT
CONT	$COEFF_1$	$TYPE_1$	$PROFILE_1$	$FIRST_1$	$SECOND_1$	$THIRD_1$	$FOURTH_1$	$FIFTH_1$	CONT
CONT	$COEFF_2$	$TYPE_2$	$PROFILE_2$	$FIRST_2$	$SECOND_2$	$THIRD_2$	$FOURTH_2$	$FIFTH_2$	CONT
CONT			…	etc	…				

FOILSEC	100								+F1
+F1	0.1	NACA	5M	2	4	0	10	34	+F2
+F2	1.0	USER	LINEAR	10	20	30			

Field	Contents
ID	Identification number that is referred to by a **PAFOIL8** bulk data card. (Integer > 0) (See Remark 1)
$COEFF_i$	A coefficient to multiply to the airfoil section. (Real ≥ 0.0) (See Remark 2)
$ITYPE_i$	Character string either “NACA” or “USER”. For TYPE=“NACA”, airfoil is an NACA-series type of airfoil section For TYPE=“USER”, airfoil is a user-defined airfoil section (Character, Default=“NACA”)
$PROFILE_i$	Character string For TYPE=“NACA” PROFILE can be one of followings: “4”, “4M”, “5”, “5M”, “16”, “63”, “63A”, “64”, “64A”, “65”, “65A”, “66”, “67” (Character, Default = “4”) For TYPE=“USER” If PROFILE=“LINEAR”, use linear interpolation to interpolate the airfoil section from the user-defined airfoil thickness distribution. Otherwise, use cubic spline for interpolation. (Character, Default = “CUBIC”)

$FIRST_i$ $SECOND_i$ $THIRD_i$ $FOURTH_i$ $FIFTH_i$	For TYPE="NACA"

PROFILE="4", NACA 4-digit airfoil

- $FIRST_i$ the maximum camber in percent chord
- $SECOND_i$ the maximum camber location in tenths of chord
- $THIRD_i$ the airfoil thickness in percent chord
- $FOURTH_i$ and $FIFTH_i$ are not used
- Example: NACA 2412

PROFILE="4M", NACA 4-digit modified airfoil

- $FIRST_i$ the maximum camber in percent chord
- $SECOND_i$ the maximum camber location in tenths of chord
- $THIRD_i$ the airfoil thickness in percent chord
- $FOURTH_i$ the first and second digit of the appended number (the first digit = 0, 3, 6, or 9, which indicates leading edge radius index number; the second digit indicates the location of maximum thickness in tenths of chord)
- and $FIFTH_i$ is not used
- Example: NACA 2412-04

PROFILE="5", NACA 5-digit airfoil

- $FIRST_i$ the design lift coefficient, C_l = $FIRST_i$*3/20
- $SECOND_i$ the location of maximum camber in tenths of chord (= $SECOND_i$/20)
- $THIRD_i$ =0: a non-reflexed, =1: a reflexed camberline
- $FOURTH_i$ = the airfoil thickness in percent chord
- $FIFTH_i$ is not used
- Example: NACA 24012

PROFILE="5M", NACA 5-digit modified airfoil

- $FIRST_i$ the design lift coefficient, C_l = $FIRST_i$*3/20
- $SECOND_i$ the location of maximum camber in tenths of chord (= $SECOND_i$/20)
- $THIRD_i$ =0: a non-reflexed, =1: a reflexed camberline
- $FOURTH_i$ the airfoil thickness in percent chord
- $FIFTH_i$ the first and second digit of the appended number (the first digit = 0, 3, 6, or 9, which indicates leading edge radius index number; the second digit indicates the location of maximum thickness in tenths of chord)
- Example: NACA 24012-34

PROFILE="16", NACA 16-series airfoil

- $FIRST_i$ the design lift coefficient in tenths
- $SECOND_i$ the airfoil thickness in percent chord
- $THIRD_i$, $FOURTH_i$, and $FIFTH_i$ are not used

Example: NACA 16-212

PROFILE="63", "63A", "64", "64A", "65", "65A", "66", and "67"

- NACA 6-series airfoil
- $FIRST_i$ the design lift coefficient in tenths
- $SECOND_i$ the airfoil thickness in percent chord
- $THIRD_i$, $FOURTH_i$, and $FIFTH_i$ are not used

Example: NACA 63-412, NACA 65A-310

For TYPE="USER"

FIRST$_i$ is the identification number of an **AEFACT** bulk data card used to specify the x- coordinate locations, in percentage of the chord length, where the thickness and camber are specified. The first value listed in the **AEFACT** bulk data card must be 0.0 an the last value must be 100.0

SECOND$_i$ is the identification number of **AEFACT** bulk data card used to specify the half thickness of the airfoil in percentage of the chord length. (Integer > 0)

THIRD$_i$ is the identification number of an **AEFACT** bulk data card used to specify the camber of the airfoil in percentage of the chord length.

FOURTH$_i$ and FIFTH$_i$ are not used

(Integer > 0)

Remarks:

1. The **FOILSEC** bulk data card is referred to by a **PAFOIL8** bulk data card to define an NACA-series type of airfoil section.

2. The resulting airfoil shape is the superposition of all airfoil sections multiplied by COEFF$_i$. Thus, the resulting airfoil shape is:

$$F(x) = \sum_{i=1}^{n} COEFF_i \times f_i(x)$$

where

$F(x)$ is the resulting airfoil shape as a function of the chord (x)

and $f_i(x)$ is the ith airfoil section

GENBASE

Generates an Aerodynamic Database

Description: Generates an aerodynamic database by referring to a number of **AEROGEN** bulk data cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
GENBASE	IDBASE	AEROFILE		GEOFILE		HEAT			CONT
CONT	$IDAERO_1$	$IDAERO_2$	...	-etc-	...				

GENBASE	100	AEROBASE.DAT		GEOFILE.DAT		AHEAT			CONT
CONT	1	3	4	131	5	7	9		+EF

Field	Contents
IDBASE	Unique identification number referred to by a **GENBASE** Case Control Command. (Integer > 0) (See Remark 1)
AEROFILE	Character string up to 16 characters to specify a file name on which the aerodynamic database is to be exported. (Character) (See Remark 2)
GEOFILE	Character string up to 16 characters to specify a file name on which the aerodynamic panel data is to be exported. (Character) (See Remark 3)
HEAT	Character string up to 8 characters to specify a base file name to store the aeroheating data of panels. (Character, Default = "THERMAL")
$IDAERO_i$	Identification number of an **AEROGEN** bulk data card whose corresponding aerodynamic force and moment coefficients will be stored on the file AEROFILE. (Integer > 0)

Remarks:

1. The aerodynamic database generated by the **GENBASE** bulk data card can be used to perform a trajectory analysis of the vehicle.
2. An typical aerodynamic database is shown as follows:

```
Card 1  X34 Aerothermodynamic database from M=1.5 to M=8.8
Card 2  GEOFIL.DAT
Card 3        REFC        REFB        REFS        REFX        REFY        REFZ  NO AESURFZ LENGTH UNIT   MASS UNIT
Card 4  3.5304E+02  1.0000E+00  1.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00           0          IN        SLIN
Card 5        MACH           H       ALPHA        BETA       PRATE       QRATE       RRATE          CD          CY          CL          CR          CM          CN       FILE
Card 6  1.5000E+00  0.0000E+00  3.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  4.7686E+03  1.2617E-01  1.1027E+04  4.6634E+01 -1.9792E+04  3.3097E+01  AHEAT0001
   .    5.1500E+00  0.0000E+00  3.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  3.8865E+03  6.9125E-01  1.1325E+04 -7.4989E+02 -1.9346E+04 -4.1903E+03  AHEAT0002
   .    8.8000E+00  0.0000E+00  3.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  3.8374E+03  2.8343E-02  1.1386E+04 -1.9853E+02 -1.9353E+04 -1.7430E+03  AHEAT0003
   .    1.5000E+00  1.5780E+06  3.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  5.1654E+03 -3.2127E-01  1.0999E+04 -5.6140E+02 -1.9791E+04 -1.6990E+03  AHEAT0004
   .    5.1500E+00  1.5780E+06  3.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  6.3605E+03  1.2547E+01  1.1067E+04 -1.2254E+04 -1.9173E+04 -6.6229E+04  AHEAT0005
   .    8.8000E+00  1.5780E+06  3.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  5.2456E+03  1.6441E+00  1.1292E+04 -3.1720E+03 -1.9339E+04 -2.7381E+04  AHEAT0006
   .    1.5000E+00  3.1560E+06  3.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.3660E+04 -7.3367E+00  1.0569E+04 -4.2465E+03 -1.9974E+04 -1.0582E+04  AHEAT0007
   .    5.1500E+00  3.1560E+06  3.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  5.1512E+04  2.2051E+02  6.5877E+03 -2.1063E+05 -1.6333E+04 -1.1364E+06  AHEAT0008
   .    8.8000E+00  3.1560E+06  3.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  3.0403E+04  2.7328E+01  9.7425E+03 -5.1925E+04 -1.9257E+04 -4.4761E+05  AHEAT0009
   .    1.5000E+00  0.0000E+00  1.6500E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.5877E+04 -2.5960E-01  4.3676E+04 -1.8265E+02 -7.2515E+04 -3.2579E+02  AHEAT0010
   .    5.1500E+00  0.0000E+00  1.6500E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.5466E+04 -1.2262E+00  4.3661E+04  1.9281E+03 -7.1762E+04  6.7346E+03  AHEAT0011
   .    8.8000E+00  0.0000E+00  1.6500E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.5245E+04 -8.9774E-01  4.3311E+04 -7.3544E+02 -7.1111E+04 -2.0132E+03  AHEAT0012
   .    1.5000E+00  1.5780E+06  1.6500E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.6393E+04 -1.1190E-01  4.3495E+04  3.0469E+03 -7.2485E+04  6.9882E+03  AHEAT0013
   .    5.1500E+00  1.5780E+06  1.6500E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.8241E+04  9.6145E+00  4.2741E+04 -2.8185E+04 -7.1617E+04 -7.0603E+04  AHEAT0014
   .    8.8000E+00  1.5780E+06  1.6500E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.6958E+04 -5.2334E+01  4.2869E+04  5.1457E+03 -7.1225E+04  5.0333E+04  AHEAT0015
   .    1.5000E+00  3.1560E+06  1.6500E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  2.4384E+04 -3.1922E+00  4.1101E+04 -2.3071E+04 -7.2579E+04 -5.3624E+04  AHEAT0016
   .    5.1500E+00  3.1560E+06  1.6500E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  8.2579E+04 -4.0963E+02  2.2161E+04  5.4569E+05 -7.0172E+04  1.9318E+06  AHEAT0017
   .    8.8000E+00  3.1560E+06  1.6500E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  4.3647E+04 -3.4296E+02  3.4939E+04 -2.0096E+05 -7.0979E+04 -5.7587E+05  AHEAT0018
   .    1.5000E+00  0.0000E+00  3.0000E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  4.1349E+04 -7.0364E-01  6.8519E+04 -9.0037E+02 -1.2242E+05 -6.5616E+02  AHEAT0019
   .    5.1500E+00  0.0000E+00  3.0000E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  3.8741E+04  2.8312E+00  6.4171E+04 -2.4243E+03 -1.1407E+05 -4.9951E+03  AHEAT0020
   .    8.8000E+00  0.0000E+00  3.0000E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  3.7622E+04 -7.3016E-01  6.2407E+04 -1.7534E+03 -1.1090E+05 -3.0921E+03  AHEAT0021
   .    1.5000E+00  1.5780E+06  3.0000E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  4.2186E+04 -3.8035E+00  6.7928E+04  3.0840E+04 -1.2229E+05  3.8979E+04  AHEAT0022
   .    5.1500E+00  1.5780E+06  3.0000E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  4.1593E+04  5.0351E+01  6.2696E+04 -4.3075E+04 -1.1435E+05 -8.8017E+04  AHEAT0023
   .    8.8000E+00  1.5780E+06  3.0000E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  3.9371E+04 -1.1889E+01  6.1769E+04 -3.1468E+04 -1.1144E+05 -5.5046E+04  AHEAT0024
   .    1.5000E+00  3.1560E+06  3.0000E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  5.1238E+04 -2.6218E+01  6.2284E+04  1.2330E+05 -1.2191E+05  1.5767E+05  AHEAT0025
   .    5.1500E+00  3.1560E+06  3.0000E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  9.5214E+04  8.6174E+02  3.4684E+04 -7.4185E+05 -1.1933E+05 -1.5154E+06  AHEAT0026
card 6  8.8000E+00  3.1560E+06  3.0000E+01  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  7.2894E+04 -1.9852E+02  4.8503E+04 -5.1925E+05 -1.2061E+05 -9.0796E+05  AHEAT0027
```

Card 1: Character string that is specified by the **TITLE** Case Control Command.

Card 2: Character string specified by the GEOFILE entry on which the aerodynamic panel data is stored

Card 3: Character string where:

REFC:	Reference chord
REFB:	Reference span
REFS:	Reference area
REFX:	X location of the momentum center
REFY:	Y location of the momentum center
REFZ:	Z location of the momentum center
No AESURFZ:	Number of control surfaces
LENGTH:	Length unit of the aerodynamic model
MASS UNIT:	Mass unit of the aerodynamic model

Card 4: The values of REFC, REFB, REFS, REFX, REFY, REFZ, No AESURFZ, LENGTH UNIT, and MASS UNIT, respectively, that are specified by the **AEROZ** bulk data card. (Real, Format = 6E12.4, I12, 2A12).

Card 5: Character string where

MACH:	Mach number
H:	Altitude with unit = LENGTH UNIT
ALPHA:	Angle of attach in degree
BETA:	Side slip angle in degree
PRATE:	Non-dimensional roll rate. PRATE = PB/2V Where p is the roll rate in rad/sec, b is the reference span (REFB) and V is the freestream velocity
QRATE:	Non-dimensional pitch rate. QRATE = qc/2V Where q is the pitch rate in rad/sec, c is the reference chord (REFC).

RRATE: Non-dimensional yaw rate. RRATE = rb/2V
Where r is the yaw rate in rad/sec

C_D: Drag Coefficient $C_D = \frac{D}{q_\infty (REFS)}$, (D is the drag force)

C_Y: Side Force Coefficient $C_Y = \frac{Y}{q_\infty (REFS)}$, (Y is the side force)

C_L: Lift Coefficient $C_L = \frac{L}{q_\infty (REFS)}$, (L is the lift force)

CR: Roll Moment Coefficient $C_\ell = \frac{\ell}{q_\infty (REFS)(REFB)}$, ($\ell$ is the roll moment)

CM: Pitch Moment Coefficient $C_M = \frac{M}{q_\infty (REFS)(REFC)}$, (M is the pitch moment)

CN: Yaw Moment Coefficient $C_N = \frac{N}{q_\infty (REFS)(REFB)}$, (N is the yaw moment)

FILEi: Character string up to 12 characters that is that file name on which the aerodynamic data of each panel is stored. This file contains a matrix in the OUTPUT4 format (See the description of the OUTPUT4 format). This matrix has 8 columns and n rows where *n* is the number of surface panels and the 8 columns are:

Column 1: Perturbation U velocity on the right hand side of the aerodynamic model
Column 2: Perturbation V velocity on the right hand side of the aerodynamic model
Column 3: Perturbation W velocity on the right hand side of the aerodynamic model
Column 4: Cp on the right hand side of the aerodynamic model
Column 5: Perturbation U velocity on the right left side of the aerodynamic model
Column 6: Perturbation V velocity on the right left side of the aerodynamic model
Column 7: Perturbation W velocity on the right left side of the aerodynamic model
Column 8: Cp on the left hand side of the aerodynamic model

Note: The first 8 characters are the character specified by the HEAT entry and the last 4 characters contain an integer starts from “0001” to “000n” where *n* is the total number of **AEROGEN** bulk data cards referred to by the IDAERO$_i$ entry.

Card 6: The value of those parameters in Card 5 (13E12.4, A12)

Note that these values are specified by the **AEROGEN** bulk data cards. Thus, the number of card 6 is the number of **AEROGEN** bulk data cards that are referred to by the $IDAERO_i$ entry.

3. The panel data is stored in the following format:

Card 1	NPANEL, NGRID	Format
NPANEL	Number of panels	Integer > 0
NGRID	Number of grid points	Integer > 0

L=1

Card 2	IDG, x, y, z	Format
IDG	Identification of the grid point	Integer
x, y, z	x, y, and z location of the grid point	Real

Repeat Card 2 for NGRID times

L = L+1

L=1

Card 3	IDP, ID1, ID2, ID3, ID4	Format
IDP	Identification number of the panel	Integer
ID1, ID2, ID3, ID4	Identification number of the grid points at the four corners of the panel	Integer

Repeat Card 3 for NPANEL times

L=L+1

GRID

Grid Point

Description: Defines the location of a surface grid point or a reference grid point.

Format and Example:

1	2	3	4	5	6	7	8	9	10
GRID	ID	CP	X	Y	Z		PS		

1	2	3	4	5	6	7	8	9	10
GRID	2	3	1.0	2.0	3.0		315		

Field	Contents
ID	Grid point identification number (Integer > 0) (See Remark 1)
CP	Identification number of coordinate system in which the location of the grid is defined (Integer > 0 or Blank) (See Remark 2)
X, Y, Z	Location of the grid point in coordinate system **CP** (Real)
PS	Flag for indicating a surface grid point or a reference grid point. PS = 0 or blank, the grid is a surface grid. PS ≠ 0, the grid is a reference grid point. (Integer) (See Remark 3)

Remarks:

1. All grid point identification numbers must be unique.
2. The meaning of X1, X2 and X3 depend on the type of coordinate system, **CP**, as follows:

TYPE	X	Y	Z
Rectangular	X	Y	Z
Cylindrical	R	θ (deg)	Z
Spherical	R	θ (deg)	ϕ (deg)

Note: Also see **CORDij** entry descriptions.

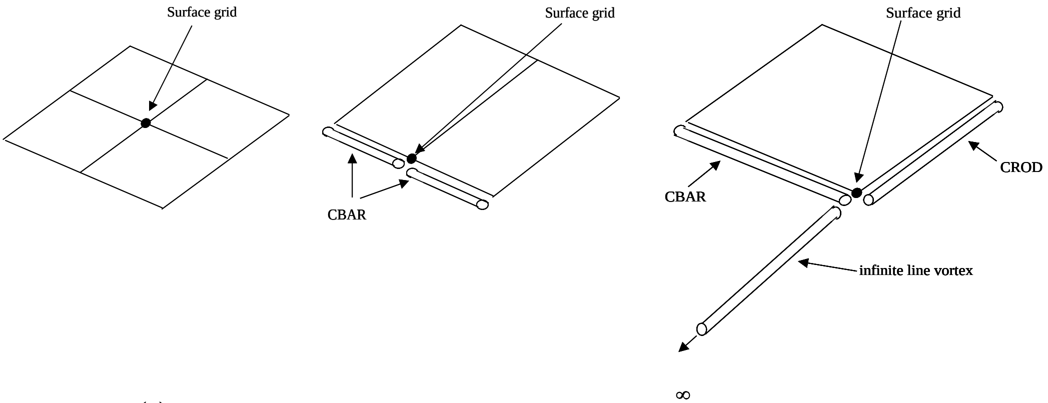
3. There are two types of grid points that can be included in the bulk data input; the surface grid points and the reference grid points, where

Surface grid point: a point located on the surface of the aerodynamic model, which is discretized by the CQUAD4 and/or CTRIA3 panels. This implies that a surface grid point must be a corner point of the CQUAD4/CTRIA3 panels. A surface grid point that is not attached to any CQUAD4/CTRIA3 panel gives fatal error.

Reference grid point: A point usually used to define the CSHEAR panel for wake modeling. Because the potential on the CSHEAR panel is equal to the potential at the surface grid points where the wake surface starts. The reference grid point does not introduce additional unknowns to the problem. Also, the reference grid point can be used as a dummy point for defining a local coordinate system by the **CORD1R**, **CORD1S** or **CORD1C** bulk data card.

Note:

Except being the corner point of three CTRIA3 panels, each surface grid point must be at least the corner point of four panels/elements. For instance, four CQUAD4/CTRIA3 panels as shown in Figure(a), two CQUAD4/CTRIA3 panels and two CBAR elements as shown in Figure(b) or one CQUAD4/CTRIA3 panel, one CROD element and one CBAR element with an infinite line vortex (PA or PB entry > 0) as shown in Figure(c).



(a) (b) (c)

The above condition is automatically checked by the program for all surface grid points. If this condition of any surface grid point is not satisfied, fatal error occurs. However, this condition can be relaxed by specifying the **PARAM** bulk data card (See description of the **PARAM** bulk data card with entry NAME = “GRDPAN”)

GRIDFRC

Direct Forces at FEM Grid Points

Description: Defines a control force at a set of structural finite element grid points.

Format and Example:

1	2	3	4	5	6	7	8	9	10
GRIDFRC	LABEL	TYPE	SISOID	GFORCE					CONT
CONT	IDGRID1	COMP1	FACTOR1	REMARK1	IDGRID2	COMP2	FACTOR2	REMARK2	CONT
CONT		…	-etc-	…					

GRIDFRC	GFORCE	SYM							+G
+G	97	3	3.0	FORCE3					

Field	Contents
LABEL	Unique alphanumeric string up to 8 characters used to identify the control surface. (Character) (See Remark 1)
TYPE	Type of force. (Character) SYM Symmetric force ANTI Anti-symmetric force ASYM Asymmetric force
SISOID	Not used.
GFORCE	Character string referring to the name of a matrix that is imported by a **DMI** bulk data card or **'ASSIGN MATRIX='** Executive Control Command. This matrix contains NGSET rows and one column of force at all structural d.o.f. where NGSET = 6 × numbering structural grid points (Character or blank)
IDGRIDi	Identification number of a structural finite element grid points that is imported from the **'ASSIGN FEM='** Executive Control Command. (Integer > 0) (See Remark 2)
COMPi	Component number 1, 2, 3, 4, 5, or 6 representing the degree of freedom of the control force. 1, 2 and 3 represent the forces along the x, y and z directions, respectively. 4, 5 and 6 represent the moments about the x, y and z directions, respectively. (Integer > 0) (See Remark 3)
FACTOREi	Multiplication factor (Real)
REMARKi	Any character string with no embedded blanks to describe the control force.

Remarks:

1. **GRIDFRC** can be selected as a control force for the TRIM analysis.
2. The degrees of freedom of the force or moment are defined in the output displacement coordinates of the grid in the structural finite element model (i.e., the local coordinate system for displacements of the structural finite element grid).

3. The units of forces and moments are FMMUNIT * (FMLUNIT/sec^2) and FMMUNIT * (FMLUNIT^2/sec^2), respectively, where FMMUNIT and FMLUNIT are defined in the **AEROZ** bulk data card.

INCLUDE

Insert an External File into the Bulk Data Section

Description: Inserts an external file into the Bulk Data Section. The **INCLUDE** statement may appear anywhere within the Bulk Data Section of the input deck.

Format and Example:

INCLUDE ‘filename’

The following INCLUDE statement is used to obtain the Bulk Data from another file called External.dat:

BEGIN BULK

INCLUDE ‘External.dat’

ENDDATA

Field	Contents
filename	Physical filename of the external file to be inserted. The user must supply the name according to installation or machine requirements. It is recommended that the filename be enclosed by single right-hand quotation marks.

Remarks:

1. The **INCLUDE** statement does not allow continuations. The total length of the statement must be 72 characters or less.

INPCFD

Replaces ZONAIR Solution by CFD Solution

Description: Imports the steady-mean flow solution by interpolating the Computational Fluid Dynamics (CFD) Solution computed at a structured mesh to the ZONAIR surfaces panel model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
INPCFD	IDCFD	TRANSF	OMITCFD	FORMCFD	CFDMESH		CFDOUT		

INPCFD	10	20	1	P3D	CFD.GRID		CFD.P3D		

Field	Contents
IDCFD	If IDCFD is a positive integer, it refers to the identification number of an **AEROGEN** bulk data card. The pressure coefficients on the rigid aircraft at the flight condition defined by the **AEROGEN** bulk data card with ID=IDCFD computed by the program are replaced by the CFD solution. (Integer). If IDCFD is a negative integer, it is referred to by a **TRIMINP** or **WT1CFD** bulk data card for computing the pressure derivatives with respect to the trim variable. Note that to rapidly verify the imported pressure coefficient, it is recommended that the **PARAM** bulk data card with entry NAME="BYPASS" be used to bypass the AIC computation. (Integer, See Remark 1)
TRANSF	Identification number of a **CORD2R** bulk data card defining a coordinate system in which the CFD mesh is located. Note that TRANSF can be a negative integer. This negative sign implies that the CFD mesh is located in the negative Y-axis. (Integer, default = 0) (See Remark 2)
OMITCFD	Identification number of an **OMITCFD** bulk data that defines the CFD surface mesh index. (Integer > 0) (See Remark 3)

FORMCFD Character sting to specify the format of the CFD mesh and solution. The **INPCFD** bulk data card reads in the CFD mesh and solution in the PLOT3D format. Because there are various options of the PLOT3D format, the format, of the CFD file must be one of the characters shown in the following table:

For Formatted:

Solution Normalized for	**Formatted**	
	Without IBLANK	With IBLANK
$\rho_\infty = 1.0$ $a_\infty = 1.0$	P3D or P3D1	IP3D or IP3D1
$\rho_\infty = 1.0$ $P_\infty = 1.0$	P3D2	IP3D2
$\rho_\infty = 1.0$ $V_\infty = 1.0$	P3D3	IP3D3

For Unformatted:

Solution Normalized for	**Unformatted**							
	Single Precision				**Double Precision**			
	Little-endian		Big-endian		Little-endian		Big-endian	
	Without IBLANK	With IBLANK	Without IBLANK	With IBLANK	Without IBLANK	With IBLANK	Without IBLANK	With IBLANK
$\rho_\infty = 1.0$ $a_\infty = 1.0$	UP3D or UP3D1	IUP3D or IUP3D1	UP3DB or UP3DB1	IUP3DB or IUP3DB1	UDP3D or UDP3D1	IUDP3D or IUDP3D1	UDP3DB or UDP3DB1	IUDP3DB or IUDP3DB1
$\rho_\infty = 1.0$ $P_\infty = 1.0$	UP3D2	IUP3D2	UP3DB2	IUP3DB2	UDP3D2	IUDP3D2	UDP3DB2	IUDP3DB2
$\rho_\infty = 1.0$ $V_\infty = 1.0$	UP3D3	IUP3D3	UP3DB3	IUP3DB3	UDP3D3	IUDP3D3	UDP3DB3	IUDP3DB3

For Binary:

Solution Normalized for	**Binary**							
	Single Precision				**Double Precision**			
	Little-endian		Big-endian		Little-endian		Big-endian	
	Without IBLANK	With IBLANK	Without IBLANK	With IBLANK	Without IBLANK	With IBLANK	Without IBLANK	With IBLANK
$\rho_\infty = 1.0$ $a_\infty = 1.0$	BP3D or BP3D1	IBP3D or IBP3D1	BP3DB or BP3DB1	IBP3DB or IBP3DB1	BDP3D or BDP3D1	IBDP3D or IBDP3D1	BDP3DB or BDP3DB1	IBDP3DB or IBDP3DB1
$\rho_\infty = 1.0$ $P_\infty = 1.0$	BP3D2	IBP3D2	BP3DB2	IBP3DB2	BDP3D2	IBDP3D2	BDP3DB2	IBDP3DB2
$\rho_\infty = 1.0$ $V_\infty = 1.0$	BP3D3	IBP3D3	BP3DB3	IBP3DB3	BDP3D3	IBDP3D3	BDP3DB3	IBDP3DB3

- "Formatted", "Unformatted" or "Binary" indicates that the CFD files are in ASCII format, unformatted, or binary, respectively.
- "Solution normalized" indicates that the CFD solution can be normalized using three options where ρ_∞ is the freestream density, a_∞ is the freestream speed of sound, P_∞ freestream pressure, and V_∞ is the freestream velocity.
- "Without IBLANK" or "with IBLANK" indicates that the CFD mesh file is with or without IBLANK array, respectively.
- "Single precision" or "Double precision" indicates that the CFD files are generated by single precision computation or double precision computation, respectively.
- "Little_endian" or "Big_endian" (see Remark 4)
  Little_endian and big_endian are different types of data formats adopted by computer platforms. On Windows machines or other little_endian systems, CFD mesh and solution files created by big_endian machines such as SGI and HP can be used with proper setting of FORMCFD to handle data conversion.
  For little_endian usage, the CFD files were generated in the same type of computer system as the one where ZONAIR is running.
  For big_endian usage, the ZONAIR is running on a little_endian system such as PC/Windows but the CFD files were generated in a big_endian computer system.

For instance, for a unformatted and double precision CFD solution with IBLANK array and being normalized for $\rho_\infty = 1.0$ and $P_\infty = 1.0$ FORMCFD = "IUDP3DB2" if "big_endian" is true and FORMCID = "IUDP3D2" if "Little-endian" is true. (Character, default = "P3D")

CFDMESH — Character string up to 16 characters to specify the file name that contains the CFD mesh. ". If the first character starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character) (See Remark 5)

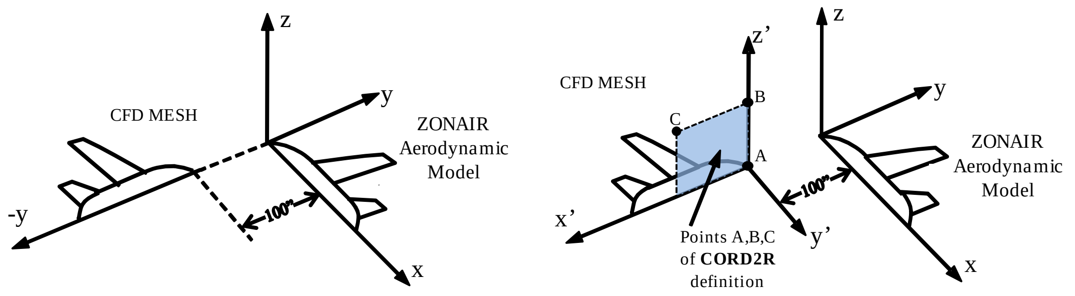
CFDOUT — Character string up to 16 characters to specify the file name that contains the CFD solution. If the first character starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character) (See Remark 6)

<u>Remarks:</u>

1. The **INPCFD** bulk data card is used to import the CFD solution from a structured CFD code. This feature allows ZONAIR to compute more accurate incremental aeroelastic loads due to structural flexibility effects using CFD generated rigid loads.

2. Because the CFD mesh may be oriented in an arbitrary fashion with respect to the aerodynamic model, it is required to transform the CFD mesh so that the CFD surface mesh and the ZONAIR aerodynamic model overlap with each other. This can be achieved by introducing a **CORD2R** bulk data card with identification number = TRANSF that defines a coordinate system where the CFD

mesh is located. In the following figure, the X'-Y'-Z' system is the local coordinates defined by a **CORD2R** bulk data card whereas X-Y-Z is the aerodynamic coordinates of the ZONAIR aerodynamic model.



In the example, the nose of the fuselage of the CFD surface mesh is located at x=z=0 and y = -100 (with respect to the ZONAIR aerodynamic model) whereas that of the ZONAIR aerodynamic model at x=y=z=0. To transform the CFD mesh, it is required to specify a **CORD2R** bulk data card such as

CORD2R	-50		0.0	-100.0	0.0	0.0	-100.0	1.0	+C
+C	0.0	-101.0	1.0						

In addition, because the above figure shows that the CFD surface mesh is located in the negative y' axis, the entry TRANSF must be a negative integer (in this case, TRANSF = -50) to "flip" the CFD mesh from the negative y-axis to the positive y-axis.

3. Because ZONAIR only requires the CFD solution on the surface mesh to replace the program computed pressure coefficients by those computed by CFD, specifying the CFD surface mesh index can avoid the reading of all CFD mesh into the computer memory.

4. Big_endian and little_endian are two ways of representing data format. Little_endian stores data with increasing numeric significance in increasing memory addresses. By contrast, big_endian stores data with increasing numeric significance in decreasing memory addresses. x86 processors adopt little_endian format. Little_endian systems include PC/Windows; big_endian systems include SGI and HP.

5. The CFD mesh must be in the PLOT3D format. For the formatted file, all data are written in the free format. For the unformatted file, all data are stored in the binary format. The PLOT3D format is shown as follows:

Card Set 1	**NBLK**
NBLK	Number of blocks of the CFD mesh (Integer > 0)
Example	2
Card Set 2	**(IMAX(L), JMAX(L), KMAX(L), L = 1, NBLK)**

IMAX(L), JMAX(L), KMAX(L)	IMAX, JMAX, and KMAX are the number of grid points along the I, J, and K directions of each block, respectively. (Integer > 0)

L=1

Card Set 3	**If FORMCFD = 'P3D', 'UP3D', or 'UDP3D'.** **(((x(i,j,k),i=1, IMAX(L)),j=1, JMAX(L)),k=1, KMAX(L)),** **(((y(i,j,k),i=1, IMAX(L)),j=1, JMAX(L)),k=1, KMAX(L)),** **(((z(i,j,k),i=1, IMAX(L)),j=1, JMAX(L)),k=1, KMAX(L))** **otherwise** **(((x(i,j,k),i=1, IMAX(L)),j=1, JMAX(L)),k=1, KMAX(L)),** **(((y(i,j,k),i=1, IMAX(L)),j=1, JMAX(L)),k=1, KMAX(L)),** **(((z(i,j,k),i=1, IMAX(L)),j=1, JMAX(L)),k=1, KMAX(L)),** **(IBLANK(i,j,k), i=1, IMAX(L), j=1, JMAX(L), k=1, KMAX(L))**
x(i,j,k),y(i,j,k), z(i,j,k) and IBLANK (i,j,k)	x(i,j,k), y(i,j,k), and z(i,j,k) are the x,y, and z locations of the grid points (Real). For FORMCFD = UDP3D, x, y, and z are in double precision. IBLANK (i,j,k) are the indices of each grid point for blanking (Integer)

Repeat Card Set 3 NBLK times.

L = L+1

6. The CFD solution must be computed either by the Euler solver or the Navier-stokes solver. Its format is shown as follows:

Card Set 1	**NBLK**	**Format**
NBLK	Number of blocks of the CFD mesh	Integer > 0

L=1

Card Set 2	**(IMAX(L), JMAX(L), KMAX(L), L = 1, NBLK)**
IMAX(L), JMAX(L), KMAX(L)	IMAX, JMAX, and KMAX are the number of grid points along the I, J, and K directions of each block, respectively. (Integer > 0)

Card Set 3	**FMACH, ALPHA, RE, TIME**	Format
FMACH ALPHA RE TIME	Mach number Angle of Attack Reynolds number Time step	Real or double precision

Card Set 4	**(((RHO(i,j,k),i=1, IMAX(L)),j=1, JMAX(L)),k=1, KMAX(L)), (((RU(i,j,k),i=1, IMAX(L)),j=1, JMAX(L)),k=1, KMAX(L)), (((RV(i,j,k),i=1, IMAX(L)),j=1, JMAX(L)),k=1, KMAX(L)), (((RW(i,j,k),i=1, IMAX(L)),j=1, JMAX(L)),k=1, KMAX(L)), (((E(i,j,k),i=1, IMAX(L)),j=1, JMAX(L)),k=1, KMAX(L))**	Format
RHO(i,j,k), RU(i,j,k), RV(i,j,k) RW(i,j,k) E(i,j,k)	Non-dimensionalized density Non-dimensionalized momentum along x Non-dimensionalized momentum along y Non-dimensionalized momentum along z Non- dimensionalized total energy per unit volume	Real or Double precision

Repeat Card Sets 2 and 3 NBLK times

L = L+1

Note that FMACH and ALPHA must match the Mach number and angle of attack specified in the **AEROGEN and MACH** bulk data cards. Otherwise, a warning message occurs.

INPCFD1

Imports CFD Solution from an Unstructured CFD Code

Description: Imports the steady-mean flow solution by interpolating the Computational Fluid Dynamics (CFD) Solution computed at an unstructured mesh to the ZONAIR surface panel model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
INPCFD1	IDCFD	TRANSF	DATA	CFDFILE		NORMCFD	XSCALE	GAMMA	+CONT
+CONT	XFORM	FILEMESH		FILESOL		AERONM		PINF	

INPCFD1	10	-20	CFX	CFDFILE.DAT		2	12.0	1.132	+C
+C	TECPLOT	MESH.DAT		CP.DAT				16632.0	

Field	Contents
IDCFD	If IDCFD is a positive integer, it refers to the identification number of an **AEROGEN** bulk data card. The pressure coefficients at the flight condition defined by the **AEROGEN** bulk data card with ID=IDCFD computed by the program are replaced by the CFD solution. If IDCFD is a negative integer, it is referred to by a **TRIMINP** or **WT1CFD** bulk data card for computing the pressure derivatives with respect to the trim variable. **INPCFD1** is to replace the ZONAIR computed pressure coefficient distribution by the unstructured CFD solution. Only the pressure coefficients are replaced. Other flow solutions computed by ZONAIR like local Mach numbers, velocity components are not replaced. Thus, only the pressure coefficients computed by CFD are required by ZONAIR for interpolation. Note that to rapidly verify the imported pressure coefficient, it is recommended that the **PARAM** bulk data card with entry NAME="BYPASS" be used to bypass the AIC computation. (Integer ≠ 0, See Remark 1)
TRANSF	Identification number of a **CORD2R** bulk data card defining a coordinate system in which the CFD mesh is located. Note that TRANSF can be a negative integer. This negative sign implies that the CFD mesh is located in the negative Y-axis. (Integer, Default = 0) (See Remark 2)

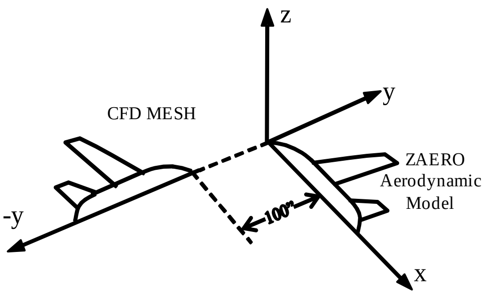
DATA	Character string to specify the type of result stored on the external file CFDFILE. Character or Blank For DATA = "PLOT3D" the CFD results are in terms of RHO, RHOU, RHOV, RHOW, and E, where RHO is the density, RHOU, RHOV, and RHOW are the non-dimensional momentum along x, y, and z, respectively, and E is the energy, and the normalization method is specified by the field NORMCFD.(See remark 3) For DATA = "FUN3D" the CFD solutions are computed by FUN3D. (See Remark 4) For DATA = "CFX" the CFD solutions are computed by CFX™. (See Remark 5) For DATA ≠ "PLOT3D", nor "FUN3D", nor "CFX", the format of the CFD results is shown in Remark 6. (See remark 6)
CFDFILE	Character string to specify the file name that contains the unstructured CFD mesh and solution in ASCII format. If the first character starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character cannot be blank)
NORMCFD	NORMCFD = 1, solution is normalized for $\rho_\infty = 1.0$, $a_\infty = 1.0$ NORMCFD = 2, solution is normalized for $\rho_\infty = 1.0$, $p_\infty = 1.0$ NORMCFD = 3, solution is normalized for $\rho_\infty = 1.0$, $V_\infty = 1.0$ where ρ_∞ is the freestream speed density, a_∞ is the freestream spread of sound, p_∞ is the freestream pressure, and V_∞ is the freestream velocity. Note that NORMCFD is used only if DATA = "PLOT3D". (Integer > 0, Default = 1)
XSCALE	A global-scale factor that is multiplied to the x, y, and z coordinates of all CFD grid points. (Real > 0.0, Default = 1.0)
GAMMA	Specific heat ratio used in the CFD computation. (Real > 1.0, Default = 1.4)
XFORM	Format of the output file specified in the entities FILEMESH and FILESOL. FORM = "TECPLOT" for generating a TECPLOT file. FORM = "PATRAN" for generating a PATRAN neutral file. FORM = "IDEAS" for generating a I-DEAS universal file. FORM = "FEMAP" for generating a FEMAP neutral file. FORM = "ANSYS" for generating a ANSYS supported neutral file. FORM = "NASTRAN" for generating a NASTRAN bulk data deck. FORM = "NASTL" for generating a NASTRAN bulk data deck with **GRID** entries in large field format (i.e., allows for higher degree of numerical accuracy over the FORM = "NASTRAN" option). (Character, Default = "TECPLOT")

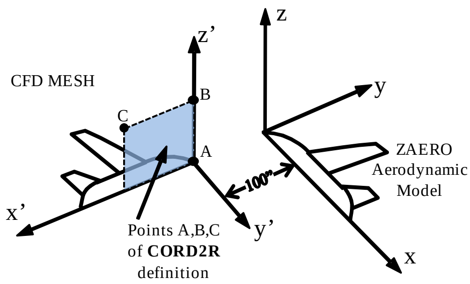
FILEMESH	Character string up to 16 characters to specify the filename to store the surface boxes and CFD grid point for plotting. The objective of the FILEMESH entries is to output a graphical file that allows the user to verify the overlapping between the ZONAIR panel model and those CFD surface grid points. If the first character starts with a dollar sign “$”, the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character or Blank).
FILESOL	Character string up to 16 characters to specify the filename to store the interpolated CFD C_P on each panel. This file allows the user to verify the interpolated pressure coefficients on ZONAIR panel model (Character or Blank).
AERONM	The name of a data file in which the aerodynamic model is stored in a PATRAN neutral file. ONLY USED IF FORM=”PATRAN”. If the first character of AERONM starts with a dollar sign “$”, the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. PATRAN requires that the aerodynamic model be stored in a neutral file and that analysis results be stored in a results file. Therefore, the AERONM entry is used to assign a name for a neutral file that contains the aerodynamic model, while the FILENM entry specifies a file that will contain the unsteady pressure results. For more details, please see Section 7.2, PATRAN Compatible Output. (Character, Default = “AEROGEOM.PAT”).
PINF	Dimensional free stream pressure. Used only if DATA=”CFX”. The length unit involved in PINF must be the same as that of the dimensional flow solutions computed by CFX; not the length unit specified in the **AEROZ** bulk data card. Not specifying PINF when DATA=”CFX” leads to a fatal error. (Real>0.0, Default=1.E-30)

Remarks:

1. The **INPCFD1** bulk data card is used to import the CFD solution from an unstructured CFD code into ZONAIR. ZONAIR interpolates the CFD computed pressure distribution from the CFD surface mesh to ZONAIR panel model. This feature allows ZONAIR to compute more accurate incremental aeroelastic loads due to structural flexibility effects using CFD generated rigid loads. Because the pressure distribution computed by CFD for asymmetric flight conditions must be computed on a full span model, for this case the ZONAIR panel model also must be a full span one.

2. Because the CFD mesh may be oriented in an arbitrary fashion with respect to the ZONAIR aerodynamic model, it is required to transform the CFD mesh so that the CFD surface mesh and the ZONAIR aerodynamic model overlap with each other. This can be achieved by introducing a **CORD2R** bulk data card with an identification number = TRANSF that defines a coordinate system where the CFD mesh is located. In the following figure, the x’-y’-z’ system is the local coordinates defined by a **CORD2R** bulk data card whereas x-y-z is the aerodynamic coordinates of the ZONAIR aerodynamic model.





In the example, the nose of the fuselage of the CFD surface mesh is located at x=z=0 and y=−100 (with respect to the ZONAIR aerodynamic model) whereas that of the ZONAIR aerodynamic model is at x=y=z=0. To transform the CFD mesh, it is required to specify a **CORD2R** bulk data card such as

CORD2R	-50		0.0	-100.0	0.0	0.0	-100.0	1.0	+C
+C	0.0	-101.0	1.0						

In addition, because the above figures show that the CFD surface mesh is located in the negative y' axis, the entry TRANSF must be a negative integer (in this case, TRANSF = -50) to flip the CFD mesh from the negative y-axis to the positive y-axis.

3. If DATA = "PLOT3D", the format of the data stored in CFDFILE is shown as follows:

Card Set 1	**NSGRID, NSELEM (Free Format)**
NSGRID	Number of surface grid points. (Integer)
NSELEM	Number of surface elements. (Integer)

Card Set 2	**x, y, z, RHO, RHOU, RHOV, RHOW, E, (Free Format)**
x, y, z	x, y, and z location of the surface grid point. (Real)
RHO	Non-dimensional density. (Real)
RHOU	Non-dimensional momentum along x. (Real)
RHOV	Non-dimensional momentum along y. (Real)
RHOW	Non-dimensional momentum along z. (Real)
E	Non-dimensional total energy. (Real)

Repeat Card Set 2 NSGRID times

4. If DATA='FUN3D", the CFDFILE can be directly generated by FUN3D shown as follows:

```
title="aero loads for ddfdrive"
variables="x","y","z","id","cp","cfx","cfy","cfz","temp","dtdn"
zone t="mdo body 1", i=48570, j=96370, f=fepoint
```

```
   0.703852462768555E+002 -0.318498802185059E+002  0.167400093078613E+002      54391
0.751327893951425E+000 -0.814100758142384E-002 -0.147702302434989E-001
0.444282142572714E-001  0.104369716260980E+001  0.358825266389701E+002
  :
     37663     37665     41701     41701
```

This file can be obtained by running FUN3D with the option "--write_aero_loads_to_file". The namelist input file for FUN3D should specify the &massoud_output section, e.g.,:

```
&massoud_output
    n_bodies = 1               ! define one (and only one body for input)
    nbndry(1) = 7              ! body 1 consists of 7 boundaries
    boundary_list(1) = '1,2,4,7,8,9,11'     ! these boundaries
/
```

where the *boundary_list* array lists the surface indices which consists of the wall and engine inlets/outlets surfaces. If the user prefers to create this surface file by himself, only variables for *x*, *y* and *z* are needed.

Note that among those variables listed in CFDFILE:

```
variables="x","y","z","id","cp","cfx","cfy","cfz","temp","dtdn"
```

only x, y, z, and cp are used. This is to say that at least x, y, z and cp must be included in CFDFILE.

5. If DATA = "CFX", at each surface grid, the X, Y, Z location of the grid as well as the absolute pressure, P_a, (not the relative pressure) at the surface grid computed by CFX must be listed in the file CFDFILE like:

```
[Name]
wall

[Data]
X [ m ], Y [ m ], Z [ m ], Absolute Pressure [ Pa ]
4.05548394e-01, 1.13591296e-03, 1.20433091e-04, 1.81823652e+04
4.06399995e-01, 0.00000000e+00, 0.00000000e+00, 1.82605098e+04

..........................................................................
..........................................................................

4.04300362e-01, 0.00000000e+00, 2.96312210e-04, 1.81441797e+04
```

   If the length unit of the CFX mesh is different from that of the panel model specified in the **AEROZ** bulk data card, the entry XSCALE can be used for the unit conversion.

   Note that since the above CFX data format does not provide the connectivity of the grids, when using the entry FILEMSH to verify the overlapping between ZONAIR panel model and CFX surface mesh, the CFD grids must be treated as scattered grid pints.

6. If DATA ≠ "PLOT3D" nor "FUN3D", nor "CFX", the format of the data stored in CFDFILE is shown as follows:

Card Set 1	**NSGRID, NSELEM (Free Format)**

NSGRID NSELEM	Number of surface grid points. (Integer) Number of surface elements. (Integer)

Card Set 2	**x, y, z, RHO, U, V, W, C_p, P_0, M, S (Free Format)**
x, y, z	x, y, and z location of the surface grid point. (Real)
RHO	Non-dimensional density. (Real)
U, V, W	Non-dimensional velocity components along x, y, and z directions, respectively. (Real)
C_p	Pressure coefficients. (Real)
P_0	Non-dimensional pressure. (Real)
M	Local Mach number. (Real)
S	Entropy. Not used by the program. (Real)

Repeat Card Set 2 NSGRID times

Card Set 3	**IDS1, IDS2, IDS3, IDS4 (Free Format)**
IDS1, IDS2, IDS3, IDS4	Grid point indices of the four corner points of the surface elements. Note that for triangular element setting IDS3 = IDS4 is recommended. (Integer)

Repeat Card Set 3 NSELEM times.

The definition of those flow variables is shown below:

Nomenclature

M_∞	=	free stream Mach number
a_∞	=	free stream speed of sound
ρ_∞	=	free stream density
p_∞	=	free stream pressure
U_∞	=	free stream velocity
T_∞	=	free stream temperature
R	=	universal gas constant
p	=	local pressure
u	=	local u-velocity component
v	=	local v-velocity component
w	=	local w-velocity component
T	=	local temperature
s	=	local entropy
γ	=	ratio of specific heats $(c_p / c_v) = 1.4$

A. FIELDVIEW (subscript: fv) convention for reference

1. Non-dimensional Pressure (p_{fv}) $$p_{fv} = \frac{p}{\rho_\infty U_\infty^2} \quad \text{(A.1)}$$
2. Non-dimensional U Velocity (u_{fv}) $$u_{fv} = \frac{u}{U_\infty} \quad \text{(A.2)}$$
3. Non-dimensional V Velocity (v_{fv}) $$v_{fv} = \frac{v}{U_\infty} \quad \text{(A.3)}$$
4. Non-dimensional W Velocity (w_{fv}) $$w_{fv} = \frac{w}{U_\infty} \quad \text{(A.4)}$$

5. Non-dimensional Temperature (T_{fv}) $$T_{fv} = \frac{T}{T_\infty} \qquad \text{(A.5)}$$

B. INPCFD1 (subscript: inp) convention for use with DATA ≠ "PLOT3D"
(8 variables in Card Set 2 and Card Set 5 in CFDFILE)

Note: ZONAIR requires that the velocity components be normalized by the speed of sound instead of the free stream velocity. Therefore, the velocity components from FieldView which are normalized by the free stream velocity U_∞ are multiplied by free stream Mach number M_∞ to obtain velocity components that are normalized by the speed of sound.

1. U-Velocity (u_{inp})

$$u_{inp} = u_{fv} M_\infty = \frac{u}{U_\infty}\frac{U_\infty}{a_\infty} = \frac{u}{a_\infty} \qquad \text{(B.1)}$$

2. V-Velocity (v_{inp})

$$v_{inp} = v_{fv} M_\infty = \frac{v}{U_\infty}\frac{U_\infty}{a_\infty} = \frac{v}{a_\infty} \qquad \text{(B.2)}$$

3. W-Velocity (w_{inp})

$$w_{inp} = w_{fv} M_\infty \frac{w}{U_\infty}\frac{U_\infty}{a_\infty} = \frac{w}{a_\infty} \qquad \text{(B.3)}$$

4. Pressure Coefficient ($C_{P_{inp}}$)

$$C_{P_{inp}} = \frac{p - p_\infty}{\frac{1}{2}\rho_\infty U_\infty^2}$$

substituting from (A.1) $p = p_{fv}\rho_\infty U_\infty^2$

$$C_{P_{inp}} = \frac{p_{fv}\rho_\infty U_\infty^2 - p_\infty}{\frac{1}{2}\rho_\infty U_\infty^2} = 2p_{fv} - \frac{p_\infty}{\frac{1}{2}\rho_\infty U_\infty^2}$$

since $U_\infty^2 = M_\infty^2 a_\infty^2$ and $a_\infty^2 = \gamma R T_\infty$ and $p_\infty = \rho_\infty T_\infty R$

$$C_{P_{inp}} = 2\left(p_{fv} - \frac{\rho_\infty T_\infty R}{\rho_\infty M_\infty^2 \gamma R T_\infty}\right)$$

$$C_{P_{inp}} = 2\left(p_{fv} - \frac{1}{\gamma M_\infty^2}\right) \qquad \text{(B.4)}$$

5. Local Mach Number (M_{inp})

Mach number is defined as: $M_\infty = \dfrac{U_\infty}{a_\infty}$

It follows that local Mach number is therefore defined as: $M = \dfrac{U}{a}$

where the absence of ∞ indicates "local" values.

Since the total velocity is the magnitude of the velocity components: $U = \sqrt{u^2 + v^2 + w^2}$

$$M_{inp} = \frac{\sqrt{u^2 + v^2 + w^2}}{a} = \frac{\sqrt{\left(\frac{u}{U_\infty}\right)^2 + \left(\frac{v}{U_\infty}\right)^2 + \left(\frac{w}{U_\infty}\right)^2}}{\frac{a}{U_\infty}}$$

and since locally $a^2 = \gamma RT$

$$M_{inp} = \frac{\sqrt{\left(\frac{u}{U_\infty}\right)^2 + \left(\frac{v}{U_\infty}\right)^2 + \left(\frac{w}{U_\infty}\right)^2}}{\frac{\sqrt{\gamma RT}}{U_\infty}}$$

substituting A.2 through A.5 we get

$$M_{inp} = \frac{\sqrt{u_{fv}^2 + v_{fv}^2 + w_{fv}^2}}{\frac{\sqrt{\gamma RT_\infty T_{fv}}}{U_\infty}} = \frac{\sqrt{u_{fv}^2 + v_{fv}^2 + w_{fv}^2}}{\frac{a_\infty \sqrt{T_{fv}}}{U_\infty}} = \frac{\sqrt{u_{fv}^2 + v_{fv}^2 + w_{fv}^2}}{\frac{\sqrt{T_{fv}}}{M_\infty}}$$

$$M_{inp} = \frac{\sqrt{u_{fv}^2 + v_{fv}^2 + w_{fv}^2}}{\sqrt{T_{fv}}} M_\infty \tag{B.5}$$

6. Density (ρ_{inp})

Defining the non-dimensional density as

$$\rho_{inp} = \frac{\rho}{\rho_\infty}$$

Per the ideal gas law, density is defined as $\rho_\infty = \frac{p_\infty}{T_\infty R}$

It follows that the local density is defined as $\rho = \frac{p}{TR}$ where the absence of ∞ indicates "local" values. Since $a_\infty^2 = \gamma RT_\infty$ and $M_\infty = \frac{U_\infty}{a_\infty}$, solving for R we get

$$R = \frac{U_\infty^2}{\gamma M_\infty^2 T_\infty}$$

substituting this into the local density defined above and rearranging we have

$$\rho = \frac{p}{\frac{T}{T_\infty}\left(\frac{U_\infty^2}{M_\infty^2}\right)}\gamma$$

non-dimensionalizing the equation by dividing both sides by ρ_∞ and rearranging yields

$$\rho_{inp} = \frac{\rho}{\rho_\infty} = \frac{\frac{p}{\rho_\infty U_\infty^2}}{\frac{T}{T_\infty}}\gamma M_\infty^2$$

substituting A.1 and A.5 yields

$$\rho_{inp} = \frac{p_{fv}}{T_{fv}} \gamma M^2 \tag{B.6}$$

7. Entropy (s_{inp})

Defining the non-dimensional entropy as

$$s_{inp} = \frac{s}{\left(p_\infty / \rho_\infty^\gamma \right)} \tag{B.7.1}$$

One common definition for entropy in the CFD world is given by

$s = \frac{p}{\rho^\gamma} - const$ where *const* typically equals $\frac{p_\infty}{\rho_\infty^\gamma}$

substituting *s* into B.7.1 and reducing yields

$$s_{inp} = \frac{p}{\rho^\gamma} \frac{\rho_\infty^\gamma}{p_\infty} - 1 \tag{B.7.2}$$

since the non-dimensional density is defined as $\rho_{inp} = \frac{\rho}{\rho_\infty}$, Eqn. B.7.2 can be re-written as

$$s_{inp} = \frac{p}{\rho_{inp}^\gamma} \frac{1}{p_\infty} - 1 \tag{B.7.3}$$

given that $a_\infty^2 = \gamma R T_\infty$ and $p_\infty = \rho_\infty T_\infty R$

p_∞ can be manipulated to give $p_\infty = \rho_\infty \frac{\gamma R T_\infty}{\gamma} = \rho_\infty \frac{U_\infty^2}{\gamma M_\infty^2}$

substituting into B.7.3 yields

$$s_{inp} = \frac{p}{\rho_\infty U_\infty^2} \frac{\gamma M_\infty^2}{\rho_{inp}^\gamma} - 1$$

substituting A.1 yields

$$s_{inp} = p_{fv} \frac{\gamma M_\infty^2}{\rho_{inp}^\gamma} - 1 \tag{B.7}$$

8. Pressure (p_{inp})

Defining the non-dimensional pressure as

$$p_{inp} = \frac{p}{p_\infty}$$

substituting that $p_\infty = \rho_\infty T_\infty R$

$$p_{inp} = \frac{p}{\rho_\infty T_\infty R}$$

multiplying the numerator and denominator by γU_∞^2 and rearranging yields

$$p_{inp} = \frac{p}{\rho_\infty U_\infty^2} \cdot \frac{\gamma U_\infty^2}{\gamma R T_\infty}$$

since $a_\infty^2 = \gamma R T_\infty$ and $M_\infty = \frac{U_\infty}{a_\infty}$, we have

$$p_{inp} = \frac{p}{\rho_\infty U_\infty^2} \cdot \gamma M_\infty^2$$

substituting A.1 yields

$$p_{inp} = p_{fv} \gamma M_\infty^2 \tag{B.8}$$

INPDMI

Replaces ZONAIR Solution by External Input

Description: Imports the users-supplied pressure coefficients via a direct matrix input coefficients in the OUTPUT4 format to replace the pressure coefficient computed by ZONAIR.

Format and Example:

1	2	3	4	5	6	7	8	9	10
INPDMI	IDAERO	NAME							

INPDMI	100	CP.DAT							

Field	Contents
IDAERO	If IDAERO is a positive integer, it refers to the identification number of an **AEROGEN** bulk data card. The pressure coefficients at the flight condition defined by the **AEROGEN** bulk data card with ID=IDAERO computed by the program are replaced by the CFD solution. (Integer). If IDAERO is a negative integer, it is referred to by a **TRIMINP** or **WT1CFD** bulk data card. Note that to rapidly verify the imported pressure coefficient, it is recommended that the **PARAM** bulk data card with entry NAME="BYPASS" be used. (Integer, See Remark 1)
NAME	Character string that matches a matrix name specified by a **DMI** bulk data card or an **'ASSIGN MATRIX='** Executive Control Command. This matrix contains only one column. The row contains the pressure coefficient of each panel to be imported. (Character) (See Remark 2)

Remarks:

1. The **INPDMI** bulk data card is used to import the user-supplied rigid pressure coefficients on each aerodynamic panel to replace those computed by ZONAIR. These pressure coefficients also can be the CFD/wind tunnel data processed by the **INPCFD**, **INPCFD1**, **CPSPLN**, or, **CPSPLNL** bulk data card and saved via the **PLTCP** bulk data card with entry FORM="OUTPUT4".

2. The row must contain J-set number of pressure coefficients, where J-set is the total number of aerodynamic panels. The sequence of the J-set is: the first group of panels starts from all CTRIA3 and CQUAD4 panels that refer to the **MATBODY** bulk data card with the lowest identification number. Within this group of panels, CTRIA3 panels are first assigned to the J-set then followed by the CQUAD4 panels. The last group of panels in the J-set are those referring to the **MATBODY** bulk data card with the highest identification number. If a thin wing is modeled by the **CAERO7** bulk data card, the last set of the J-set is the panels on the upper side of the CAERO7 macroelement followed by the panels on the lower side of the CAERO7 macroelement. (see the pressure coefficient output in the standard output file).

JETFRC

Control Forces of Jet

Description: Defines a control force due to jet on a set of aerodynamic panels.

Format and Example:

1	2	3	4	5	6	7	8	9	10
JETFRC	LABEL	TYPE							CONT
CONT	PANLST1	JETVEL1	PANLST2	JETVEL2	…	-etc-			

JETFRC	VTHRUST	ANTI							+J
+J	1	0.1	4	0.3	7	-0.01			

Field	Contents
LABEL	Unique alphanumeric string up to 8 characters used to identify the control force. (Character) (See Remark 1)
TYPE	Type of force (Character) SYM — Symmetric force ANTI — Anti-symmetric force ASYM — Asymmetric force
PANLSTi	Identification number of a **PANLSTi** bulk data card defining a list of aerodynamic panels where the jet is applied.
JETVELi	Jet velocity divided by the freestream velocity. (Real)

Remarks:

1. **JETFRC** can be selected as a control force for the ASE, TRIM or transient analysis. Among all **AESURFZ**, **AESLINK**, **GRIDFRC**, **PZTMODE**, and **JETFRC** bulk data cards, LABEL must be unique.

JIGCP

Pressure Coefficients on Jig Shape

Description: Corrects the pressure coefficients measured on the rigid cruise shape to those on the jig shape. Note that to activate **JIGCP** bulk data card, the executive control command "**SOLUTION 1**" must be specified.

Format and Example:

1	2	3	4	5	6	7	8	9	10
JIGCP	IDJIG	DMI	IDAERO	FILENM		FORM	TYPE	EXTFILE	CONT
CONT	PANLST1	PANLST2	...	-etc-	...				

JIGCP	100	SMODAL	100	OUTPUT.CP			YES	101	+J
+J	101	121							

Field	Contents
IDJIG	Identification number that is referred to by the **JIGCP** case control command. (Integer > 0) (See Remark 1)
DMI	Matrix name contains the generalized coordinate solution computed by the JIGSHP module. This matrix can be imported by the **DMI** bulk data card. (Character) (See remark 2)
IDAERO	Identification number of an **AEROGEN** bulk data card by which computed (or interpolated from the wind tunnel measured data or CFD computed results) pressure coefficients on the cruise shape to be corrected to those on the jig shape. (Integer > 0) (See remark 3).
FILENM	The name of a data file in which the corrected pressure coefficients on the jig shape is stored in the OUTPUT4 format. This file name is always in the upper case. In case the input file name is given in the lower case, the program converts it to the upper case. If the first character starts with a dollar sign “$”, the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character) (See remark 4)

FORM	FORM = "TECPLOT" for generating the TECPLOT™ file. FORM = "PATRAN" for generating the PATRAN™ neutral/results file. FORM = "IDEAS" for generating the I-DEAS™ universal file. FORM = "FEMAP" for generating a FEMAP™ neutral file. FORM = "ANSYS" for generating an ANSYS supported neutral file. FORM = "NASTRAN" for generating a NASTRAN bulk data deck with PLOAD4 cards to define the pressure loads. FORM = "ESA" for generating a PEGASUS readable file. (Character, Default = "TECPLOT")
TYPE	For TYPE = "YES" the control surface deflection angles are included in the plot file. (Character)
EXTFILE	Identification number of an **EXTFILE** bulk data card in which the corrected pressure coefficients on the jig shape along with the aerodynamic panel model are stored for graphic display. If EXTFILE = 0, the entries FORM and TYPE are not used. (Integer ≥ 0)
PANLSTi	Identification number of a **PANLST2/PANLST3** (**PANLST1** is not allowed) bulk data card to list the identification numbers of panels of which the pressure coefficients are excluded from the correction process. (Integer ≥ 0) (See remark 5)

Remarks:

1. The wind tunnel measured or CFD computed pressure coefficients are usually on the cruise shape. However, for loads analysis with static aeroelastic effects, those pressure coefficients should be on the jig shape from which the static aeroelastic analysis starts. These pressure coefficients on the jig shape can be obtained by the **JIGCP** bulk data card from those on the cruise shape.

2. The generalized coordinate solution must be obtained by the JIGSHP module that outputs the generalized coordinate solution in the standard output file in terms of the **DMI** bulk data card as follows:

```
DMI     SMODAL  0       2       2               DMIL            21      1
DMIL            SMODAL          1                       1+0.000000000E+00+CONT
+CONT   +0.000000000E+00+0.000000000E+00+2.733796835E-02-1.815778436E-03+CONT
+CONT   -7.506751444E-06+9.512930992E-04+5.081548006E-04+1.638944959E-04+CONT
+CONT   -3.156289677E-05-9.941014287E-05+1.375459533E-07-1.008164219E-07+CONT
+CONT   +9.998018413E-09+3.613671495E-08-3.632124162E-06-1.374753964E-07+CONT
+CONT   -1.477877110E-08+2.177931613E-08+3.416700523E-08-1.212421896E-08
```

   The user can cut-and-paste the above **DMI** bulk data card into the standard input file then the entry DMI to the name of this matrix.

3. The **AEROGEN** bulk data card can refer to any Mach number and angle of attack at which the pressure distribution (replaced by the **INPCFD, INPCFD1,CPSPLN, or CPSPLNL** bulk data card) on the cruise shape is corrected for the jig shape by the following equation.

$$C_{Pjig}(M,\alpha)=C_{Pcruise}(M,\alpha)-\left[AIC(M,\alpha)\right]\left[\phi\right]\left\{\xi\right\}$$

where

C_{Pjig} is the pressure distribution on the jig shape.

$C_{Pcruise}$ is the pressure distribution on the cruise computed by CFD or measured by wind tunnel test.

$\left[AIC\right]$ is the aerodynamic influence coefficient matrix.

$\left[\phi\right]$ is the mode shapes imported by the "ASSIGN FEM= " executive control command and activated by the "SOLUTION 1" executive control command.

$\left\{\xi\right\}$ is the generalized coordinate solution specified by the entry DMI.

Thus

$\left[\phi\right]\left\{\xi\right\}$ is the structured deformation from the cruise shape to the jig shape.

and

$\left[AIC\right]\left[\phi\right]\left\{\xi\right\}$ is the incremental pressure distribution due to the deformation from the cruise shape to the jig shape.

4. The corrected pressure distribution on the jig shape at the flight condition defined by the **AEROGEN** bulk data card with ID = IDAERO is stored in the OUTPUT format. To perform the loads analysis starting from the jig shape, the user can import this corrected pressure distribution into the program by the **INPDMI** bulk data card.

5. Usually, only the wing shape of the jig shape is different from that of the cruise shape. Therefore, it is recommended that the pressure coefficients on other aerodynamic components be excluded from the pressure correction process using the entry PANLSTi. For the **CAERO7** bulk data card, the identification numbers of the lower surface panels are the same as those of the upper surface except with a negative sign. For instance, for a **CAERO7** bulk data card with ID = 1001 and this **CAERO7** bulk data card has 100 panels, to refer to its lower surface panels, the following **PANLST2** bulk data card can be used.

PANLST2	1	1001	-1100	THRU	-1001				

JIGSHP

Determines the Jig Shape

Description: Determines the jig shape from the desired cruise shape at the designed flight condition. Note that to activate the **JIGSHP** bulk data card, the executive control command "SOLUTION 1" must be specified.

Format and Example:

1	2	3	4	5	6	7	8	9	10
JIGSHP	IDJIG	QINF	IDAERO	FILECP		FORM	SCALE	IDEXT	CONT
CONT	PANLST1	PANLST2	...	-etc-	...				

JIGSHP	100	1.02	200	CP.DAT		TECPLOT	3.0	100	+C
+C	101	102	103						

Field	Contents
IDJIG	Identification number that is referred to by the **JIGSHP** case control command. (Integer > 0) (See Remark 1)
QINF	Dynamic pressure at which the sought after jig shape automatically deforms to the desired cruise shape under the aerodynamic loads.(Real > 0.0)
IDAERO	Identification number of an **AEROGEN** bulk data card to specify the flight condition at which the desired cruise shape is designed for the best aerodynamic efficiency. (Integer > 0) (See remark 2)
FILECP	Character string to specify a file name on which the pressure coefficients on the sought after jig shape is stored in the OUTPUT4 format. (Character) (Default = "OUTPUT4_CP") (See remark 3)
FORM	FORM = “TECPLOT” for generating the TECPLOT™ file. FORM = “PATRAN” for generating the PATRAN™ neutral/results file. FORM = “IDEAS” for generating the I-DEAS™ universal file. FORM = “FEMAP” for generating a FEMAP™ neutral file. FORM = “ANSYS” for generating an ANSYS supported neutral file. FORM = “NASTRAN” for generating a NASTRAN bulk data deck with PLOAD4 cards to define the pressure loads. FORM = “ESA” for generating a PEGASUS readable file. (Character, Default = “TECPLOT”)
SCALE	Factor applied to the deformation from the cruise shape to the jig shape for the clarity of graphic display. (Real, Default = 1.0)
IDEXT	Identification number of an **EXTFILE** bulk data to specify a file name on which the jig shape aerodynamic model along with the pressure distribution on the jig shape is stored. (Integer ≥0)

PANLSTi	Identification number of a **PANLST2/PANLST3** (**PANLST1** is not allowed) bulk data card to list the identification numbers of panels of which the pressure coefficients are excluded from the correction process. (Integer ≥ 0) (See remark 4)

Remarks:

1. Usually, the aerodynamic shape of aircraft is designed to provide the best aerodynamic efficiency at the cruise condition by assuming the aircraft to be rigid. However, because of the aerodynamic loads, this cruise shape may deform and depart from the desired shape. One way to circumvent this issue is to design a jig shape that at the cruise condition deforms back to the desired cruise shape. This jig shape can be determined by the **JIGSHP** bulk data card.

2. The pressure distribution on the cruise shape at the flight condition specified by the **AEROGEN** bulk data card can be computed by ZONAIR or replaced by the CFD solution using the **INPCFD**/**INPCFD1** bulk data card or replaced by the wind tunnel measurement using the **CPSPLN**/**CPSPLNL** bulk data card.

3. The pressure distribution on the jig shape is computed by the following method:

   Let $C_{P_{jig}}$ be the sought after pressure coefficients on the jig shape, then the difference between the given pressure coefficients on the desired cruise shape ($C_{P_{cruise}}$) and $C_{P_{jig}}$ is the incremental pressure coefficient due to the structural deformation which can be computed from the aerodynamic influence coefficient (AIC) matrix such as:

   $$\left\{C_{P_{cruise}}\right\} - \left\{C_{P_{jig}}\right\} = [AIC]\left[\phi_e\right]\left\{\xi\right\}$$

   where $\left[\phi_e\right]$ is the elastic mode shape matrix and $\left\{\xi\right\}$ is the sought after generalized modal coordinates of the elastic modes.

   $\left\{\xi\right\}$ can be related to $C_{P_{jig}}$ by the following static aeroelastic equation:

   $$[\left[K_{ee}\right] - q_\infty [Q]]\left\{\xi\right\} = q_\infty \left[\phi_e\right]^T \left[S_{kj}\right]^T \left\{C_{P_{jig}}\right\}$$

   or

   $$\left\{\xi\right\} = \left[A\right]\left\{C_{P_{jig}}\right\}$$

   where $\left[A\right] = q_\infty [\left[K_{ee}\right] - q_\infty [Q]]^{-1} \left[\phi_e\right]^T \left[S_{kj}\right]^T$, $\left[K_{ee}\right]$ is the generalized stiffness matrix of the elastic modes, $[Q] = \left[\phi_e\right]^T \left[AIC\right]\left[\phi_e\right]$ is the generalized aerodynamic force matrix and $[S_{kj}]$ is the integration matrix to convert pressure to forces. q_∞ is the dynamic pressure at which the sought after jig shape automatically deforms to the desired cruise shape under the aerodynamic loads with static aeroelastic effects.

Therefore,

$$[AIC][\phi_e][A]\left\{C_{P_{jig}}\right\} = \left\{C_{P_{cruise}}\right\} - \left\{C_{P_{jig}}\right\}$$

Or

$$\left\{C_{P_{jig}}\right\} = \left[I + [AIC][\phi_e][A]\right]^{-1}\left\{C_{P_{cruise}}\right\}$$

Which yields:

$$\{\xi\} = [A]\left[I + [AIC][\phi_e][A]\right]^{-1}\left\{C_{P_{cruise}}\right\}$$

Finally, the structural deformation $\{x\}$ from the cruise shape to the jig shape can be obtained by the product of mode shape matrix and the generalized coordinates:

$$\{x\} = -[\phi_e]\{\xi\}$$

where

C_{Pjig} is the pressure distribution on the jig shape.

$C_{Pcruise}$ is the pressure distribution on the cruise computed by CFD or obtained by wind tunnel test.

$[AIC]$ is the aerodynamic influence coefficient matrix.

$[\phi]$ are the mode shapes imported by the "ASSIGN FEM= " executive control command and activated by the "SOLUTION 1" executive control command.

$\{\xi\}$ is the generalized coordinate solution specified by the entry DMI.

Thus

$[\phi]\{\xi\}$ is the structure deformation from the cruise shape to the jig shape.

and

$[AIC][\phi]\{\xi\}$ is the incremental pressure distribution due to the deformation from the cruise shape to the jig shape.

4. The corrected pressure distribution on the jig shape at the flight condition defined by the **AEROGEN** bulk data card with ID = IDAERO is stored in the OUTPUT format.

5. Usually, only the wing shape of the jig shape is different from that of the cruise shape. Therefore, it is recommended that the pressure coefficients on other aerodynamic components be excluded from the pressure correction process using the entry PANLSTi. For the **CAERO7** bulk data card, the identification numbers of the lower surface panels are the same as those of the upper surface except with a negative sign. For instance, for a **CAERO7** bulk data card with ID = 1001 and this **CAERO7** bulk data card has 100 panels, to refer to its lower surface panels, the following **PANLST2** bulk data card can be used.

PANLST2	1	1001	-1100	THRU	-1001				

JOINTHK

Join Two THKWINGs

Description: Joins two thick-wing components that are generated by two **THKWING** bulk data cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
JOINTHK	LID	THWNG1	RT1	THWNG2	RT2				

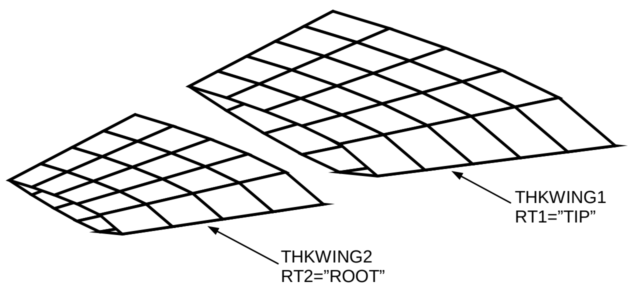
JOINTHK	100	1001	TIP	2001	ROOT				

Field	Contents
LID	Identification number. (Integer > 0) (See Remark 1)
THKWNG1	Identification number of a **THKWING** bulk data card. (Integer > 0)
RT1	Character either "ROOT" or "TIP" For RT1 = "ROOT" The root section of the thick-wing component is attached to another thick-wing component defined by THKWNG2. RT1 = "TIP" The tip section of the thick-wing component is attached to another thick-wing component defined by THKWNG2
THKWNG2	Same as THKWNG1 but for the second thick-wing component
RT2	Same as RT1 but for the THKWNG2

Remarks:

1. The **JOINTHK** bulk data card internally generated a set of **RBAR** bulk data cards that merge the grid points along "RT1" of "THKWNG1" with those along "RT2" of "THKWNG2".

   Note that the chordwise divisions of THKWNG1 and THKWNG2 must be the same. Otherwise, a fatal error occurs. See the following figure as an example.



LESUCT Additional Lift due to Vortex Roll-up

Description: Activates the inclusion of additional lift due to vortex roll-up from the wing leading edge using the Polhamus leading edge suction analogy..

Format and Example:

1	2	3	4	5	6	7	8	9	10
LESUCT	IDMACH								CONT
CONT	$CAERO7_1$	$FACTOR_1$	$CAERO7_2$	$FACTOR_2$	--	etc	--		

LESUCT	10								+LE
+C	1000	1.0	2000	0.5					

Field	Contents
IDMACH	Identification number of a **MACH** bulk data card at which the additional lift due to vortex roll-up from the wing leading edge is included. (Integer>0) (See Remark 1)
$CAERO7_i$	Identification number of a **CAERO7** bulk data card of which the additional lift due to vortex roll-up from the wing leading edge is included. (Integer>0) (See Remark 2)
$FACTOR_i$	A factor applied to the computed leading edge suction of the $CAERO7_i$ macroelement. (Real, default=0.0)

Remarks:

1. To activate the inclusion of additional lift due to leading edge vortex roll-up, the **LESUCT** bulk data card must be specified. Using the Polhamus leading edge suction analogy, the leading edge suction force is first computed. Then, this leading edge suction force is treated as the additional lift due to vortex roll-up from the wing leading edge. Note that the **LESUCT** bulk data card is only applied to the **CAERO7** bulk data card..

2. Any **CAERO7** bulk data card that is not referred to by the entry $CAERO7_i$ is not included in the lift due to vortex roll-up.

LMDSAVE

Save or Retrieve Matrices Created by the LOADMOD Bulk Data Cards

Description: Save or retrieve matrices created by the **LOADMOD** bulk data cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
LMDSAVE	SAVE	FILENM							
LMDSAVE	ACQUIRE	LOADMOD.DAT							

Field	Contents
SAVE	Character string either "SAVE" or "AQUIRE". For SAVE = "SAVE", the matrices created by the **LOADMOD** bulk data cards are saved in an external file. For SAVE = "ACQUIRE", those matrices are retrieved. (Character) (See Remark 1)
FILENM	Unformatted file name to store the matrices created by the **LOADMOD** bulk data cards. If the first character of FILENM starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character)

LOADMOD **Load Mode Generator**

Description: Defines the load mode of a set of aerodynamic panels for computing component loads.

Format and Example:

1	2	3	4	5	6	7	8	9	10
LOADMOD	LID	LABEL	CP	SETK	SETG				

LOADMOD	10	XSHEAR	1	1					

Field	Contents
LID	**LOADMOD** identification number (Integer > 0) (See Remark 1)
LABEL	Type of loads defined by the load mode (Character) Must be one of the following: XSHEAR Shear force along X-axis of the coordinate system CP. YSHEAR Shear force along Y-axis of the coordinate system CP. ZSHEAR Shear force along Z-axis of the coordinate system CP. XMOMENT Bending moment about X-axis of the coordinate system CP. YMOMENT Bending moment about Y-axis of the coordinate system CP. ZMOMENT Bending moment about Z-axis of the coordinate system CP.
CP	Identification number of a rectangular coordinate system (**CORD2R** bulk data card). (Integer ≥ 0) (See Remark 2)
SETK	Identification number of a **PANLST1**, **PANLST2** or **PANLST3** bulk data card used to define the aerodynamic panel id's. (Integer ≥ 0)
SETG	Identification number of **SET1** bulk data card used to define the structural grid points (Integer ≥ 0) used only for flexible loads analysis. (See Remark 3)

Remarks:

3. The **LOADMOD** bulk data card can be used to compute the loads (including aerodynamic loads and inertial loads) of a component, for instance the wing or an under-wing store. All component loads defined by the **LOADMOD** bulk data card exist in the Bulk Data Section will be automatically computed.

4. If CP=0, the basic coordinate system is used.

5. All structural grid points associated with the component should be included in the **SET1** bulk data card. Missing structural grid points that have attached mass can lead to incorrect inertial loads.

MACH

Generates Aerodynamic Matrices At a Given Mach Number

Description: Generates Aerodynamic Influence Coefficient matrix at a given mach number.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MACH	IDMACH	MACHNO	METHOD	RELAXW	VISCOUS	SAVE	FILENM		
MACH	100	0.8	0		10	ACQU	\ZONAIR\AIC08		

Field	Contents
IDMACH	Identification number (Integer > 0) (See Remark 1)
MACHNO	Mach number (Real ≥ 0.0)
METHOD	Flag for defining the aerodynamic method (Integer) METHOD = 0 For subsonic and supersonic aerodynamics by solving the linear potential equation. METHOD = 2 For hypersonic aerodynamics
RELAXW	Identification number of a **RELAXW** bulk data card for wake relaxation. (Integer ≥ 0 or Blank) (See Remark 2)
VISCOUS	The absolute value of VISCOUS is the identification number of a **VISCOUS** bulk data card to define the viscous parameters for skin friction computation and to introduce the viscous vortex model for the CROD elements. (Integer (See Remark 3)
SAVE	Save the Aerodynamic Influence Coefficient (AIC) matrices generated by the current **MACH** bulk data card to file "FILENM" or retrieve AIC from "FILENM". (Characters or blank) SAVE = SAVE saves the AIC data SAVE = ACQUIRE or ACQU retrieves an existing file containing AIC data. Otherwise do not save or retrieve data
FILENM	File name (up to 16 characters) to specify the file name on which the AIC data is saved or retrieved. If the first character starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character or Blank) (See Remark 4)

Remark:

1. The **MACH** bulk data card is referred to by an **AEROGEN** bulk data card. However, the existence of a **MACH** bulk data card in the Bulk Data Section automatically triggers the program to compute the aerodynamic matrices even if this **MACH** bulk data card is not referred to be any **AEROGEN** bulk data card. Because computing aerodynamic matrices usually requires large amount of computer time, the user should exclude any unused **MACH** bulk data card in the Bulk Data Section.

2. If RELAXW = 0, no wake relaxation is performed. Thus, the wake shape generated by the WAKENET/VORNET (if any) macroelements remains unchanged.

3. If VISCOUS = 0, the inviscid vortex model of the line vortex (CROD element) is used which would yield infinite velocity influence coefficient at the center of the vortex core. For VISCOUS < 0, the aerodynamic forces and moments due to the skin friction drag will NOT be computed.

4. If SAVE = “SAVE”, the AIC matrices will be saved on an unformatted data file with file name = “FILENM” as the archival data entity. If SAVE = “ACQUIRE”, or “ACQU”, the AIC matrices will be retrieved from the data file with name = “FILENM”. In this case, a large amount of computing time can be saved.

MATBODY

Aerodynamic Component

Description: Defines an aerodynamic component by grouping a set of CQUAD4/CTRIA3 panels.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MATBODY	MID	LABEL	TYPE	NOSEGRD	BLUNT	NAXIS	NRAD	FRICT	CONT
CONT	RADIUSi	PANLSTi	RADIUSi	PANLSTi	…	-etc-			

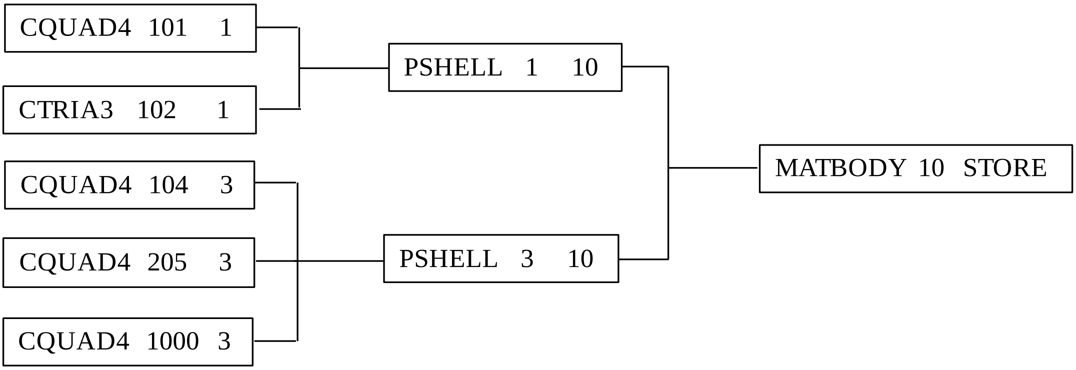
MATBODY	1	STORE	BODY	101	YES	4	5		+M
+M	0.1	10	0.2	30	0.4	35	0.4	40	

Field	Contents
MID	Unique identification number (Integer > 0) (See Remark 1)
LABEL	Unique character string to define the name of the aerodynamic component (Character)
TYPE	Character string either “WING” or “BODY” used either only for hypersonic aerodynamics or for computing the component form drag factor. (Character, default=”BODY”) (See Remark 2)
NOSEGRD	Identification number of a **GRID** bulk data card with entry PS = 0 or blank to specify the grid point located at the nose of the body. Used only if TYPE = “BODY”. (Integer)
BLUNT	Character string either “YES” or “NO”. For BLUNT = “YES” and TYPE = “BODY” the nose of the body is a blunt nose. For BLUNT = “YES” and TYPE = “WING” the leading edge of the wing is a round leading edge. Used only for hypersonic aerodynamics. (Character)
NAXIS, NRAD	Define a set of NAXIS × NRAD panels that represent the nose region of the body or leading edge region of the wing. Used only for BLUNT = “YES” and for hypersonic aerodynamics. NAXIS is the number of panels in each strip along the streamwise direction and NRAD is the total number of panel-strips along the circumferential direction for Body or spanwise direction for Wing. (Integer > 1) (See Remark 3)
FRICT	Component form drag factor for computing the skin friction drag. Active only if the **VISCOUS** bulk data card is referred to by the **MACH** bulk data card. (Real>0.0, default=1.0) (See remark 4)

RADIUS$_i$	Radius of the nose or leading edge for panel-strip with NRAD = *i*. (Real ≥ 0.0)
PANLST$_i$	Identification number of a **PANLST2** bulk data card that lists NAXIS panel identification numbers for panel-strip with NRAD = *i*. (Integer > 0) (See Remark 2)

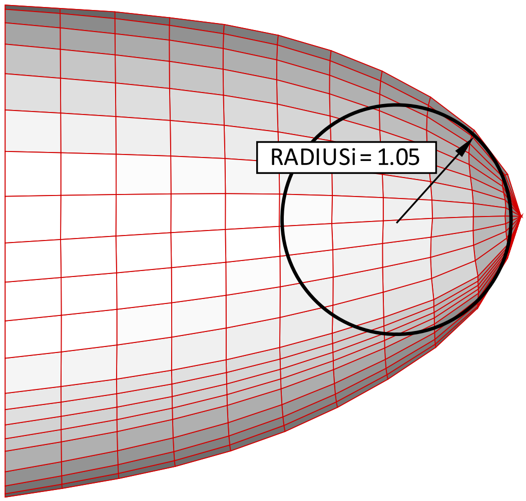
<u>Remark:</u>

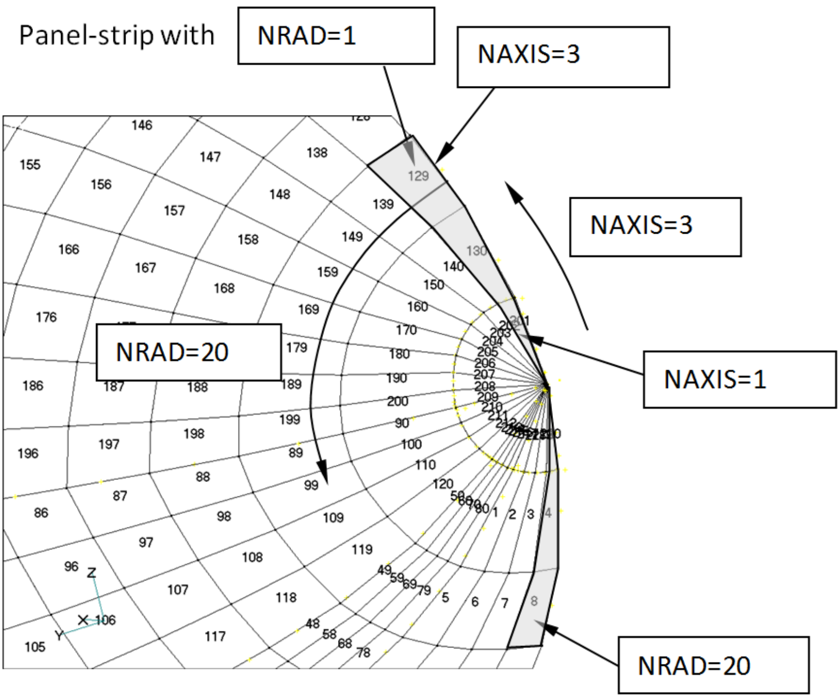
1. The **MATBODY** bulk data card is referred to by the **PSHELL** bulk data card. All panels that refer to the **PSHELL** bulk data card and the **MATBODY** bulk data card are grouped into one aerodynamic component. In the following example, the panels 101, 102, 104, 205, and 1000 are grouped into one aerodynamic component called "STORE".



2. TYPE, NOSERAD, BLUNT, NAXIS, NRAD, RADIUS$_i$, and PANLST$_i$ are used only for hypersonic aerodynamics. NAXIS, NRAD, RADIUS$_i$ and PANLST$_i$ are used only if BLUNT = "YES".

3. The following example shows a sample input of the **MATBODY** bulk data card for a blunt nose body with nose radius = 1.05.


RADIUSi = 1.05


Panel-strip with
NRAD=1
NAXIS=3
NAXIS=3
NRAD=20
NAXIS=1
NRAD=20

```
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
MATBODY      110   FUSEL    BODY     265     YES       3      20
           1.050     501   1.050     502   1.050     503   1.050     504
           1.050     505   1.050     506   1.050     507   1.050     508
           1.050     509   1.050     510   1.050     511   1.050     512
           1.050     513   1.050     514   1.050     515   1.050     516
           1.050     517   1.050     518   1.050     519   1.050     520
$
PANLST2      501     110     201     130     129
PANLST2      502     110     202     140     139
PANLST2      503     110     203     150     149
PANLST2      504     110     204     160     159
PANLST2      505     110     205     170     169
PANLST2      506     110     206     180     179
PANLST2      507     110     207     190     189
PANLST2      508     110     208     200     199
PANLST2      509     110     209      90      89
PANLST2      510     110     210     100      99
PANLST2      511     110     211     110     109
PANLST2      512     110     212     120     119
PANLST2      513     110     213      50      49
PANLST2      514     110     214      60      59
PANLST2      515     110     215      70      69
PANLST2      516     110     216      80      79
PANLST2      517     110     217       1       5
PANLST2      518     110     218       2       6
PANLST2      519     110     219       3       7
PANLST2      520     110     220       4       8
```

4. If TYPE="WING", FRICT should be calculated according to the following equation:

$$FRICT = \left[1 + \frac{0.6}{(x/c)_{\max}}\left(\frac{t}{c}\right) + 100.\left(\frac{t}{c}\right)^4\right]\left[1.34\left(COS\Lambda_{\max}\right)^{0.28}\right]$$

Where $(x/c)_{\max}$ is the the chordwise location of the airfoil maximum thickness point. $\left(\frac{t}{c}\right)$ is the maximum airfoil thickness normalized by the wing chord length. $\Lambda_{\max}$ is the sweep angle of the wing of the maximum-thickness line.

If TYPE="BODY", FRICT should be calculated by:

For fuselage and smooth canopy: $FRICT = \left(1. + \frac{60}{f^3} + \frac{f}{400}\right)$

For Nacelle and smooth external store: $FRICT = \left(1. + \frac{0.35}{f}\right)$

Where $f = l/d = l/\sqrt{(4/\pi)A_{\max}}$, l is the length of the body, A_{max} is the maximum cross section area.

MATCHLD Matching Given Sectional Loads

Description: Corrects the pressure coefficients generated by the **AEROGEN** bulk data card to match a given set of sectional loads

Format and Example:

1	2	3	4	5	6	7	8	9	10
MATCHLD	IDAERO	Q	NX	NY	NZ	PDOT	QDOT	RDOT	CONT
CONT	$LOADMOD_1$	$VALUE_1$	$LOADMOD_2$	$VALUE_2$	$LOADMOD_3$	$VALUE_3$	...	etc	

MATCHLD	100	0.67			2.0				+M
+M	10	3.4	20	4.1					

Field	Contents
IDAERO	Identification number of an **AEROGEN** bulk data card whose generated pressure coefficients are to be corrected (Integer >0) (See Remark 1).
Q	Dynamic pressure whose length unit must be consistent with those defined in the **AEROZ** bulk data card (Real > 0.0, Default = 1.0).
NX, NY, NZ	Accelerations along x, y, z directions, respectively (Real, default = 0.0) (See Remark 2)
PDOT, QDOT, RDOT	Angular accelerations about x, y and z axes, respectively. The moment center is defined by the REFX, REFY and REFZ in the **AEROZ** bulk data card (Real, default=0.0).
$LOADMOD_i$	Identification number of a **LOADMOD** bulk data card to define a sectional load integration vector. If the given sectional load is at the left hand side of a half span model $LOADMOD_i$ must be a negative integer (Integer $\neq 0$).
$VALUE_i$	The given sectional load, such as wing root bending moment and control surface hinge moment, with which the corrected pressure coefficient match (Real).

Remarks:

1. The functionality of the **MATCHLD** bulk data card is to correct the pressure coefficients generated by the **AEROGEN** bulk data card so that the sectional loads computed using the corrected pressure coefficients match a given set of sectional loads. This is achieved by minimizing the difference between the pressure coefficients generated by the **AEROGEN** bulk data card, $\left\{C_{p_z}\right\}$, and the sought corrected pressure coefficients, $\left\{C_{p_c}\right\}$, shown as follows:

   Minimizing $\left\{\left\{C_{p_z}\right\}-\left\{C_{p_c}\right\}\right\}^T\left\{\left\{C_{p_z}\right\}-\left\{C_{p_c}\right\}\right\}$

While satisfying the following constraint functions:

$$q_\infty [L_K]^T [SKJ]^T \{C_{p_c}\} = \{\ell_{given}\}$$

Where $[L_K]$ is the sectional loads integration matrix defined by the **LOADMOD** bulk data cards to integrate the forces on aerodynamic panels for sectional loads. $[SKJ]$ is the integration matrix to convert pressure coefficients to forces. $\{\ell_{given}\}$ is a given sectional load vector, and q_∞ is the dynamic pressure.

Using the Lagrange Multiplier technique, $\{C_{p_c}\}$ can be obtained by:

$$\{C_{p_c}\} = A^T \left[AA^T\right]^{-1} \left\{\{\ell_{given}\} - A\{C_{p_z}\}\right\} + \{C_{p_z}\}$$

Where

$$A = q_\infty [L_K]^T [SKJ]^T$$

2. If one of the NX, NY, NZ, PDOT, QDPT or RDOT is not zero then inertial loads effect is included in $\{\ell_{given}\}$, the constraint function becomes:

$$q_\infty [L_K]^T [SKJ]^T \{C_{p_c}\} - [L_G]^T \{F_i\} = \{\ell_{given}\}$$

Where $\{F_i\}$ is the inertial force vector at structural grids and $[L_G]$ is the sectional loads integration matrix defined by the **LOADMOD** bulk data cards to integrate the inertial forces for sectional loads. The inertial force vector is computed by the following equation:

$$\{F_i\} = [M_{GG}][\phi_R]\{\ddot{X}\}$$

Where $[M_{GG}]$ is the G-set mass matrix, $[\phi_R]$ is the 6 degree-of-freedom rigid body modal matrix and $\{\ddot{X}\}$ is acceleration vector at the aerodynamic moment center specified by the REFX, REFY, and REFZ entries in the **AEROZ** bulk data card shown as follows:.

$$\{\ddot{X}\} = \{N_x, N_y, N_z, \dot{P}, \dot{Q}, \dot{R}\}^T$$

To include the initial loads effect, the user must

a) Specify SOULTION 1 executive control command to import the structural modal solution.

b) Import the MGG matrix by the “ASSIGN MATRIX=” executive control command.

c) Specify the entry SETG in the **LOADMOD** bulk data card.

MATWAKE — Grouping a Set of CSHEAR Panels

Description: Defines the label of a curved wake surface by grouping a set of CSHEAR panels.

Format and Example:

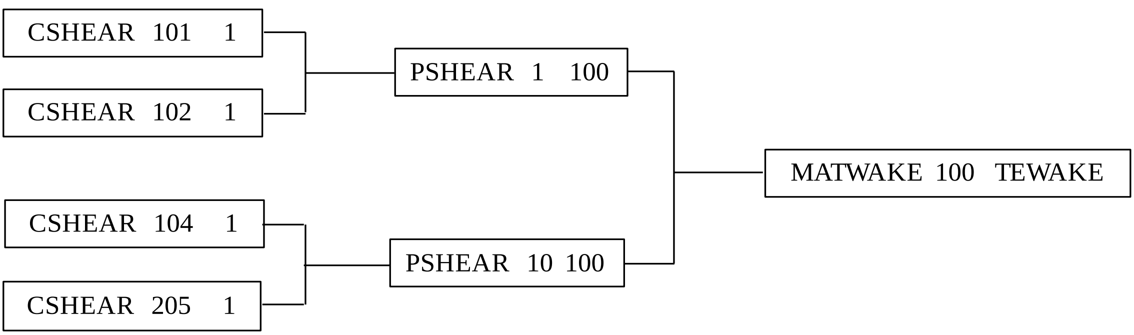
1	2	3	4	5	6	7	8	9	10
MATWAKE	MID	LABEL							

MATWAKE	101	TEWAKE							

Field	Contents
MID	Unique identification number. (Integer > 0) (See Remark 1)
LABEL	Unique character string to define the name of the curved wake surface. (Character)

Remarks:

1. The **MATWAKE** bulk data card is referred to by the **PSHEAR** bulk data cards. All CSHEAR panels that refer to the **PSHEAR** bulk data card and the **MATWAKE** bulk data card are grouped into one curved wake surface. In the following example, the CSHEAR panels 101, 102, 104, and 205 are grouped into one curved wake surface called TEWAKE.



OMITCFD

Defines the Surface Mesh

Description: Defines the surface mesh index of a structured CFD mesh to avoid the reading of all CFD grid points into the computer memory.

Format and Example:

1	2	3	4	5	6	7	8	9	10
OMITCFD	IDOMIT	GAMMA	FORM	FILEMESH		FILESOL		GSCALE	CONT
CONT	BLOCK$_1$	ISTART$_1$	IEND$_1$	JSTART$_1$	JEND$_1$	KSTART$_1$	KEND$_1$		CONT
CONT	BLOCK$_2$	ISTART$_2$	IEND$_2$	JSTART$_2$	JEND$_2$	KSTART$_2$	KEND$_2$		CONT
CONT			...	-etc-	...				

OMITCFD	100	1.133	TECPLOT	SURFACE.PLT		SOLUTION.PLT		12.0	+OMT
+OMT	1	3	101	5	91	1	4		+OMT
+OMT	2	101	191	1	41	1	5		

Field	Contents
IDOMIT	Identification number that is referred to by an **INPCFD** bulk data card. (Integer > 0) (See Remark 1)
GAMMA	Specific heat ratio used in the CFD computation. (Real > 1.0, default = 1.4)
FORM$_i$	Format of the output file specified in the entry FILENM: FORM = “TECPLOT” for generating a TECPLOT file FORM = “PATRAN” for generating a PATRAN neutral file FORM = “IDEAS” for generating a I-DEAS universal file FORM = “FEMAP” for generating a FEMAP neutral file FORM = “ANSYS” for generating a ANSYS supported neutral file FORM = “NASTRAN” for generating a NASTRAN bulk data deck
FILEMESH	Character string up to 16 characters to specify the filename to store the surface boxes and CFD grid points for plotting. If the first character starts with a dollar sign “$”, the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character or Blank) (See Remark 2)
GSCALE	A global scale factor applying to the x, y, and z of all CFD grid points. (Real > 0.0)

FILESOL	Charter string up to 16 characters to specify the filename to store the interpolated Cp and Mach numbers on the surface panels. If the first character starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character or Blank)
BLOCK_i	Block index of the CFD mesh. (Integer > 0)
ISTART_i IEND_i JSTART_i JEND_i KSTART_i KEND_i	Indices of the I-J-K to define the CFD surface grid points. The surface grid points are those between ISTART_i and IEND_i, JSTART_i and JEND_i, and KSTART_i and KEND_i, where $\text{IEND}_i > \text{ISTART}_i > 0$, $\text{JEND}_i > \text{JSTART}_i > 0$, and $\text{KEND}_i > \text{KSTART}_i > 0$. (Integer > 0) (See Remark 3)

<u>Remarks:</u>

1. The **OMITCFD** bulk data card is referred to by an **INPCFD** bulk data card. Because ZONAIR only requires the CFD solution on the surface mesh to replace the program computed pressure coefficients by the CFD solution, specifying the surface mesh index can avoid the reading of all CFD grid points into the computer memory.

2. The objective of the FILEMESH entries is to output a graphical file that allows the user to verify the overlapping between the ZONAIR surface boxes and those CFD grid points near the surface mesh.

3. The CFD grid points defined by BLOCKi, ISTARTi, IENDi, JSTARTi, JENDi, KSTARTi, and KENDi are the CFD surface mesh.

OMITMOD

Delete Structural Modes

Description: Delete structural modes from the database permanently.

Format and Example:

1	2	3	4	5	6	7	8	9	10
OMITMOD	SYMM	MAXMOD							CONT
CONT	MODE1	MODE2	MODE3		…	-etc-			

OMITMOD	ANTI	20							+OMT
+OMT	1	2	3	4					

Field	Contents
SYMM	Character string to specify the boundary condition of which the structural modes are to be deleted. SYMM = "SYM" for symmetric modes. SYMM = "ANTI" for anti-symmetric modes. SYMM = "ASYM" for asymmetric modes. (Character) (See Remark 1)
MAXMOD	All structural modes whose indices are greater than MAXMOD are deleted. Note that if MAXMOD = 0, no mode is deleted. (Integer ≥ 0, Default = index of the highest mode)
MODE*i*	Optional indices of the structural mode(s) that are to be deleted. In addition to any specified MAXMOD. Note: MODE*i* can be used by itself without specifying a MAXMOD entry. (Integer ≥ 0)

Remarks:

1. The **OMITMOD** bulk data card is not referred to by any other bulk data card. Its existence "triggers" the program to delete some of the modes that are imported by the **'ASSIGN FEM='** Executive Control Command. It should be noted that the remaining modes are used by the **TRIM** analysis.

OUTINP

Output a Valid Aerodynamic Model

Description: Outputs a valid aerodynamic model to an ASCII file

Format and Example:

1	2	3	4	5	6	7	8	9	10
OUTINP	FILENM								

1	2	3	4	5	6	7	8	9	10
OUTINP	$1200								

Field	Contents
FILENM	The name of the file that stores the generated data. This file name is always in uppercase letters. In case the input name is given in lowercase letters, the program will convert it to uppercase. If the fist character starts with a dollar sign "$", the rest if the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character) (See Remark 1)

Remarks:

1. The input file may contain the automatic panel model generator such as the **THKWING**, **AUTOBAR**, **AUTOROD**, **AUTOTIP** bulk data cards etc. The **OUTINP** bulk data card outputs the aerodynamic model after those automatic panel model generators have been processed.

OUTPUT4 — Export a Matrix Data Entity

Description: Exports a matrix data entity in the OUTPUT4 format to a data file. See description of **'ASSIGN MATRIX='** Executive Control Command for the definition of the OUTPUT4 format.

Format and Example:

1	2	3	4	5	6	7	8	9	10
OUTPUT4	MATNAM	FILENM		FORM					

1	2	3	4	5	6	7	8	9	10
OUTPUT4	AJJS0002	SYMAIC02.DAT		UNFORM					

Field	Contents
MATNAM	The name of the matrix to be exported (Character) (See Remark 1)
FILENM	Character string specifying the name of the data file in which the data of the matrix is stored. The file name is always in uppercase. In case the input file name is given in lowercase, the program converts it to uppercase. If the first character of FILENM starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character)
FORM	Character string either "FORMAT", "FORMAT23" or "UNFORM". For FORM = "FORMAT" the output file is in ASCII with 5E16.9 format. FORM = "FORMAT23" the output file is in ASCII with 3D23.16 format. FORM = "UNFORM" the output file is unformatted. (Character, Default = "FORMAT")

Remarks:

1. **OUTPUT4** is not referred to by other bulk data cards. The existence of **OUTPUT4** in the bulk data input "triggers" the program to export the matrix. Multiple **OUTPUT4** input cards can co-exist.

2. All matrices listed in the following matrices can be exported:

Matrix Name	**Description**	**Size (row×column)**	**Type**
AJJS000*i*	Symmetric/asymmetric aerodynamic influence coefficient (AIC) matrix relates normal wash, {*W*} on each panels to the derivative of the pressure coefficients C_p, with respect to a unit normal wash vector of {*W*} by the following equation: $\{Cp\} = [AJJS000i]^T \left[[FJKS000i]^T - [DJKS000i]^T \right] \{W\}$ Note that *i* is the index of the **AEROGEN** bulk data card. For instance, if there are three **AEROGEN** bulk data cards shown below: AEROGEN 101 ……. AEROGEN 201 ……. AEROGEN 301 ……. the matrix name of the third **AEROGEN** (ID=301) is AJJS0003. {*W*}can be a rigid body mode. For instance, {*W*}=pitch rigid mode with a unit aplitude α. Then, {*Cp*}= $\{\partial Cp / \partial \alpha\}$. Or, {*W*}can be a control surface kinematic mode with a unit aplitude δ. Then, {*Cp*}=$\{\partial Cp / \partial \delta\}$ Or, {*W*}can be a structural mode shape vector associated with a generalized coordinate ξ. Then, {*Cp*}=$\{\partial Cp / \partial \xi\}$	Jset × Jset where Jset is the number of panels	Real
AJJA000*i*	Same as AJJS000i but for anti-symmetric AIC matrix, existed only for a half-span aerodynamic model.	Jset × Jset	Real
FJKS000*i* and DJKS000*i*	AJJS000i, FJKS000i, and DJKS000i jointly compute the pressure derivatives that lead to (1) aerodynamic stability derivatives due to rigid body mode such as C_{L_α}, C_{m_α}, C_{y_β}, C_{l_β}, C_{n_β}, (2) aerodynamic stability derivatives due to control surface inematic mode such as C_{L_δ}, C_{m_δ}, C_{y_δ}, C_{l_δ}, C_{n_δ}, (3) Generalized aerodynamic force matrix: [QHH] = $[SPHIK]^T$\{EFCS000i\}	Kset × Jset where Kset = 6 × Jset	Real
FJKA000*i* and DJKA000*i*	Same as FJKS000*i* and DJKS000*i* but for the anti-symmetric $\{W\}$. For instance {*W*} is a rigid body yaw mode of a half-span aerodynamic model.	Kset × Jset	Real

UGTKG	Spline matrix relates 6 d.o.f. structural displacement at structural grid to aerodynamic boxes, i.e. $\{x_a\} = [UGTKG]^T \{x_s\}$ where x_a is the 6 d.o.f., displacements at aerodynamic boxes, x_s is the 6 d.o.f. displacements at structural grid Note that the size of x_s is Gset=6×(number of structural grud points) On each aerodynamic box, x_a has 6 d.o.f., namely h_x, h_y, h_z, h_z, h_y' and h_z', where h_x, h_y and h_z are the displacement along x, y and z directions of the aerodynamic coordinate. h_z, h_z' and h_z' are the slope of h_x, h_y, and h_z, respectively with respect to the x-axis. i.e. $h_x' = \frac{\partial h_x}{\partial x}$, $h_y' = \frac{\partial h_y}{\partial x}$, $h_z' = \frac{\partial h_z}{\partial x}$. Note that UGTKG could be a highly sparse matrix.	Gset × Kset where Gset = 6 × numbers of structural grid points	Real
SPHI	Symmetric mode shape matrix at structural d,o,f imported by the **‘ASSIGN FEM=’** Executive Control Command.	Gset × Hset where Hset = number of modes	Real
APHI	Same as SPHI but for anti-symmetric modes.	Gset × Hset	Real
EFCS000*i*	Matrices relates the symmetric/asymmetric modes to the aerodynamic force derivatives on panels. $[EFCS000i] = [SKJR]^T [AJJS000i]^T$ $\left[[FJKS000i]^T - [DJKS000i]^T\right][SPHIK]$	Kset × Hset	Real
EFCA000i	Same as EFCS000i but for the anti-symmetric modes	Kset × Hset	Real
SMHH	Generalized symmetric/asymmetric mass matrix imported by the **‘ASSIGN FEM=’** Executive Control Command.	Hset × Hset	Real
AMMH	Same as SMHH but for the anti-symmetric structures	Hset × Hset	Real
SKHH	Generalized symmetric/asymmetric stiffness matrix imported by the **‘ASSIGN FEM=’** Executive Control Command.	Hset × Hset	Real
AKHH	Same as SKHH but for the anti-symmetric structures.	Hset × Hset	Real

SPHIK	Symmetric/asymmetric modal matrix on panel model computed by $\left[SPHIK\right]=\left[UGTKG\right]^{T}\left[SPHI\right]$	Kset × Hset	Real
APHIK	Same as SPHIK but for the anti-symmetric modes	Kset × Hset	Real
SMGH	Symmetric/asymmetric modal mass matrix $\left[SMGH\right]=\left[M_{GG}\right]\left[SPHI\right]$ Where M_{GG} is the G-set mass matrix	Gset × Hset	Real
AMGH	Same as SMGH but for the anti-symmetric mode.	Gset × Hset	Real
SCNTLK	Symmetric/asymmetric control surface kinematic modes at aerodynamic panels.	Kset × NCS where NCS is the number of **AESURFZ** bulk data cards with entry TYPE = “SYM”	Real
ACNTLK	Anti-symmetric control surface kinematic modes at aerodynamic panels.	Kset × NCA where NCA is the number of **AESURFZ** bulk data cards with entry TYPE = “ANTISYM”	Real
SCNTLG	Same as ACNTLK but at structural grid.	Gset × NCS	Real
ACNTLG	Same as ACNTLK but at structural grid.	Gset × NCA	Real
SKJR	Integration matrix converts C_p to forces, $\{F\}$, on aerodynamic panels $\left\{F\right\}=\left[SKJR\right]^{T}\left\{C_p\right\}$.	Jset × Kset	Real

3. The OUTPUT4 format is always in non-sparse format.

PAFOIL7 — Airfoil Section Property

Description: Defines the airfoil cross sections at the root and tip of a wing-like aerodynamic component; referenced by the **CAERO7** and **THKWING** bulk data cards.

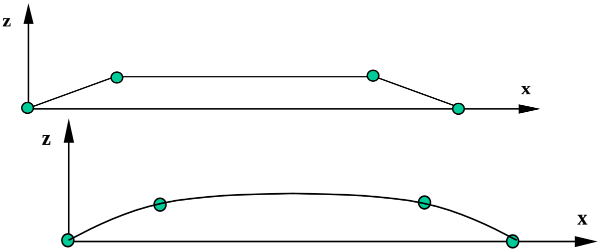
Format and Example:

1	2	3	4	5	6	7	8	9	10
PAFOIL7	ID	ITAX	ITHR	ICAMR	RADR	ITHT	ICAMT	RADT	
PAFOIL7	1	-201	202	203	0.1	211	212	0.1	

Field	Contents
ID	**PAFOIL7** identification number. (Integer > 0)
ITAX	Identification number of an **AEFACT** bulk data card used to specify the x- coordinate locations, in percentage of the chord length, where the thickness and camber are specified. ITAX can be a negative number (where ABS (ITAX) = **AEFACT** bulk data card identification number) to request linear interpolation. (Integer) (See Remark 1)
ITHR	Identification number of an **AEFACT** bulk data card used to specify the half thickness of the airfoil at the wing root. (Integer ≥ 0)
ICAMR	Identification number of an **AEFACT** bulk data card used to specify the camber of the airfoil at the wing root. Note that the positive values are along the normal vector of the CAERO7 macroelement. See remark 7 of the **CAERO7** bulk data card. (Integer ≥ 0)
RADR	Leading edge radius at the root normalized by the root chord (Real ≥ 0.0)
ITHT	Identification number of an **AEFACT** bulk data card used to specify the thickness at the wing tip. (Integer ≥ 0)
ICAMT	Identification number of an **AEFACT** bulk data card used to specify the camber at the wing tip. (Integer ≥ 0)
RADT	Leading edge radius at the tip by the tip chord. (Real ≥ 0.0)

Remarks:

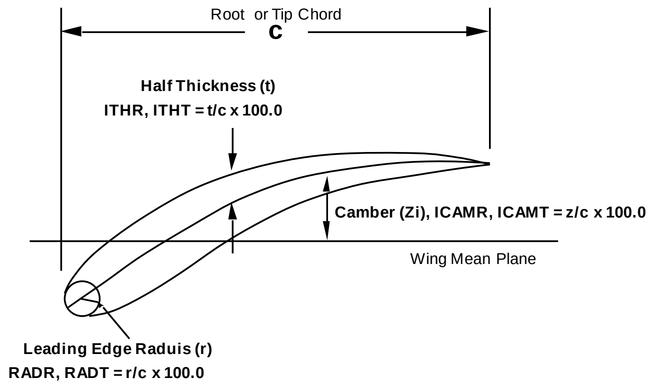
1. The ITAX x-coordinate values listed in the **AEFACT** bulk data card must start with 0.0 and end with 100.0. If ITAX is a positive integer, then a cubic interpolation is used between the airfoil points established by the ITAX, ITHR, ICAMR, RADR, ICAMT, and RADT entries. However, ITAX can be a negative number, which implies that a linear interpolation is used between the airfoil points. For example, if the desired airfoil shape at the wing root is shown in (a) below, and a positive value for ITAX were used, the resulting airfoil shape would be that shown in (b) which is incorrect. In this case a negative value for ITAX is required to generate the airfoil shape shown in (a).



(a) (b)

Note: The number of x-coordinate values must be at least 3.

2. The values listed in the **AEFACT** bulk data cards with identification numbers of ITH(R)/(T), ICAM(R)/(T) and RAD(R)/(T) are in percentage of the root/tip chord lengths (c), respectively . For instance, in the following figure, the ITHR represents the half thickness distribution computed by (t/c)* 100, where t is the half thickness and c is the chord at the root. The ITHT represents similar values at the tip chord. ICAM(R)/(T) and RAD(R)/(T) similarly denote camber and leading edge radius, computed by their respective equations shown in the figure below.



Note: The positive camber is in the same direction of the normal vector of the CAERO7 macroelement. See Remark 6 of the **CAERO7** bulk data card for the definition of the normal vector.

3. The number of values listed in the AEFACT cards for ITAX, ITHR, ICAMR, ITHT, and ICAMT must be the same.

4. The camber and thickness distributions are computed by linear interpolation from the wing root to the wing tip.

PAFOIL8 **Airfoil Section Property**

Description: Defines an NACA series type of airfoil section at the root and tip of a wing-like aerodynamic component referenced by the **CAERO7** bulk data card. Note that the **PAFOIL8** bulk data card is an alternative form of the **PAFOIL7** bulk data card except for defining an NACA series type of airfoil section.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PAFOIL8	ID	RADR	IROOT	RADT	ITIP	PRINT	INTERP	REVERSE	
PAFOIL8	100	1.0	101	1.5	102	1	LINEAR	YES	

Field	Contents
ID	Identification number that is referred to by a **CAERO7** bulk data card. (Integer > 0) (See Remark 1)
RADR	Leading edge radius at the root normalized by the root chord in percentage of the chord length. (Real ≥ 0.0)
IROOT	Identification number of an **FOILSEC** bulk data card to define the airfoil section at root chord. (Integer > 0)
RADT	Same as RADR except for the tip chord. (Real ≥ 0.0)
ITIP	Same as IROOT except for the tip chord. (Integer > 0)
PRINT	Flag for printing out the airfoil shape on the standard output file. PRINT=1 for printing. (Integer)
INTERP	Character string either “LINEAR” or “CUBIC”. For INTERP = “LINEAR,” use linear interpolation to interpolate the airfoil thickness distribution to the CAERO7 macroelement. Otherwise, cubic spline is used. (Character, Default = “CUBIC)
REVERSE	Character string either “Yes” or “No”. For REVERSE = “YES”, the resulting airfoil shape of the upper and lower surface is reversed. (Character, Default = “NO”) (See Remark 2)

Remarks:

1. The **PAFOIL8** bulk data card is an alternative form of the **PAFOIL7** bulk data card. If the ZONA7U or ZTRAN unsteady aerodynamic method is activated (see the METHOD entry in the **MKAEROZ** bulk data card), one of the **PAFOIL7** and **PAFOIL8** bulk data card must be referred to by the **CAERO7** bulk data card.
2. If the CAERO7 macroelement is located on the left hand side and is modeled from the wing root to wing tip, the airfoil shape must be upside down to follow the normal vector convention of the **CAERO7** bulk data card (See Remark 5 of the **CAERO7** bulk data card). In this case, REVERSE = “YES” must be used.

PANADD Adding PANLST2/PANLST3 Bulk Data Cards

Description: Internally generates a **PANLST2** bulk data card by adding other **PANLST2**/**PANLST3** bulk data card together.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PANADD	SETID	PANLST1	PANLST2	PANLST3	PANLST4	PANLST5	PANLST6	PANLST7	CONT
CONT	PANLST8	-etc-							

PANADD	100	200	THRU	204					

Field	Contents
SETID	Unique set identification number of the internally created **PANLST2** bulk data card (Integer > 0)
$PANLST_i$	Identification number of the **PANLST2**/**PANLST3** bulk data cards in which the listed panel identification number are all added together and listed in the internally generated **PANLST2** bulk data card.

PANLST1 — Set of Aerodynamic Panels

Description: Defines a set of aerodynamic thin-wing panels that are generated by the **CAERO7** bulk data card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PANLST1	SETID	MACROID	PANEL1	PANEL2					
PANLST1	100	111	111	118					

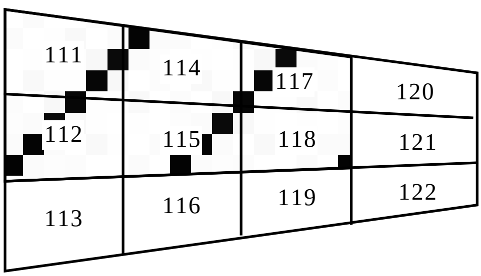
Field	Contents
SETID	Unique set identification number. (Integer > 0) (See Remark 1)
MACROID	Identification number of a **CAERO7** bulk data card to which the aerodynamic panels listed in the set belongs. (Integer ≥ 0) (See Remark 2)
PANEL1	Identification number of the first aerodynamic thin-wing panel. (Integer > 0)
PANEL2	Identification number of the last aerodynamic thin-wing panel. (Integer > PANEL1) (See Remark 3)

Remarks:

1. **PANLST1** is referred to by **SPLINEi**, **ATTACH**, **LOADMOD**, **JETFRC**, and/or **AESURFZ** bulk data card.

2. MACROID is used to define a spline plane for the infinite plate spline method (**SPLINE1** bulk data card).

3. The following sketch shows the panels identified via PANEL1 and PANEL2 entries, if PANEL1 = 111, PANEL2 = 118 and MACROID = 111.



PANLST2 Set of Aerodynamic Panels

Description: Defines a set of aerodynamic panels.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PANLST2	SETID	MACROID	PANEL1	PANEL2	PANEL3	PANEL4	PANEL5	PANEL6	CONT
CONT	PANEL7	-etc-							

PANLST2	100	101	101	THRU	200				

Field	Contents
SETID	Set identification number. (Integer > 0) (See Remark 1)
MACROID	Identification number of a **CAERO7**, **BODY7** or **MATBODY** bulk data card to which the aerodynamic panels listed in the set belong. (Integer > 0)
PANELi	Identification number of aerodynamic panels. (Integer > 0) (See Remark 2)

Remarks:

1. **PANLST2** is referred to by **SPLINEi**, **ATTACH**, **LOADMOD**, **JETFRC**, and/or **AESURFZ** bulk data card.

2. Field number 5 can be a character string “THRU”. This implies that all aerodynamic panels with identification numbers starting with PANEL1 and ending with PANEL3 are included in the list.

3. If **PANLST2** is not referred to by the **SPLINE1** bulk data card, multiple **PANLST2** bulk data cards with the same SETID are allowed. In this case, all aerodynamic panels listed in all **PANLST2** with the same SETID are included in the set. For instance, the following two **PANLST2** bulk data cards with the same SETID = 10:

PANLST2	10	101	1	THRU	3				

PANLST2	10	101	104	25					

yield 5 aerodynamic panels with identification numbers of 1, 2, 3, 25, and 104, respectively.

PANLST3 — Set of Aerodynamic Panels

Description: Defines a set of aerodynamic panels by the **LABEL** entry in **CAERO7**, **BODY7**, or the **MATBODY** bulk data cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PANLST3	SETID	LABEL1	LABEL2	LABEL3	…	-etc-	…		

PANLST3	100	WING	HTAIL						

Field	Contents
SETID	Unique set identification number. (Integer > 0) (See Remark 1)
LABELi	Character string that matches the entry **LABEL** in the **CAERO7, BODY7,** or **MATBODY** bulk data cards. (Character) (See Remark 2)

Remarks

1. **PANLST3** is referred to by **SPLINEi**, **ATTACH**, **LOADMOD**, **JETFRC**, and/or **AESURFZ** bulk data card.

2. All aerodynamic panels of the **CAERO7** or **BODY7** macroelement (with **LABEL** defined in the **CAERO7** or **BODY7** bulk data card) as well as all CQUAD4/CTRIA3 panels referred to by the **MATBODY** bulk data card are included in the set.

   Note : If **PANLST3** is referred to by the **SPLINE1** bulk data card, only one LABEL entry is allowed.

PANRMV

Removes the Panel Identification numbers listed in the PANLST2/PANLST3 Bulk Data Card

Description: Internally generates a **PANLST2** bulk data card by removing the panel identification numbers listed in a **PANLST2**/**PANLST3** bulk data card from those listed in other **PANLST2**/**PANLST3** bulk data cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PANRMV	SETID	IDPAN	PANLST1	PANLST2	PANLST3	PANLST4	PANLST5	PANLST6	CONT
CONT	PANLST7	-etc-							

PANRMV	100	200	300	400					

Field	Contents
SETID	Unique set identification numbers of the internally created **PANLST2** bulk data card (Integer > 0)
IDPAN	Identification number of a **PANLST2**/**PANLST3** bulk data card in which some listed panel identification numbers are removed.
$PANLST_i$	Identification number of the **PANLST2**/**PANLST3** bulk data card in which the listed panel identification numbers are used to remove the same panel identification numbers listed in the **PANLST2**/**PANLST3** bulk data card with identification number IDPAN.

PARAM

Values of Parameters

Description: Alters values for parameters used in the computation.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PARAM	NAME	VALUE							

PARAM	GRDPAN	3							

Field	Contents
NAME	Parameter name. (Character)
VALUE	Parameter valued based on the parameter type. (Integer, Real or Character)

Remarks:

The list of all parameters is shown in the following table:

NAME	PARAMETER TYPE	DEFAULT	DESCRIPTION
BYPASS	Integer	0	If VALUE matches with the identification number of the **MACH** bulk data card, the computation/retrieving of the AIC matrix is bypassed and the pressure coefficients on all panels are set to be zero. It is expected that this zero pressure must be replaced by **INPDMI**/**INPCFD**/**INPCD1**/**CPSPLN**/**CPSPLNL** bulk data card. In addition, the program terminates after the lift and the moment of this subcase are computed, and the rest of the subcases are not processed. This feature allows the user to rapidly verify the mapping of imported pressure distribution on the panel model. After verified, this **PARAM** bulk data card must be removed.
CHECKNM	Character	YES	If any CQUAD4/CTRIA3 panel whose normal vector is toward inside of the configuration, a fatal error occurs. This condition can be turned off by specifying VALUE = “NO”.
ELEMEPS	Real	1.0×10^{-5}	If the distance of two corner grid points of a CQUAD4 panel is within ELEMEPS, fatal error occurs.
GRDPAN	Integer	4	Number of CQUAD4/ CTRIA3/ CBAR/ CROD/ CSHEAR that are connected by a surface grid. If this number of a surface grid is less than GRDPAN, fatal error occurs. See description of the **GRID** bulk data card.

LESUC	Integer	0	Specifying VALUE>0 acitvatives the Polhamus leading suction analogy to compue the lift due to vortex roll-up.
MAXANG	Real	45.0	A maximum turning angle in degrees that is used in the search procedure to find the surface grid points. This search procedure is used by the **CAERO7**, **THKWING**, **SLICE**, **AUTOROD**, and **AUTOBAR** bulk data cards.
STREAM	Real	1.0×10^{-4}	Tolerance used for streamline computation.

TINY	Real	1.0×10^{-5}	If the value of y location of a grid point is less than TINY, the y value will be considered zero. This is to ensure that all grid points of a symmetric model have y = 0.0 on the x – z plane.
WINGEPS	Real	1.0×10^{-5}	A small tolerance for the CAERO7 panels. If the normal distance between a CAERO7 panel and a control point on the CAERO7 panel is less than WINGEPS, this distance is reset to be zero.
NODIV	Character	NO	In the static aeroelastic /trim analysis, the program computes the lowest divergence dynamic pressure. If this divergence dynamic pressure is smaller than the input dynamic pressure in the **TRIM** or **FLEXLD** bulk data card, a fatal error occurs. This fatal error can be replaced by a warning message by specifying VALUE=”YES”.

PCHFILE

Imports a NASTRAN Punch File

Description: Imports a NASTRAN Punch output file that contains the modal values of element forces, stresses, strains, etc.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PCHFILE	IDPCH	FILENM							CONT
CONT	ELLST1	FIELD1	LABEL1	REMARK1	ELLST2	FIELD2	LABEL2	REMARK2	CONT
CONT	...	-etc-	...						

PCHFILE	10	NAST.PCH							+PCH
+PCH	1000	2	ELFRC	BEAM	1001	3	ELFRC	QUAD4	+PCH
+PCH	2001	1	ELSTRN	TRIA3					

Field	Contents
IDPCH	Unique identification number. (Integer > 0) (See Remark 1)
FILENM	Character string specifying the name of the file that is generated by NASTRAN in the punch format. If the first character of FILENM starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character) (See Remark 2)
ELLST$_i$	Identification number of a structural element whose modal values (forces, stresses, strains, … etc) are to be read from the punch file. (Integer > 0)
FIELD$_i$	The FIELD'th component of the modal values of the element is to be read from the punch file. (Integer > 0) (See Remark 3)
LABEL$_i$	Character string to define a label for describing these modal values. For output, this label consists of the first six characters of LABEL$_i$ and the last two characters are replaced by the integer defined by FIELD$_i$. For instance for LABEL$_i$ = "ELFORCE" and FIELD$_i$ = 2, the output label becomes "ELFORC02".
REMARK$_i$	Not used.

Remarks:

1. The **PCHFILE** bulk data card imports the modal values of a structural parameter that can be element forces, stresses, strains, etc., from the NASTRAN punch file. These modal values are used to

compute the resulting structural parameter by the superposition of modal values and the generalized modal coordinates.

2 To generate a NASTRAN punch file, the user must specify a **NASTRAN** Case Control Command such as

FORCE (PUNCH) = ALL
or
STRESS (PUNCH) = n

in the NASTRAN Case Control Section for a modal an analysis where n is the identification number of the SET **NASTRAN** Case Control Command to list a set of element identification numbers for output. Note that the "= ALL" option is not recommended because it produces a large amount of data which could significantly increase the ZONAIR computational time.

3. A typical NASTRAN punch file is shown as follows:

```
$TITLE   = AC02 MODAL ANALYSIS                                                 1
$SUBTITLE= LANCZOS                                                             2
$LABEL   =                                                                     3
$ELEMENT FORCES                                                                4
$REAL OUTPUT                                                                   5
$SUBCASE ID =           1                                                      6
$ELEMENT TYPE =          34                                                    7
$EIGENVALUE = -0.2910688E-03  MODE =     1                                     8
     21000             1.268963E-06     -1.242571E-04      1.035389E-05        9
-CONT-                -1.243219E-02     -4.542464E-09      6.153965E-06       10
-CONT-                -1.456141E-04     -2.811976E-08                         11
     21020             1.036433E-05     -1.251435E-02      3.007680E-05       12
-CONT-                -2.564698E-02     -9.856237E-09      6.566319E-06       13
-CONT-                -2.457500E-04      5.680340E-08                         14

     ............................................................
     ............................................................

     27535            -2.303272E-04      5.782545E-04      1.750886E-07      258
-CONT-                 7.776543E-08     -4.610047E-07      1.156353E-06      259
-CONT-                -3.834066E-08      1.687854E-04                        260
$TITLE   = AC02 MODAL ANALYSIS                                               292
$SUBTITLE= LANCZOS                                                           293
$LABEL   =                                                                   294
$ELEMENT FORCES                                                              295
$REAL OUTPUT                                                                 296
$SUBCASE ID =           1                                                    297
$ELEMENT TYPE =          34                                                  298
$EIGENVALUE = -0.2734564E-03  MODE =     2                                   299
     21000            -2.032439E-07     -2.753735E-05     -1.646139E-06      300
-CONT-                 2.614506E-01      7.214478E-10     -1.307391E-04      301
-CONT-                 1.409557E-05     -3.745799E-08                        302
     21020            -1.775028E-06      2.614317E-01     -4.958345E-06      303
-CONT-                 7.044209E-01      1.591658E-09     -2.214946E-04      304
-CONT-                 2.378039E-05     -1.662002E-07                        305
     ............................................................
     ............................................................
     27535            -6.439090E-04     -7.998943E-05     -2.486631E-07      549
-CONT-                 1.699664E-08     -1.287321E-06     -1.600129E-07      550
-CONT-                -2.293527E-07      4.723957E-04                        551
```

In the example shown above, each element has 8 components of modal values. The entry FIELD$_i$ is used to select a particular component for output.

PLTAERO

ASCII Text File Generation for Plotting the Aerodynamic Model

Description: Defines name of a data file on which the data for plotting the aerodynamic model is stored.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PLTAERO	SETID	THKWING	FEMGRID	OFFSET	FORM	FILENM		WAKE	

PLTAERO	100	YES	YES	100000	TECPLOT	AERO.PLT		NO	

Field	Contents
SETID	Identification number. (Integer > 0) (See Remark 1)
THKWING	Character string either “YES” or “NO”. For THKWING = “YES”, the thickness of the aerodynamic panels generated by the **CAERO7** bulk data card is included (both upper and lower surfaces are presented in the ASCII text file). Otherwise, only the mean plane of the **CAERO7** bulk data card is included. (Character, Default = “NO”)
FEMGRID	Character string either “YES” or “NO” for inclusion of structural grid points in the plot file. Active only for aeroelastic analysis. (Character) (See Remark 2)
OFFSET	Active only if FEMGRID = “YES”. The identification numbers of all structural grid points are increased by OFFSET. (Integer ≥ 0, or Blank) (See Remark 3)
FORM	FORM = “TECPLOT” for generating a TECPLOT™ file FORM = “PATRAN” for generating a PATRAN™ neutral file. In the neutral file, the external identification numbers of all panels are replaced by their internal identification numbers. FORM = “PATRAN1” for generating a PATRAN™ neutral file. In the neutral file, the identification numbers of all panels are their external identification numbers. If the entry THKWING="YES" is specified, the lower surface panels of CAERO7 macroelements have the same identification numbers as those of their corresponding upper surface panels except with a negative sign. FORM = IDEAS for generating an I-DEAS™ universal file. FORM = “FEMAP” for generating a FEMAP™ neutral file. FORM = “ANSYS” for generating an ANSYS supported neutral file. FORM = “NASTRAN” for generating a NASTRAN bulk data deck. Note that the p

	FORM = “CATIA” for generating STL file. (Character, default = “TECPLOT”) (See Remark 4) Note that for FORM=”NASTRAN”, the panels IDs start from 1 and incrementally increase by 1. If the user requires the panel IDs to be the same as the input IDs, please specify the entry THKWING=”YESD”. For this case, the signs of panel IDs on the lower surace of the CAERO7 are opposite from those on the upper surface.
FILENM	The name of the data file in which the data for plotting the aerodynamic model is stored. This file name is always in the upper case. In case the input file name is given in the lower case, the program converts it to the upper case. (Character)
WAKE	Character string either “YES” or “NO”. For WAKE=“YES”, the CSHEAR panels generated by the WAKENET or VORNET bulk data card (if any) are included in the data file (Character, Default=“YES”)

Remarks:

1. SETID is not referred to by other bulk data cards. The existence of **PLTAERO** in the bulk data input “triggers” the generation of a data file for the purpose of plotting the aerodynamic model. SETID is used for error message output only.

2. Users may want to graphically display the aerodynamic and structural models together. Setting FEMGRID = “YES” writes the structural grid points in the aerodynamic coordinates along with the aerodynamic model data in the output data file. This option is useful to assist in setting up the spline input.

3. Since the structural model and the aerodynamic model may contain grids that have the same identification numbers, inclusion of the structural grids in the aerodynamic grids creates problems for plotting. OFFSET is used to circumvent this problem by offsetting all structural grid point identification numbers with the integer of OFFSET. One exception to this is for the FEMAP output file, which stores the FEM grids in POINT, format allowing for duplicate structure and aerodynamic grids.

4. TECPLOT™, FEMAP™ and I-DEAS™ are commercially available graphical software programs. I-DEAS™ universal file output are data sets 781 and 780 for aerodynamic grids and aerodynamic panels, respectively. PATRAN™is the pre- and post-processor of NASTRAN. FEMAP™ neutral file output are Data Blocks 403 and 404 for aerodynamic grids and aerodynamic panels, respectively. Structural grid points are displayed as points through Data Block 570. The ANSYS output is a FEMAP neutral file that can be read in by an ANSYS neutral file translator developed by PADT Inc. (also see Section 7.1 – **PLTAERO**).

PLTCP

ASCII Text File Generation For Plotting the Aerodynamic Results

Description: Defines the name of a data file in which the data for plotting the aerodynamic results are stored.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PLTCP	IDPLT	IDAERO	TYPE	FORM	FILENM		AEROGM		
PLTCP	10	10	NO	PATRAN	PLOTCP.DAT		AERONM.PAT		

Field	Contents
IDPLT	Identification number. (Integer > 0) (See Remark 1)
IDAERO	Identification number of an **AEROGEN** bulk data card. (Integer > 0) (See Remark 2)
TYPE	Character string either "YES" or "NO" For TYPE = "YES" the control surface deflection angles are included in the plot file (Character,Default="NO")).
FORM	FORM = "TECPLOT" for generating the TECPLOT™ file. For TYPE="NO", the aerodynamic results (pressure cofficients and local Mach numbers) are presented at the grid points. For TYPE="YES", the aerodynamic results are presented on panels. FORM = "PATRAN" for generating a PATRAN™ neutral/results file. In the neutral/result file, the external identification numbers of all panels are replaced by their internal identification numbers. FORM = "PATRAN1" for generating a PATRAN™ neutral file. In the neutral file, the identification numbers of all panels are their external identification numbers. The lower surface panels of CAERO7 macroelements have the same identification numbers as those of their corresponding upper surface panels except with a negative sign. FORM = "IDEAS" for generating the I-DEAS™ universal file. FORM = "FEMAP" for generating a FEMAP™ neutral file. FORM = "ANSYS" for generating an ANSYS supported neutral file. FORM = "NASTRAN" for generating a NASTRAN bulk data deck with PLOAD4 cards to define the pressure loads. (see remark 3) FORM = "ESA" for generating a PEGASUS readable file. FORM = "OUTPUT4" for outputting the pressure coefficients on all panels in the OUTPUT4 format. (Character, Default = "TECPLOT") (See Remark 4)

FILENM	The name of a data file in which the data for plotting the aerodynamic pressures is stored. This file name is always in the upper case. In case the input file name is given in the lower case, the program converts it to the upper case. If the first character starts with a dollar sign “$”, the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (character)
AERONM	The name of a data file in which the aerodynamic model is stored in a PATRAN neutral file. ONLY USED IF FORM = “PATRAN” or "PATRAN1". (Character, Default = “AEROGEOM.PAT”) (See Remark 5)

Remarks:

1. IDPLT is not referred to by other bulk data cards. The existence of each **PLTCP** in the bulk data input “triggers” the generation of a data file for the purpose of plotting the aerodynamic results. IDPLT is used for error message output only.

2. The aerodynamic results generated by the **AEROGEN** include pressure coefficients and local Mach numbers. If the **INPCFD**, **INPCFD1, CPSPLN**, or, **CPSPLNL** bulk data card is specified, the pressure distribution on the panel model computed by the **AEROGEN** bulk data card is replaced by CFD/wind tunnel result for visualization.

3. For FORM=”NASTRAN”, the panels IDs start from 1 and incrementally increase by 1. If the user requires the panel IDs to be the same as the input IDs, please specify FORM=”NASTL”. For this case, the signs of panel IDs on the lower surace of the CAERO7 are opposite from those on the upper surface.

4. The format of the data file is defined by the entry FORM. The data of the aerodynamic model together with the aerodynamic results are stored in the data file FILENM. Using the TECPLOT™ or PATRAN™ software (depends on FORM = “TECPLOT” or FORM = “PATRAN"/"PATRAN1"), these aerodynamic results of each aerodynamic panel can be displayed on the aerodynamic model.

5. PATRAN requires that the aerodynamic model be stored in a neutral file and that analysis results be stored in a results file. Therefore, the AERONM entry is used to assign a name for a neutral file that contains the aerodynamic model, while the FILENM entry specifies a file that will contain the aerodynamic results. Compatible Output.

PLTDCP

ASCII Text File Generation For Plotting the Derivatives of Pressure Coefficients

Description: Defines the name of a data file in which the data for plotting the derivatives of pressure coefficients

Format and Example:

1	2	3	4	5	6	7	8	9	10
PLTCP	IDPLT	IDAERO	TYPE	FORM	FILENM		AEROGM		
PLTCP	10	10	ALPHA	PATRAN	PLOTCP.DAT		AERONM.PAT		

Field	Contents
IDPLT	Identification number. (Integer > 0) (See Remark 1)
IDAERO	Identification number of an **AEROGEN** bulk data card. To activate the **PLTDCP** bulk data card, the entry STABDRV in the **AEROGEN** bulk data card must be "YES" (Integer > 0).
TYPE	Character string: TYPE = "ALPHA", Pressure derivatives with respect to (w.r.t.) angle of attack, dCp/dα (1/rad). TYPE="BETA", Pressure derivatives w.r.t. side slip angle dCp/dβ (1/rad). TYPE="PRATE", Pressure derivatives w.r.t. non-dimensional roll rate, dCp/d(pb/2V). TYPE="QRATE", Pressure derivatives w.r.t. non-dimensional pitch rate, dCp/d(qc/2V). TYPE="RRATE", Pressure derivatives w.r.t. non-dimensional yaw rate, dCp/d((rb/2V). TYPE=the entry LABEL of the **AESURFZ** or **AESLINK**, Pressure derivatives w.r.t. control surface deflection angle, dCp/dδ (1./rad).
FORM	FORM = "TECPLOT" for generating the TECPLOT™ file. For TYPE="NO", the aerodynamic results (pressure cofficients and local Mach numbers) are presented at the grid points. For TYPE="YES", the aerodynamic results are presented on panels. FORM = "PATRAN" for generating a PATRAN™ neutral/results file. In the neutral/result file, the external identification numbers of all panels are replaced by their internal identification numbers.

	FORM = “PATRAN1” for generating a PATRAN™ neutral file. In the neutral file, the identification numbers of all panels are their external identification numbers. The lower surface panels of CAERO7 macroelements have the same identification numbers as those of their corresponding upper surface panels except with a negative sign.
	FORM = “IDEAS” for generating the I-DEAS™ universal file.
	FORM = “FEMAP” for generating a FEMAP™ neutral file.
	FORM = “ANSYS” for generating an ANSYS supported neutral file.
	FORM = “NASTRAN” for generating a NASTRAN bulk data deck with PLOAD4 cards to define the pressure loads. (see remark 3)
	FORM = “ESA” for generating a PEGASUS readable file.
	FORM = “OUTPUT4” for outputting the pressure coefficients on all panels in the OUTPUT4 format.
	(Character, Default = “TECPLOT”)
FILENM	The name of a data file in which the data for plotting the aerodynamic pressures is stored. This file name is always in the upper case. In case the input file name is given in the lower case, the program converts it to the upper case. If the first character starts with a dollar sign “$”, the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (character)
AERONM	The name of a data file in which the aerodynamic model is stored in a PATRAN neutral file. Only used if FORM = “PATRAN” or "PATRAN1".
	(Character, Default = “AEROGEOM.PAT”)

Remarks:

1. IDPLT is not referred to by other bulk data cards. The existence of each **PLTDCP** in the bulk data input “triggers” the generation of a data file for the purpose of plotting the pressure coefficient derivatives if the entry STABDRV=”YES” in the **AEROGEN** bulk data card. IDPLT is used for error message output only.

PLTMODE

ASCII Text File Generation for Plotting the Interpolated Structural Mode on Aerodynamic Model

Description: Defines name of a data file in which the data for plotting the interpolated structural mode on the aerodynamic model are stored. The **PLOTMOD** bulk data card is active only if the **'SOLUTION 1'** Executive Control Command is specified.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PLTMODE	SETID	SYM	MODE	TYPE	MAXDISP	FORM	FILENM		CONT
CONT	AERONM								

PLTMODE	100	SYM	10		0.2	PATRAN	PLOTMODE.DAT		
	AEROMODE.PAT								

Field	Contents
SETID	Identification number. (Integer > 0) (See Remark 1)
SYM	Symmetry condition of the structural modes corresponding to the BOUNDARY entry in the 'ASSIGN FEM=' Executive Control Command. (Character). SYM = "SYM" for symmetric condition SYM = "ANTI" for anti-symmetric condition SYM = "ASYM" for asymmetric condition
MODE	Index of the structural modes. (Integer > 0) (See Remark 2)
TYPE	Not used.
MAXDISP	A fraction of the reference chord defined by the REFC entry in the **AEROZ** bulk data card to define the maximum displacement of the mode. (Real > 0.0, Default = 1.0) (See Remark 3)
FORM	FORM = "TECPLOT" for generating the TECPLOT file. FORM = "PATRAN" for generating the PATRAN neutral/results file. FORM = "IDEAS" for generating an I-DEAS universal file. FORM = "FEMAP" for generating a FEMAP neutral file. FORM = "ANSYS" for generating an ANSYS supported neutral file FORM = "NASTRAN" for generating a NASTRAN bulk data deck. (Character, Default = "TECPLOT"). (See Remark 4)

FILENM	The name of the data file in which the data for plotting the interpolated structural mode is stored. This file name is always in the upper case. In case the input file name is given in the lower case, the program converts it to the upper case. If the first character starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character)
AERONM	The name of a data file in which the aerodynamic model is stored in a PATRAN neutral file. ONLY USED IF FORM="PATRAN". (Character, Default = "AEROGEOM.PAT") (See Remark 5)

Remarks

1. SETID is not referred to by other bulk data cards. The existence of each **PLTMODE** in the bulk data input "triggers" the generation of a data file for the purpose of plotting the interpolated structural mode on the aerodynamic model. SETID is used for error message output only. Note that **PLTMODE** bulk data card is activated only if the Executive Control Command **'SOLUTION 1'** is specified.

2. **PLTMODE** generates a data file that contains one interpolated structural mode with index = MODE. This structural mode is defined in the **'ASSIGN FEM='** executive control statement with BOUNDARY = "SYM". The interpolation of structural modes from the structural grid points to the aerodynamic model is performed by the SPLINE module. Graphical display of the interpolated mode is useful to detect any error in the spline input.

3. Since the structural mode is the eigenvector obtained by the structural analysis, the magnitude of the mode may not be of the same order as the size of the aerodynamic model. To circumvent this problem, it is recommended to define the maximum displacement of the mode by MAXDISP × REFC.

4. The format of the data file is defined by the FORM entry. The interpolated modal data are added to the x, y, and z values of the aerodynamic grids to create a deformed aerodynamic model. Using the TECPLOT or PATRAN software (depends on FORM = "TECPLOT" or = "PATRAN"), the deformed aerodynamic model can be displayed graphically. For I-DEAS universal file output, data sets 781 and 780 are used for displaying the aerodynamic grids and boxes, respectively. A data set 55 is used to output the six degree-of-freedom displacements at all aerodynamic grid. For FEMAP neutral file format, Data Blocks 403 and 404 are used for displaying the aerodynamic grids and boxes, respectively. Data Block 451 is used for displaying the deformed mode shape (TOTAL Translation), X-axis translation (T1), Y-axis translation (T2), and Z-axis translation (T3). The interpolated mode shape can either be statically deformed or animated. The ANSYS output is a FEMAP neutral file that can be read in by an ANSYS neutral file translator developed by PADT Inc. (also see Section 7.3 – **PLTMODE**).

5. PATRAN requires that the aerodynamic model be stored in a neutral file and that analysis results be stored in a results file. Therefore, the AERONM entry is used to assign a name for a neutral file that contains the aerodynamic model, while the FILENM entry specifies a file that will contain the displacement results. For more details, please see Section 7.3, PATRAN Compatible Output.

PLTPANS

ASCII Text File Generation for Plotting Panel List and Structural Grid List

Description: Requests plotting data file generation for the aerodynamic panels/boxes and/or the structural grids of interest.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PLTPANS	SETID	SETK	SETG	FORM	FLNM		PROJ	CP	

PLTPANS	100	100		TECPLOT	PANS.PLT			

Field	Contents
SETID	Identification number (Integer > 0) (See Remark 1)
SETK	Identification number of a **PANLST1**, **PANLST2** or **PANLST3** bulk data card that lists the aerodynamic box identification numbers. (Integer >=0; Default=0) (See Remark 2)
SETG	Identification number of a **SETi** bulk data card that lists the structural grid points. (Integer >= 0; Default=0) (See Remark 2)
FORM	Character, Default="TECPLOT". Only Tecplot format is supported.
FILENM	The name of data file in which the plotting data are stored. The file name is always in the uppercase. In case the input file name is given in the lowercase, the program converts it to uppercase. If the first character of FILENM starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the file name is specified. This feature allows for the file name up to 56 characters. (Character)
PROJ	Integer flag to determine whether the coordinates are projected to the x-y plane defined by CP entry. If 0, no projection. (Integer >=0, Default=0) (See Remark 3)
CP	Identification number of a **CORD2R** bulk data card whose x-y plane defines the projection plane. If CP = 0, the basic coordinate system is assumed. (Integer >=0, Default=0)

Remarks:

1 SETID is not referred to by other bulk data cards. The existence of each **PLTPANS** in the input "triggers" the generation of a data file for the purpose of plotting. SETID is used for error message output only. The data file generations are within the geometry module, therefore "SOL -1" executive control command does not affect **PLTPANS** bulk data processing.

2 The aerodynamic panels/boxes and the structural grids of interests are written out into separate zones. If SETK or SETG is zero, then the corresponding zone for the aerodynamic panels or the structural grids will be skipped.

3 By projection, **PLTPANS** can be used to verify a **CORD2R** bulk data card set up.

PLTSURF

ASCII Text File Generation for Plotting the Aerodynamic Control Surface

Description: Defines name of a data file in which the data for plotting the deflected aerodynamic control surface on the aerodynamic model are stored.

Format and Example:

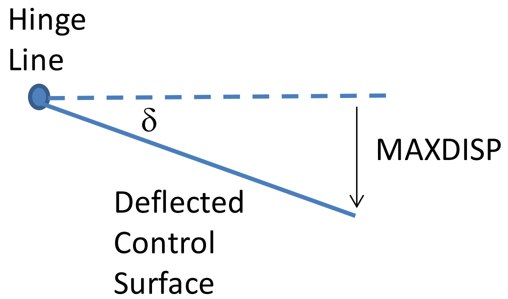
1	2	3	4	5	6	7	8	9	10
PLTSURF	SETID	LABEL	MAXDISP	FORM	FILENM		AERONM		
PLTSURF	100	RUDDER	2.0	PATRAN	PLOT.PLT		AEROMODE.PLT		

Field	Contents
SETID	Identification number. (Integer > 0) (See Remark 1)
LABEL	Character string that matches the LABEL entry of an **AESURFZ** bulk data card. (Character)
MAXDISP	A physical displacement in the model units (i.e., FMLUNIT entry specified on the **AEROZ** card) at the furthest distance of the control surface from the hinge line. Used only for visualization. (Real, Default = 1.0) (See Remark 2)
FORM	FORM = "TECPLOT" for generating the TECPLOT file. FORM = "PATRAN" for generating the PATRAN neutral/results file. FORM = "IDEAS" for generating an I-DEAS universal file. FORM = "FEMAP" for generating a FEMAP neutral file. FORM = "ANSYS" for generating an ANSYS supported neutral file. FORM = "NASTRAN" for generating a NASTRAN bulk data deck. FORM = "NASTL" for generating a NASTRAN bulk data deck with **GRID** entries in large field format (i.e., allows for higher degree of numerical accuracy over the FORM="NASTRAN" option). (Character, Default = "TECPLOT") (See Remark 3)
FILENM	The name of the data file in which the data for plotting the deflected control surface is stored. This file name is always in the upper case. In case the input file name is given in the lower case, the program converts it to the upper case. If the first character of FILENM starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character)
AERONM	The name of a data file in which the aerodynamic model is stored in a PATRAN neutral file. ONLY USED IF FORM = "PATRAN". If the first character of AERONM starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character, Default = "AEROGEOM.PAT") (See Remark 4)

Remarks:

1. SETID is not referred to by other bulk data cards. The existence of each **PLTSURF** in the bulk data input "triggers" the generation of a data file for the purpose of plotting the deflected control surface on the aerodynamic model. SETID is used for error message output only.

2. The control surface deflection angle can be computed from MAXDISP per the following figure.



3. The format of the data file is defined by the FORM entry. The control surface deflection data are added to the *x*, *y*, and *z* values of the aerodynamic grids to create a deformed aerodynamic model. Using the TECPLOT or PATRAN software (depends on FORM = "TECPLOT" or = "PATRAN"), the deformed aerodynamic model can be displayed graphically. For I-DEAS universal file output, data sets 781 and 780 are used for displaying the aerodynamic grids and boxes, respectively. A data set 55 is used to output the six degree-of-freedom displacements at all aerodynamic grid. For FEMAP neutral file format, Data Blocks 403 and 404 are used for displaying the aerodynamic grids and boxes, respectively. Data Block 451 is used for displaying the deformed mode shape (TOTAL Translation), x-axis translation (T1), y-axis translation (T2), and z-axis translation (T3). The interpolated mode shape can either be statically deformed or animated. The ANSYS output is a FEMAP neutral file that can be read in by an ANSYS neutral file translator developed by PADT Inc.

4. PATRAN requires that the aerodynamic model be stored in a neutral file and that analysis results be stored in a results file. Therefore, the AERONM entry is used to assign a name for a neutral file that contains the aerodynamic model, while the FILENM entry specifies a file that will contain the displacement results. For more details, please see Section 7.5, PATRAN Compatible Output.

PLTTRIM

Generation of an ASCII Text File for the Post-Processing of the Static Aeroelastic/Trim Analysis

Description: Defines the name of a data file in which the aerodynamic pressure distribution, deformed aerodynamic model or flight loads generated by the static aeroelastic/trim analysis are stored.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PLTTRIM	IDPLT	IDTRIM	FLEX	TYPE	FORM	FILENM		SCALE	CONT
CONT	AERONM								

PLTTRIM	100	10	FLEX	DEFORM	TECPLOT	PLTTRIM.PLT			

Field	Contents
IDPLT	Identification number. (Integer > 0) (See Remark 1)
IDTRIM	Identification number of a **TRIM** bulk data card. (Integer > 0) (See Remark 2)
FLEX	Character String either "FLEX" or "RIGID" (Character, Default = "FLEX") FLEX = "FLEX" for the results of the flexible aircraft FLEX = "RIGID" for the results of the rigid aircraft
TYPE	Character string (Character) TYPE = "FORCE" Stores the flight loads in terms of NASTRAN **FORCE** and **MOMENT** bulk data cards at the structural finite element grid point on the ASCII file. The user can insert this file into the NASTRAN model for detailed stress analysis by performing a static structural analysis. TYPE = "CP" Stores the distributed aerodynamic pressure distribution of the undeformed aerodynamic model on the file. TYPE = "DEFORM" Stores the deformed aerodynamic model along with pressure distribution on the file. If FLEX = 'RIGID', the deformation is due to the rigid body motion of the trim variables. If FLEX = 'FLEX', the deformation also includes the structural deflection. TYPE = "ELASTIC" Stores the deformed aerodynamic model along with pressures on the file. The deformation includes only the structural deflection (no rigid body motion).

FORM	Character string (Character)	
	FORM = “TECPLOT”	for generating the TECPLOT™ file
	FORM = “PATRAN”	for generating the PATRAN™ neutral/results file
	FORM = “IDEAS”	for generating an I-DEAS™ universal file
	FORM = “FEMAP”	for generating a FEMAP™ neutral file
	FORM = “ANSYS”	for generating an ANSYS supported neutral file
	FORM = “ABAQUS”	for generating an ABAQUS supported file
	FORM = “NASTRAN”	for generating a NASTRAN bulk data deck containing **FORCE** and **MOMENT** bulk data cards
	FORM = "OUTPUT4"	If TYPE="CP", outputs the pressure coefficients in the OUTPUT4 format.
	Note: If TYPE = “FORCE”, only FORM=NASTRAN, FORM=IDEAS, and FORM = ABAQUS are supported. (Default = “TECPLOT”) (See Remark 3)	
FILENM	The name of the file that stores the generated data. This file name is always in the uppercase letters. In case the input file name is given in the lowercase letters, the program will convert it to the uppercase. If the first character starts with a dollar sign “$”, the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character)	
SCALE	Amplification factor of the deformation. (Real $\neq$ 0.0, Default=1.0)	
AERONM	The name of a data file in which the aerodynamic model is stored in a PATRAN neutral file. Only used if FORM=”PATRAN”. If the first character starts with a dollar sign “$”, the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character, Default = “AEROGEOM.DAT”) (See Remark 4)	

Remarks

1. IDPLT is not referred to by other bulk data card. The existence of each **PLTTRIM** in the bulk data input “triggers” the generation of a data file for the post-processing of the static aeroelastic/trim analysis.

2. If no **TRIM** bulk data card with IDTRIM existing in the Bulk Data Section, the ASCII file will not be generated. But this does not result a fatal error.

3. IDEAS output of **FORCE** and **MOMENT** are stored in universal dataset 782 for both Left-Hand-Side (LHS) and Right-Hand-Side (RHS) load sets. The ANSYS output is a FEMAP neutral file that can be read in by an ANSYS neutral file translator developed by PADT Inc. (also see Section 7.4 – **PLTTRIM**).

4. PATRAN requires that the aerodynamic model be stored in a neutral file and that analysis results be stored in a results file. Therefore, the AERONM entry is used to assign a name for a neutral file that contains the aerodynamic model, while the FILENM entry specifies a file that will contain the displacement or steady pressure results (depending on whether TYPE=DEFORM or TYPE=CP).

PSHEAR

Properties of the CSHEAR Panel

Description: Imposes the constant potential condition on the CSHEAR panels and relates the values of the constant potential to that at a surface grid.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PSHEAR	PID	MATWAKE	GRIDA	SIDEA	GRIDB	SIDEB	ATTACH	EPS	

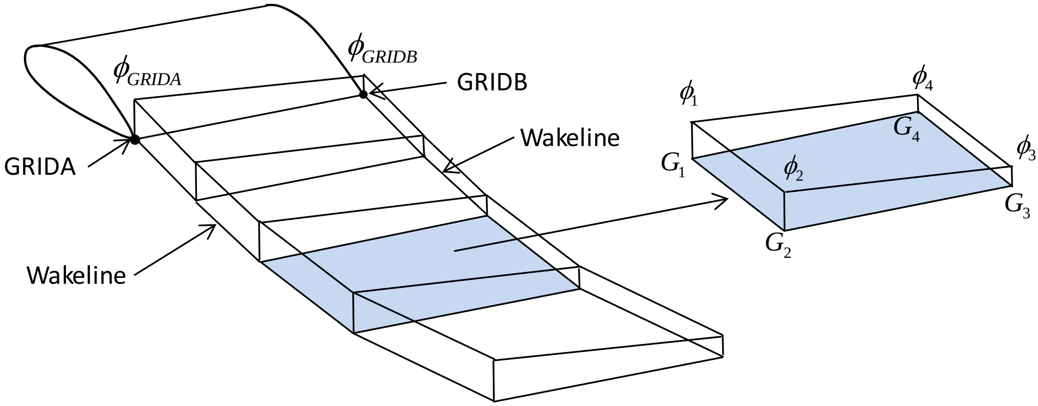
PSHEAR	101	100	40	1	50	3			

Field	Contents
PID	Unique identification number. (Integer > 0) (See Remark 1)
MATWAKE	Identification number of a **MATWAKE** bulk data card. (Integer > 0)
GRIDA	Identification number of a surface grid where the potential of the SIDEA edge of the **CSHEAR** panel is originated. (Integer > 0)
SIDEA	Index of the four side edges of the CSHEAR panel along which the potential is constant and equal to that at the surface grid GRIDA. (Integer = 1,2,3, or 4) (See Remark 2)
GRIDB	Same as GRIDA but for the second index of the SIDEB edge. (Integer > 0)
SIDEB	The second index of the side edge. (Integer = 1,2,3, or 4)
ATTACH	The identification number of a CQUAD4 or CTRIA3 panel where the surface grids GRIDA and GRIDB are located. (Integer > 0, or Blank) (See Remark 3)
EPS	Small tolerance to detect the skewness of the CSHEAR panel (Real > 0.0, Default = 0.001)

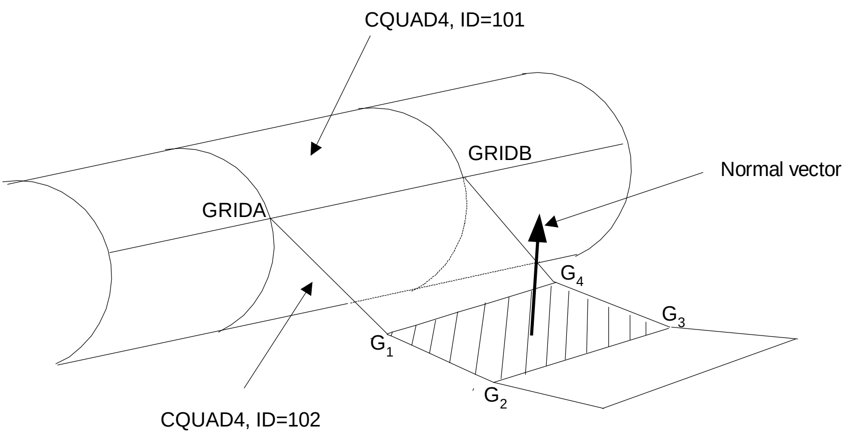
Remarks:

1. The **PSHEAR** bulk data card is referred to by a **CSHEAR** bulk data card.

   The boundary condition of the wake surface is that the potential is constant along each wake line. In the following figure, the symbols ϕ_{GRIDA} and ϕ_{GRIDB} represent the potential at the surface grid points GRIDA and GRIDB, respectively. The entries GRIDA, SIDEA, GRIDB, and SIDEB impose the condition by specifying SIDEA = 1 and SIDEB = 3. So that $\phi_1 = \phi_2 = \phi_{GRIDA}$ and $\phi_3 = \phi_4 = \phi_{GRIDB}$.



2. For a wake surface attached to the trailing edge of a thick wing component, normally there is only one CQUAD4/CTRIA3 panel on which both the surface grids GRIDA and GRIDB are located. In this case, this panel can be automatically identified by the program and the entry ATTACH can be blank. However, if there are two CQUAD4/CTRIA3 panels on which GRIDA and GRIDB are located, the identification number of one of these two panels must be specified by ATTACH. In the following figure, there are two CQUAD4's (ID = 101 and 102) on which GRIDA and GRIDB are located. For a CSHEAR panel with grid sequence G1, G2, G3 and G4, which define the normal vector as shown in the figure. ATTACH = 101 must be selected because CQUAD4 ID = 101 is located above the CSHEAR panel ("above" and "below" are defined by the normal vector of the CSHEAR panel).



PSHELL

Property of the CQUAD4/CTRIA3 Panels

Description: Specifies the property of the CQUAD4/CTRIA3 Panels.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PSHELL	PID	MID1	EPS	INCLINE	FLOWIN	ITYPE	IPFOR	CPFACT	CONT
CONT	XOFF	YOFF	ZOFF						

PANLST2	100	1	0.001	1	100.0	0	0	0.5	+PSH
+PSH	0.0	0.0	-10.0						

Field	Contents
PID	Unique identification number. (Integer > 0) (See Remark 1)
MID1	Identification number of a **MATBODY** bulk data card. (Integer > 0)
EPS	Tolerance to detect the skewness of the panel. (Real, Default = 0.0001)
INCLINE	Flag for Superinclined panel and active only for Mach number > 1. Incline = 0, not Superinclined panel. Incline ≠ 0, Superinclined panel. (Integer ≥ 0) (See Remark 2)
FLOWIN	Amount of flow in percentage of the flow contained in the stream tube in front of (engine inlet) or behind (engine nozzle) the panel, which penetrates into/out to the panel. FLOWIN = 100, implies that 100% of the flow penetrates into/out the panel. (Real, 0.0 ≤ FLOWIN ≤ 100.0)
ITYPE	ITYPE=0 panel boundary condition depends on the flight condition (α, β, ρ, q, and r) ITYPE=1 panel is used to model the wind tunnel walls or ground where α=β=ρ=q=r=0.0. (Integer)
IPFOR	Flag for pressure formula to compute the pressure coefficients (C_p). IPFOR = 0 Exact isentropic C_p formula IPFOR = 1 $C_p = -2(u + (1 - M_\infty^2)u^2 + v^2 + w^2)$ IPFOR = 2 $C_p = -2u$ where u, v, and w are the perturbation velocity components (Integer ≥ 0)
CPFACT	A factor applied to C_p (Real ≥ 0.0 or Blank, Default = 1.0)

XOFF, YOFF, ZOFF	A offset for the centroid of the panel along the x, y, and z direction, respectively. Used only in the separation process of panels into upper and lower groups by the **RBE2** and **SLICE** bulk data card or a CAERO7 attached to a body. (Real, Default = 0.0) (see Remark 3)

Remarks:

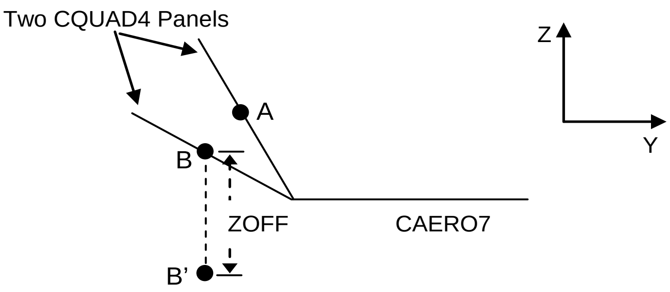
1. **PSHELL** bulk data card is referred to by the **CQUAD4** and **CTRIA3** bulk data cards.

2. If the inclination angle of the panel exceeds the Mach cone angle in supersonic/hypersonic flow (Mach cone angle = $\sin^{-1}(1/M)$ where M = free stream Mach number), the linear theory fails. This kind of panel orientation is classified as "superinclined panel." Special treatment will be performed by the program to circumvent the superinclined panel problem if incline ≠ 0.

3. When a **RBE2/SLICE** bulk data card is used or a CAERO7 macroelement is attached to a body, the program needs to separate those involved CQUAD4/CTRIA3 panels into upper surface and lower surface groups. This separation process may fail and cause a fatal error printed in the output file as follows:

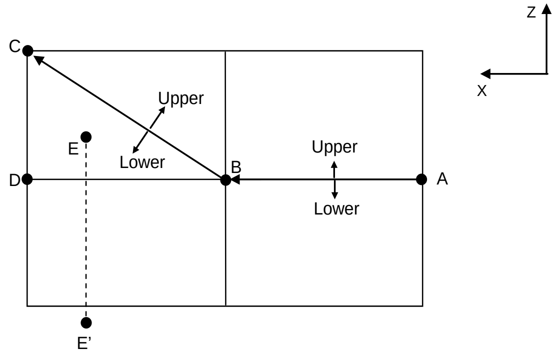
   THE PROGRAM FAILED TO SEPARATE THOSE PANELS SURROUNDING THIS GRID INTO UPPER & LOWER GROUPS

   Shown in the following figure is a CAERO7 attached to two CQUAD4 panels, because the centroid of both panels (points A and B) are located on the upper side of the CAERO7, this separation process will fail because point B should be identified as the lower side panel. Instead of point B, if point B' is used, the separation process may work because A is located on the upper side of the CAERO7 and B' is on the lower side. The point B' is calculated by moving point B with a large negative ZOFF value so that it is located in the lower side of the CAERO7 macroelement.



   Another case where the separation process may fail is a sharp turn occurred in the search vectors involved in the **SLICE/RBE2** bulk data card. In the following figure, this sharp turn occurs at point B between the vectors A → B and B → C. For the CTRIA3 with three corner grid points BCD, its centroid is located on the upper side of vector A → B but becomes the lower side of vector B → C. This is a fatal error because this CTRIA3 should be on both of the lower sides of vectors A → B and B → C. This fatal error can be removed by introducing a large negative ZOFF for this

CTRIA3 so that its centroid is moved from E to E'. Now because E' is located on the lower side of vector A → B and B → C, the separation process can identify this CTRIA3 as the lower side panel.



PZTMODE

Control Force Due to Smart Structural Actuation

Description: Defines a control force generated by the structural deformation due to smart structural actuation for trim analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PZTMODE	LABEL	TYPE	MNAME	ACTID					

1	2	3	4	5	6	7	8	9	10
PZTMODE	PZT1	SYM	INPUT4						

Field	Contents
LABEL	Unique alphanumeric string of up to eight characters used to identify the smart structural modes. (Character) (See Remark 2)
TYPE	Type of boundary condition. (Character) (See Remark 2) SYM symmetric ANTI anti-symmetric ASYM asymmetric
MNAME	Matrix name that is imported by the **'ASSIGN MATRIX='** Executive Control Command or **DMI** bulk data cards. (Character) (See Remark 3)
ACTID	Not used.

Remarks:

1. **PZTMODE** is equivalent to the **AESURFZ** bulk data card, except that **AESURFZ** provides the aerodynamic control forces due to control surface deflection, whereas **PZTMODE** gives the aerodynamic control forces due to the structural deformation. This structural deformation can be induced by a smart structural type of actuator.

2. Among all **PZTMODE**, **AESURFZ, AESLINK**, **JETFRC**, and **GRIDFRC** bulk data cards, no duplicated LABEL is allowed.

3. The matrix imported by the **'ASSIGN MATRIX='** Executive Control Command must have one column and g-set number (6 × number of structural grid points) of rows. The elements of the matrix are the structural deformation in six degrees of freedom at all structural finite element grids.

RBAR **Combines Two Grid Points into One Point**

Description: Combines two grid points into one point by removing one grid point from the aerodynamic model.

Format and Example:

1	2	3	4	5	6	7	8	9	10
RBAR	SETID	IDGRD	DEPGRD1	DEPGRD2	...	-etc-	...		CONT

RBAR	10	101	201						

Field	Contents
SETID	Set identification number. (Integer > 0) (See Remark 1)
INDGRD	Identification number of a grid point that is defined as an independent grid point. (Integer > 0) (See Remark 2)
$DEPGRD_i$	Identification number of a grid point that is defined as a dependent grid point. (Integer > 0)

Remarks:

1. SETID is not referred to by other bulk data cards. The existence of the **RBAR** bulk data card triggers the program to combine two BEM grid points into one point.

2. The dependent grid point is removed from the aerodynamic model. Its identification number is replaced by that of the independent grid point.

   Note that the PS entries of the dependent grid and the independent grid must be the same, i.e., a reference grid point cannot be replaced by a surface grid point or vice versa.

RBE2

Wake Condition Behind the Thick-Wing and Body Junction

Description: Imposes the potential jump condition at grid points that are attached to the wake sheet generated by the thick-wing component.

Format and Example:

1	2	3	4	5	6	7	8	9	10
RBE2	EID	GRIDU	GRIDL	CBAR	IDTE				CONT
CONT	GRID1	GRID2	...	-etc-	...				

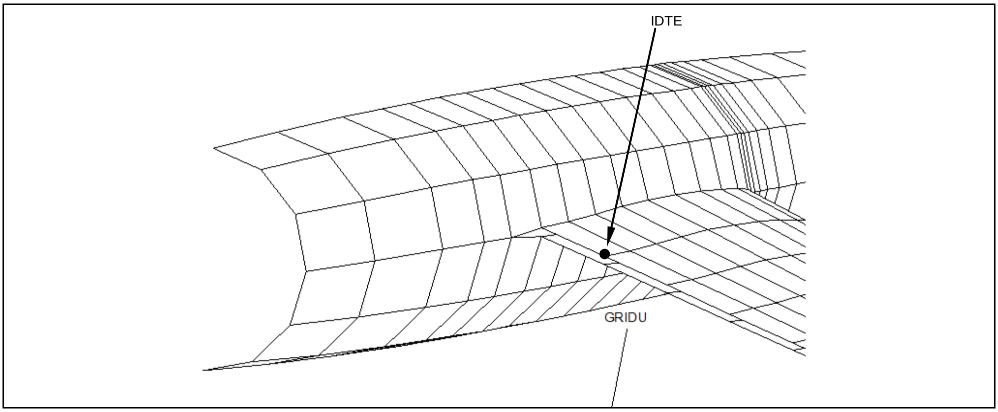
RBE2	1	51	52	YES					+RBE
+RBE	211	311	412	963	319				

Field	Contents
EID	Identification number (Integer > 0) (See Remark 1)
GRIDU	Absolute value of GRIDU is the identification number of a surface grid point (**GRID** bulk data card with entry PS = 0 or blank) that is at the upper trailing edge of the thick-wing and body junction (Integer ≠ 0) (See Remark 2)
GRIDL	Absolute value of GRIDL is the identification number of a surface grid point that is at the lower trailing edge of the thick-wing and body junction (Integer ≠ 0) (See Remark 3)
CBAR	Character string either “YES” or “NO”. If CBAR = “YES”, a set of CBAR elements are automatically generated by the program along GRIDU/GRIDL and $GRID_i$ (Character, Default = “YES”) (See Remark 4)
IDTE	Optional input. IDTE is the identification number of a grid point that is located at the thick wing trailing edge and is connected with GRIDU by a CQUAD4/CTRIA3 element. The normal vector of this CQUAD4/CTRIA3 element is used to separate those panels along GRID*i* into upper and lower sets of panels. However, if IDTE = 0, this normal vector could be automatically determined by the program. (Integer, Default = 0)
$GRID_i$	Absolute value of $GRID_i$ is the identification number of a surface grid point on the body that is attached to the wake sheet generated by the thick-wing component. Note that $GRID_1$ can be a character string “AUTO”. In this case, all GRID*i* are not required for input. They could be automatically determined by the program. (Integer ≠ 0 or Character) (see Remark 5)

Remarks:

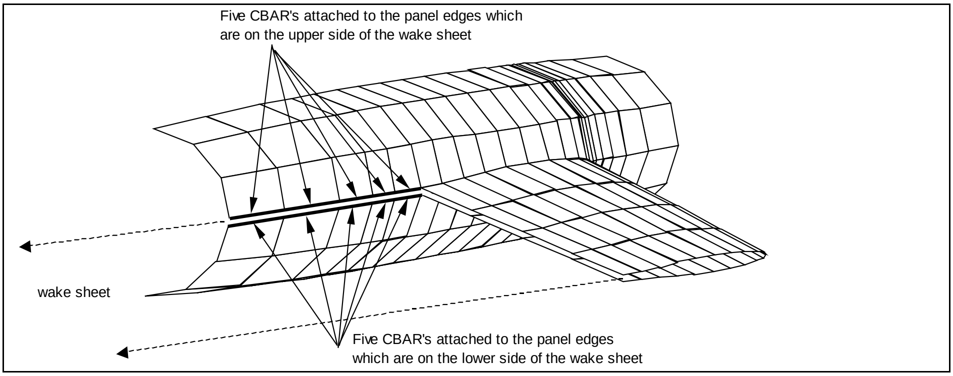
1. For a thick-wing and body combination, the wake sheet generated by the thick-wing component creates potential jump (discontinuity of velocity potential across the wake sheet) at those grid points (on the body component) that are attached to the wake sheet. The **RBE2** bulk data card is used to satisfy the potential jump condition at those grid points.

2. GRIDU and GRIDL must be the grid points at the junction of the trailing edge of the thick-wing component and the body. In the figure show below, GRIDU = 51 and GRIDL = 52. Because CBAR/WAKENET elements must be also defined at the trailing edge of the thick-wing component by the user, GRIDU and GRIDL are also implicitly attached to those CBAR/WAKENET elements. This condition will be automatically identified by the program. If there is no CBAR/WAKENET associated with GRIDU and GRIDL, fatal error occurs.

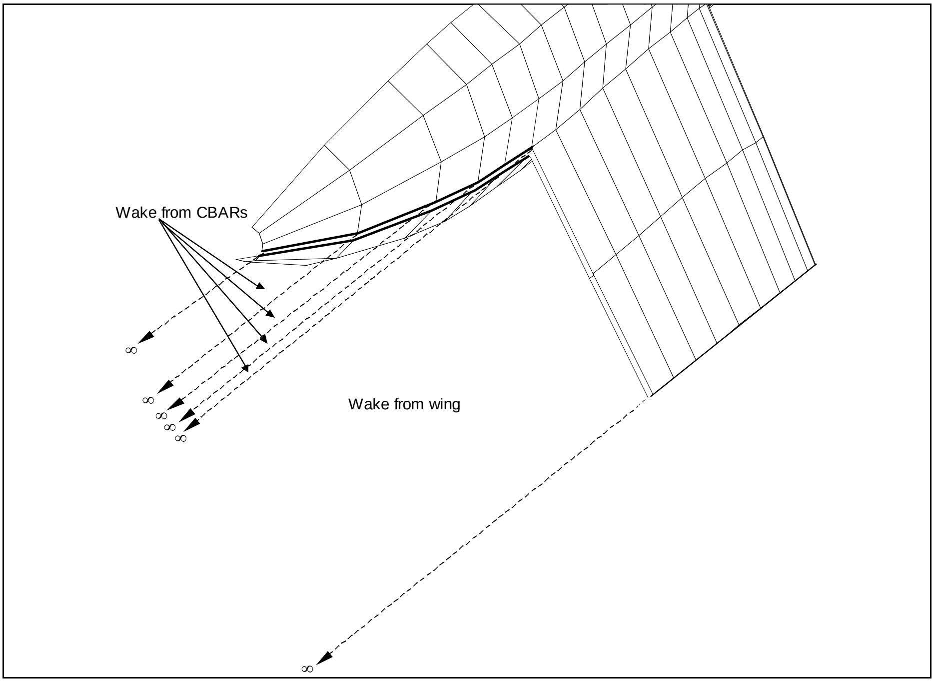


3. For a symmetric aerodynamic model (XZSYM = "YES" in the **AEROZ** bulk data card), only modeling half of the configuration is required even for a vertical tail whose mean plane is located on the X-Z plane. This is to say that because of the absence of the left-hand-side surface of the vertical tail surface, there is only one grid point at the trailing edge of the vertical tail's right-hand side surface (if it is modeled as a trick-wing component) and the fuselage junction. In this case, GRIDL = 0 is required.

4. For CBAR = "YES", the program will internally generate two sets of CBAR elements between these body GRID points starting from the GRID point at the root of the "thick wing" trailing edge. One set of CBAR are attached to the body panels, which are on the upper side of the wake whereas the other is attached to the lower side as show in the following figure.



These CBAR's generate additional wake sheets extending to infinity so that the gap between the root of the wake sheet and the body can be filled up by these wake sheets.



It should be noted that these internally generated CBAR elements can be individually removed even if the entry CBAR= "YES". This is done by specifying negative identification numbers of two consecutive grid points including GRIDU and GRIDL. For instance, if GRIDU < 0 and $GRID_1$ < 0, the internally generated CBAR between these two grids is removed.

5. The X-location of $GRID_i$ must be from upstream to downstream (from the grid point immediately behind the trailing edge of the thick-wing component to the grid point at the end of the body). In the figure show above, $GRID_i$ =211, 311, 412, 963 and 319.

   The negative sign of $GRID_i$ (including GRIDU and GRIDL) is to avoid the generation of the CBAR elements even if entry CBAR="YES". This is activated if two consecutive $GRID_i$, for example both $GRID_i$ and $GRID_{i+1}$ or both GRIDU/GRIDL and $GRID_1$, have negative sign. In this case, the segment between $GRID_i$ and $GRID_{i+1}$ or GRIDU/GRIDL and $GRID_1$ will not have the CBAR elements.

RELAXW

Wake Relaxation

Description: Performs wake relaxation on the WAKENET/VORNET macroelements by an iterative technique.

Format and Example:

1	2	3	4	5	6	7	8	9	10
RELAXW	SETID	MAXIT	CONVERG	OMEGA	NPLOT	FORM	FILENM		CONT
CONT	LABEL1	LABEL2	...	-etc-	...				

RELAXW	10	6	0.001	0.2	1	TECPLOT	WAKE.PLT		+RE
+RE	VOR1	WAKE1	WAKE2						

Field	Contents
SETID	Identification Number. (Integer > 0) (See Remark 1)
MAXIT	Maximum number of iterations. (Integer > 0, Default = 5)
CONVERG	Convergent criteria. (Real > 0.0, Default = 0.001)
OMEGA	Relaxation factor. (1.0 ≥ Real > 0.0, Default = 0.5)
NPLOT	Incremental step at which the plot file for the wake shape is written on the external file “FILENM”. (Integer > 0, NPLOT ≤ MAXIT)
FORM	FORM = “TECPLOT” for generating a TECPLOT file FORM = “PATRAN” for generating a PATRAN neutral file FORM = “IDEAS” for generating an I-DEAS universal file FORM = “FEMAP for generating a FEMAP neutral file FORM = “ANSYS” for generating an ANSYS supported neutral file FORM = “NASTRAN” for generating a NASTRAN bulk data deck
FILENM	The name of the data file in which the data for plotting the aerodynamic model with relaxed wake surface is stored. This file name is always in the upper case. In case the input file name is given in the lower case, the program converts it to the upper case. (Character).
$LABEL_i$	Character string that matches one of the LABEL entries of a WAKENET or VORNET macroelement. (Character) (See Remark 2)

Remarks:

1. The **RELAXW** bulk data card is referred to by the **MACH** bulk data card.

2. Only those WAKENET and VORNET macroelements whose LABEL entries are referred to by the **RELAXW** bulk data card are subjected to wake relaxation.

SET1 Set Definition for Aerodynamic Analysis

Description: Defines a set of integers by a list.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SET1	SID	G1	G2	G3	G4	G5	G6	G7	CONT
CONT	G8	...	-etc-	...					

SET1	3	31	62	93	124	16	17	18	+BC
+BC	19								

Alternate Form:

1	2	3	4	5	6	7	8	9	10
SET1	SID	G1	THRU	G2					

Field	Contents
SID	Set identification number (Integer > 0)
Gi	List of integers (Integer > 0)

Remarks:

1. When using the THRU option, all intermediate quantities are assumed to exist.

2. **SET1** is a general purpose bulk data card to define a set of integers. It is referred to by many other bulk data cards to define a list of bulk data card identification numbers, indices of modes, aerodynamic panel divisions, etc.

SETADD

Set Definition

Description: Defines a set of integers as a union integer set defined on the **SET1** bulk data cards.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SETADD	SETID	$SET1_1$	$SET1_2$	$SET1_3$	...	-etc-	...		

SETADD	10	101	200	300	400				

Alternate Form:

SETADD	10	$SET1_1$	THRU	$SET1_2$					

Field	Contents
SETID	Unique identification number. No duplicated identification number between **SETADD** and **SET1** bulk data card is allowed. (Integer$\neq$ 0) (See Remark 1)
$SET1_i$	Identification number of a **SET1** bulk data card.

Remarks:

1. The **SETADD** bulk data card defines a list of integers by collecting all integers listed in the **SET1** bulk data cards with identification numbers being equal to $SET1_i$
2. SETID can be a negative integer. In this case, the program will automatically remove duplicate integers in the collected list of integers. However, the integer of the entry in the bulk data card that refers to the **SETADD** bulk data card still must be positive.

SLICE

Slice a Closed Wing Trailing Edge

Description: Slices a closed wing trailing edge and wing tip into upper and lower surfaces and automatically adds CBAR/CROD/RBE2 along the edges of the surface.

Format and Example:

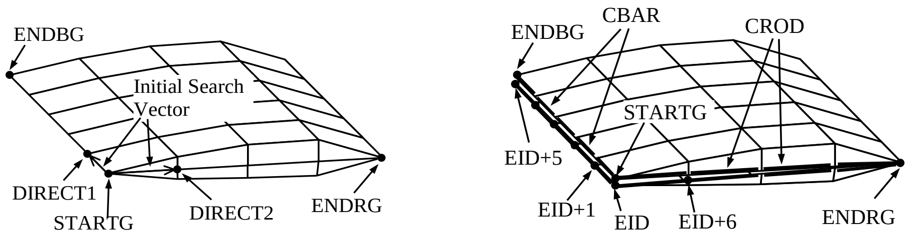
1	2	3	4	5	6	7	8	9	10
SLICE	EID	STARTG	ENDBG	DIRECT1	RBE2	ENDRG	DIRECT2	SPLIT	

SLICE	100	101	130	0	NO	141	153		

Field	Contents
EID	Unique element identification number. Note that for multiple **SLICE** bulk data cards, they are processed according to the ascending order of EID. Also, the **SLICE** bulk data card is processed before the **AUTOBAR**, **AUTOROD**, **AUTOTIP**, or **AUTOVOR** bulk data card is processed. (Integer ≠ 0) (See Remark 1)
STARTG	Identification number of a surface grid point that is located at the trailing edge of the wing tip from which the slicing action starts. Note that STARTG can be a negative integer. In this case, the grid STARTG is not split into upper and lower grid points. (Integer)
ENDBG	Identification number of a surface grid point at which the slicing action for the trailing edge ends. STARTG and ENDBG must be located at the trailing edge of the wing. (Integer) (See Remark 2)
DIRECT1	Optional input. DIRECT1 is the identification number of a surface grid point to define the initial search vector to slice the trailing edge. (Integer ≥ 0)
RBE2	Character string either “YES”, “NOCBAR” or “NO”. If RBE2= “YES” or “NOCBAR”, a RBE2 element is automatically generated for handling the trailing wake behind the wing-body junction. Please refer to the **RBE2** bulk data card for detailed description. (Character, Default = “YES”) (See Remark 3)
ENDRG	Identification number of a surface grid point at which the slicing action for the wing tip ends. STARTG and ENDRG must be located at the wing tip edge. If ENDRG ≤ 0 or ENDRG = STARTG, the slicing action for the wing tip is deactivated. (Integer) (See Remark 4)
DIRECT2	Same as DIRECT1 but for the wing tip. (Integer ≥ 0)
SPLIT	Character either “YES” or “NO”. If SPLIT = “YES”, the ENDRG grid point is split into upper and lower grid points. (Characters, Default = “NO”) (See Remark 5)

Remarks:

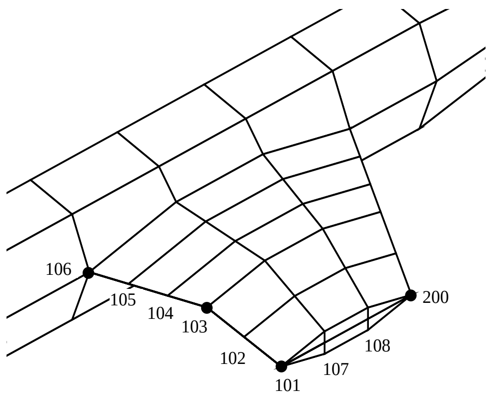
1. The objective of the **SLICE** bulk data card is to automatically convert a wing-like panel model with closed wing trailing edge and tip (Figure (a)) into an opened trailing edge and tip model To achieve this, the program will automatically generate a set of grid points that are attached to those panels on the lower surface. Note that the identification numbers of this set of grid points start with EID. The user must ensure that there is no duplicated identification number between this set of grid points and the other grid points. A set of CBAR elements will be automatically generated and attached to the upper and lower surface of the opened trailing edge. However, this generation of CBAR elements along the trailing edge can be deactivated by specified a negative EID. A set of CROD elements are also automatically generated and attached to the upper and lower surface along the opened wing tip. (Figure (b)).



(a) Closed wing trailing edge and tip *(b) Opened wing trailing edge and tip*

2. ENDBG can be equal to STARTG to deactivate the slicing action along the trailing edge. In addition, ENDBG can be a negative integer. This can deactivate the generation of a grid point at ENDBG, i.e. the edge at ENDBG is still closed.

3. If the grid point ENDBG is located at the trailing edge of the wing-body junction, RBE2 must be “YES” or “NOCBAR” to automatically create the trailing wake along the surface grid points behind the wing-body junction. For “NOCBAR”, the entry CBAR in this automatically generated RBE2 is set to be “NO”.



It should be noted that for the example shown in the figure above, two **SLICE** bulk data cards are required;

SLICE	201	101	-103		NO	200		NO	

SLICE	205	103	106		YES	0			

The first **SLICE** bulk data card slices the edges between the grid points 101 and 103, as well as, 101 and 200 and automatically generates grid points 201, 202, 203, and 204 where 201 and 202 are attached to the panels along the trailing edge on the lower surface and 203 and 204 are attached to the panels along the tip on the lower surface. The second **SLICE** bulk data card slices the edges between the grid points 103 and 106 and generates grid points 205, 206, 207, and 208. A RBE2 element is also internally generated with entries GRIDU=106, GRIDL=208, and GRID1="AUTO". Note that there is no slicing action along the wing tip by the second **SLICE** bulk data card because ENDRG=0.

4. If ENDRG ≠ STARTG, the automatically generated CBAR elements along the wing trailing edge at the wing tip will include the infinite vortex line (See entries PA and PB in the description of the CBAR bulk data card for which PA or PB equals the absolute value of ENDRG.)

5. If the grid point ENDRG is located at the leading edge of the wing tip, SPLIT must be "NO". This is because the two sets of line vortex along the upper and lower surfaces of the wing tip are originated from the leading edge, thereby they must share the same grid point ENDRG.

6. The **SLICE** bulk data card may fail to separate the CQUAD4/CTRIA3 panels into upper and lower surface groups if a sharp turn along the trailing edge of the wing exists. This triggers the program to print out the following error message.

   THE PROGRAM FAILED TO SEPARATE THOSE PANELS SURROUNDING THIS GRID INTO UPPER & LOWER GROUPS

   A typical case for which the **SLICE** bulk data card may fail is the sharp turn at the trailing edge of a winglet and the wing. To circumvent this problem, the user can use the entries XOFF, YOFF, and ZOFF in the **PSHELL** bulk data card (See remark 3 of the **PSHELL** bulk data card.)

SPLINE0 Zero Displacement of Aerodynamic Panels

Description: Imposes a zero displacement condition on aerodynamic panels. The **SPLINE0** bulk data card is active only if the **'SOLUTION 1'** Executive Control Command is specified.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPLINE0	EID	MODEL	CP	SETK					

SPLINE0	100			20					

Field	Contents
EID	Unique element identification number. (Integer > 0) (See Remark 1)
MODEL	Not used.
CP	Not used.
SETK	Refers to a **PANLST1**, **PANLST2** or **PANLST3** bulk data card that lists the aerodynamic panel identification numbers, (Integer > 0)

Remarks:

1. EID is only used for error output. **SPLINE0** is used only for computing the flexible loads.

2. A typical case of imposing the zero displacement condition on aerodynamic panels is the modeling of the wind tunnel wall on which a zero-displacement condition is desired. Since the panels representing the wind tunnel wall are not attached to the structural model, the zero displacement condition can be specified by using the **SPLINE0** bulk data card.

SPLINE1 — Surface Spline Method

Description: Defines an infinite plate spline method for displacements and loads transferal between **CAERO7** macroelement and structural grid points. The **SPLINE1** bulk data card is active only if the **'SOLUTION 1'** Executive Control Command is specified.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPLINE1	EID	MODEL	CP	SETK	SETG	DZ	EPS		

SPLINE1	100			20	30	0.0			

Field	Contents
EID	Unique element identification number. (Integer > 0) (See Remark 1)
MODEL	Not used.
CP	Identification number of a **CORD2R** bulk data card that is defined in the structural basic coordinate system. The X-Y plane of this **CORD2R** bulk data card defines the spline plane. All structural grid points listed by the entry SETG are projected onto this spline plane for performing the infinite spline method. (Integer ≥ 0 or Blank) (See Remark 2)
SETK	The identification number of a **PANLST1**, **PANLST2** or **PANLST3** bulk data card that lists the aerodynamic panel identification numbers. (Integer > 0)
SETG	The identification number of a **SETi** bulk data card that lists the structural grid points to which the spline is attached. (Integer > 0)
DZ	Linear attachment flexibility. (Real ≥ 0.0) (See Remark 3)
EPS	Multiplication factor to obtain a small tolerance to detect any duplicated location of structural grid points. The tolerance is computed by EPS*REFC, where REFC is the reference chord defined in the **AEROZ** bulk data card (Real ≥ 0.0, Default = 0.01). (See Remark 4)

Remarks:

1. EID is only used for error output. **SPLINE1** is used only for computing the flexible loads.

2. If no CP is specified, the plane defined by the macroelement specified in the **PANLSTi** bulk data card is used for the spline plane.

3. The attachment flexibility (units of area) is used for smoothing the interpolation. If DZ = 0.0, the spline will pass through all deflected grid points. If DZ is much greater than the spline area, a least square plane fit will be applied. Intermediate values will provide smoothing.

4. If any two or more structural point locations projected on the spline plane are nearly the same, the spline matrix is singular. EPS is used to detect this condition.

SPLINE2 — Beam Spline Method

Description: Defines a beam spline method for the **BODY7** or **CAERO7** macroelement. The **SPLINE2** bulk data card is active only if the **'SOLUTION 1'** Executive Control Command is specified.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPLINE2	EID	MODEL	SETK	SETG	DZ	EPS	CID	CURV	

SPLINE2	100		10	20	0.0	0.02		0.0	

Field	Contents
EID	Unique element identification number. (Integer > 0) (See Remark 1)
MODEL	Not used.
SETK	The identification number of a **PANLST1**, **PANLST2** or **PANLST3** bulk data card that lists the aerodynamic box identification numbers. (Integer > 0)
SETG	The identification number of a **SETi** bulk data card that lists the structural grid points to which the spline is attached. (Integer > 0)
DZ	Linear attachment flexibility. (Real ≥ 0.0)
EPS	Multiplication factor to obtain a small tolerance to detect any duplicated location of structural grid points. The tolerance is computed by EPS*REFC, where REFC is the reference chord defined in the **AEROZ** bulk data card. (Real ≥ 0.0, Default = 0.01)
CID	Identification number of a **CORD2R** bulk data card that is defined in the structural basic coordinate system whose y-axis defines the spline axis, i.e., the line of the beam. All structural grid points listed by the entry SET6 are projected onto this axis for performing the beam spline method. (Integer ≥ 0 or blank; not used for **BODY7**) (See Remark 2)
CURV	Curvature effects of the torsion stiffness. (Real ≥ 0.0, Default = 1.0) (See Remark 3)

Remarks:

1. Unlike **SPLINE1** and **SPLINE3**, that require only the transitional degrees of freedom (d.o.f) of the structural grid, the beam spline method also requires the rotational d.o.f for both accurate displacement and slope spline at the aerodynamic boxes. Therefore, the user must ensure that the structural grid (defined by entry SETG) have no unwanted constraints at their rotational degrees of freedom.

   Warning: The beam spline method can accurately transfer the displacement from the structural grid to the aerodynamic grid. But when transferring the aerodynamic forces back the structured grid, it does not ensure the conservation of forces. Thus, if the user wishes to obtain the loads at the structural grid using the **PLTTRIM** or **PLTTIME** bulk data cards. **SPLINE2** is not recommended. The user can add additional grid points in the structural model and connect those grid points to the beam structure by rigid elements then uses **SPLINE1** or **SPLINE3** bulk data card for spline.

2. If the macroelement specified in the **PANLSTi** bulk data card is a **CAERO7**, the spline axis is the y-axis of the coordinate system **CORD2R** with identification number = CID. In this case, the y-

axis represents a line along which the original structural grid points are located. Note that the structure grid point locations are those in the structural finite element model before the ACSID and the FLIP entries of the **AEROZ** bulk data card are applied. If the macroelement is a **BODY7**, CID is not used and the spline axis is the x-axis of the **ACOORD** bulk data card associated with the **BODY7** macroelement.

3. Specifying CURV = 0.0 gives the agreement with the SPLINE2 of MSC.Nastran because that of MSC.Nastran does not include the curvature effect of the torsion stiffness of the beam.

SPLINE3 — 3D Spline Method

Description: Defines a 3-D spline using the thin-plate spline method. The **SPLINE3** bulk data card is active only if the "SOLUTION 1" . is specified

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPLINE3	EID	MODEL	CP	SETK	SETG	DZ	EPS		

SPLINE3	100			1	10				

Field	Contents
EID	Unique element identification number. (Integer > 0)
MODEL	Not used.
CP	Not used.
SETK	The identification number of a **PANLST1**, **PANLST2** or **PANLST3** bulk data card that lists the aerodynamic panel identification numbers. (Integer > 0)
SETG	Refers to a **SETi** bulk data card that lists the structural grid points to which the spline is attached. (Integer > 0)
DZ	Linear attachment flexibility. (Real ≥ 0.0).
EPS	Multiplication factor to obtain a small tolerance to detect any duplicated location of structural grid points. The tolerance is computed by EPS*REFC, where REFC is the reference chord defined in the **AEROZ** bulk data card. (Real ≥ 0.0, Default = 0.01)

Remarks:

1. **SPLINE3** employs the Thin Plate Spline (TPS) method. Unlike the infinite plate spline method employed by the **SPLINE1** bulk data card, the **SPLINE3** does not require that a spline plane be defined. All structural grid points are located in 3-D space. Therefore, the TPS method can be considered as a 3D spline method.

2. Two restrictions are associated with the 3D spline method:

   (a) Similar to **SPLINE1**, no two or more structural points can be at the same location.

   (b) All of the structural points cannot be located in the same plane.

   EPS is the tolerance used to detect the above two conditions.

SPLINEF — Spline Matrix for Force Mapping

Description: Generates the force spline matrix to map the aerodynamic forces at the aerodynamic grids to the structural grids by altering the **SPLINE1**, **SPLINE2** or **SPLINE3** bulk data card.

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPLINEF	EID	IDSPLINE	SET1						

SPLINEF	100	200	300						

Field	Contents
EID	Identification number that is used only for error message output (Integer >0) (See Remark 1)
IDSPLINE	Identification number of a **SPLINE1**, **SPLINE2** or **SPLINE3** bulk data card, whose entry SETG is replaced by the SET1 entry of the **SPLINEF** bulk data card. (Integer >0) (See Remark 2)
SET1	Identification number of a **SET1** or **SETADD** bulk data card to list a set of identification numbers of structural grid points that are used to generate the force spline matrix. (Integer >0) (See Remark 3)

Remarks:

1. The **SPLINEF** bulk data card is optional. Its existence "triggers" the program to generate a different force spline matrix from the displacement spline matrix. There are two spline matrices generated by the spline module:

$$\{h\} = [UGTKG]^T \{x\}$$

$$\{F_s\} = [UGFRC]\{F_a\}$$

where *{x}* is the G-set displacement at the structural grid points
{h} is the k-set displacement at the aerodynamic boxes
$\{F_a\}$ is the aerodynamics forces at the aerodynamic boxes
$\{F_s\}$ is the G-set forces at the structural grid points
[UGTKG] is the displacement spline matrix
and *[UGFRC]* is the force spline matrix

If there is no **SPLINEF** bulk data card specified, then *[UGFRC] = [UGTKG]*

2. The spline module first generates the *[UGTKG]* matrix by processing all **ATTACH**, **SPLINE0**, **SPLINE1**, **SPLINE2**, and **SPLINE3** bulk data cards. Then the spline module processes the **SPLINEF** bulk data cards to alter the **SPLINE1**, **SPLINE2** or **SPLINE3** bulk data cards by a new set of structural grid points involved in the force spline. The new set of spline bulk data cards along

with all of the rest of the unaltered spline bulk data cards (not referred to by the **SPLINEF** bulk data card) are used to generate the *[UGFRC]* matrix.

3. To ensure a continuous displacement and slopes at the aerodynamic grid points by the displacement spline matrix, the generation of *[UGTKG]* matrix may need more structural grid points. However, to achieve a good force spline, it is recommended to select less structural grid points involved in the *[UGFRC]* matrix. This is because one aerodynamic box produces only one aerodynamic force. If there are more than one structural grid points located on one aerodynamic box, the *[UGFRC]* matrix needs to split one aerodynamic force at more than on structural grid points. This may result in an irregular distribution of the force distribution at the structural grid points. Note that based on the principle of virtual work, the conservation of the total force is ensured by the *[UGFRC]* matrix, but it may result a in a poor distribution of forces if the structural grid points involved in the force spline are not carefully selected.

SPLINEM **Save or Retrieve the Spline Matrix**

Description: Saves the spline matrix on an external file for the cold start job or retrieves the spline matrix from the external file for the restart job. The **SPLINEM** bulk data card is active only if the **'SOLUTION 1'** Executive Control Command is specified

Format and Example:

1	2	3	4	5	6	7	8	9	10
SPLINEM	SAVE	FILENM							
SPLINEM	ACQU	spline.dat							

Field	Contents
SAVE	Character string either "SAVE" or "ACQUIRE". For SAVE = "SAVE", save the spline matrix on the file "FILENM". For SAVE = "ACQUIRE", retrieve the spline matrix from the file "FILENM". (Character) (See Remark 1)
FILENM	File name to specify the file name on which the spline matrix is saved or retrieved. If the first character of FILENM starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character) (See Remark 2)

Remarks:

4. The **SPLINEM** bulk data card is not referred to by any other bulk data card. Its existence in the input file "triggers" the program to save/retrieve the spline matrix. Computation of the spline matrix for a large number of FEM grid points could be time consuming. The **SPLINEM** bulk data card can avoid the recomputation of the spline matrix if both the aerodynamic and the structural finite element grid points are unchanged.

5. Because the spline matrix is independent of Mach number, the spline matrix can be first saved in the cold start job and then retrieved for other Mach numbers in the restart job.

THERMAL

Aeroheating Analysis

Description: Performs the aeroheating analysis at a specified flight condition.

Format and Example:

1	2	3	4	5	6	7	8	9	10
THERMAL	SETID	IDAERO	TEMP	ALT	HOTWALL	TRANS	IGAS	EMIS	CONT
CONT	STREAM	FORM	FILENM		AEROGM				

THERMAL	10	20	200.0F	10000.0	YES	1	0	0.8	+THR
+THR	ALL	TECPLOT	THERMAL.PLT						

Field	Contents
SETID	Identification Number. (Integer > 0) (See Remark 1)
IDAERO	If IDAERO > 0 IDAERO is the identification number of an **AEROGEN** bulk data card that defines the flight condition for the aeroheating analysis. If IDAERO < 0 |IDAERO| is the identification number of a **FLEXLD** bulk data card to perform an aeroheating analysis with structural flexibility effects. In this case, **"SOL 1"** and "**ASSIGN FEM ="** executive control commands must be specified.
TEMP	Initial surface temperature, TEMP is a real number with a character "F" or "C" attached to the end. For instance TEMP = 200.0F is 200° F and TEMP = 200.0C is 200° C.
ALT	Altitude whose unit must be consistent with the length unit specified in the FMLUNIT entry of the **AEROZ** bulk data card. (Real)
HOTWALL	Character either "YES" or "NO" to define the type of boundary condition on the aerodynamic surface. HOTWALL = "YES"; Radioactive equilibrium boundary condition. The surface temperature defined in the TEMP entry is used as the initial temperature condition. HOTWALL = "NO"; Cold wall boundary condition. The temperature on the surface is fixed at TEMP. (Character)

TRANS	Specifies the assumption of Laminar or turbulent flow. TRANS = 0 the program automatically determines the transition of the flow TRANS = 1 entire flow is assumed to be laminar TRANS = 2 entire flow is assumed to be turbulent (Integer)
IGAS	Specifies the options of real or ideal gas IGAS = 0 for ideal gas IGAS = 1 for ideal gas for Helium IGAS = 2 for real gas. (Integer)
EMIS	Emissitivity, used only for HOTWALL = “YES” (Real, Default = 0.8)
STREAM	STREAM can be either a character string or integer to define the aerodynamic panels whose streamlines are included in the plot file “FILENM” STREAM = “ALL” Streamline of all aerodynamic panels are included STREAM = 0 No streamline is included STREAM > 0 STREAM is an integer representing the identification number of a **PANLST2** bulk data card that lists a set of panel identification numbers whose streamlines are included. (Character or Integer) (See Remark 2)
FORM	FORM = “TECPLOT” for generating a TECPLOT™ file FORM = “PATRAN” for generating a PATRAN™ neutral file FORM = “IDEAS” for generating an I-DEAS™ universal file FORM = “FEMAP” for generating a FEMAP™ neutral file FORM = “ANSYS” for generating an ANSYS supported neutral file FORM = “NASTRAN” for generating a NASTRAN bulk data deck PLOAD4 cards to define the aeroheating results FORM = “ESA” for generating a PEGASUS readable file (Character, Default = “TECPLOT”)
FILENM	The name of the data file in which the data for plotting the aeroheating results is stored. This file name is always in the upper case. In case the input file name is given in the lower case, the program converts it to the upper case. If the first character starts with a dollar sign “$”, the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input (Character) (See Remark 3)

AERONM	The name of a data file in which the aerodynamic model is stored in a PATRAN neutral file. ONLY USED IF FORM = "PATRAN" (Character, Default = "AEROGEOM.PAT") (See Remark 4)

Remarks:

1. The **THERMAL** bulk data card is referred to by a **THERMAL** Case Control Command that invokes the program to compute the aeroheating results. These results include temperature heat flux, skin friction coefficient, pressure, and flow transition (from laminar flow to turbulent flow) distribution on the aerodynamic model.

2. Every streamline starts from the stagnation point and ends at the control point of the aerodynamic panel. These streamlines are computed based on the inviscid surface velocities generated by the **AEROGEN** bulk data card. The aeroheating results are calculated along each streamline using a one-dimensional boundary layer method.

3. The aeroheating results stored on file "FILENM" include
   - The aerodynamic panel model with both upper and lower surfaces of the CAERO7 macroelements being modeled.
   - The pressure coefficients, the friction coefficients, the heat transfer coefficients, the wall enthalpy, the wall temperatures, the heat flux, the wall pressure and the flow laminar/transition/turbulent regime at the aerodynamic grid points.
   - The streamlines for the stagnation point to the control points of the aerodynamic panels. (Include only if STREAM $\neq$ 0)

4. PATRAN requires that the aerodynamic model be stored in a neutral file and that analysis results be stored in a results file. Therefore, the AEROGM entry is used to assign a name for a neutral file that contains the aerodynamic model, while the FILENM entry specifies a file that will contain the aeroheating results.

THKWING Aerodynamic Thick-Wing Component

Description: Defines an aerodynamic wing macroelement of a thick-wing component.

Format and Example:

1	2	3	4	5	6	7	8	9	10
THKWING	WID	PSHELL	ACOORD	NSPAN	NCHORD	LSPAN	PAFOIL7	AUTOTIP	CONT
CONT	XRL	YRL	ZRL	RCH	ATTR	LRCHD	RWAKE	CANTR	CONT
CONT	XTL	YTL	ZTL	TCH	ATTT	LTCHD	TWAKE	CANTT	

THWING	101	100	8	5	4	20	0	TIP	+BC
+BC	0.0	0.0	0.0	1.0	YES	4	3	50.0	+EF
+EF	0.0	1.0	0.0	1.0	NO	0	0	0.0	

Field	Contents
WID	Unique identification number (Integer > 0) (See Remark 1)
PSHELL	Identification number of a **PSHELL** bulk data card. (Integer > 0)
ACOORD	Identification number of **ACOORD** (specifying a local coordinate system and orientation) bulk data card (Integer ≥ 0 or Blank, Default = 0) (See Remark 2)
NSPAN	Number of spanwise divisions of the thick-wing component (Integer ≥ 2)
NCHORD	Number of chordwise divisions of the thick-wing component (Integer ≥ 2)
LSPAN	Identification number of **AEFACT** bulk data card used to specify the spanwise divisions of the thick-wing component in percentage of the wing span. The number of values listed in **AEFACT** must be NSPAN and must start with 0.0 and end with 100.0. If LSPAN = 0, then NSPAN evenly distributed spanwise divisions are used. (Integer ≥ 0) (See Remark 3)
PAFOIL7	Identification number of a **PAFOIL7/PAFOIL8** bulk data card to specify sectional airfoil coordinates. (Integer > 0)

AUTOTIP Character either “BOTH”, “BOTHC”, “ROOT”, “ROOTC”, “TIP”, “TIPC” or “NONE”

AUTOTIP = “BOTH”: a “TIP” modeling is performed for both the root and tip sections with internally generated flat panels.

AUTOTIP = “BOTHC”: a “TIP” modeling is performed for both the root and tip sections with internally generated round panels.

AUTOTIP = “ROOT”: a “TIP” modeling is performed for the root section with flat panels

AUTOTIP = “ROOTC”: a “TIP” modeling is performed for the root section with round panels

AUTOTIP = “TIP”: a “TIP” modeling is performed for the tip section with flat panels

AUTOTIP = “TIPC”: a “TIP” modeling is performed for the tip section with round panels

AUTOTIP = “NONE”; no “TIP” modeling

(Character, Default = “NONE”) (See Remark 4)

XRL
YRL
ZRL X, Y, and Z location of the root chord leading edge (Real)

RCH Length of the root chord (Real)

ATTR Character string either “YES”, “NOBR”, or NO”. For ATTR = “YES”, “NOBR” the root the thick-wing component is attached to is a body component. Note that for ATTR = “NOBR”, no CBAR elements are generated along that surface grid points behind the root of the thick-wing component. (Represented by **CQUAD4, CTRIA3**, or **BODY7** bulk data cards). (Character)

LRCHD For ATTR = “NO”;

LRCHD is the identification number of an **AEFACT** bulk data card used to specify the root chord divisions of the wing component in percentage of the root chord. The number of values listed in **AEFACT** must be NCHORD and must start with 0.0 and end with 100.0. If LRCHD = 0, then NCHORD evenly distributed chordwise divisions for the root is used. (Integer ≥ 0)

For ATTR = “YES”, or “NOBR”;

LRCHD is the identification number of a **SET1** bulk data card that lists NCHORD identification number of the surface grid points (**GRID** bulk data card with entry PS = 0 or blank). (Integer >0)

Note that LRCHD also can be a character string = “AUTO” that triggers the program to automatically search for the surface grid points along the wing-body junction (Character = “AUTO”) (See Remark 5)

RWAKE	Identification number of a **SET1** bulk data card that lists a set of identification numbers of the surface grid points. These grid points are located behind the root of the thick-wing component where the wake from the wing root is attached. (Integer ≥ 0) Note that RWAKE also can be a character string = "AUTO" that triggers the program to automatically search for the surface grid points located behind the root of the thick-wing component. (Character = "AUTO") (See Remark 6)
CANTR	A cant angle in degrees to adjust the grid points at the wing-body junction. CANTR is active only if ATTR = "YES". (Real, Default = 0.0) (See Remark 7)
XTL YTL ZTL	X, Y, and Z location of the tip chord leading edge (Real)
TCH	Length of the tip chord (Real)
ATTT	Same as ATTR but for the tip of the thick-wing component (Character)
LTCHD	Same as LRCHD but for the tip of the thick-wing component (Integer ≥ 0)
TWAKE	Same as RWAKE but for the tip of the thick-wing component (Integer ≥ 0)
CANTT	Same as CANTR but for the tip section. (Real)

Remarks:

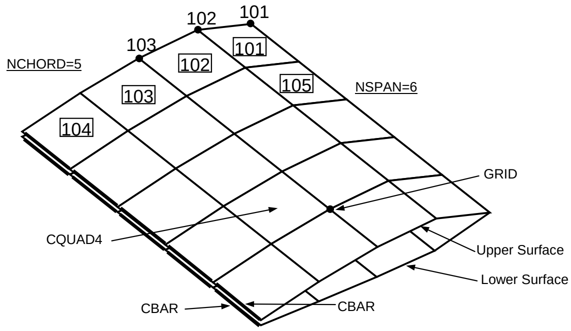
1. The **THKWING** bulk data card automatically generates a set of surface grid points, CQUAD4/CTRIA3 elements on the upper and lower surface of the thick-wing components. In addition, a set of CBAR elements are also automatically generated along the upper and lower surfaces of the trailing edge grid points.

   Note that the input entries of the **THKWING** bulk data card are very similar to those of the **CAERO7** bulk data card. However, the **THKWING** bulk data card generates a thick-wing component that is modeled by a set of **GRID**, **CQUAD4**, **CTRIA3** and **CBAR** bulk data cards whereas the **CAERO7** bulk data card generates a sheet of vortex and source singularities distributed on the main plane of the thin-wing.

2. All coordinate locations defined above in XRL, YRL, ZRL, XTL, YTL**,** and ZTL are in the local wing coordinate system defined by the **ACOORD** bulk data card.

3. The thick-wing component has NCHORD-1 chordwise strips and NSPAN-1 spanwise strips of the panels on the upper surface and the lower surface of the thick-wing component, respectively. Two sets of NCHORD×NSPAN surface grid points are automatically generated by the **THKWING** bulk data card. The first set of grid points is on the upper surface and the second set on the lower surface of the thick-wing component. The starting identification number of those grid points is defined by WID and the identification number of the last grid points is (WID-1)+2×NCHORD×NSPAN. The

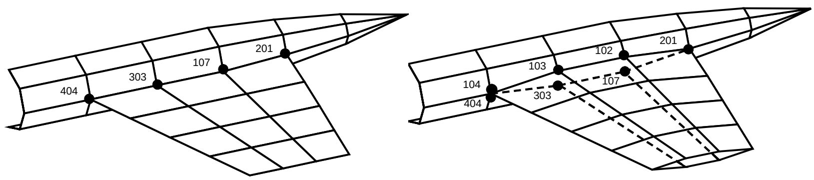
user must make sure that no duplicate identification numbers exist between those automatically generated grid points and other grid points defined by the **GRID** bulk data card. Likewise, 2×(NCHORD-1)×(NSPAN-1) CQUAD4/CTRIA3 elements are also automatically generated with starting identification numbers being WID. No duplicated identification number is allowed between those automatically generated CQUAD4/CTRIA3 elements and those defined by the **CQUAD4**/**CTRIA3** bulk data cards. See the following figure as an example.



4. An **AUTOTIP** bulk data card is internally generated by the program to model the root or tip section of the thick-wing component, respectively. For AUTOTIP=”BOTH”, “ROOT”, or “TIP”, the entry CIRLCE=”FLAT” is specified in the internally generated **AUTOTIP** bulk data card. For AUTOTIP=”BOTHC”, “ROOTC”, or “TIPC”, the entries CIRLCE=”CIRRCLE” and NLINE=3 are specified in the internally generated **AUTOTIP** bulk data card. See the description of the **AUTOTIP** bulk data card for details.

5. The surface grid points listed in the **SET1** bulk data card defines the wing-body junction so that the program can create a “hole” on the body. All grid points around this “hole” on the body are connected to the grid points of the root section of the thick-wing component.

   In the figure shown below, the surface grid points 201, 107, 303, and 404 are listed in the **SET1** bulk data card. The program will automatically move the locations of those grid points to the lower surface of the root section of the thick-wing component. The grid points on the upper surface of the root section are generated by the program. Note that the size of the “hole” on the body is defined by the **PAFOIL7/PAFOIL8** bulk data card.

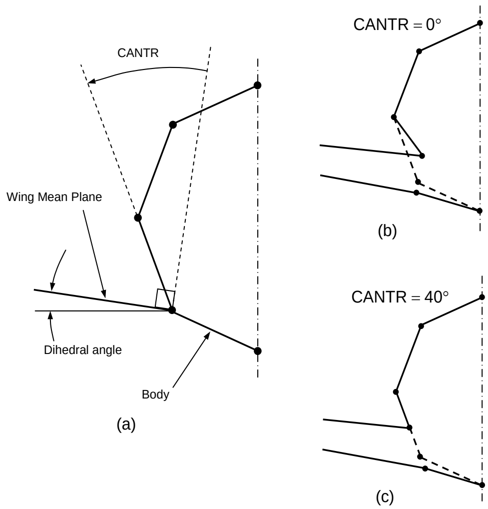


   Note that if LRCHD = “AUTO”, the number of surface grid points along the wing-body junction must be equal to NCHORD. Otherwise, a fatal error occurs.

   If the airfoil section defined by the **PAFOIL7** bulk data card is highly cambered, the program may have difficulty to create a hole on the body. In this case the user can use the XOFF, YOFF and ZOFF entries in the **PSHELL** bulk data card to help the program for creating the hole. For example, in the figure above all panels above grid point 201, 107, 303, and 404 (including panels ahead of the leading edge and behind the training edge) should refer to the **PHSELL** bulk data card whose entry ZOFF is a big positive number and the panels below those grid points should refer to the **PSHELL** card whose entry ZOFF is a big negative number.

6. The RWAKE entry is very similar to that of the **CAERO7** bulk data card except an **RBE2** bulk data card is internally generated by the program to account for such a potential jump across the wake sheet (See the RWAKE entry of the **CAERO7** bulk data card and the description of the **RBE2** bulk data card).

7. CANTR determines the CANT angle of the “hole” on the body. It can be used to improve the smoothness of the grid points at the wing-body junction. In the following figure, Figure (a) depicts a wing-body configuration without the wing thickness. Figure (b) presents a wing-body configuration with the wing thickness and CANTR = 0.0. Figure (c) is the same as Figure (b) except CANTR = 40°.



TREFFTZ

Trefftz Plane for Computing Induced Drag

Description: Defines a Trefftz plane for computing the induced drag

Format and Example:

1	2	3	4	5	6	7	8	9	10
TREFFTZ	IDBULK	ACOORD	XPLANE	YSPAN	ZUPPPER	ZLOWER	AEFACTY	AEFACTZ	

TREFFTZ	1000	100	1000.0	500.0	100.	200.0	10		

Field	Contents
IDBULK	Identification number of an **AEROGEN** bulk data card whose resulting induced drag is computed by the Trefftz plane. (Integer>0) (See remark 1).
ACOORD	Identification number of an **ACOORD** bulk data card in which the Trefftz plane is located. (Integer ≥ 0).
XPLANE	Streamwise location of the Trefftz plane in the local coordinates defined by the **ACOORD** bulk data card. (Real ≥ 0.0). (See Remark 2).
YSPAN	Span of the Trefftz plane located in the local coordinates defined by the **ACOORD** bulk data card. For a full span aerodynamic model (XZSYM=”NO” in the **AEROZ** bulk data card), The width of the Trefftz plane is from -SPAN to +SPAN. For a half span aerodynamic model, the width is from 0.0 to +SPAN. (Real > 0.0). (See Remark 3).
ZUPPER	The top of the Trefftz plane located in the local coordinates defined by the **ACOORD** bulk data card. (Real ≥ 0.0).
ZLOWER	The bottom of the Trefftz plane measured from the origin of local coordinates defined by the **ACOORD** bulk data card to the bottom of the Trefftz plane. (Real ≥ 0.0).
AEFACTY	Identification number of an **AEFACT** bulk data card to further divide the spanwise integration zone from one zone into several zones. The starting number of the values listed in the **AEFACT** bulk data card must be 0.0 and the ending value must be 100.0. Therefore, those values listed in the **AEFACT** bulk data card are the percentages of the span of the Trefftz plane (Integer ≥ 0). (Default= one zone from 0.0 to 100.0).
AEFACTZ	Same as AEFACTY except for the integration along the vertical direction. (Integer ≥ 0). (Default= one zone from 0.0 to 100.0). (See Remark 4)

Remarks:

1. There are two methods to compute the induced drag. The first is by integrating the pressure distribution over the panel model (default output). But this method is well-known to be sensitive to the fineness of the panel model. The second method is to define a vertical plane, called the Trefftz plane located far away behind the panel model. Integrating the square of the perturbation velocities along the span and vertical directions on the Trefftz plane yields the induced drag.

   However, numerical experience shows that the Trefftz plane method only works for the thick wing model (wing is modeled by placing **CQUAD4**/**CTRIA3/CBAR/CROD** elements on the upper and lower surfaces of the wing). For the thin wing model (wing modeled by **CAERO7** bulk data card), the Trefftz plane method does not work well. Furthermore, for aerodynamic model involving bodies, the Trefftz plane method may not be accurate either.

2. Typically, the Trefftz plane located five times of the wing span downstream of the aerodynamic panel model would be sufficiently large.

3. Typically, the width of the Trefftz plane is twice of the wing span would be sufficiently large.

4. Because of the line vortex shedding from the wing tip near which a large variation of the perturbation velocity occurs, a small integration zone in which the line vortex is located at its center should be defined. For instance, if the value specified in the YSPAN entry is twice of the wing span, the spanwise integration zones can be divided into four zones using the AEFACTY entry like listing 0.0, 48.0, 50.0, 52.0 and 100.0 in the **AEFACT** bulk data card.

TRIM

Static Aeroelastic / Trim Analysis

Description: Defines the flight condition, rigid body mass matrix, trim degrees of freedom and trim variables for a trim analysis. To include the structural flexibility effects in the trim analysis, it is required to specify the **'ASSIGN FEM='** and **'SOLUTION 1'** Executive Control Commands. Otherwise, the trim analysis is performed on the rigid aircraft.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TRIM	TRIMID	IDAERO	QINF	IDOBJ	IDCONS	RHOX	RHOY	RHOZ	CONT
CONT	WTMASS	WEIGHT	IXX	IXY	IYY	IXZ	IYZ	IZZ	CONT
CONT	TRNACC	NX	NY	NZ	PDOT	QDOT	RDOT	LOADSET	CONT
CONT	IDVAR1	VAL1	IDVAR2	VAL2	-etc-				

TRIM	100	90	1200.0	10	20	2.7	0.0	1.0	+T1
+T1	0.03108	1600.00	5.0+05	-2.9+05	1.9+06	-8.7+03	0.0	2.4+06	+T2
+T2	G	NONE	0.0	FREE	0.2	0.0	FREE	100	+T3
+T3	100	25.0	300	FREE	400	FREE	200	FREE	+T4
+T4	500	1.0	900	0.0					

Field	Contents
TRIMID	Unique set identification number. (Integer > 0) (See Remark 1)
IDAERO	Identification number of an **AEROGEN** bulk data card that defines the flight condition used for the static aeroelastic / trim analysis. (Integer > 0) (See Remark 2)
QINF	Dynamic pressure. (Real > 0.0) (See Remark 3)
IDOBJ	Identification number of a **TRIMOBJ** bulk data card that defines the objective function to be minimized. Active only for an over-determined trim system. (Integer ≥ 0)
IDCONS	Identification number of a **TRIMCON** bulk data card that defines a set of constraint functions to be satisfied. Active only for an over-determined trim system. (Integer ≥ 0)

RHOX, RHOY, RHOZ	x, y, and z components, respectively, of a vector from the aerodynamic moment center (REFX, REFY and REFZ in the **AEROZ** bulk data card) to the center of gravity (C.G.) of the configuration. Thus, the center of gravity is computed by: $x_{C.G.} = REFX + RHOX$ $y_{C.G.} = REFY + RHOY$ $z_{C.G.} = REFZ + RHOZ$ (Real)
WTMASS	Factor to convert weight to mass. WTMASS = 1/g , where g is the gravitational acceleration. (Real > 0.0)
WEIGHT	The weight of the whole aircraft. (Real > 0.0) (See Remark 4)
IXX, IXY, IYY, IXZ, IYZ, IZZ	The weight moment of inertia about the center of gravity (C.G.) of the whole aircraft, where the x, y and z denote the rotational axis that are associated with the aerodynamic model. (Real) (See Remark 4) Note: IXX, IYY and IZZ must be greater than zero.
TRNACC	Character string to specify the units of the accelerations (NX, NY, NZ, PDOT, QDOT and RDOT) of the trim degrees of freedom. (Character, Default = 'G') TRNACC = "TRUE", The units of the acceleration are FMLUNIT/sec^2, (where FMLUNIT is the length unit defined by the **AEROZ** bulk data card) for NX, NY and NZ, and rad/sec^2 for PDOT, QDOT and RDOT. TRNACC = "G", NX, NY and NZ are specified in terms of gravity (g), where PDOT, QDOT and RDOT in terms of rad/FMLUNIT.
NX, NY, NZ	Translational accelerations along the x, y and z axis, respectively, of the aerodynamic model. (Character or Real) (See Remark 5) Three options are available: Characters "NONE" The trim degree of freedom associated with the translational acceleration is eliminated from the trim system. Characters "FREE" The translational acceleration is a "FREE" trim degree of freedom. The value of the translational acceleration is unknown and to be solved by the trim system. Real Value The translational acceleration is fixed and given by the real value.
PDOT, QDOT, RDOT	Angular acceleration about the center of gravity (CG) at the x, y and z axis, respectively, of the aerodynamic model. (Character or Real) (See Remark 5) Similar to NX, NY and NZ, characters "NONE", "FREE", or real values can be specified.

LOADSET	Identification number of a **SET1** bulk data card that specifies a set of identification numbers of **TRIMFNC** or **TRIMADD** bulk data card. All values of the trim functions defined by the **TRIMFNC** or **TRIMADD** bulk data card are computed and printed out. (Integer ≥ 0)
IDVARi	Identification number of a **TRIMVAR** bulk data card to define a trim variable. (Integer > 0) (See Remark 6)
VALi	Value of the trim variable IDVARi. (Character or Real) (See Remark 6) Two options are available: Characters "FREE" The value of the trim variable is an unknown and to be solved by the trim system. Real Value The value of the trim variable is fixed and given by the real value.

Remarks:

1. For the static aeroelastic / trim analysis, the **TRIM** discipline must be selected in the Case Control Section with **TRIM** = TRIMID.

   Note: To compute the distributed inertial loads of a free-free structure (i.e. with rigid body vibration modes), it is required to:

   - specify the rigid body d.o.f. in the "SUPORT" entry of the **'ASSIGN FEM='** Executive Control Command
   - import the SMGH (from symmetric/asymmetric finite element modal analysis) or/and the AMGH (from anti-symmetric modal analysis) matrices by the **'ASSIGN MATRIX='** Executive Control Command.

2. The aerodynamics at the flight condition defined by the **AEROGEN** bulk data card are treated as the mean flow condition for the trim analysis. For instance, if ALPHA = 10.0 degrees is specified in the **AEROGEN** bulk data card, the values of all trim variables are treated as perturbed values about the 10 degrees mean angle of attack.

3. The units of the dynamic pressure must be consistent with the mass and length units specified in the FMMUNIT and FMLUNIT entries of the **AEROZ** bulk data card. In fact, all mass and length units involved in the **TRIM** bulk data card must be consistent with FMMUNIT and FMLUNIT, respectively.

4. WEIGHT, IXX, IYY, … are multiplied by WTMASS to convert weight to mass. These values define a 6×6 rigid body mass matrix such as:

$$\begin{bmatrix} \text{WEIGHT} & & & & & \\ & \text{WEIGHT} & & & & \\ & & \text{WEIGHT} & & & \\ & & & \text{IXX} & \text{IXY} & \text{IXZ} \\ & & & \text{IXY} & \text{IYY} & \text{IYZ} \\ & & & \text{IXZ} & \text{IYZ} & \text{IZZ} \end{bmatrix} \times \frac{1}{g}$$

It should be noted that WEIGHT, IXX, IYY, … must account for two sides of aircraft even if only half of the configuration (XZSYM = "YES" in the **AEROZ** bulk data card) is modeled. Also, unlike the conventional definition, the coupling terms IXY, IXZ and IYZ have <u>NO</u> negative sign in the above matrix. These mass of moment interia values can be obtained from the NASTRN output file such as follows.

```
O U T P U T   F R O M   G R I D   P O I N T   W E I G H T   G E N E R A T O R
.........................................................................
.........................................................................
                                    I(S)
               *  7.639202E+05 -1.757623E+05 -1.441086E+04 *
               * -1.757623E+05  1.942568E+06  4.185864E+04 *
               * -1.441086E+04  4.185864E+04  2.684407E+06 *
```

5. If NX, NY, NZ, PDOT, QDOT and/or RDOT = "NONE", then its associated degree of freedom of the 6 rigid body motions (three translational and three rotational degrees of freedom) is eliminated from the trim system. The remaining degrees of freedom are defined as "*trim degrees of freedom*" of the trim system. Among these trim degrees of freedom, if "FREE" is specified, then the associated degrees of freedom are defined as "*free trim degrees of freedom*". If real values are given, the associated trim degrees of freedom are defined as "*given trim degrees of freedom*".

6. If "FREE" is specified, the trim variable is defined as "*free trim variable*". If real value is given, the trim variable is defined as "*given trim variable*". The number of free trim degrees of freedom plus the number of free trim variables are the total number of unknowns of the trim system. If the total number of unknowns of the trim system is equal to the number of trim degrees of freedom (including both free and given trim degrees of freedom), the trim system is defined as "*determined trim system*" since the number of equations and unknowns are equal. If the total number of unknowns is greater than the number of trim degrees of freedom, the trim system is defined as "*over-determined trim system*". Solving the over-determined trim system requires the minimization of a user defined objective function (a **TRIMOBJ** bulk data card referred to by the IDOBJ entity of the **TRIM** bulk data card) while subjected to a set of user defined constraint functions (a **TRIMCON** bulk data card that is referred to by the IDCONS entity of the **TRIM** bulk data card). If the total number of unknowns is less than the number of trim degrees of freedom, the trim system is unsolvable and a fatal error will occur.

TRIMADD

Defines a Trim Function as a Function of Other Trim Functions

Description: Defines a trim function as a function of other trim functions. The function is expressed as:

$$F = \left\{ \left\{ \left[\left(S_0 \, F_0^{C_0} \oplus S_1 \, F_1^{C_1} \right)^{E_1} \oplus S_2 \, F_2^{C_2} \right]^{E_2} \oplus S_3 \, F_3^{C_3} \right\}^{E_3} \oplus S_4 \, F_4^{C_4} \right\}^{E_4} + \ldots$$

where $\oplus$ represents '+', '-', '$*$', or '/ '.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TRIMADD	IDFNC	S_0	F_0	C_0					CONT
CONT	$SYMBOL_1$	S_1	F_1	C_1	E_1				CONT
CONT	$SYMBOL_2$	S_2	F_2	C_2	E_2	-etc-			

TRIMADD	100	1.0	101	-0.5					+T1
+T1	+	2.0	102	1.0	2.0				+T2
+T2	-	-1.0	111	2.0	-1.0				

Field	Contents
IDFNC	Unique identification number (among all **TRIMFNC** and **TRIMADD** bulk data cards) (Integer > 0) (See Remark 1)
S_0	Real coefficients shown in the above equation (Real)
F_0	Identification number of a **TRIMFNC** bulk data card whose value is represented by the symbol F_0 shown in the above equation (Integer > 0)
C_0	Real coefficients shown in the above equation (Real, Default = 1.0)
$SYMBOL_i$	Character string either '+', '-', '$*$', or '/ ' (see the symbol '$\oplus$' shown in the above equation) (Character)
F_i	Identification number of a **TRIMFNC** bulk data card whose value is represented by the symbol F_i shown in the above equation. If F_i is zero, the value is assumed to be zero. (Integer $\geq$ 0)
C_i	Real coefficients shown in the above equation (Real, Default = 1.0)

E_i Real coefficients shown in the above equation (Real, Default = 1.0)

Remarks:

IDFNC is referred to by the **TRIMOBJ** x, y, and z components, respectively, of a vector from the aerodynamic moment center (REFX, REFY and REFZ in the **AEROZ** bulk data card) to the center of gravity (C.G.) of the configuration. Thus, the center of gravity is computed by:

1. And **TRIMCON** bulk data cards to define the objective function and constraint functions for over-determined trim systems. IDFNC can also be referred to by the **TRIM** bulk data card through the **SET1** bulk data card to print out the values of the trim functions.

2. **TRIMADD** can be used to construct a trim function by a complex expression that cannot be defined by a single **TRIMFNC** bulk data card. The following example shows how to construct the Von-Mises stress formula by the **TRIMADD** bulk data card.

   The Von-Mises stress formula is expressed as follows:

$$g = \left[\left(\frac{\sigma_x}{A_x}\right)^2 + \left(\frac{\sigma_y}{A_y}\right)^2 - \frac{\sigma_x\ \sigma_y}{A_x\ A_y} + \left(\frac{\tau_{xy}}{A_{xy}}\right)^2 \right]^{1/2}$$

   where σ_x, σ_y and τ_{xy} are the stresses of an element in the finite element mode, and A_x, A_y and A_{xy} are constants.

   To construct the Von-Mises stress formula by the **TRIMADD** bulk data card, it is required first to specify three **TRIMFNC** bulk data cards which define three trim functions referring to σ_x, σ_y and τ_{xy} stresses of an element, respectively. The identification numbers of these **TRIMFNC** cards, for instance, are ID_1, ID_2 and ID_3. The entries of the **TRIMADD** bulk data card are

   for the term $-\dfrac{\sigma_x\ \sigma_y}{A_x\ A_y}$:

   $S_0 = -\dfrac{1}{A_x}$, $F_0 = ID_1$, $C_0 = 1.0$ SYMBOL$_1$ = '*', $S_1 = \dfrac{1}{A_y}$, $F_1 = ID_2$, $C_1 = 1.0$, $E_1 = 1.0$

   for the term $\left(\dfrac{\sigma_x}{A_x}\right)^2$: SYMBOL$_2$ = '+', $S_2 = \dfrac{1}{A_x^2}$, $F_2 = ID_1$, $C_2 = 2.0$, $E_2 = 1.0$

   for the term $\left(\dfrac{\sigma_y}{A_y}\right)^2$: SYMBOL$_3$ = '+', $S_3 = \dfrac{1}{A_y^2}$, $F_3 = ID_2$, $C_3 = 2.0$, $E_3 = 1.0$

   for the term $\left(\dfrac{\tau_{xy}}{A_{xy}}\right)^2$: SYMBOL$_4$ = '+', $S_4 = \dfrac{1}{A_{xy}^2}$, $F_4 = ID_3$, $C_4 = 2.0$,

   and finally $E_4 = 0.5$.

TRIMCON

Constraint Functions for the Static Aeroelastic/Trim Analysis

Description: Defines a set of constraint functions (G_i) to be satisfied for solving the over-determined trim system. G_i is defined as:

$$G_i = (F_i - S_i)^{E_i} \quad < \text{ or } > \quad V_i$$

where F_i represents the value of a trim function.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TRIMCON	IDCONS								CONT
CONT	$IDFNC_1$	S_1	E_1	$GTORLT_1$	$VALUE_1$				CONT
CONT	$IDFNC_2$	S_2	E_2	$GTORLT_2$	$VALUE_2$				CONT
CONT	-etc-								

TRIMCON	101								+T1
+T1	100	0.0	1.0	GT	100.0				+T2
+T2	200	1.0	2.0	LT	200.0				+T3
+T3	205	0.0	2.0	GT	0.33				

Field	Contents
IDCONS	Unique identification number (Integer > 0) (See Remark 1)
$IDFNC_i$	Identification number of a **TRIMFNC** or **TRIMADD** bulk data card whose value is represented by the symbol F_i shown in the above equation (Integer > 0)
S_i and E_i	Real coefficients shown in the above equation (Real) Note: E_i cannot be zero.
$GTORLT_i$	Character string either "GT" or "LT" (Character) "GT" represents that $(F_i - S_i)^{E_i}$ must be greater than V_i "LT" represents that $(F_i - S_i)^{E_i}$ must be less than V_i
$VALUE_i$	Constraint value represented by the symbol V_i shown in the above equation (Real)

Remarks:

1. IDCONS is referred to by the **TRIM** bulk data card. The **TRIMCON** bulk data card is active only for the over-determined trim system. All G_i serve as a set of constraint functions that must be satisfied simultaneously by the trim variables.
2. Since $(F_i - S_i)$ could be negative, the user must select proper values of E_i to avoid complex number resulting from the constraints functions.

TRIMFNC **Trim Function**

Description: Defines a trim function whose value is dependent on the trim variables and trim degrees of freedom.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TRIMFNC	IDFNC	TYPE	LABEL	RHS	ISSET	IASET	REMARK		
TRIMFNC	10	MODAL	DMI	LHS	MATRIXR	MATRIXL	STRESS.AT.CBAR		

Field	Contents
IDFNC	Unique identification number (Integer > 0) (See Remark 1)
TYPE	Character string. One of "AERO", "FEM" or "MODAL" (Character) TYPE = "AERO" the trim function is evaluated based on the aerodynamic model TYPE = "FEM" the trim function is evaluated based on the structural finite element model TYPE = "MODAL" the trim function is evaluated based on the user supplied modal data
LABEL	Character string that must match one of the following characters:

For TYPE = "AERO"

Characters	Description
CDL	Induced drag coefficient. Please see the definition of C_d in the **TRIMVAR** bulk data card.
CY	Side force coefficient. Please see the definition of C_y in the **TRIMVAR** bulk data card.
CL	Lift coefficient. Please see the definition of C_L in the **TRIMVAR** bulk data card.
CR	Roll moment coefficient. Please see the definition of C_l in the **TRIMVAR** bulk data card.
CM	Pitch moment coefficient. Please see the definition of C_m in the **TRIMVAR** bulk data card.
CN	Yaw moment coefficient. Please see the definition of C_n in the **TRIMVAR** bulk data card.
CP	Center of aerodynamic pressure. $CP = -\frac{CM}{CL} \times REFC$

Characters	Description
NX, NY, NZ, PDOT, QDOT, or RDOT	The acceleration of the trim degrees of freedom is defined as a trim function.
TRIMVAR	The value of a trim variable is defined as the trim function. The identification number of the trim variable is specified in the ISSET entry of the **TRIMFNC** bulk data card.
LOADMOD	The component loads due to the aerodynamic loads at a set of aerodynamic boxes that are specified in SETK entry of the **LOADMOD** bulk data card is defined as the trim function. The identification number of the **LOADMOD** bulk data card is defined in the ISSET entry of the **TRIMFNC** bulk data card. (See Remark 2)

<u>For TYPE = “FEM”</u>

LABEL can either be “LOADMOD”, “LOADMOD1”, “GRIDDISP”, or “FORCE”.

Characters	Description
LOADMOD	The component loads due to the aerodynamic loads and inertial loads at a set of structural finite element grid points that are specified in the SETG entry of the **LOADMOD** bulk data card is defined as the trim function. The identification number of the **LOADMOD** bulk data card is defined in the ISSET entry of the **TRIMFNC** bulk data card. (See Remark 2)
LOADMOD1	Same as LABEL = “LOADMOD” except the aerodynamic component loads are obtained by integrating the aerodynamic pressure over those aerodynamic boxes defined by the SETK entry of the **LOADMOD** bulk data card. Note that for LABEL = “LOADMOD,” the aerodynamic forces are first transferred from the aerodynamic grids to the structural grids using the spline matrix. Then, the aerodynamic component loads are obtained by integrating the aerodynamic forces at those structural grids defined by the SETG entry of the **LOADMOD** bulk data card. Because of the force transferral using the spline matrix, the conservation of forces is not always ensured. On the other hand, for LABEL = “LOADMOD1,” because there is no force transferral involved, it gives the most accurate results of the component loads.
GRIDDISP	The displacement at a structural finite element grid point is defined as the trim function. The grid point identification number is specified in the ISSET entry and the component number is specified in the IASET entry (see Remark 2).
FORCE	The force at a structural finite element grid point is defined as the trim function. The grid point identification number is specified in the ISSET entry and the component number is specified in the IASET entry.

<u>For TYPE = “MODAL”</u>

The resultant value from the superposition of the modal data of the flexible aircraft is defined as a trim function. LABEL must be either "AEFACT" or "DMI".

Characters	Description
LABEL = "AEFACT"	The modal data is specified by the **AEFACT** bulk data card. The identification number of the **AEFACT** bulk data card for the symmetric (or asymmetric) modal data is specified in the ISSET entry whereas the anti-symmetric modal data in the IASET entry. (See Remark 3)
LABEL = "DMI"	The modal data is imported either by the **DMI** bulk data card or the **'ASSIGN MATRIX='** Executive Control Command. The name of the matrix that contains the symmetric (or asymmetric) modal data is specified in the ISSET entry whereas the anti-symmetric modal data in the IASET entry. (See Remark 3)
LABEL = "PCHFILE"	For the structural parameters defined by a **PCHFILE** bulk data card. ISSET and IASET are the identification number of a **PCHFILE** bulk data card that imports a NASTRAN punch output file containing the symmetric and anti-symmetric modal values of element forces, stresses, or strains, respectively. The trim results of all structural parameters listed in the $ELLST_i$ and $FIELD_i$ entries of the **PCHFILE** bulk data card are printed out. Note that for output, the LABEL and ISSET entries of the **TRIMFNC** bulk data card are replaced by the $LABEL_i$ and $ELLST_i$ entries of the **PCHFILE** bulk data card, respectively.

RHS Character string to specify whether the trim function is evaluated on the right hand side (RHS) or the left hand side (LHS) of the configuration. (Character) (See Remark 4)
Two options are available:
RHS = "RHS" on the right side of the configuration
RHS = "LHS" on the left hand side of the configuration

ISSET ISSET is active only if the trim system is asymmetric or symmetric. (Integer or Character)

ISSET is used only for (1) TYPE = "AERO" and LABEL = "TRIMVAR" or "LOADMOD"
(2) TYPE = "FEM" and LABEL = "LOADMOD", or
(3) TYPE = "MODAL".

(1) TYPE = "AERO"
LABEL = "TRIMVAR" ISSET is an integer that is the identification number of a **TRIMVAR** bulk data card listed in the **TRIM** bulk data card.
LABEL = "LOADMOD" or "LOADMOD1" ISSET is an integer that is the identification number of a **LOADMOD** bulk data card.

(2) TYPE = “FEM”
LABEL = “LOADMOD”
or "LOADMOD1" — ISSET is an integer that is the identification number of a **LOADMOD** bulk data card.

LABEL = “GRIDDISP” / LABEL = “FORCE” — ISSET is an integer that is the identification number of a structural finite element grid point.

(3) TYPE = “MODAL”

LABEL = “AEFACT” — ISSET is an integer that is the identification number of the **AEFACT** bulk data card containing the modal data associated with the symmetric modes. The number of data must be the same as the number of the symmetric modes. Used only for symmetric or asymmetric trim system.

LABEL = “DMI” — ISSET is a character string that is the name of the matrix imported either by the **DMI** bulk data card or **‘ASSIGN MATRIX=’** Executive Control Command. The modal data contained in the matrix is associated with symmetric modes. The number of rows of the matrix must be the same as the symmetric modes. Used only for symmetric or asymmetric trim system.

LABEL = “PCHFILE” — ISSET is an integer that is the identification number of a **PCHFILE** bulk data card to specify the symmetric (or asymmetric) modal data

IASET — IASET is active only for anti-symmetric or asymmetric trim system.

(1) TYPE = “MODAL”

LABEL = “AEFACT” — IASET is an integer that is the identification number of the **AEFACT** bulk data card containing the modal data associated with the anti-symmetric modes. The number of modal data must be the same as the number of anti-symmetric modes.

LABEL = “DMI” — IASET is a character string that is the name of the matrix imported either by the **DMI** bulk data card or **‘ASSIGN MATRIX=’** Executive Control Command. The modal data contained in the matrix is associated with the anti-symmetric modes. The number of rows of the matrix must be the same as the number of anti-symmetric modes.

LABEL = “PCHFILE” — Same as ISSET but for the anti-symmetric modal data.

(2) TYPE = “FEM”
LABEL = “GRIDDISP”
or = “FORCE”, — The component number of the displacement at the structural finite element grid point whose identification number is specified by ISSET (Integer, either 1, 2, 3, 4, 5, or 6).

REMARK — Character String up to 16 with <u>no</u> embedded blanks to give description of the trim function (Character) (See Remark 5)

Remarks:

1. IDFNC is referred to by the **TRIMOBJ** and **TRIMCON** bulk data cards to define the objective function and constraint functions for over-determined trim systems. IDFNC can also be referred to by the **TRIM** bulk data card through the **SET1** or **SETADD** bulk data card to print out the values of the trim functions.

2. For TYPE = "FEM", the component loads include the aerodynamic and inertial loads. In this case, the matrix [SMGH] must be imported by the **'ASSIGN MATRIX='** Executive Control Command with MNAME = 'SMGH' for symmetric trim system (trim degrees of freedom involving only NX, NY and/or QDOT). For anti-symmetric trim system (trim degrees of freedom involving only NY, PDOT and/or RDOT), the matrix [AMGH] must be imported by the **'ASSIGN MATRIX='** Executive Control Command with MNAME = 'AMGH'. For asymmetric trim system (trim degrees of freedom involve both symmetric and anti-symmetric trim systems), both [SMGH] and [AMGH] matrices must be imported. It should be noted that if the computation of inertial loads is invoked, the SUPORT entry in the **'ASSIGN FEM='** Executive Control Command must be specified to define the degrees of freedom of the rigid body modes of the structural finite element model.

   Note: The sign of the component loads is defined in the structural finite element basic coordinate that is specified by the ACSID entry of the **AEROZ** bulk data card.

3. Since the ZONAIR static aeroelastic/trim analysis employs the modal approach to solve the trim system of the flexible aircraft, any structural quantities such as element stresses, forces, displacements, etc, can be obtained by the superposition of their respective modal data of each mode. These modal data must be imported from the structural finite element analysis. For instance, to obtain the modal data of stress by NASTRAN, the user can use the **NASTRAN** Case Control Command such as STRESS=ALL in the NASTRAN free vibration analysis. The user can select the modal stresses of a particular element or a group of element of interest and import these data to ZONAIR by the **AEFACT** bulk data card (for one element), **DMI** bulk data card or **'ASSIGN MATRIX='** Executive Control Command (for a group of elements).

   Note: If LABEL = "DMI" or "PCHFILE" is specified, the **TRIMFNC** bulk data card can represent many trim functions. The number of trim functions depends on the number of columns of the matrix.

4. For a symmetric configuration (XZSYM = "YES" in the **AEROZ** bulk data card), ZONAIR requires only the modeling of half of the configuration. For asymmetric trim system, ZONAIR superimposes the results of the symmetric trim system and the anti-symmetric trim system to obtain the results on both sides of the configuration. The entry RHS is used only if LABEL = "TRIMVAR" or "LOADMOD" for TYPE = "AERO", TYPE = "FEM" and TYPE = "MODAL". For asymmetric configuration (XZSYM = "NO" in the **AEROZ** bulk data card), RHS must be "RHS".

5. Since all entries of the bulk data cards cannot have embedded blanks, the blanks for separating words will lead to a fatal error. For instance, the description "STRESS AT CBAR" has embedded blanks which are not allowed. To circumvent this problem, it is recommended to use a period (".") between the words such as "STRESS.AT.CBAR".

TRIMINP Imports Pressure Derivatives

Description: Replaces the program computed pressure derivatives of a trim variable by the user supplied values.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TRIMINP	IDINP	A1	INPCFD1	A2	INPCFD2	FORM	FILENM		
TRIMINP	100	-2.0	-200	2.0	-250	TECPLOT	TRIM_CP.PLT		

Field	Contents
IDINP	Identification number that is referred to by the **TRIMVAR** bulk data card. (Integer > 0) (See Remark 1)
A1	A factor applied to the imported pressure coefficients by the entry INPCFD1. (Real) (See Remark 2)
INPCFD1	A negative integer referring to an **INPCFD**, **INPCFD1**, **INPDMI**, **CPSPLNL** or **CPSPLN** bulk data card that imports the first set of user supplied pressure coefficients. (Integer ≤ 0) (See Remark 3)
A2	Same as A1 except for INPCFD2.
INPCFD2	Same as INPCFD1 except for the second set of user supplied pressure coefficients. (Integer ≤ 0)
FORM	Format of the output file “FILENM” FORM = “TECPLOT” for generating the TECPLOT file FORM = “PATRAN” for generating the PATRAN neutral/results file FORM = “IDEAS” for generating an I-DEAS universal file FORM = “FEMAP” for generating a FEMAP neutral file FORM = “ANSYS” for generating an ANSYS supported neutral file FORM = “NASTRAN” for generating a NASTRAN bulk data deck (Character, Default = “TECPLOT”).

FILENM — The name of the data file in which the data for plotting the imported pressure derivatives on the aerodynamic model is stored. This file name is always in the upper case. In case the input file name is given in the lower case, the program converts it to the upper case. If the first character of FILENM starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character or Blank)

Remarks:

1. The **TRIMINP** bulk data card is referred to by the **TRIMVAR** bulk data card. The pressure derivatives (dC_p/d (trim variable)) computed by the program of a trim variable on the rigid aircraft is replaced by those imported by the **TRIMINP** bulk data card. Once these pressure derivatives are replaced, the aerodynamic stability derivatives of the trim variable are recomputed accordingly in the trim analysis.

2. A1, INPCFD1, A2 and INPCFD2 jointly construct the pressure derivatives of a trim variable. For instance, if the first set of pressure coefficients is at angle of attack = 1.0 degrees and the second set pressure coefficients at angle of attack = 1.5 degrees, the pressure derivatives of the trim variable "ALPHA" (See description of the **TRIMVAR** bulk data card) are computed as:

$$dC_p \,/\, d(\,ALPHA\,) = \frac{(INPCFD2)-(INPCFD1)}{1.5-1.0} = 2.0(INPCFD2 - INPCFD1)$$

   where INPCFD1 and INPCFD2 represent the first and second sets of the imported pressure coefficients

   Therefore, A1 = -2.0 and A2 = 2.0

   For the trim variable "THKCAM", INPCFD2 can be blank so that the mean flow pressure coefficients are those imported by INPCFD1 with A1 = 1.0.

   It should be noted that the unit of the pressure derivatives is in 1.0/degree for "ALPHA", "BETA" and all control surfaces. For trim variables "PRATE", "QRATE", and "RRAET", the unit is in 1.0/(pb/2V), 1.0/(qc/2V) and 1.0/(rb/2V), respectively.

3. INPCFD1 and INPCFD2 must be negative to refer to an **INPCFD**, **INPCFD1**, **INPDMI**, **CPSPLNL** or **CPSPLN** bulk data card that has a negative identification number.

   It should be noticed that if the entry INPCFD refers to a **INPCFD** or **INPCFD1** bulk data card and the **TRIMVAR** bulk data card that the **TRIMINP** bulk data card is referred to is a control surface trim variable, the pressure interpolation from the CFD surface mesh to ZONAIR panel model may introduce incorrect interpolated pressure. This is because the pressure interpolation scheme performed by the **TRIMINP** bulk data card is based on the closest-point approach. For a control point on a ZONAIR panel, the **INPCFD/INPCFD1** bulk data card finds the closest CFD point then takes the CFD computed pressure at this point to replace the ZONAIR computed pressure on the ZONAIR panel. This closest-point approach normally is accurate if the trim variable defined by the **TRIMVAR** bulk data card is THKCAM, ALPHA or BETA. This is because the surface of the aerodynamic configuration defined by both CFD surface mesh and ZONAIR panel model match with each other. However, if the **TRIMVAR** bulk data card is a control surface trim variable, the CFD surface mesh is the one with deflected control surface while the ZONAIR panel model is the one without deflected control surface. In this case the closest-point approach may take incorrect CFD pressure from the CFD surface point to replace the pressure on the ZONAIR panel. To circumvent this problem, one can follow the steps described below:

(1) Defines an **AEROGEN** bulk data card that specifies the control surface deflection angle to be the same as that of the CFD surface mesh. Based on the control surface deflection angle, the **AEROGEN** bulk data card can internally create a panel model that shares the same surface definition as the CFD surface mesh with the deflected control surface.

(2) Specifies an **INPCFD**/**INPCFD1** bulk data card whose identification number is the same as that of the **AEROGEN** bulk data card. The **INPCFD**/**INPCFD1** bulk data card is the one defined by the entry INPCFD of the **TRIMINP** bulk data card is referring to.

(3) Executes the **AEROGEN** bulk data card to replace the ZONAIR computed pressures by those computed by CFD. These interpolated pressures are accurate since both CFD surface mesh and ZONAIR panel model have the same deflected control surface.

(4) Specifies a **PLTCP** bulk data card with the entry FORM=”OUTPUT4” to export the interpolated pressures on ZONAIR panel model on a file.

(5) For the trim analysis, uses the ‘**ASSIGN MATRIX**=’ executive control command to import this interpolated pressures on ZONAIR panel model.

(6) In the **TRIMINP** bulk data card, instead of referring to the **INPCFD**/**INPCFD1** bulk data card, the entry INPCFD refers to an **INPDMI** bulk data card whose matrix name matches with that specified in the ‘**ASSIGN MATRIX**=’ executive control command.

TRIMLNK — Trim Variable Linking

Description: Defines a set of coefficient and trim variable identification number pairs for trim variable linking.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TRIMLNK	IDLINK	SYM	$COEFF_1$	$IDVAR_1$	$COEFF_2$	$IDVAR_2$	$COEFF_3$	$IDVAR_3$	CONT
CONT	$COEFF_4$	$IDVAR_4$	-etc-						

TRIMLNK	10	SYM	1.0	100	0.5	200			

Field	Contents
IDLINK	Unique identification number (Integer > 0) (See Remark 1)
SYM	Character string to define the type of aerodynamic stability derivatives that are generated by the trim variable linking (Character) (See Remark 2) SYM = “SYM” for longitudinal stability derivatives SYM = “ANTI” for lateral stability derivatives SYM = “ASYM” for both longitudinal and lateral stability derivatives
$COEFF_i$	Coefficient to define the linear relationship between the dependent and independent trim variables (Real) (See Remark 3)
$IDVAR_i$	Identification number of a **TRIMVAR** bulk data card to define a dependent trim variable (Integer > 0) (See Remark 3)

Remarks:

1. IDLINK is referred to by the TIMLNK entry in the **TRIMVAR** bulk data card. The trim variable defined in the **TRIMVAR** bulk data card that refers to IDLINK is called “independent trim variable” whereas the trim variables whose identification numbers are listed in $IDVAR_i$ entries of the **TRIMLNK** bulk data cards are called “dependent trim variables.” The **TRIMLNK** bulk data card provides a feature that allows the user to establish a linear relationship between the dependent trim variables and the independent trim variable. For instance, the deflections of the leading edge and trailing edge flaps of fighters are often scheduled according to the angle of attack for optimum lift to drag ratio. To model such a so-called “flap-scheduling” control surfaces, the user can specify ALPHA to be the independent trim variable and the leading and trailing edge flaps as the dependent trim variables.

2. The type of aerodynamic stability derivative generated by both independent and dependent trim variables must be the same. Thus, the SYM entry in the **TRIMLNK** bulk data card serves as input

error detector. If the SYM entry is different from the SYM entries specified in the **TRIMVAR** bulk data cards, a fatal error occurs.

3. The resulting aerodynamic stability derivatives of the variable-linked trim variable are computed based on the following equation:

$$\begin{pmatrix} \text{Resulting Aerodynamic} \\ \text{Stability Derivatives} \end{pmatrix} = \begin{pmatrix} \text{Aerodynamic Stability} \\ \text{Derivatives of the} \\ \text{Independent} \\ \text{Trim Variable} \end{pmatrix} + \sum_i \text{Coeff}_i \begin{pmatrix} \text{Aerodynamic Stability} \\ \text{Derivatives of the} \\ \text{i}^{\text{th}} \text{ Dependent} \\ \text{Trim Variable} \end{pmatrix}$$

TRIMOBJ

Objective Function for the Static Aeroelastic/Trim Analysis

Description: Defines an objective function to be minimized for solving the over-determined trim system. The objective function (*OBJ*) is defined as:

$$OBJ = \sum_{i=1} \left[C_{1i} (F_i - S_{1i})^{E_{1i}} + C_{2i} (F_i - S_{2i})^{E_{2i}} \right]^{E_i}$$

where F_i is the value of a trim function.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TRIMOBJ	IDOBJ								CONT
CONT	IDFNC$_1$	C1$_1$	S1$_1$	E1$_1$	C2$_1$	S2$_1$	E2$_1$	E$_1$	CONT
CONT	IDFNC$_2$	C1$_2$	S1$_2$	E1$_2$	C2$_2$	S2$_2$	E2$_2$	E$_2$	CONT
CONT	-etc-								

TRIMOBJ	10								+T1
+T1	100	0.001	0.0	2.0	0.0	0.0	0.0	1.0	+T2
+T2	201	1.0	100.0	1.0	1.0	90.0	1.0	2.0	

Field	Contents
IDOBJ	Unique Identification number (Integer > 0) (See Remark 1)
IDFNC$_i$	Identification number of an **TRIMFNC** or **TRIMADD** bulk data card whose value is represented by the symbol F_i shown in the above equation (Integer > 0)
C1$_i$, S1$_i$, E1$_i$, C2$_i$, S2$_i$, E2$_i$, and E$_i$	Real coefficients shown in the above equation (Real) (See Remark 2) Note: Only E$_i$ cannot be zero.

Remarks:

1. IDOBJ is referred to by the **TRIM** bulk data card. The **TRIMOBJ** bulk data card is active only for the over-determined trim system. The resulting objective function is the summary of a set of trim functions combined according to the equation shown above.

2. Since $(C_{1i} \; F_i - S_{1i})$ or $(C_{2i} \; F_i - S_{2i})$ could be negative, the user must select proper value of $E1_i$, $E2_i$ and E_i to avoid complex number resulting from the objective function.

TRIMSEN

Sensitivity Analysis

Description: Assigns a list of name of direct matrix input as design variables for Trim analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TRIMSEN	IDSEN	IDFLT	FILENM						CONT
CONT	LABEL1	THICK1	MASS1	STIFF1	LABEL2	THICK2	MASS2	STIFF2	CONT
CONT	-etc-								

TRIMSEN	10								+T1
+T1	QUAD1	0.1	DMIG1	DMIG2	QUAD2	0.03	DMIG3	DMIG4	+T2
+T2	ROD1	0.2	DMIG5	DMIG6					

Field	Contents
IDSEN	Unique identification number. (Integer > 0) (See Remark 1)
IDFLT	Identification number of a **TRIM** Case Control Command of which the sensitivities of a response will be computed. (Integer > 0) (See Remark 2)
FILENM	Character string to specify a file name on which the sensitivities of the forces at structural grid points are stored. If the first character starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input (Character or Blank)
LABEL*i*	Any character string to define the name of the design variable. LABEL*i* is used only for identifying the design variable in the output. (Character)
THICK*i*	THICK*i* could represent the thickness of a membrane element, the area of a rod element or area moment of inertia of a beam element. (Real > 0.0) (See Remark 3)
MASS*i*	Character string that matches the entry NAME of a **DMIG/DMI** bulk data card or MNAME of **′ASSIGN MATRIX=′** Executive Control Command. This matrix is used as the elementary mass matrix of the design variable with value of THICK*i*. (Character)
STIFF*i*	Character string that matches the entry NAME of a **DMIG/DMI** bulk data card or MNAME of **′ASSIGN MATRIX=′** Executive Control Command. This matrix is used as the elementary stiffness matrix of the design variable with value of THICK*i*. (Character)

Remarks

1. IDSEN is used for error message output only.

2. The **TRIMSEN** bulk data card refers to a **TRIM** Case Control Command by the entry IDFLT. One **TRIMSEN** bulk data card can specify multiple design variables. The derivatives of the trim responses with respect to the unit value of each design variable will be computed as the sensitivity analysis. These trim responses are specified in the **TRIMFNC** bulk data cards that are referred to by the **TRIM** bulk data card through a **SET1** bulk data card.

3. It is assumed that the elementary mass and stiffness matrices are linearly varying with respect to the design variables. Therefore, the derivatives of the total mass and stiffness matrices can be obtained by dividing MASS*i* and STIFF*i* by THICK*i*. Specifically, the derivatives of the total mass (M_{gg}) and stiffness (K_{gg}) matrices defined at the Structural *g-set* degrees of freedom with respect to V_i are:

$$\frac{\partial M_{gg}}{\partial V_i} = \frac{[MASSi]}{THICKi}, \frac{\partial K_{gg}}{\partial V_i} = \frac{[STIFFi]}{THICKi}$$

   where V_i represents the i^{th} design variable.

TRIMVAR

Trim Variable Bulk Data Card

Description: Defines a trim variable for the static aeroelastic/trim analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
TRIMVAR	IDVAR	LABEL	LOWER	UPPER	TRIMLNK	DMI	SYM	INITIAL	CONT
CONT	DCD	DCY	DCL	DCR	DCM	DCN			

TRIMVAR	100	ALPHA	-50.0	50.0	10	AFORCE	SYM		+T1
+T1	0.01	NONE	NONE	NONE	NONE	NONE			

Field	Contents
IDVAR	Unique identification number (Integer > 0) (See Remark 1)
LABEL	Character string to define the trim variable (Character, cannot be blank) (See Remark 2)
LOWER	The lower limit of the trim variable. Active only for the over-determined trim system. (Real, Default = - 1.0×10^{30})
UPPER	The upper limit of the trim variable. Active only for the over-determined trim system. (Real, Default = + 1.0×10^{30}) (See Remark 3) Note: UPPER must be greater than LOWER.
TRIMLNK	Identification number of a **TRIMLNK** bulk data card for trim variable linking. (Integer ≥ 0) (See Remark 4)
DMI	Optional input to replace the program computed derivative of the pressure coefficients on the rigid aircraft with respect to the trim variable by the user-supplied values If DMI is a character string, this character string is the NAME entry of a **DMI** bulk data card or the MNAME entry of an **'ASSIGN MATRIX='** Executive Control Command that contains the user supplied dC_p / d(trim variable). If DMI is an integer, this integer is the identification number of a **TRIMINP** bulk data card that defines the user supplied dC_p / d(trim variable). (Character, integer or Blank) (See Remark 5)
SYM	Character string to define the types of the aerodynamic stability derivative generated by the trim variable. (Character) (See Remark 6) SYM = "SYM" for longitudinal stability derivative SYM = "ANTI" for lateral stability derivative SYM = "ASYM" for both longitudinal and lateral stability derivatives

INITIAL	Initial guess of the trim variable for the minimization computation of an over-determined trim system (Real)
DCD, DCY, DCL, DCR, DCM, DCN	User input aerodynamic stability derivatives of the rigid aircraft. (Character or Real, default = "NONE") (See Remark 7) Two options are available: Character "NONE" — use program-computed value Real Value — user input value to replace the program-computed value

Remarks:

1. IDVAR is referred to by the IDVAR*i* entry in the **TRIM** bulk data card.

2. There are three types of trim variable:

- *The Program-Assigned Trim Variables*

  The program-assigned trim variables are those variables whose aerodynamic stability derivatives and the derivatives of the distributed aerodynamic pressures are computed internally by the program. Each program-assigned trim variable has a "hot-wired" label. If the character string specified in the LABEL entry matches the hot-wired label, the program internally computed aerodynamic stability derivatives are used for solving the trim system. These program-assigned trim variables are listed as follows:

Hot-Wired Label	Description	Unit	Type of Aerodynamic Stability Derivatives
ALPHA	Angle of Attack	degree	Longitudinal Stability Derivative
BETA	Side Slip Angle	degree	Lateral Stability Derivative
PRATE	Roll Rate	pb / 2V	Lateral Stability Derivative
QRATE	Pitch Rate	qc / 2V	Longitudinal Stability Derivative. QRATE can be pre-determined by $\text{QRATE} = \left[\frac{(N_z - 1)g}{V}\right]\frac{C}{2V}$ where N_z is the load factor, g is the acceleration due to gravity, V is the velocity, and C is the reference chord (REFC defined in the **AEROZ** bulk data card)

RRATE	Yaw Rate	rb / 2V	Lateral Stability Derivative
THKCAM	Aerodynamic load at the mean Flow Condition defined by the **AEROGEN** bulk data card. If **INPDMI** or **INPCFD/INPCFD1** bulk data card is used to replace ZONAIR computed pressures with the imported pressures, the loads at the mean flow condition are based on the imported loads.	None	Longitudinal aerodynamic forces and moments. It is recommended that THKCAM always be included for the symmetric trim system with entry VAL = 1.0 in the **TRIM** bulk data card.

where *p*, *q* and *r* are the roll rate, pitch rate and yaw rate (in rad/sec), respectively, about the aerodynamic moment center REFX, REFY and REFZ defined in the **AEROZ** bulk data card. *b* and *c* are the reference span (REFB) and reference chord (REFC) defined in the **AEROZ** bulk data card. *V* is the free-stream velocity and is not required for input.

The longitudinal aerodynamic stability derivatives are:

$$\frac{d(C_d)}{d(\text{trim variable})} \qquad \frac{d(C_L)}{d(\text{trim variable})} \qquad \frac{d(C_m)}{d(\text{trim variable})}$$

The lateral aerodynamic stability derivatives are:

$$\frac{d(C_y)}{d(\text{trim variable})} \qquad \frac{d(C_l)}{d(\text{trim variable})} \qquad \frac{d(C_n)}{d(\text{trim variable})}$$

where $C_d = \dfrac{D}{q_\infty S}$, D is the drag force,

$C_L = \dfrac{L}{q_\infty S}$, L is the lift force,

$C_m = \dfrac{M_y}{q_\infty S c}$, M_y is the pitch moment about REFX, REFY and REFZ,

$C_y = \dfrac{Y}{q_\infty S}$, Y is the side force,

$C_\ell = \dfrac{M_x}{q_\infty S b}$, M_x is the roll moment about REFX, REFY and REFZ,

$C_n = \dfrac{M_z}{q_\infty S b}$, M_z is the yaw moment about REFX, REFY and REFZ,

and

q_∞ is the dynamic pressure, S is the reference area (REFS), c is the reference chord (REFC) and b is the reference span (REFB).

Note: All aerodynamic stability derivatives are for both sides of the configuration even if only half of the configuration (XZSYM = "YES" in the **AEROZ** bulk data card) is modeled.

- *Control Surface Type of the Trim Variables*

  The control surface type of the trim variables are those defined in the **AESURFZ**, **AESLINK, PZTMODE**, **JETFRC**, and **GRIDFRC** bulk data cards. If the character string specified in the LABEL entry of the **TRIMVAR** bulk data card matches the LABEL entry of **AESURFZ**, **AESLINK, PZTMODE**, **JETFRC** or **GRIDFRC**, the program-computed aerodynamic stability derivatives of the control surfaces (**AESURFZ**, **AESLINK, PZTMODE**, **JETFRC**, or **GRIDFRC**) are used for solving the trim system.

  The type of the aerodynamic stability derivatives depend on the TYPE entry in the **AESURFZ**, **AESLINK, PZTMODE**, **JETFRC**, or **GRIDFRC** bulk data cards. For TYPE = "SYM", they are the longitudinal aerodynamic stability derivatives. For TYPE = "ANTI", they are the lateral aerodynamic stability derivatives. For TYPE = "ASYM", they include both longitudinal and lateral aerodynamic stability derivatives.

  Note: The unit of the aerodynamic control surface (**AESURFZ** and **AESLINK**) is degrees. The unit of **PZTMODE**, **JETFRC** and **GRIDFRC** is defined by the users and is marked as "N/A" in the output.

- *User-Defined Trim Variables*

  The character string specified in the LABEL entry that does not match any of the program-assigned and control surface type of the trim variables are classified as user-defined trim variable. For the user-defined trim variables, the entries SYM, DCD, DCY, DCL, DCR, DCM, and DCN in the **TRIMVAR** bulk data card must be specified.

  Note: The unit of the user-defined trim variables is defined by the user and is marked as "N/A" in the output.

3. LOWER and UPPER are the so-called "side constraints" for solving the over-determined trim system. Thus, the solution of the free trim variables (defined as "FREE" in the VAL*i* entry of the **TRIM** bulk data card) must be within LOWER and UPPER.

4. If TRIMLNK = 0, then the trim variable is not linked with other trim variable. For description of trim variable linking, please see **TRIMLNK** bulk data card.

5. DMI provides a feature that allows the user to replace the program-computed dC_p / d(trim variable) of the rigid aircraft by those computed by other aerodynamic methods or wind tunnel measurement.

If DMI is a character string that is the name of a matrix, the matrix, either imported by the **DMI** bulk data card or the **'ASSIGN MATRIX='** Executive Control Command, must have one column and J-set rows, where J-set is the number of aerodynamic panels of the aerodynamic model. The sequence of the J-set is: the first group of panels starts from all CTRIA3 and CQUAD4 panels that refer to the **MATBODY** bulk data card with the lowest identification number. Within this group of panels, CTRIA3 panels are first assigned to the J-set then followed by the CQUAD4 panels. The last group of panels in the J-set are those refer to the **MATBODY** bulk data card with the highest identification number. If a thin wing is modeled by the **CAERO7** bulk data card, the last set of the J-set is the panels on the upper side of the CAERO7 macroelement followed by the panels on the lower side of the CAERO7 macroelement (see the pressure coefficient output in the standard output file).

If DMI is an integer, this integer is the identification number of a **TRIMINP** bulk data card that defines the user supplied dC_p / d(trim variable).

Note: (1) If DMI option is activated, the program computed aerodynamic stability derivatives of the rigid aircraft (DCD, DCY, DCL, DCR, DCM, and DCN) are also automatically recomputed by integrating the user supplied dC_p / d(trim variable).

(2) If DMI entry is blank, the program-computed dC_p / d(trim variable) is used for the program-assigned trim variables and control surface type of trim variables. For the user-defined trim variables, dC_p / d(trim variable) is assumed to be zero.

6. For the program-assigned trim variable and the control surface type of trim variables, the SYM entry is ignored since the types of the aerodynamic stability derivatives are already defined by the trim variables. For the user-defined trim variables, the SYM entry must be specified.

7. $\text{DCD} = \dfrac{\mathrm{d}(C_d)}{\mathrm{d(trim\ variable)}}$, $\text{DCY} = \dfrac{\mathrm{d}(C_y)}{\mathrm{d(trim\ variable)}}$,

$\text{DCL} = \dfrac{\mathrm{d}(C_L)}{\mathrm{d(trim\ variable)}}$, $\text{DCR} = \dfrac{\mathrm{d}(C_\ell)}{\mathrm{d(trim\ variable)}}$,

$\text{DCM} = \dfrac{\mathrm{d}(C_m)}{\mathrm{d(trim\ variable)}}$, $\text{DCN} = \dfrac{\mathrm{d}(C_n)}{\mathrm{d(trim\ variable)}}$

Note: For the user-defined trim variables, DCD, DCY, DCL, DCR, DCM, and DCN cannot be "NONE". Thus, all aerodynamic stability derivatives of the user-defined trim variables must be specified by real values.

VISCOUS

Viscous Vortex Model

Description: Defines the viscous parameters for computing the skin frictions and introducing the viscous vortex model of the line vortex (CROD) elements.

Format and Example:

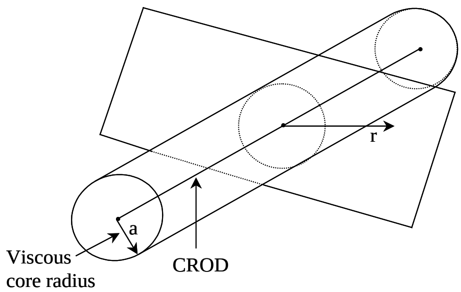
1	2	3	4	5	6	7	8	9	10
VISCOUS	SID	ALT	TYPE	A	VIS	DENS	VEL	PRES	
VISCOUS	10	NONE	LAMB	0.1	2.59E-9	1.14E-7	12000.0		

Field	Contents
SID	Unique identification number (Integer > 0)
ALT	Character string or real number. If ALT is a real number, ALT is the altitude at which the viscous parameters (entries VIS, DENS, VEL, and PRES) are automatically computed based on the standard atmospheric table; i.e. VIS, DENS, VEL, and PRES are not required for input. Note that the units of ALT is in FMLUNIT where FMLUNIT is the length unit of the aerodynamic model defined in the **AEROZ** bulk data card. If ALT = "NONE". The viscous parameters are defined in the VIS, DENS, VEL, and PRES entries (Real or Characters)
TYPE	Character to define the vortex model (Character, Default = "SCHL") (See Remark 2)
A	Radius of the viscous core (Real ≥ 0.0)
VIS	Viscosity in FMMUNIT/FMLUNIT/Sec where FMMUNIT and FMLUNIT are the mass and length units defined in the AEROZ bulk data card. Required only if ALT = "NONE" (Real, Default = 2.59e-09 slinch/inch/s)
DENS	Density in FMMUNIT/FMLUNIT**3. Required only if ALT = "NONE". (Real, Default = 1.14e-07slinch/inch**3)
VEL	Freestream velocity in FMLUNITS. Required only if ALT = "NONE". (Real, Default = 12000. inch/sec)
PRES	Pressure in FMUNIT/FMLUNIT/Sec^2. Required only if ALT = "NONE" (Real, Default = 14.69 lbf/in^2)

Remarks:

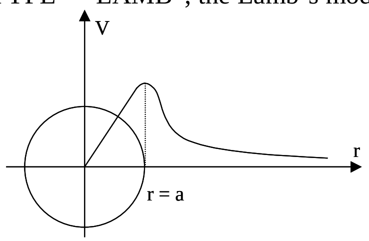
1. The **VISCOUS** bulk data card is referred to by a **MACH** bulk data card to perform two analyses. (1) Computes the aerodynamic influence from the line vortex element modeled by CROD based on the viscous core model discussed in Remark 2. This cam avoid the singularity due to the line vortex. (2) Computes the streamlines from the stagnation point to each panel and apply a two-dimensional boundary method along each streamline. This can lead to the inclusion of viscous effects in the solution such as skin friction drag. Note that if the entry VISCOUS in the **MACH** bulk data card is negative, only the first analysis is performed.

2. The following figure shows that the CROD element generates the induced velocity as a function of *r*.



For an inviscid vortex model, the induced velocity is a function of 1/*r* which is singular at *r* = 0. The **VISCOUS** bulk data card introduces a viscous core model to circumvent this singularity problem.

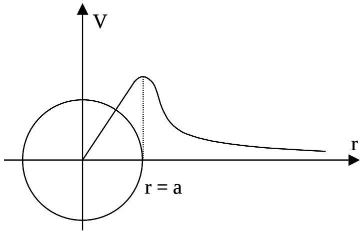
For TYPE = “LAMB”, the Lamb’s model is used. The induced velocity is shown as follows:



$$V = \frac{1}{r}\left(1 - e^{-\frac{r^2 V_\infty}{4\mu L}}\right)$$

where is the freestream velocity defined by the VEL entry, μ is defined in the VIS entry, and L is the length of the line vortex starting from the grid point specified in the GRID0 entry of the **CROD** bulk data card.

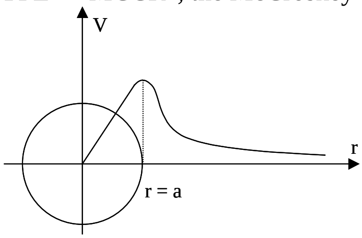
For TYPE = “SCHL”, the Schlinker’s model is used. The induced velocity is shown as follows:



$$V = \frac{1}{r}\left(1 - e^{-1.25643\left(\frac{r}{a}\right)^2}\right)$$

where *a* is the radius of the viscous core defined in the A entry.

For TYPE = “MCCR”, the McCroskey’s model is used. The induced velocity is shown as follows:



$$V = \frac{1}{r}\left(1 - e^{-\left(\frac{r}{a}\right)^2}\right)$$

VORNET — Macroelement for Vortex Roll-Up Model

Description: Defines a macroelement to automatically generate a set of CSHEAR, CROD and CBAR elements for the modeling of a vortex roll-up sheet.

Format and Example:

1	2	3	4	5	6	7	8	9	10
VORNET	IDVOR	LABEL	TIPGRID	NFED	NTIP	NWAKE	CBAR		CONT
CONT	$GRIDU_1$	$GRIDL_1$	$DIVDE_1$	$IDSET_1$	$REFSTRT_1$	$ROLLUP_1$	$REFGRID_1$		CONT
CONT		...	-etc-	...					CONT
CONT	$GRIDU_N$	$GRIDL_N$	$DIVIDE_N$	$IDSET_N$	$REFSTRT_N$	$ROLLUP_N$	$REFGRID_N$		

*N = NTIP + NFED

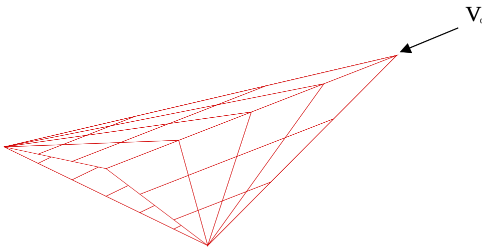
VORNET	100	VORTEX	101	10	4	0.1	YES		+V
+V	101	201	EVEN	401	10001	CYCLE	301		+V
+V	102	202	SET1	10					+V
+V	40001	40001	CDS	402	20001	LINE			

Field	Contents
IDVOR	Identification number (Integer > 0) (See Remark 1)
LABEL	An arbitrary character string used to define a label for the vortex roll-up surface (Character)
TIPGRID	Identification number of a surface grid point where the roll-up vortex starts. Note that TIPGRID can be a negative integer. This gives the generation of the roll-up vortex sheet by following the left hand rule about the vortex line. Otherwise, it follows the right hand rule. (Integer $\neq 0$) (See Remark 2)
NFED	Number of vorticity feeding points along each vortex roll-up line (Integer > 0)
NTIP	Number of vortex roll-up lines along the wing side edge in the streamwise direction (Integer > 0)
NWAKE	Number of vortex roll-up lines along the streamwise direction in the wake region (Integer ≥ 0) (See Remark 3)
CBAR	Character string either “YES” or “NO”. For CBAR = “YES,” a set of CBAR elements are automatically generated and attached to the last vortex roll-up line. (Character, Default = “YES”) (See Remark 4)

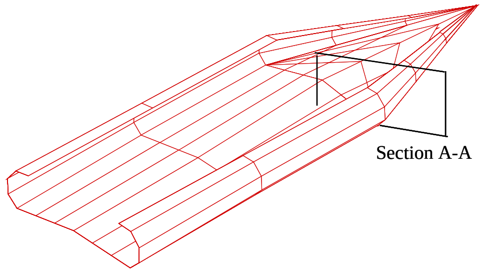
$GRIDU_i$, $GRIDL_i$	For $1 \le i \le$ NTIP, $GRIDU_i$ and $GRIDL_i$ are the identification numbers of two surface grid points located at the wing side edge where the ith roll-up vortex line starts. Note that $GRIDU_i \ne GRIDL_i$. For NTIP $< i \le$ NTIP + NWAKE, $GRIDU_i$ and $GRIDL_i$ are the identification numbers of two reference grid points located along the wake line that is shed from the wing tip. Note that $GRIDU_i = GRIDL_i$ is allowed. (Integer > 0) (See Remark 5)
$DIVIDE_i$	Character string either "SET1", "COS", or "EVEN" to define the locations of the NFED points along the ith roll-up vortex line. Note that for $DIVIDE_i \ne$ "SET1", NFED number of reference grid points will be internally generated by the program whose identification numbers start from $REFSTRT_i$ and incrementally increase by one. (Character) (See Remark 6)
$IDSET_i$	For $DIVIDE_i$ = "SET1", $IDSET_i$ is the identification number of a **SET1** bulk data card that lists NFED identification numbers of reference grid points defined by the **GRID** bulk data card with entry PS $\ne$ 0. Also, for $DIVIDE_i$ = "SET1", the entries $REFSTRT_i$, $ROLLUP_i$, and $REFGRID_i$ are not used. For $DIVIDE_i \ne$ "SET1", $IDSET_i$ is the identification number of a reference grid point where the *i*th roll-up vortex line ends. (Integer > 0) (See Remark 7)
$REFSTRT_i$	An integer to define the identification number of those reference grid points internally generated by the program. The identification of the first reference points along the ith roll-up vortex line is $REFSTRT_i$ and the last point is $REFSTRT_i$ +NFED-1. Note that $REFSTRT_i$ must be properly assigned so that among all reference grid points, no duplicated identification number occurs. (Integer > 0)
$ROLLUP_i$	Character string either "LINE" or "CIRCLE" to define the shape of the ith roll-up vortex line. (Character, Default = "CIRCLE") (See Remark 8)
$REFGRID_i$	Identification number of a reference grid point to define a plane where the *i*th roll-up vortex line is placed. This plane is constructed based on the three points, $REFGRID_i$, $IDSET_i$ and $GRIDU_i/GRIDL_i$. For $REFGRID_i$ = 0 or blank, this plane is defined by two points ($IDSET_i$ and $GRIDU_i$/ $GRIDL_i$) and a tangential vector of the panels where $GRIDU_i$ and $GRIDL_i$ are attached. (Integer $\ge$ 0 or Blank) (See Remark 9)

Remarks:

1. The **VORNET** bulk data card automatically generates a set of reference grid points and connects these points by a set of internally generated CSHEAR, CROD and CBAR elements to model the roll-up vortex shed from the wing side edge. The following figure shows a 70-degree delta wing and its sought vortex roll-up model.

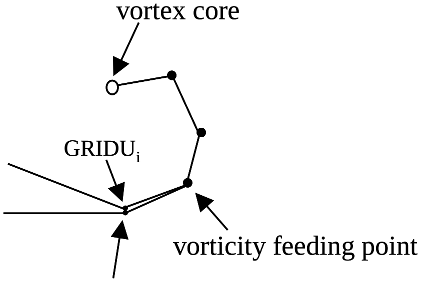


70° delta wing surface panel model

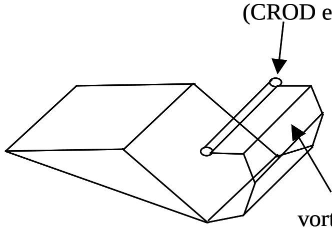


70° delta wing with vortex roll-up model

In this above figure, there are a total of 5 vortex roll-up lines, 3 at the wing leading edge and 2 in the wake region (entry NTIP = 3 and entry NWAKE = 2). The following figure is the zoom-in view of the section A-A, which depicts the structure of a vortex roll-up line.

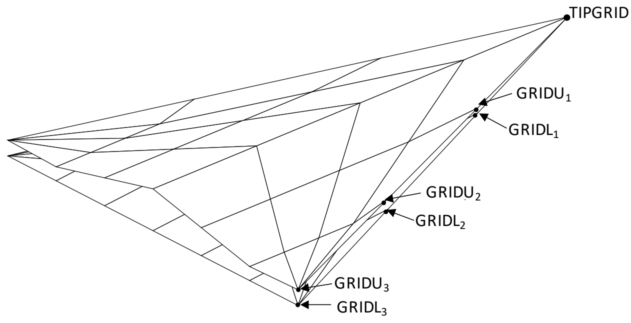


Generated by following the right hand rule
if TIPGRID > 0
Section A-A



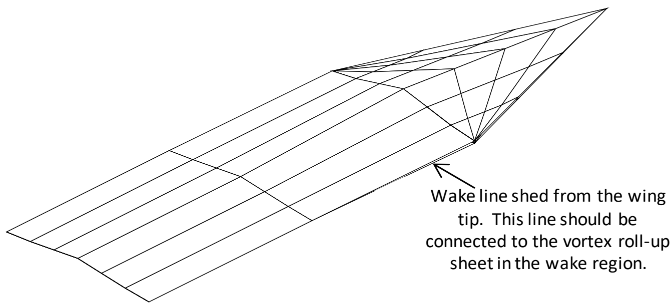
Each vortex roll-up line consists of a set of vorticity feeding points and a vortex core located at the last vorticity feeding point. In this example, there are four vorticity feeding points, therefore, entry NFED = 4. Between two vortex roll-up lines, the vortex cores are connected by a CROD element and the vorticity feeding points are connected by a set of CSHEAR elements. These CSHEAR and CROD elements and their connectivities are automatically generated by the program.

2. In order to introduce vorticity due to the potential difference between the upper and lower wing surfaces and to feed this vorticity into the vortex roll-up line, the user must first separate the surface grid points along the wing side edge into two sets of grid points except the first surface grid point at the leading edge where the vortex core starts. One set of grid points is along the upper surface and the other along the lower surface. In the following figure, the leading edge of the 70-degree delta wing is separated by two sets of three surface grid points except the first surface grid point.



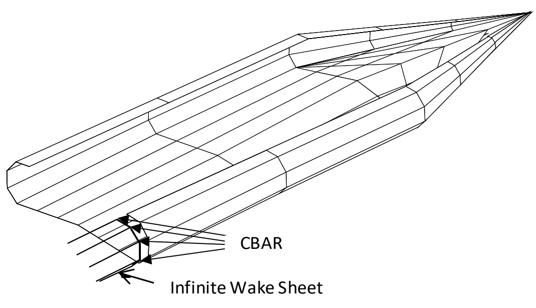
This first surface grid point is specified in the entry TIPGRID.

3. The entire vortex roll-up model should consist of three regions: the vortex roll-up sheet from the wing leading edge to the trailing edge, the vortex roll-up sheet in the wake region and the wake sheet behind the wing trailing edge. The number of vortex roll-up lines in the first region is defined by entry NTIP and in the wake region is defined by entry NWAKE. The wake sheet behind the wing trailing edge can be specified using the **WAKENET** bulk data card. An example of the wake sheet behind the wing trailing edge of the 70-degree delta wing is shown below.



This wake sheet is connected to the vortex roll-up sheet in the wake region along the wake line shed from the wing tip.

4. These program generated CBAR elements are shown in the following figure. The program consequently sweeps these CBAR elements into infinity and forms a set of infinite wake sheets.

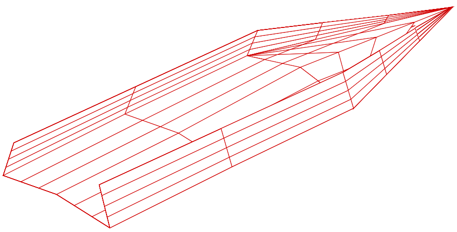


5. ZONAIR always processes the **WAKENET** bulk data cards prior to the **VORNET** bulk data cards. Therefore, if the **WAKENET** bulk data card is used to generate the wake sheet behind the wing trailing edge, a set of internally generated reference grid points due to the **WAKENET** bulk data card are available and can be referred to by the **VORNET** bulk data cards. For the *i*th vortex roll-up line in the wake region, $GRIDU_i$ and $GRIDL_i$ can be the identification numbers of those reference grid points internally generated by the WAKENET bulk data card.

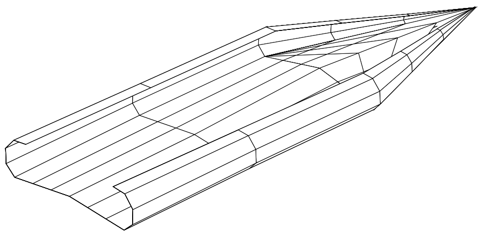
6. FOR $DIVIDE_i$ = "SET1", these reference grid points must be specified by the user (the **GRID** bulk data cards with entry PS > 0) and listed in the **SET1** bulk data card. For $DIVIDE_i$ = "COS" or "EVEN", the locations of these NFED internally generated reference grid points are defined by the entries $IDSET_i$, $REFSTRT_i$, $ROLLUP_i$ and $REFGRID_i$. Note that for $DIVIDE_i$ = "EVEN", these NFED reference grid points are evenly distributed along each vortex roll-up line. For $DIVIDE_i$ = "COS", the distribution is calculated based on the cosine function.

7. In order to determine the locations of the vorticity feeding points, the locations of the starting and ending points of each vortex roll-up line must be specified by the user. The location of the starting point is determined by the average position between $GRIDU_i$ and $GRIDL_i$ whereas the ending points where the vortex core is located must be defined by the user using a reference grid point with identification number = $IDSET_i$.

8. For $ROLLUP_i$ = "LINE", the shape of the *i*th vortex roll-up line is a straight line. For $ROLLUP_i$ = "CIRCLE", the shape is a half circle with the two ending points at the starting and ending points of the vortex roll-up line.



ROLLUP = "LINE"



ROLLUP = "CIRCLE"

9. The tangential vector is the average lateral vectors of the upper and lower panels where $GRIDU_i$ and $GRIDL_i$ are attached.

WAKENET

Wake Macroelement for Curved Wake Surface

Description: Defines a wake macroelement to automatically generate a set of CSHEAR panels for modeling a curved wake surface.

Format and Example:

1	2	3	4	5	6	7	8	9	10
WAKENET	IDWAKE	LABEL	NX	NY	SLOPE	LINE1	LINEY	LINETE	CONT
CONT	$GRIDU_1$	$GRIDL_1$	$DIVDE_1$	$IDAEF_1$	$GRIDA_1$	$GRIDREF_1$	$LENGTH_1$	$CNTLX_1$	CONT
CONT		...	-etc-	...					CONT
CONT	$GRIDU_{NY}$	$GRIDL_{NY}$	$DIVIDE_{NY}$	$IDAEF_{NY}$	$GRIDA_{NY}$	$GRIDREF_{NY}$	$LENGTH_{NY}$	$CNTLX_{NY}$	

WAKENET	101	WAKE	10	3	0.0	NONE	CROD	CBAR	+W
+W	104	106	EVEN		0		10.0	100.0	+W
+W	234	239	COS		150		8.0	50.0	+W
+W	107	207	SET1	10		103	10.0	90.0	

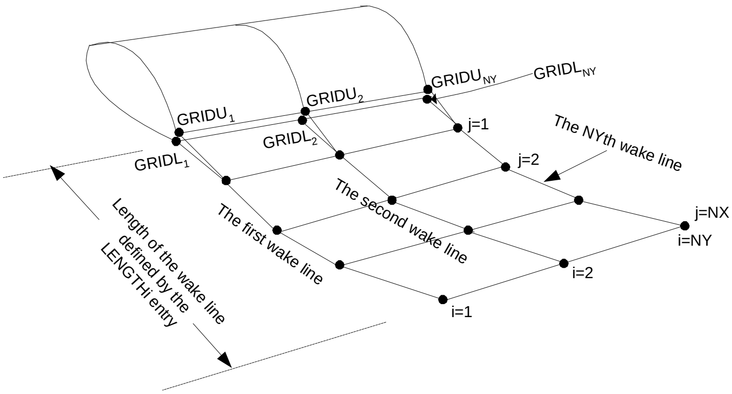
Field	Contents
IDWAKE	Identification number (Integer > 0) (See Remark 1)
LABEL	An arbitrary character string used to define a label for the wake surface (Character)
NX	Number of points along the streamwise direction of each wake line. (Integer > 0)
NY	Number of wake lines in the spanwise direction. (Integer > 1) (See Remark 2)
SLOPE	Slope in degrees specifying the angle of the wake at $CNTLX_i$. (Real, See Remark 3)
LINE1	Character string either “CROD”, “CBAR” or “NONE” For LINE1 = “CROD”, a set of CROD elements is generated along the first wake line LINE1 = “CBAR”, a set of CBAR elements is generated along the first wake line LINE1 = “NONE”, no CROD nor CBAR is generated (Character, default = “NONE”)
LINENY	Same as LINE1 but along the last wake line. (Character, default = “NONE”)
LINETE	Same as LINE1 but along the trailing edge of the wake surface. (Character, default = “CBAR”) (See Remark 4)

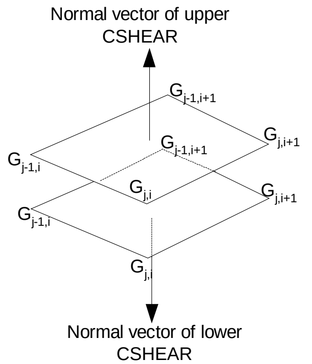
$GRIDU_i$, $GRIDL_i$	Identification number of two surface grid points usually located on the upper and lower surface at the trailing edge of a thick wing component where the *i*th wake line starts. (Integer, See Remark 5)
$DIVIDE_i$	Character string either "SET1", "AEFACT", "COS", or "EVEN" to define the streamwise location of reference grid points along the *i*th wake line. Note that for $DIVIDE_i \neq$ "SET1", NX number of reference grid points will be internally generated by the program. (Character, default = "EVEN") (See Remark 6)
$IDAEF_i$	For $DIVIDE_i$ = "SET1", $IDAEF_i$ is the identification number of a **SET1** bulk data card that lists a set of identification numbers of reference grid points defined by the **GRID** bulk data card with entry PS $\neq 0$. However, if *i*=1 (the first wake line) or *i*=NY (the last wake line), list of identification numbers of surface grid points is also allowed. Note that for $DIVIDE_i$ = "SET1", the entries $GRIDA_i$, $GRIDREF_i$, $LENGTH_i$ and $CNTLX_i$ are not used. (See Remark 7) For $DIVIDE_i$ = "AEFACT", $IDAEF_i$ is the identification number of an **AEFACT** bulk data card that lists a set of real values to define the streamwise location of the reference grid points along the ith wake line. For $DIVIDE_i$ = "COS" or "EVEN", $IDAEF_i$ is not used.
$GRIDA_i$	Identification number of a reference grid point to define the angle of the ith wake line at $GRIDU_i$ and $GRIDL_i$. For $GRIDA_i$ = 0 or blank, the program will determine the angle using the average value of the streamwise tangential angles of the panels where $GRIDU_i$ and $GRIDL_i$ are attached. Note that $GRIDA_i$ is not used if $DIVIDE_i$ = "SET1". (Integer or blank) (See Remark 8)
$GRIDREF_i$	An integer to define the identification number of those reference grid points internally generated by the program. The identification of the first reference grid point is $GRIDREF_i$ and the last point is $GRIDREF_i$ +NX-1. $GRIDREF_i$ is not used if $DIVIDE_i$ = "SET1". Note that $GRIDREF_i$ must be properly assigned so that among all reference grid points, no duplicated identification number occurs. (Integer > 0, default = 1) (See Remark 9)
$LENGTH_i$	The length of the ith wake line along the streamwise direction. $LENGTH_i$ is not used if $DIVIDE_i$ = "SET1" (Real > 0.0, default = 1.0)
$CNTLX_i$	Defines a streamwise location along the ith wake line in terms of the percentage of $LENGTH_i$. At this streamwise location, the angle of the ith wake line is imposed by the $SLOPE_i$ entry. $CNTLX_i$ is not used if $DIVIDE_i$ = "SET1." ($0.0 <$ Real ≤ 100 , Default = 100.0) (See Remark 10)

<u>Remarks:</u>

1. The **WAKENET** bulk data card automatically generates a set of reference grid points and connects these points by a set of internally generated CSHEAR elements. The identification numbers of these CSHEAR elements start from IDWAKE and incrementally increase by one. WAKENET is used to model a curved wake surface shed from the thick wing component.

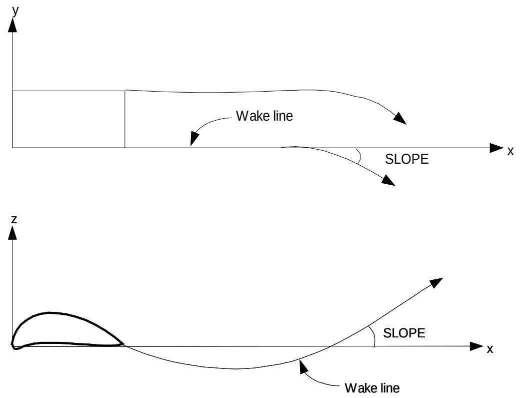
2. The following example shows a curved wake surface that is modeled by the **WAKENET** bulk data card. There are three wake lines (NY=3) and four reference grids along each wake line.



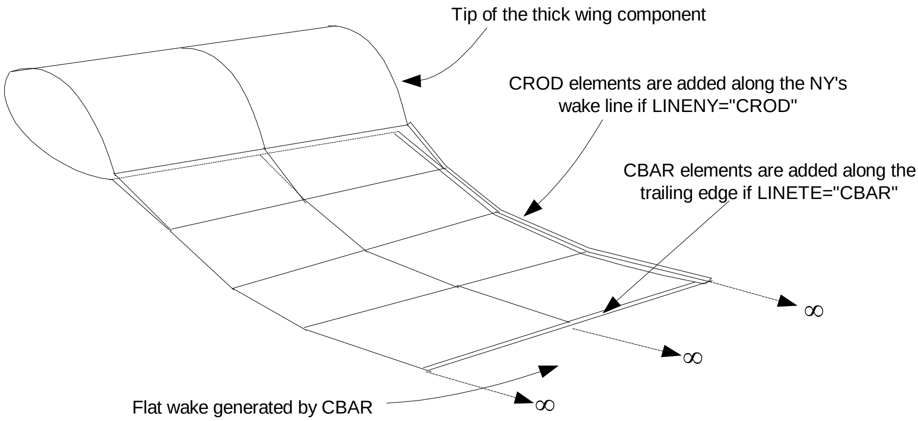


Therefore, there are totally NX · NY number of internally generated reference grid points denoted as G_{ij}, where j = 1, NX, and i = 1, NY. Two sets of CSHEAR elements are generated by the program, one set on the upper surface of the wake surface and the other set on the lower surface. Both sets of CSHEAR elements are connected by the same reference grid points except the connectivity sequence of the upper CSHEAR is $G_{j-1,i}$, $G_{j,i}$, $G_{j,i+1}$, and $G_{j-1,\, i+1}$ whereas the lower CSHEAR is $G_{j-1,i}$, $G_{j,i+1}$, $G_{j,i}$ and $G_{j-1,\, i}$. This sequence gives two opposite normal vectors between the upper CSHEAR and lower CSHEAR. It should be noted that for those CSHEAR elements immediately behind the trailing edge of the thick wing component the grid connectivity is $GRIDU_i$, $G_{1,i}$, $G_{1,i+1}$ and $GRIDU_{i+1}$ for the upper CSHEAR and $GRIDL_{i+1}$, $G_{1,i+1}$, $G_{1,i}$, and $GRIDL_i$ for the lower CSHEAR.

3. The SLOPE entry controls the direction of the wake lines at trailing edge of the wake surface. (See the following figure). The angle of the wake line at the trailing edge of the thick-wing component is defined by the $GRIDA_i$ entry.

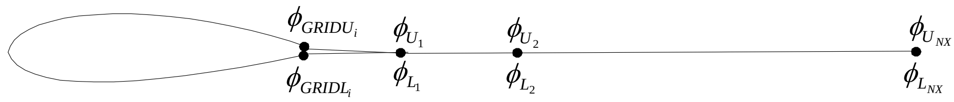


4. LINE1, LINENY, and LINETE are used to add CROD/CBAR elements along the two side edges (the first and last wake lines) and the trailing edge of the wake surface. In the following figure, the NYth wake line is at the tip of the thick wing component. Therefore, LINENY = "CROD" is recommended to model the tip vortex effects of the thick wing component. In order to extend the wake surface to infinite, LINETE = "CBAR" is recommended so that additional flat wakes (generated by the CBAR elements) are attached to the trailing edge of the curved wake surface.

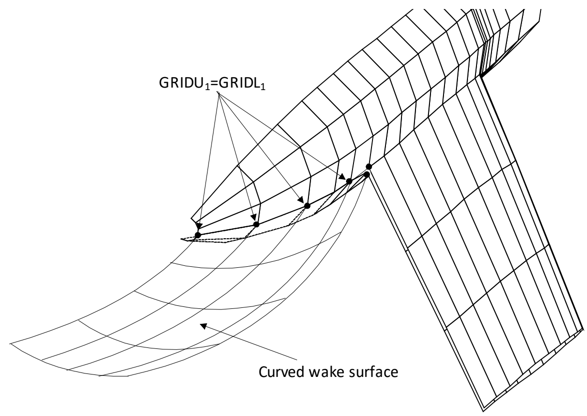


5. The potential jump across the wake surface along the same wake line must be constant and equal to the potential difference between $GRIDU_i$ and $GRIDL_i$. In the following figure, ϕ_{U_j} and ϕ_{L_j} represent the potential at the upper CSHEAR and lower CSHEAR, respectively. Program will impose the condition such that

$$\phi_{GRIDU_i} = \phi_{U_1} = \phi_{U_2} \ldots = \phi_{U_{NX}}$$
$$\phi_{GRIDL_i} = \phi_{L_1} = \phi_{L_2} \ldots = \phi_{L_{NX}}$$



Note that $GRIDL_1 = GRIDL_2 = \ldots GRIDL_{NY} = 0$ is allowed (However, $GRIDL_i$=0 and $GRIDL_{i+1} \neq 0$ is not allowed). In this case, only one set of CSHEAR elements at the upper side of the wake surface is generated. Also, $GRIDU_i = GRIDL_i$ is allowed. This is used to model a curved wake surface shed from the surface grid behind the thick-wing and body juncture where the entry $GRID_i$ of the **RBE2** bulk data card are located (see the following figure). The **RBE2** bulk data card must also be specified (with entry "CBAR" = "NO") to introduce the potential jump at $GRIDU_i$ due to the wake surface generated by the thick wing component.

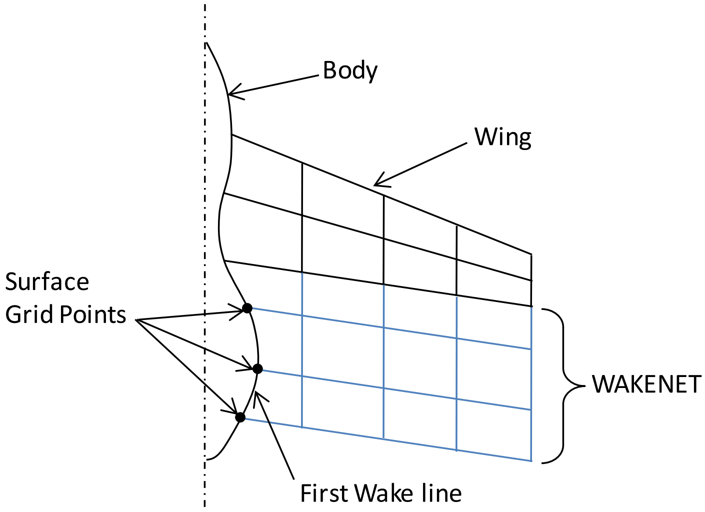


6. The $DIVIDE_i$ entry defines the streamwise distribution of the NX reference grids at the *i*th wake line. For $DIVIDE_i$ = "SET1", these NX reference grids are the input reference grids (defined by the **GRID** bulk data cards with entry PS $\neq$ 0) whose identification numbers are listed in the **SET1** bulk data card (SETID = IDAEF). For $DIVIDE_i$ = "AEFACT", the real values listed in the **AEFACT** bulk data card (SETID = IDAEF) represent the streamwise locations of these reference grids in terms of percentage of the length of the wake line (the $LENGTH_i$ entry). Therefore, these real values must be greater than 0.0 and less than or equal to 100.0. For $DIVIDE_i$ = "COS", the streamwise locations of these reference grids with respect to the $GRIDU_i$ and $GRIDL_i$ are computed by the following equation

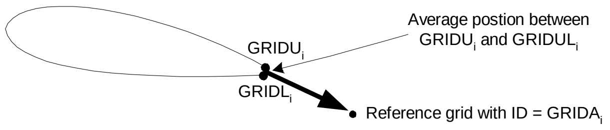
$$X_j = \cos\left[\frac{(NX - j)}{NX}\frac{\pi}{2}\right],\ j\text{=1, NX}$$

For DIVIDE = "EVEN", these NX reference grids are evenly distributed along the *i*th wake line.

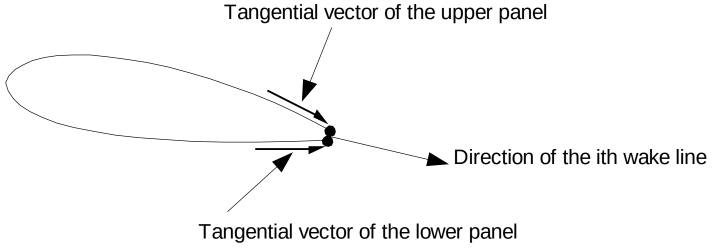
7. The following figure show that the first wake line can be defined by a set of surface grid points. In this case, those surface grid points must be a subset of those surface grid points referred by the **RBE2** bulk data card.



8. The $GRIDA_i$ entry defines the angle of the *i*th wake line at the trailing edge of the thick wing. If $GRIDA_i \neq 0$, $GRIDA_i$ is the identification number of a reference grid (input by the **GRID** bulk data card with entry PS ≠ 0) to specify a vector from $GRIDU_i$ /$GRIDL_i$ to $GRIDA_i$ (see the following figure). This vector defines the direction of the *i*th wake line at the trailing edge of the thick wing component.

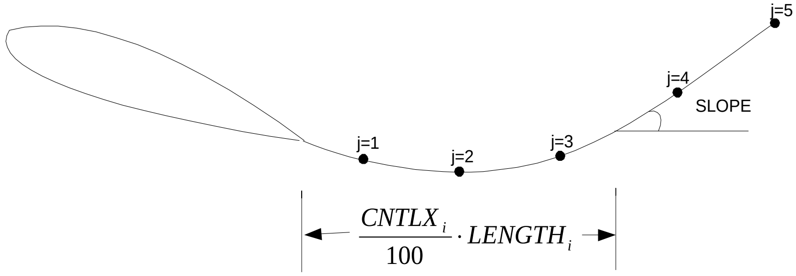


For $GRIDA_i$ = 0 or blank, the direction of the ith wake line at the trailing edge of the thick wing component is automatically computed by the average value of the tangential vectors of the panels to which the $GRIDU_i$ and $GRIDL_i$ are attached (see the figure below)



9. The user must assign a proper $GRIDREF_i$ to avoid duplicated identification numbers of the reference grid points.

10. The streamwise location where the direction of the ith wake line (defined by $SLOPE_i$) is imposed is shown in the following example.



The locations of these reference grids ahead of $CNTLX_i$ (at j = 1, 2, and 3 shown in the figure) are determined by a two-point cubic spline with imposed slopes at $\frac{CNTLX_i}{100} \cdot$ $LENGTH_i$ and at the trailing edge of the thick wing component. The locations of these reference grids behind $CNTLX_i$ (at j = 4 and 5 shown in the figure) are located along a straight line whose direction is SLOPE.

WT1AJJ Force/Moment Correction Matrix

Description: Corrects the Aerodynamic Influence Coefficient (AIC) matrix by a force correction matrix so that the forces and moments computed by the corrected AIC matrix match a given set of component forces and moments.

Format and Example:

1	2	3	4	5	6	7	8	9	10
WT1AJJ	IDMK	SYM	KINDEX	METHOD	WT1FILE				CONT
CONT	$IDFRC_1$	$IDFRC_2$	...	-etc-	...				

WT1AJJ	100	ANTI	1	UNSTEADY	WT1MAT				+W
+W	101	103	200						

Field	Contents
IDMK	Identification number of a **AEROGEN** bulk data card whose generated AIC matrix is to be corrected. (Integer > 0) (See Remark 1)
SYM	Character string either "SYM", "ASYM" or "ANTI" to specify the symmetric condition of the AIC matrix that is to be corrected by the downwash weighting matrix (Character) SYM = 'SYM' for symmetric condition SYM = 'ANTI' for anti-symmetric condition SYM = 'ASYM' for asymmetric condition
KINDEX	Not Used
METHOD	Not Used
WT1FILE	WT1FILE is a character sting representing the name of the output file that contains the computed force correction matrix. If the first character starts with a dollar sign "$", the rest of the characters must be integers. This integer is the identification number of an **EXTFILE** bulk data card where the filename is specified. This feature allows for filenames up to 56 characters to be input. (Character or Blank) (See Remark 2)
$IDFRC_i$	Identification number of a **WT1FRC** bulk data card to specify a set of given component forces and moments. (Integer>0) (See remark 3)

Remarks:

1. The **WT1AJJ** bulk data card generates a AIC weighting matrix [*WT1*] such that

$$\left\{C_{p_c}\right\} = \left[[WT1][AJJ]^T [FJK]^T - [DJK]^T\right]\left\{W\right\}$$
$$\left\{F_{given}\right\} = q_\infty [L]\{C_{p_c}\}$$

where $\left\{C_{p_c}\right\}$ is called the corrected pressure coefficients and $\{F_{given}\}$ is the given set of derivatives of component forces and moments with respect to a mode vector $\{W\}$.
q_∞ is the dynamic pressure
[*L*] is the component load integration matrix that is jointly generated by a set of **LOADMOD** bulk data cards specified in the **WT1FRC** bulk data cards.
[*WT1*] is the force correction matrix generated by the **WT1AJJ** bulk data card
[*AJJ*] is the so-called uncorrected AIC matrix directly computed by the program.
Please refers to the **OUTPUT4** bulk data card to find the actual matrix names of [*AJJ*], [*FJK*], and [*DJK*].
and $\{W\}$ is the mode by which the given set of component forces and moments are computed or measured.

Note that after [*WT1*] is computed, the corrected AIC matrix defined as *AJJ** where

$$[AJJ*]^T = [WT1][AJJ]^T$$

is stored on the run-time database to compute the aerodynamic stability derivatives and flexible loads of all modes.

Those [*AJJ*], [*FJK*], and [*DJK*] matrices can be exported by the **OUTPUT4** bulk data card and reused by importing them via the **ASSIGN MATRIX** executive control commands.

2. The **WT1FRC** bulk data card defines the mode vector $\{W\}$ and a set of derivatives of component forces and moments. The force correction matrix [*WT1*] is computed using the Lagrange Multiplier method of which these derivatives of component forces and moments are the constraint functions. The objective function is defined as $\{\{C_{p_c}\}-\{C_{p_u}\}\}^T\{C_{p_c}\}-\{C_{p_u}\}\}$, where $\{C_{p_u}\}$ is the uncorrected pressure coefficients computed by the following equation:

$$\left\{C_{p_u}\right\} = \left[[AJJ]^T [FJK]^T - [DJK]^T\right]\left\{W\right\}$$

The force correction matrix [*WT1*] is a diagonal matrix. If all diagonal terms are close to one, this implies that the difference between the pressure distributions computed by ZONAIR and CFD is not too large.

WT1CFD **Force/Moment Correction by CFD**

Description: Internally generates the **WT1AJJ** and **WT1FRC** bulk data cards using the CFD computed pressure distributions to correct the Aerodynamic Influence Coefficient (AIC) matrices for computing the aerodynamic stability derivatives and generalized aerodynamic forces of structural modes.

Format and Example:

1	2	3	4	5	6	7	8	9	10
WT1CFD	IDWT1	IDAERO	IFAJJ	IFFJK	IFDJK	IFWT1			CONT
CONT	$TRMVAR_1$	$DELTA_1$	$INPCFD_1$	$LOADMOD_1$	$FORM_1$	$CPCFD_1$	$CPAJJ_1$		CONT
CONT	$TRMVAR_2$	$DELTA_2$	$INPCFD_2$	$LOADMOD_2$	$FORM_2$	$CPCFD_2$	$CPAJJ_2$		CONT
CONT			...	-etc-	...				ETC

WT1CFD	100	103	101	102	103	104			+W1
+W1	ALPHA	1.0	-102	200	TECPLOT	105	106		+W2
+W2	HT-TAIL	-1.0	-201	300					

Field	Contents
IDWT1	Identification number that is referred to by a **WT1CFD** case control command. (Integer > 0) (See Remark 1)
IDAERO	Identification number of an **AEROGEN** bulk data card. An **INPCFD**, **INPCFD1**, **INPDMI**, **CPSPLN**, or **CPSPLNL** bulk data card with the same identification number=IDAERO must exist to replace the program computed pressure coefficients by those computed by computational fluid dynamics (CFD) or measured by wind-tunnel test. (Integer>0) (See Remark 2)
IFAJJ	Identification number of an **EXTFILE** bulk data card to store the corrected [*AJJ*] matrix in the OUTPUT4 format. (Integer>0) (See Remark 1 of the **WT1AJJ** bulk data card)
IFFJK	Identification number of an **EXTFILE** bulk data card to store the corrected [*FJK*] matrix in the OUTPUT4 format. (Integer>0)
IFDJK	Identification number of an **EXTFILE** bulk data card to store the corrected [*DJK*] matrix in the OUTPUT4 format. (Integer>0)
IFWT1	Identification number of an **EXTFILE** bulk data card to store the corrected [*WT1*] matrix in the OUTPUT4 format. (Integer≥0) (See Remark 2 of the **WT1AJJ** bulk data card)

$TRMVAR_i$	Character string either "ALPHA", "BETA", or the entry $LABEL_i$ listed in the **AEROGEN** bulk data card. (Character, default="ALPHA") (See Remark 3)
$DELTA_i$	Perturbed value in degrees from the flight condition specified by the **AEROGEN** bulk data card with identification number=IDAERO to define a perturbed flight condition. (Real≠0.0) (See Remark 4)
$INPCFD_i$	A negative integer referring to an **INPCFD**, **INPCFD1**, **INPDMI**, **CPSPLN**, or **CPSPLNL** bulk data card with negative identification number that stores the pressure coefficients computed by CFD or measured by wind tunnel test at the perturbed flight condition. (Integer<0) (See Remark 5)
$LOADMOD_i$	Identification number of a **SET1** bulk data card that lists a set of identification numbers of the **LOADMOD** bulk data cards. (Integer>0) (See Remark 6)
$FORM_i$	FORM = "TECPLOT" for generating the TECPLOT™ file. For TYPE="NO", the aerodynamic results (pressure coefficients and local Mach numbers) are presented at the grid points. For TYPE="YES", the aerodynamic results are presented on panels. FORM = "PATRAN" for generating a PATRAN™ neutral/results file. In the neutral/result file, the external identification numbers of all panels are replaced by their internal identification numbers. FORM = "PATRAN1" for generating a PATRAN™ neutral file. In the neutral file, the identification numbers of all panels are their external identification numbers. The lower surface panels of CAERO7 macroelements have the same identification numbers as those of their corresponding upper surface panels except with a negative sign. FORM = "IDEAS" for generating the I-DEAS™ universal file. FORM = "FEMAP" for generating a FEMAP™ neutral file. FORM = "ANSYS" for generating an ANSYS supported neutral file. FORM = "NASTRAN" for generating a NASTRAN bulk data deck with PLOAD4 cards to define the pressure loads. (see remark 3) FORM = "ESA" for generating a PEGASUS readable file. FORM = "OUTPUT4" for outputting the pressure coefficients on all panels in the OUTPUT4 format. (Character, Default = "TECPLOT")
$CPCFD_i$	Identification number of an **EXTFILE** bulk data card to store the derivatives of the pressure distribution computed by CFD on the panel model. The format of the data is specified by the entry FORM. (Integer≥0)
$CPAJJ_i$	Identification number of an **EXTFILE** bulk data card to store the derivatives of the pressure distribution computed by the corrected AIC matrices on the panel model. The format of the data is specified by the entry FORM. (Integer≥0) (See Remark 7)

Remarks:

1. The **WT1CFD** bulk data card first internally generates a **WT1AJJ** bulk data card and a set of **WT1FRC** bulk data cards then processes the **WT1AJJ** bulk data card to generate the corrected [*AJJ*] matrix. The **WT1CFD** bulk data card only can be applied to a full-span aerodynamic model, i.e. the entry XZSYM in the **AEROZ** bulk data card must be "NO".
   An example of the internally generated **WT1AJJ** bulk data card and a set of **WT1FRC** bulk data cards is shown below:

```
  * * * PROGRAM INTERNALY GENERATED WT1AJJ   BULK DATA CARD WITH ID=     103 * * *

$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
WT1AJJ  103     SYM     0               $1004
        1       2

  * * * PROGRAM INTERNALY GENERATED WT1FRC   BULK DATA CARD WITH ID=       1 * * *

$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
WT1FRC  1       RIGID   PITCH
        101     1.00000057.2957829.423200.0     -57.2958-.6107880.0
        102     1.00000057.29578454.66800.0     -57.2958-9.634340.0
        103     1.00000057.29578-111.4390.0     -57.29584.1834400.0

  * * * PROGRAM INTERNALY GENERATED WT1FRC   BULK DATA CARD WITH ID=       2 * * *

$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
WT1FRC  2       AESURFZ HT-TAIL
        201     1.000000-57.2958-18.00920.0     57.29578-14.41710.0
        202     1.000000-57.2958-163.4360.0     57.29578-130.8360.0
        203     1.000000-57.295869.184700.0     57.2957855.385000.0
```

2. The **AEROGEN** bulk data card defines the mean flight condition in terms of angle of attack (α_0), side slip angle (β_0), and control surface deflection (δ_{0_i}) that are specified by the entry ALPHA, BETA, and the LABEL_i and VALUE_i pair, respectively. Thus, pressure coefficients computed by CFD or measured by wind-tunnel test, defined herein as {C_{p_0}}, must be at the same mean flight condition.

3. For TRMVAR_i="ALPHA", the mode vector,{*W*} shown in Remark 1 of the **WT1AJJ** bulk data card, is a rigid body pitch mode. For TRMVAR_i="BETA", the mode vector{*W*} is a rigid body yaw mode. If TRMVAR_i matches the entry LABEL_i listed in the **AEROGEN** bulk data card, the mode vector{*W*} is a control surface kinematic mode.

4. For TRMVAR_i="ALPHA", the angle of attack is perturbed as $\alpha = \alpha_0 + DELTA_i$. For TRMVAR_i="BETA", the side slip angle is perturbed as $\beta = \beta_0 + DELTA_i$. If TRMVAR_i matches the entry LABEL_i listed in the **AEROGEN** bulk data card, the control surface deflection angle is perturbed as $\delta = \delta_0 + DELTA_i$. Note that DELTA_i must be in degrees.

5. The pressure coefficient distribution imported by the **INPCFD**, **INPCFD1**, **INPDMI**, **CPSPLN**, or **CPSPLNL** bulk data card, referred to herein as {C_{p_i}}, must be obtained at the perturbed flight condition specified by the entry DELAT_i.

6. These **LOADMOD** bulk data cards define a set of component forces and moments. The derivatives of those component forces and moments with respect to the mode vector{W} are computed by the following equation:

$$\left\{F_{given}\right\} = q_{\infty}\left[L\right]\{\{C_{p_i}\}-\{C_{p_0}\}\}/(DELTA_i \times \pi/180.0)$$

Where{F_{given}} is shown in Remark 1 of the **WT1AJJ** bulk data card, [L] is the load integration matrix created by the **LOADMOD** bulk data cards, and q_{∞} is assumed to be one.

Note that each entry TRMVAR$_i$ generates a **WT1FRC** bulk data card with the entry IDFRC=i. Thus, for i=1, 2,..n, there are n number of **WT1FRC** bulk data cards generated. In these **WT1FRC** bulk data cards, the entry LOADMOD$_i$ is the identification number of the **LOADMOD** bulk data card listed in the **SET1** bulk data card specified by the **WT1CFD** bulk data card, the entry DYNP$_i$=1.0, the entry A1=1./$(DELTA_i \times \pi/180.0)$, the entry RFORCE1=$\left[L\right]\{C_{p_i}\}$, the entry A2=-1./$(DELTA_i \times \pi/180.0)$, and the entry RFORCE2=$\left[L\right]\{C_{p_0}\}$.

It should be noticed that If TRMVAR$_i$="ALPHA", these **LOADMOD** bulk data cards should the component forces and moments associated with the wing or horizontal tail. If TRMVAR$_i$="BETA", these **LOADMOD** bulk data cards should be the component forces and moments associated with the rudder or vertical tail. If TRMVAR$_i$ matches the entry LABEL$_i$ listed in the **AEROGEN** bulk data card, these **LOADMOD** bulk data cards should the component forces and moments associated with the hinge moment of the control surface.

7. The derivatives of the pressure distribution computed by CFD on the panel model is computed by the following equation:

$$\left\{\partial C_p/\partial W\right\} = \{\{C_{p_i}\}-\{C_{p_0}\}\}/(DELTA_i \times \pi/180.0)$$

The derivatives of the pressure distribution computed by ZONAIR using the corrected [AJJ] matrix on the panel model is computed by the following equation:

$$\left\{\partial C_{p_c}/\partial W\right\} = \left[\left[WT1\right]\left[AJJ\right]^T[FJK]^T - [DJK]^T\right]\left\{W\right\}$$

The user can compare these two sets of pressure distributions to verify the accuracy of the corrected [AJJ] matrix for computing aerodynamic stability derivatives and generalized aerodynamic forces used by the static aeroelastic analysis.

8. To compute the corrected [AJJ] matrix, **WT1CFD** performs the following steps:

```
*******************************************
*        B E G I N   S T E P   1         *
*******************************************
```

```
* * *  PROCESS BULK DATA CARD AEROGEN  WITH ID=     103 WHOSE COMPUTED MEAN FLOW CP WILL BE REPLACED BY BULK DATA CARD INPDMI   * * *
```

In the step 1, the **AEROGEN** bulk data card with ID=IDAERO is processed whose computed pressure distribution at the mean flight condition on panel model is replaced by the **INPCFD**, **INPCFD1**, **INPDMI**, **CPSPLN**, or **CPSPLNL** bulk data card to generate {C_{p_0}} and the component forces and moments defined by the **LOADMOD** bulk data cards. This set of component forces and moments at the mean flight condition is referred herein as {F_0}.

The next step is to process each TRMVAR$_i$ entry. For i=1,2, n, this step is repeated n times.

```
*******************************************
*        B E G I N   S T E P   2         *
*******************************************
```

```
 * * * PROCESS BULK DATA CARD AEROGEN  WITH ID=     102 FOR TRMVAR=ALPHA    WITH INCREMENTAL VAULE=  0.1000E+01
       WHOSE COMPUTED CP WILL BE REPLACED BY BULK DATA CARD INPDMI   WITH ID=    -102 * * *
```

In the step 2, an **AEROGEN** bulk data card with IDAERO=IABS($INPCFD_i$) and with the entries ALPHA, BETA, LABEL, and VAULE being perturbed by $DELTA_i$ is internally created. This **AEROGEN** bulk data card is processed whose generated pressure distribution at the perturbed flight condition is replaced by the **INPCFD**, **INPCFD1**, **INPDMI**, **CPSPLN**, or **CPSPLNL** bulk data card with ID=$INPCFD_i$ to generate { C_{p_i} } and the component forces and moments defined by the **LOADMOD** bulk data cards. This set of component forces and moments at the perturbed flight condition is referred herein as $\{F_i\}$. With $\{F_0\}$, $\{F_i\}$, $DELTA_i$, and $TRMVAR_i$, a **WT1FRC** bulk data card with IDFRC=i is internally generated such as the one shown below::

```
   * * * PROGRAM INTERNALY GENERATED WT1FRC   BULK DATA CARD WITH ID=       1 * * *

$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
WT1FRC  1       RIGID   PITCH
        101     1.00000057.2957829.423200.0     -57.2958-.6107880.0
        102     1.00000057.29578454.66800.0     -57.2958-9.634340.0
        103     1.00000057.29578-111.4390.0     -57.29584.1834400.0
```

This step is repeated *n* times and in each step a **WT1FRC** bulk data card with IDFRC=i is internally created such as the one shown below:

```
  * * * PROGRAM INTERNALY GENERATED WT1FRC   BULK DATA CARD WITH ID=       2 * * *

$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
WT1FRC  2       AESURFZ HT-TAIL
        201     1.000000-57.2958-18.00920.0     57.29578-14.41710.0
        202     1.000000-57.2958-163.4360.0     57.29578-130.8360.0
        203     1.000000-57.295869.184700.0     57.2957855.385000.0
```

Note that these **WT1FRC** bulk data cards are processed to compute the derivaives of the component forces and moments by $\{\{F_i\}-\{F_0\}\}/(DELTA_i \times \pi / 180.0)$.

The final step is to process the **AEROGEN** bulk data card with ID=IDAERO again except that this time, the internally generated **WT1AJJ** bulk data card that refers to those internally generated **WT1FRC** bulk data cards is activated to perform the force correction method.

```
                                              *******************************************
                                              *           F I N A L   S T E P           *
                                              *******************************************

 * * *  PROCESS BULK DATA CARD AEROGEN  WITH ID=     103 TO CORRECT AJJ, FJK, AND DJK MATRICES BY THE WT1AJJ   BULK DATA CARD  * * **
```

Meanwhile, 3 internally generated **OUTPUT4** bulk data cards are created to export the corrected [*AJJ*],[*FJK*], and [*DJK*] matrices using 3 **EXTFILE** bulk data cards that are referred to by the entries $IFAJJ_i$, $IFFJK_i$, and $IFDJK_i$, respectively, such as:

```
 *** MATRIX AJJS0003 HAS BEEN EXPORTED TO FILE AJJ.DAT          DUE TO THE INPUT BULK DATA CARD OUTPUT4

 *** MATRIX FJKS0003 HAS BEEN EXPORTED TO FILE FJK.DAT          DUE TO THE INPUT BULK DATA CARD OUTPUT4

 *** MATRIX DJKS0003 HAS BEEN EXPORTED TO FILE DJK.DAT          DUE TO THE INPUT BULK DATA CARD OUTPUT4
```

These corrected matrices can be reused by importing them using the "**ASSIGN MATRIX**=" executive control commands.

WT1FRC

Component Loads for Force Correction Matrix

Description: Specifies a set of component forces and moments for generating the force correction matrix.

Format and Example:

1	2	3	4	5	6	7	8	9	10
WT1FRC	IDFRC	TYPE	LABEL						CONT
CONT	$LOADMOD_1$	$DYNP_1$	$A1_1$	$RFORCE1_1$	$IFORCE1_1$	$A2_1$	$RFORCE2_1$	$IFORCE2_1$	CONT
CONT	$LOADMOD_2$	$DYNP_2$	$A1_2$	$RFORCE1_2$	$IFORCE1_2$	$A2_2$	$RFORCE2_2$	$IFORCE2_2$	CONT
CONT			...	-etc-	...				

WT1FRC	100	RIGID	PITCH						+W
+W	101	2.0	1.0	3.4		-1.0	2.4		+W
+W	102	2.0	0.3	3.0					

Field	Contents
IDFRC	Identification number that is referred to by a **WT1AJJ** bulk data card. (Integer > 0) (See Remark 1)
TYPE	Character string to specify the type of the mode that is used to generate the given component forces/moments. (Character, default = “RIGID”) (See Remark 2)

TYPE = ‘FEM’	The structural finite element modes that are imported by the **‘ASSIGN FEM=’** Executive Control Command.
TYPE = ‘AESURFZ’	The control surface modes that are defined by the **AESURFZ**, **AESLINK**, **PZTMODE**, or **GRIDFRC** bulk data cards.
TYPE = ‘LOADMOD’	The load modes that are defined by the **LOADMOD** bulk data cards.
TYPE = ‘RIGID’	For rigid body modes.

LABEL	Defines the index of the modes.	
	For TYPE = 'FEM'	If LABEL is an integer, LABEL represents the index of the structural finite element modes (Integer > 0)
	For TYPE = 'AESURFZ'	LABEL represents the LABEL entry of the **AESURFZ**, **AESLINK**, or **PZTMODE** bulk data cards (Character)
	For TYPE = 'LOADMOD'	If LABEL is an integer, LABEL represents the identification number of the **LOADMOD** bulk data cards (Integer > 0)
	For TYPE = 'RIGID'	LABEL is a character string and must be one of the following:
	For SYM = 'SYM':	
	LABEL = "FORAFT"	Represents the for-aft translational mode,
	LABEL = "PLUNGE"	Represents the plunging mode, and
	LABEL = "PITCH"	Represents the pitching mode.
	For SYM = 'ANTI':	
	LABEL = "YTRANS"	Represents the y-translational mode,
	LABEL = "YAW"	Represents the yawing mode, and
	LABEL = "ROLL"	Represents the rolling mode,
	For SYM = 'ASYM':	
	LABEL can be one of the character strings "FORAFT", "PLUNGE", "PITCH", = "YTRANS", "YAW" or = "ROLL" (Character, Default = "PITCH")	
$LOADMOD_i$	Identification number of a **LOADMOD** bulk data card to define the component forces/moments. (Integer > 0) (See Remark 3)	
$DYNP_i$	Dynamic pressure that multiplies the component forces/moments computed by the program. (Real ≠ 0.0) (See Remark 4)	
$A1_i$	Multiplication factor to the forces/moments specified in the entries $RFORCE1_i$. (Real) (See Remark 5)	
$RFORCE1_i$	The first given set of component forces/moments. (Real)	
$IFORCE1_i$	Not used.	
$A2_i$	Multiplication factor to the forces/moments specified in the entries $RFORCE2_i$. (Real)	
$RFORCE2_i$	The second given set of component forces/moments. (Real)	
$IFORCE2_i$	Not used.	

<u>Remarks:</u>

1. The **WT1FRC** bulk data card defines a set of component force derivatives with respect to a mode. The set of component force derivatives is used to generate a force/moment correction matrix.

2. The entries TYPE and LABEL jointly define the type of mode that is used to obtain the given set of component forces and moments. For instance, if the component forces and moments are measured on a rigid aerodynamic wind-tunnel model at an angle of attack, TYPE = “RIGID” and LABEL = “PITCH” are recommended.

3. The **LOADMOD** bulk data cards will jointly generate a component load integration matrix [L] such that

$$\left\{F_{given}\right\} = q_\infty \left[L\right]\left[\left[WT1\right]\left[AJJ\right]^T\left[FJK\right]^T - \left[DJK\right]^T\right]\left\{W\right\}$$

   Please refer to the **WT1AJJ** bulk data card for the description of the above equation.

4. If the given set of component forces and moments specified in the entries RFORCE1$_i$, and RFORCE2$_i$, are obtained by wind-tunnel test, the dynamic pressure q_∞ at the wind-tunnel test condition must be given to the above equation.

5. The entries A1$_i$, RFORCE1$_i$, A2, and RFORCE2$_i$ jointly define the given ith component forces/moments derivative F_{given} as

$$F_{given} = A1 \cdot RFORCE1 + A2 \cdot RFORCE2$$

   For instance, if RFORCE1 and RFORCE2 are the hinge moments of a control surface at angles of attack (α) 1° and 0°, respectively. A1 should be 180/π and A2 should be -180/π so that

$$F_{given} = \frac{180}{\pi}\left(RFORCE1\left(\alpha = 1^\circ\right) - RFORCE2\left(\alpha = 0^\circ\right)\right)$$

   Thus, the resulting F_{given} is the derivative of the hinge moment with respect to a pitch mode with a unit pitch angle.

   F_{given} is used by the **WT1AJJ** bulk data card as the constraint function to compute the force correction matrix [*WT1*] using the Lagrange Multiplier method.

WT2AJJ

Downwash Weighting Matrix

Description: Corrects the aerodynamic influence coefficient (AIC) matrix by a downwash weighting matrix that is computed based on the given set of pressure coefficients.

Format and Example:

1	2	3	4	5	6	7	8	9	10
WT2AJJ	IDMK	SYM	TYPE	LABEL	KINDEX	METHOD	WT2FILE		CONT
CONT	FORM	A1	INPCFD1	A2	INPCFD2	PLTCP	CPFILE		CONT
CONT	$PANLST_1$	$PANLST_2$	$PANLST_3$	...	-etc-	...			

WT2AJJ	100	SYM	RIGID	PITCH			WT2FILE.DAT		+W
+W	CFD	57.1	101	-57.1	102	TECPLOT	CPL.PLT		+W
+W	10	20	30						

Field	Contents
IDMK	The identification number of a **AEROGEN** bulk data card whose generated AIC matrix is to be corrected. (Integer > 0) (See Remark 1)
SYM	Character string either “SYMM”, “ASYM” or “ANTI” to specify the symmetric condition of the AIC matrix that is to be corrected by the downwash weighting matrix (Character) SYM = ‘SYM’ for symmetric condition SYM = ‘ANTI’ for antisymmetric condition SYM = ‘ASYM’ for asymmetric condition
TYPE	Character string to specify the type of the mode that is used to generate the given pressure coefficients. (Character, Default = “RIGID”) (See Remark 2) TYPE = ‘FEM’ The structural finite element modes that are imported by the **‘ASSIGN FEM=’** Executive Control Command. TYPE = ‘AESURFZ’ The control surface modes that are defined by the **AESURFZ**, **AESLINK**, **PZTMODE**, or **GRIDFRC** bulk data cards. TYPE = ‘LOADMOD’ The load modes that are defined by the **LOADMOD** bulk data cards. TYPE = ‘RIGID’ For rigid body modes.

LABEL	Defines the index of the modes.	
	For TYPE = 'FEM'	If LABEL is an integer, LABEL represents the index of the structural finite element modes (Integer > 0)
	For TYPE = 'AESURFZ'	LABEL represents the LABEL entry of the **AESURFZ**, **AESLINK**, or **PZTMODE** bulk data cards (Character)
	For TYPE = 'LOADMOD'	If LABEL is an integer, LABEL represents the identification number of the **LOADMOD** bulk data cards (Integer > 0)
	For TYPE = 'RIGID'	LABEL is a character string and must be one of the following:

For SYM = 'SYM':

LABEL = "FORAFT"	Represents the for-aft translational mode,
LABEL = "PLUNGE"	Represents the plunging mode, and
LABEL = "PITCH"	Represents the pitching mode.

For SYM = 'ANTI':

LABEL = "YTRANS"	Represents the y-translational mode,
LABEL = "YAW"	Represents the yawing mode, and
LABEL = "ROLL"	Represents the rolling mode,

For SYM = 'ASYM':

LABEL can be one of the character strings "FORAFT", "PLUNGE", "PITCH", = "YTRANS", "YAW" or = "ROLL" (Character, Default = "PITCH")

KINDEX	Not used.
METHOD	Not used.
WT2FILE	WT2FILE is a character sting representing the name of the output file that contain the computed downwash weighting matrix. (Character or Blank)
FORM	Character string either "DMI" or "CFD" to specify the form of the given pressure coefficients. (Character)
A1	Multiplication factor to the pressure coefficients that are imported by the entry INPCFD1 (Real) (See Remark 5)
INPCFD1	For FORM = "DMI", INPCFD1 is a character string of the name of the matrix that is imported by the **DMI** bulk data card or an **'ASSIGN MATRIX='** Executive Control Command. For FORM = "CFD", INPCFD1 is an integer that is the identification number of an **INPCFD/INPCFD1/INPDMI/CPSPLN/CPSPLNL** bulk data card. (Character, Integer or Blank)
A2	Same as A1 but for the pressure coefficients imported by the entry INPCFD2. (Real)
INPCFD2	Same as INPCFD1 but for the second set of pressure coefficients.

PLTCP	Character string to specify the format of the plot file of CPFILE: PLTCP = "TECPLOT" for generating the TECPLOT file PLTCP = "PATRAN" for generating the PATRAN neutral/results file PLTCP = "IDEAS" for generating the I-DEAS universal file PLTCP = "FEMAP" for generating the FEMAP neutral file PLTCP = "ANSYS" for generating an ANSYS supported neutral file PLTCP = "NASTRAN" for generating the NASTRAN bulk data deck with PLTCP cards to define the pressures loads PLTCP = "ESA" for generating the PEGASUS readable file (Character, Default = "TECPLOT")
CPFILE	Character string up to 16 characters to specify the filename of a graphical file that contains the aerodynamic model and the ΔCp_{given}. This allows the user to verify the computed ΔCp_{given} from the entries A1, INPCFD1, A2, and INPCFD2. (Character or Blank) (See Remark 4)
PANLST$_i$	Identification number of a **PANLST*i*** bulk data card to define a set of aerodynamic box identification numbers. ΔCp_{given} on those aerodynamic boxes are replaced by the pressure computed by the uncorrected AIC matrix. (Integer ≥ 0) (See Remark 5)

Remarks:

1. The **WT2AJJ** bulk data card generates a downwash weighting matrix [WT2] such that

$$\{\Delta Cp_{given}\} = [AJJ][WT2]\{W\}$$

where $\{\Delta Cp_{given}\}$ is the given pressure coefficients that can be either computed by the CFD codes or measured by wind-tunnel test.
[AJJ] is the so-called uncorrected AIC matrix directly computed by the program
[WT2] is the downwash weighting matrix generated by the **WT2AJJ** bulk data card
and {W} is the mode by which ΔCp_{given} is computed or measured.

Note that after [WT2] is computed, the corrected AIC matrix defined as AJJ* where

$$[AJJ^*] = [AJJ]\,[WT2]$$

is stored on the run-time database to compute the flexible loads of all modes.

2. The entries TYPE and LABEL jointly define the type of mode that is used to generate ΔCp_{given}. For instance, if ΔCp_{given} is measured on a rigid aerodynamic wind-tunnel model at an angle of attack, TYPE = "RIGID" and LABEL = "PITCH" are recommended.

3. The entries A1, INPCFD1, A2, and INPCFD2 jointly define the given pressure coefficients $\{\Delta Cp_{given}\}$ as

$$\{\Delta Cp_{given}\} = A1\cdot\{Cp_1\} + A2\cdot\{Cp_2\}$$

where Cp_1 and Cp_2 are imported through the entries INPCFD1 and INPCFD2 respectively. For instance, if $\{Cp_1\}$ and $\{Cp_2\}$ are the pressure coefficients at angles of attack (α) 1° and 0°, respectively, A1 should be 180/π and A2 should be -180/π so that

$$\left\{\Delta Cp_{given}\right\} = \left\{Cp_1\left(\alpha = 1^\circ\right) - Cp_2\left(\alpha = 0^\circ\right)\right\} \cdot \frac{180}{\pi}$$

Thus, the resulting $\left\{\Delta Cp_{given}\right\}$ is the derivative of the pressure coefficient with respect to a pitch mode with a unit pitch angle.

4. The file “CPFILE” contains three sets of ΔCp . The first set is labled as INP CP that is the input $\left\{\Delta Cp_{given}\right\}$ computed by the above equation. The second set is labeled as ZON CP that is computed by ZONAIR using the uncorrected AIC. The third set is labeld as WT2 CP that is computed by ZONAIR except using the corrected AIC. Thus, the first set and third set of ΔCp should match with each other well.

5. Normally, the ΔCp_{given} provided by the CFD solution or wind-tunnel measurement at the wing leading edge is much lower than those pressures computed by the uncorrected AIC matrix. This large difference may give an over-corrected AIC matrix which could lead to poor aeroelastic/trim solutions. To specify the identification number of those aerodynamic panels along the wing leading edge by the PANLSTi entries is suggested so that ΔCp_{given} at those aerodynamic panels can adopt those computed by the uncorrected AIC matrix. Also, if some of the components in the aerodynamic model are not included in the CFD or wind tunnel model, exclusion of those components from the downwash weighting matrix by specifying the PANLSTi entry is highly recommended.

Chapter 5

GUIDELINES FOR AERODYNAMIC MODELING

This section presents some important aspects of ZONAIR aerodynamic modeling and is intended to provide information that has not been covered in the bulk data card descriptions. ZONAIR has been developed with many checks to detect any errors in the aerodynamic input. However, there are certain situations whereby incorrect modeling is not detectable by the program and may lead to incorrect results. Some of these situations can be avoided by following the modeling guidelines presented in this section.

5.1 AERODYNAMIC COORDINATE SYSTEM

The aerodynamic coordinate system is the basic coordinate system in which the entire aerodynamic model geometry is defined. Since ZONAIR solves the small disturbance potential equation:

$$\left(1-M_\infty\right)^2 \phi_{xx} + \phi_{yy} + \phi_{zz} = 0 \tag{5.1}$$

where M_∞ is the freestream Mach number and ϕ is the velocity potential, the compressible direction of the flow is inherently along the x-axis of the aerodynamic coordinate system as shown in Figure 5.1. In addition, if the configuration is symmetric about the x-z plane as the one shown in Figure 5.2, only one half of the configuration located in the positive y-axis region is required for modeling. For the half model, ZONAIR can automatically account for the aerodynamic influence between the half configuration located in the positive y-axis and the negative y-axis by a mirror image technique. Compared to a full model, this mirror image technique can reduce the size of the problem by a factor of two and save computational time. Note that this symmetry condition is specified by the XZSYM entry of the **AEROZ** bulk data card.

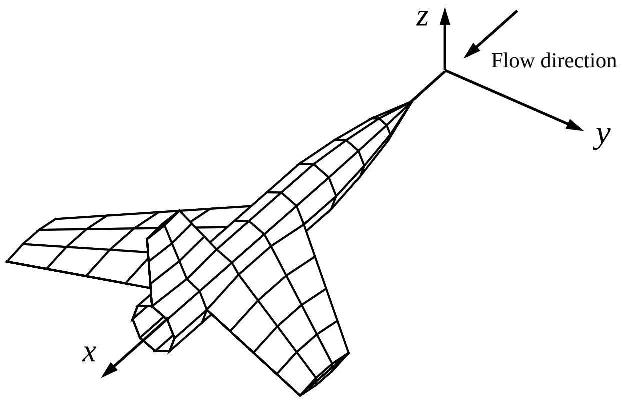


Figure 5.1 The Aerodynamic Basic Coordinate System

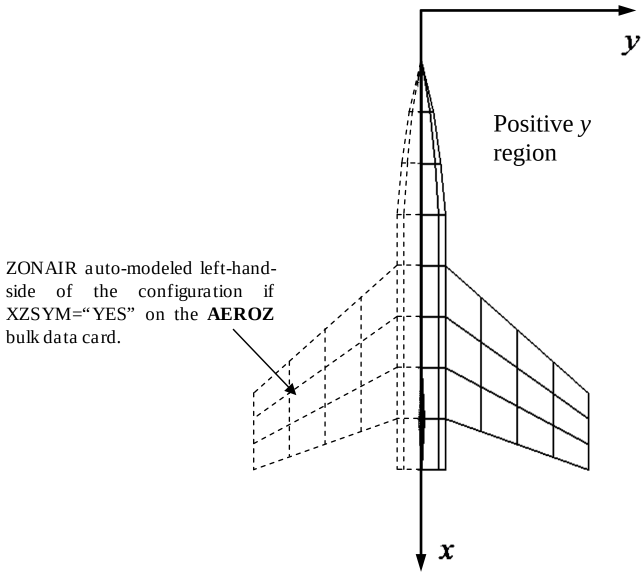


Figure 5.2 Half Model for Symmetric Configuration

The flight condition of the configuration is specified in terms of the freestream Mach number (M_∞), the angle of attack (α), side slip angle (β), roll rate (p), pitch rate (q), and yaw rate (γ). The definition of these parameters is shown in Figure 5.3.

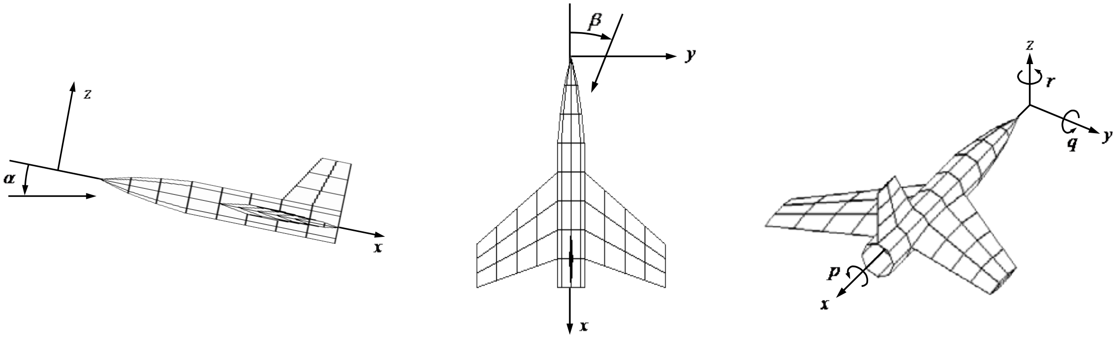


Figure 5.3 Definition of α, β, p, q, and γ

The Mach number is specified by a **MACH** bulk data card, and α, β, p, q, and γ are specified by an **AEROGEN** bulk data card. Other parameters involved in the flight condition definition are the control surface deflection, structural deformation due to smart structural actuation, and jet force which can be specified by the **AESURFZ**, **PZTMODE,** and **JETFRC** bulk data cards, respectively.

5.2 SURFACE DISCRETIZATION BY GRID POINTS AND PANELS

A ZONAIR aerodynamic panel method is normally constructed by first discretizing the configuration surface into many grid points (the **GRID** bulk data cards) and then connecting those grid points with either quadrilateral panels (the **CQUAD4** bulk data cards) or triangular panels (the **CTRIA3** bulk data cards). ZONAIR distributes an unknown constant source singularity on each panel and an unknown doublet singularity at each grid point. In addition, these doublet singularities are further linearly distributed over the panels which are surrounding this grid. This type of linear doublet distribution is called elementary singularity distribution as shown in Figure 5.4.

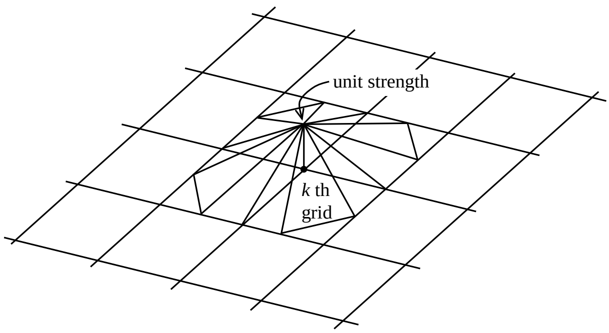


Figure 5.4 Elementary Singularity Distribution at Grid Points

At each panel, two boundary conditions shown in Figure 5.5 are imposed to solve the source and doublet strength; the Neumann boundary condition $\left(\frac{\partial \phi}{\partial n} = -\vec{V}_\infty \cdot \vec{n}\right)$ and the Dirichlet boundary condition ($\phi_L = 0$). Also, the zero-force condition $\left(\frac{\partial \phi}{\partial x} = 0\right)$ is imposed on the wake to satisfy the wake condition.

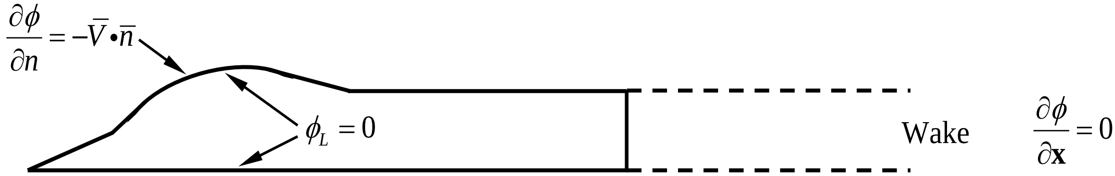


Figure 5.5 Dirichlet and Neumann Boundary Condition on Panels and Zero-Force Condition on Wake Surfaces

Once the unknown doublet singularity strength at each grid point is solved, the resulting doublet distribution over the entire panel model is obtained by the superposition of all elementary singularity distributions. It can be seen that this resulting doublet distribution is continuous over the entire panel model if all panels are "coherent" with the grid points. Any violation of this coherent requirement such as the one shown in Figure 5.6 can result in the discontinuity of doublet distribution. Because the pressure coefficient is proportional to the derivatives of the doublet distribution, the discontinuous doublet can yield an incorrect pressure jump across the incoherent panels.

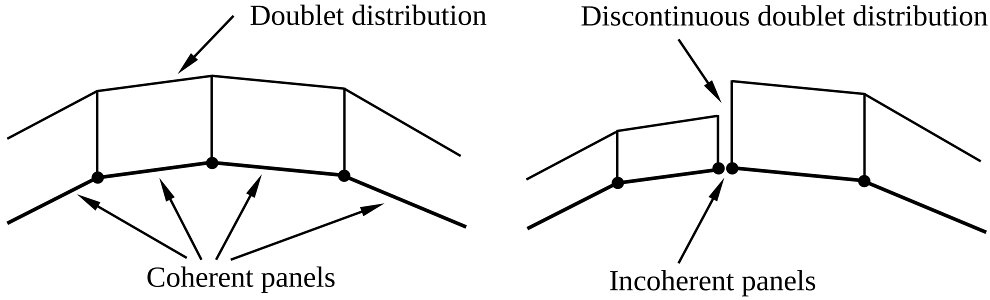


Figure 5.6 Requirement of Panel Coherence for Continuous Doublet Distribution

This implies that any grid point in the aerodynamic model must be completely surrounded by panels and the entire panel model must be "closure"; i.e., no hole or slit is allowed. For instance, the engine inlet face must be closed by panels even if physically it is a hole. ZONAIR allows the flow to penetrate into those panels to simulate the effects of the inlet by imposing the in-flow condition which is specified in the **PSHELL** bulk data card.

However, along the trailing edge of a wing and a truncated-end body or along the tip of a wing where a "free edge" exists, this closure condition cannot be satisfied because the physical surface ends along those free edges. To satisfy the closure condition requires adding a wake surface or vortex roll-up line along these free edges.

5.3 WAKE MODELING

Physically, the wake surface is a thin layer of surface containing vorticities due to the rotationality of the flow. ZONAIR models this thin vorticity layer by a doublet sheet with an infinitesimal thickness and with a constant doublet strength along the streamwise direction. This type of doublet sheet is called the wake surface. The wake surface usually starts from the trailing edge of a wing or the rear end of a truncated-end of body to simulate the vorticities shaded from those edges. There are two types of wake surfaces that can be used for the wake modeling in ZONAIR; the flat wake and the curved wake.

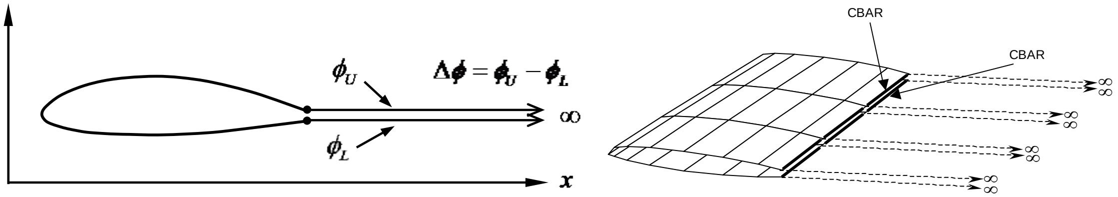


Figure 5.7 Flat Wake Modeling by CBAR Elements

Figure 5.3.1 depicts two flat wake surfaces whose leading edges are attached to the grid points at the trailing edges of the upper and lower surfaces of a wing. The trailing edge of the wake surface is extended to infinity. The flat wake surface is always parallel to the x-axis of the aerodynamic coordinate system. The wake effects are represented by the potential difference ($\Delta\phi$) between the doublet strength on the upper wake surface (ϕ_U) and on the lower wake surface (ϕ_L). Because the doublet strength is constant on the wake surface and the wake surface is flat which greatly simplifies the wake integral, an exact integral solution can be obtained for the wake integral by integrating the doublet kernel integral from the trailing edge of the wing to infinity on the flat surface. This exact integral solution is only a function of the doublet strength at the grid points along the trailing edge of the wing; i.e., the wake effects are included by evaluating the exact integral solution along the line segments at the trailing edge of the wing. ZONAIR models these line segments by the **CBAR** bulk data cards. Therefore, ZONAIR does not require the modeling of the flat wake surface which greatly reduces the modeling effort for wake modeling.

Because the accuracy of the aerodynamic results on the wing usually has little influence from the shape of the wake surface, the flat wake surface is recommended for the modeling of the wake surface. However, for a closely coupled wing-tail configuration (Figure 5.8(a)) where the wake shape from the wing dominates the downwash effects on the tail, a flat wake modeling apparently may give large discrepancy on the aerodynamics of the tail. Furthermore, for a coplanar wing-tail configuration (Figure 5.8(b)), because the flat wake surface from the wing can penetrate into the tail, a singularity may occur which is obviously incorrect. For these cases the curved wake modeling is recommended which is specified by the **WAKENET** bulk data card.

(a) Closely Coupled Wing-Tail Configuration

(b) Coplanar Wing-Tail Configuration

Figure 5.8 Cases Where the Flat Wake Surface is Not Recommended

Figure 5.9 shows a curved wake surface that is modeled by NY wake lines and NX grid points along each wake line. The locations of the NY × NX grid points are specified by the user if the shape of the wake surface is known. ZONAIR constructs two sets of the CSHEAR panels between these grid points, with one set of the CSHEAR
panels is on the lower surface. Similar to the flat wake surface, a constant doublet singularity along the chordwise direction is distributed on each CSHEAR panel to satisfy the wake condition.

However, since the wake shape is usually not known, ZONAIR provides a wake relaxation technique to determine the wake shape. The wake relaxation technique iterates the locations of the grid points on the curved wake surface until the zero-force condition of the wake is satisfied. This wake relaxation technique can be activated by using the **RELAXW** bulk data card.

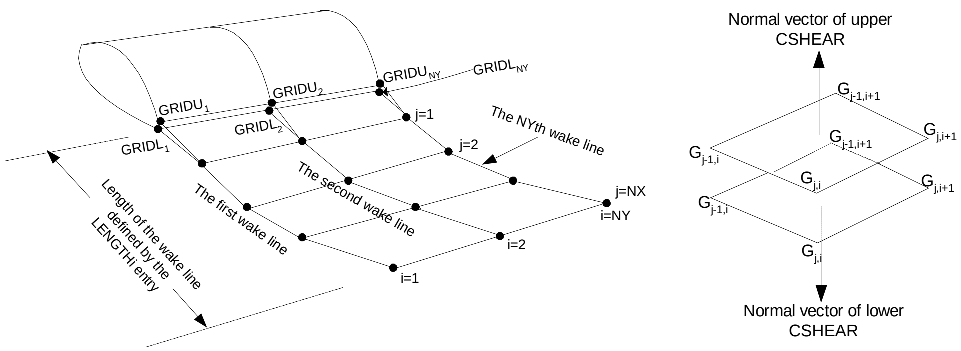
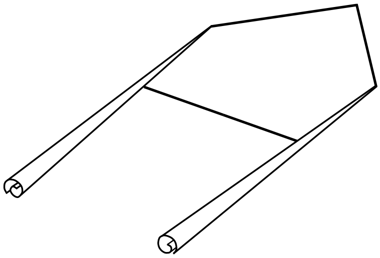


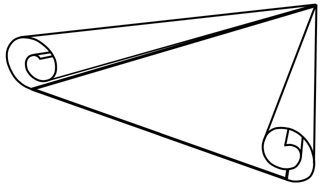
Figure 5.9 Modeling of a Curved Wake Surface

5.4 TIP VORTEX MODELING

When a wing sustains lift, flow can separate at the tip of the wing (Figure 5.10(a)) or along the leading edge of a swept wing with sharp edges (Figure 5.10(b)). This separation produces vortex sheets that roll up into strong vortices that are shed downstream. Studies of the principal vortex indicate that the vortex roll-up shape and strength are relatively independent of viscosity and can be modeled as potential flow. Two types of roll-up vortex can be modeled in ZONAIR using a line vortex element by the **CROD** bulk data card and a vortex roll-up sheet by the **VORNET** bulk data card.



(a) Vortex Roll-Up at Wing Tip



(b) Vortex Roll-Up at Wing Leading Edge

Figure 5.10 Vortex Roll-Up on a Lifting Wing

The line vortex element approximates the roll-up vortex by lumping the vortices containing the roll-up vortex sheet into line segments. Figure 5.11 shows a typical modeling of these line vortex segments (or CROD elements) along a wing tip.

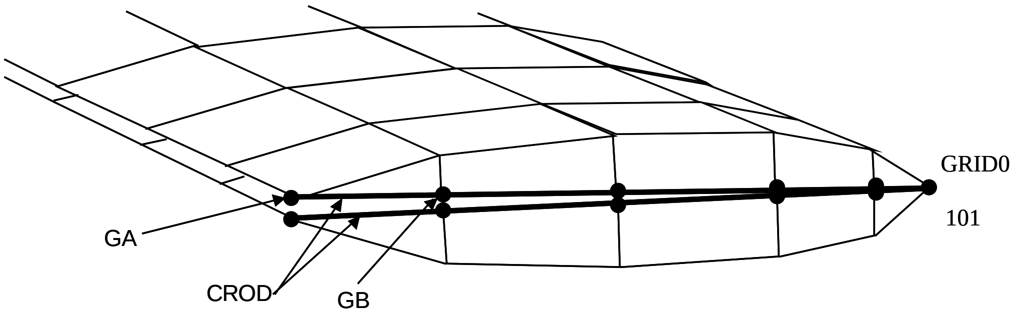


Figure 5.11 CROD Elements Along Wing Tip for Vortex Roll-Up

A linear vortex singularity is distributed along each of the line vortex segments. The strength of the vortex singularity is determined by the doublet strength at those grid points to which those line vortex segments are attached. Behind the trailing edge of the wing tip, the roll-up vortex is modeled by two line vortex elements starting from the trailing edge and extending to infinity (Figure 5.12); one line vortex element is attached to the grid points at the upper surface of the wing-tip trailing edge and the other to the lower surface. These infinite line vortex elements are specified in the **CBAR** bulk data card. Similar to the flat wake model, the infinite line vortex element is always parallel to the x-axis of the aerodynamic coordinate system. In fact, without the infinite line vortex element, a free edge occurs along the tip of the flat wake surface (generated by the CBAR element) which violates the closure condition. This is to say that a free edge either along the tip of a wing or a wake surface must be terminated by a line vortex element. The potential jump due to the line vortex element is computed by the difference in vortex strength of the line vortex at the upper and the lower surfaces.

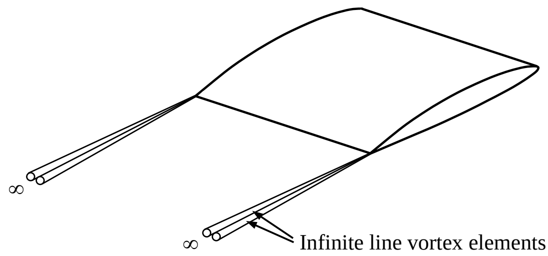


Figure 5.12 Infinite Line Vortex Elements to Model the Roll-Up Vortex Behind the Wing Trailing Edge

However, the line vortex modeling for the roll-up vortex is applicable only for low angle of attack aerodynamics. At high angle of attack condition where the roll-up vortex could "take off" from the wing tip, the structures of the roll-up vortex should be modeled by the VORNET macroelement. Figure 5.13 depicts a typical roll-up vortex modeling by the VORNET macroelement which consists of a set of CSHEAR elements for the modeling of the vorticity sheet and a set of CROD elements for the modeling of the vortex core. For the detailed description of the **VORNET** macroelement, please refer to the **VORNET** bulk data card.

It should be noted that the shape of the VORNET macroelement can be determined by the wake relaxation technique which is similar to the one for the curved wake surface.

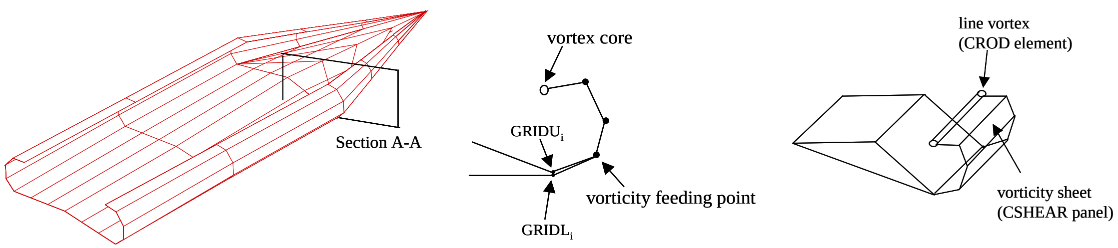
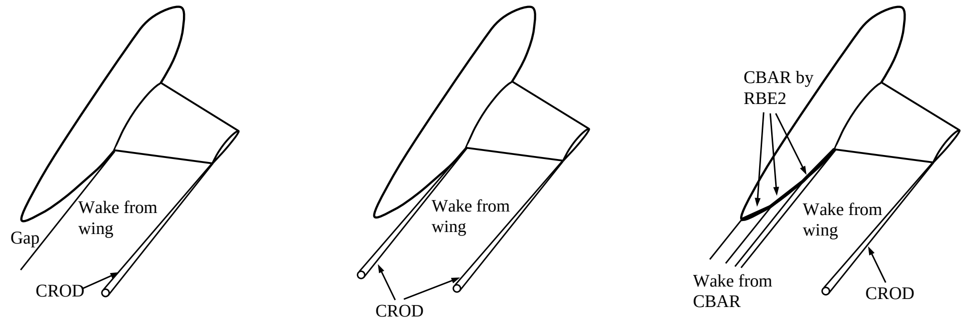


Figure 5.13 Roll-Up Vortex Modeling by the VORNET Macroelement

5.5 RBE2 FOR THE WAKE MODELING BEHIND THE WING-BODY JUNCTION

Figure 5.14(a) shows a wing-body configuration where a gap exists between the inboard of the wake from the wing and the body behind the wing-body junction. As mentioned earlier, this gap violates the closure condition because the inboard of the wing becomes a free edge, and is therefore incorrect modeling.



(a) Incorrect Modeling due to the Gap

(b) Incorrect Modeling using CROD Along the Inboard of the Wake

(c) Correct Modeling using RBE2

Figure 5.14 RBE2 for Wake Modeling Behind the Wing-Body Junction

One could satisfy the closure condition by adding a infinite line vortex element (**CROD**) along this free edge. However, this line vortex is physically unrealistic because flow cannot roll up at the wing-body junction. The correct modeling to satisfy the closure condition is to use the **RBE2** bulk data card that automatically generates a set of **CBAR** elements along those body grid points behind the trailing edge of the wing-body junction. These **CBAR** elements serve two purposes: (1) to fill up the gap so that the closure condition is satisfied (2) to impose the potential jump condition due to wake at those body grid points so that the potential jump is continuous from the wake to those body grid points. For detailed description, please refer to the description of the **RBE2** bulk data card.

5.6 THE THIN WING MODELING

It is well known that the aerodynamic influence coefficient matrix may become ill-conditioned if two surface panels are very close to each other due to the singularity behavior of the kernel integral. In fact, the matrix is singular if two surface panels coincide with each other. The ill-conditioned matrix may occur on a wing of very thin thickness if the upper and lower surfaces of the wing are modeled by the surface panels.

To circumvent this problem, a thin wing modeling technique using the **CAERO7** bulk data card is incorporated in ZONAIR. The **CAERO7** bulk data card distributes a sheet of source singularity and vortex singularity on the mean plane of the thin wing where the source singularity simulates the thickness effects, and the vortex singularity simulates the angle-of-attack and camber effects (Figure 5.15). It should be noted that this mean plane is a flat surface that has no camber even for a cambered wing. The camber effects are introduced in the boundary condition in the small disturbance sense.

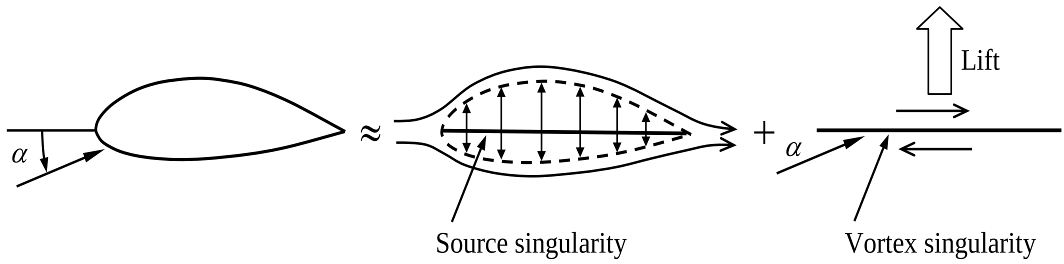


Figure 5.15 Source and Doublet Sheets on the Mean Plane of the Thin Wing Modeling

The **CAERO7** bulk data card divides the mean plane of the thin wing into several strips by the user specified spanwise divisions. Each spanwise division must be parallel to the x-axis of the aerodynamic coordinate system. Each strip is then divided into several boxes (called "wing boxes") by chordwise divisions specified at the root and the tip chords. Each **CAERO7** bulk data card represents a wing macroelement comprising (n-1) x (m-1) wing boxes (where n = the number of spanwise divisions, and m = the number of chordwise divisions).

Figure 5.16 presents a typical thin wing configuration modeled by the **CAERO7** macroelement. The solid circles on each wing box represent the control points at which boundary conditions are imposed. The control points which lie along the mid-span of each wing box is located at 85% of the wing box chord for subsonic Mach numbers and at 95% of the wing box chord for supersonic Mach numbers. The solid and the dashed lines in the wake region of the thin wing in Figure 5.16 represent the vortex lines generated by each strip of the **CAERO7** macroelement. The solid lines represent the so-called "strong vortex line", whereas the dashed lines represent the "weak vortex line."

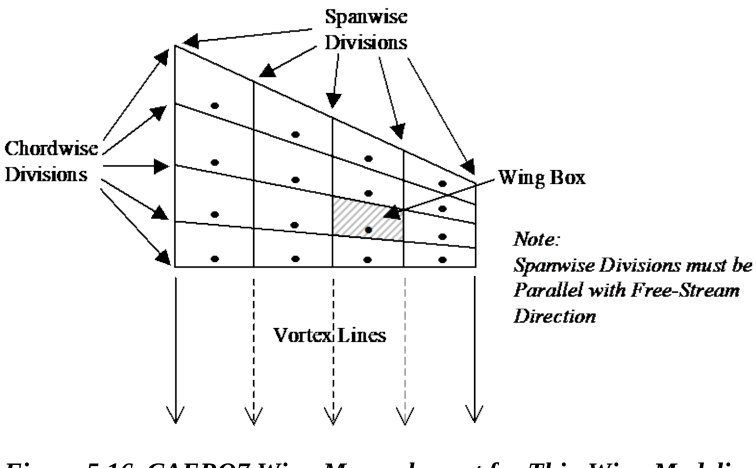


Figure 5.16 CAERO7 Wing Macroelement for Thin Wing Modeling

These vortex lines are generated due to the discontinuity between vortex singularities for two adjacent strips. Each strip sheds two “strong vortex lines” from its side edges that start at the trailing edge and shed downstream (Figure 5.17(a)). However, at edges shared by two adjacent strips, the strength of the two vortex lines partially cancels each other forming a “weak vortex line” (Figure 5.17(b)). No input is required by the user to model these vortex lines since their effects are already included as part of the vortex singularity on the wing boxes. However, due to the singular behavior of the vortex line, several restrictions must be adhered to in modeling the thin wing by **CAERO7**.

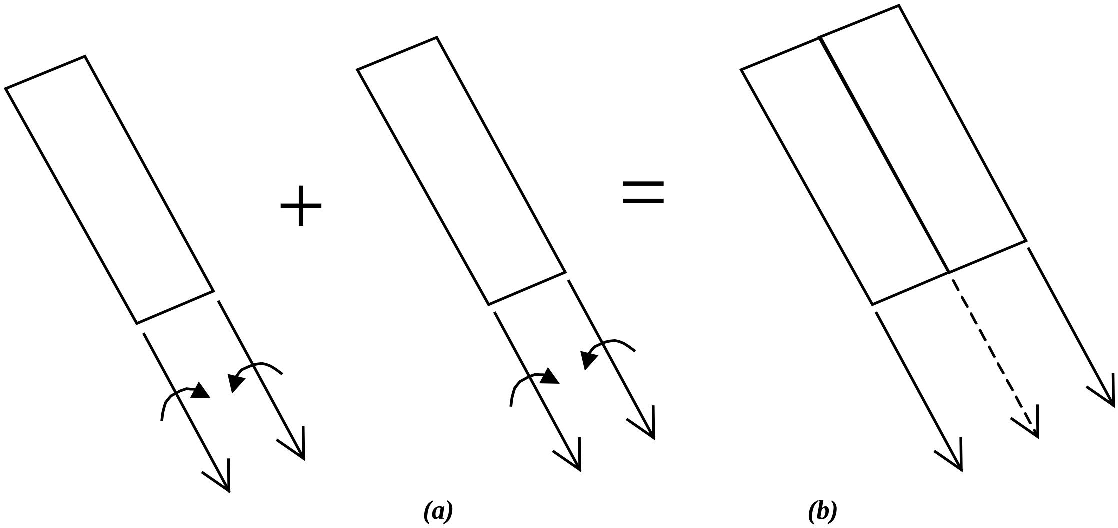


Figure 5.17 Vortex Lines Shed from CAERO7 Chordwise Strips

Figure 5.18 shows a wing-tail configuration modeled by two **CAERO7** macroelements. If the wing and tail are located in the same plane (coplanar), all spanwise divisions of the tail must be aligned with those of the wing. A violation of this requirement results in the vortex lines shed from the wing that cut through the aerodynamic boxes of the tail. Since, at the vortex line, the aerodynamic influence is singular, this yields an unrealistically large downwash effect on the tail. In fact, if a vortex line of the wing were to align with a control point on the tail, the aerodynamic matrix would become singular. This modeling restriction is still required for the case where the wing and the tail are not located in the same plane and the distance (d) along the normal direction is small (i.e., $0 \leq d \leq w$). This restriction can be relaxed only if the distance is larger than the width of the strip (w) (see Figure 5.18(b)).

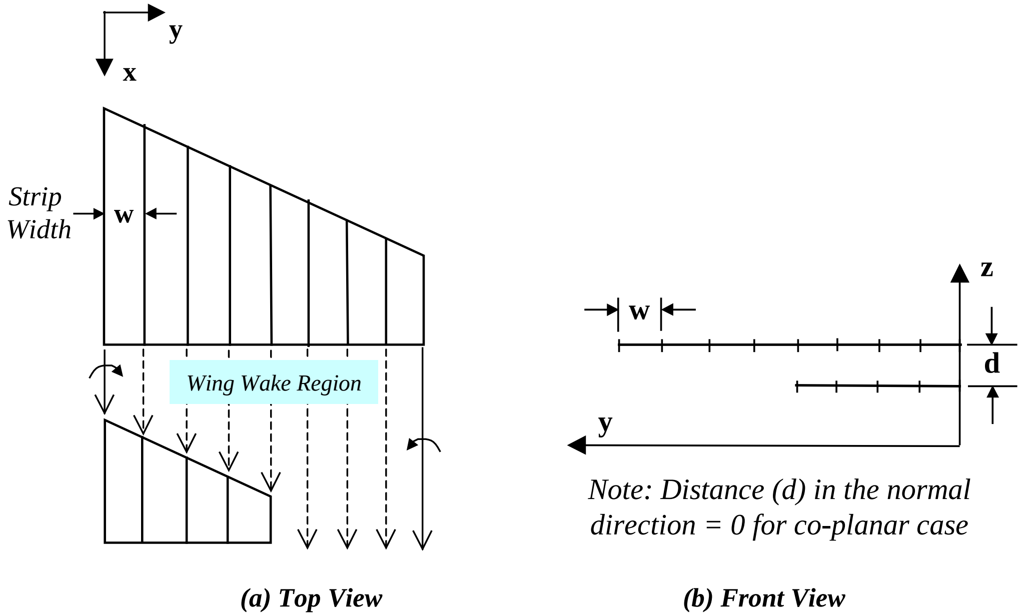


Figure 5.18 Alignment of Spanwise Divisions of a Wing-Tail Configuration Modeled by two CAERO7 Macroelements

Another configuration where the use of thin wing modeling is recommended is the coplanar wing-tail configuration. If the tail is modeled exactly by the surface panels on both its upper and lower surface such as the one shown in Figure 5.8(b), the wake from the wing may penetrate into the tail and creates a singularity in computation. However, if the tail is modeled using the **CAERO7** macroelement (Figure 5.19), this wake-penetration problem is avoided altogether because the **CAERO7** macroelement employs thin vortex and source sheets, and has no thickness; therefore no wake penetration from the wing into the tail can occur.

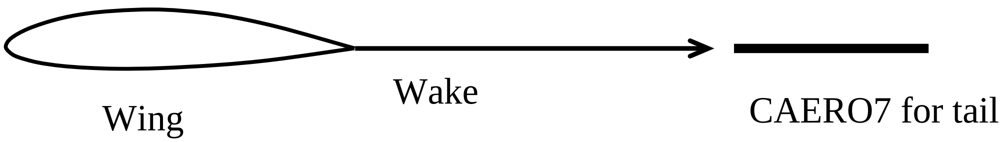


Figure 5.19 Thin Wing Modeling for the Tail to Avoid Wake Penetration from the Wing

For a wing modeled by CQUAD4/CTRIA3 elements with a round leading edge in supersonic flow (Figure 5.20), the Mach cone can cut into the wing and the potential flow theory breaks down. In this case, using the thin wing modeling can circumvent this problem.

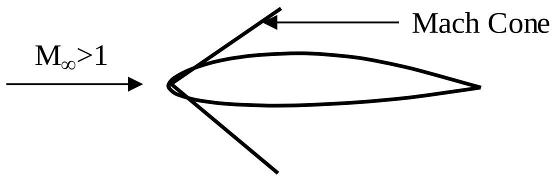


Figure 5.20 Mach Cone Cuts into Wing Leading Edge in Supersonic Flow

5.7 SUPER-INCLINED PANELS IN SUPERSONIC FLOWS

In a linearized supersonic flow formulation, the freestream Mach cone determines the region of influence. Typical supersonic panel methods generally work well if the body under consideration is fully immersed within this region of influence. However, when the supersonic freestream becomes higher and/or the body is relatively thick whereby a part of the body would be exposed outside of the zone of influence, most supersonic panel methods would cease to be applicable.

For panels placed on the inlet surface (Figure 5.21(a)) or on the nose of a thick body (Figure 5.21(b)), the local angles of incidence on some panels would be greater than the freestream Mach cone angle, this would render them lie outside of the freestream Mach cone. These panels are called “super-inclined panels” and they are the causes for numerical singularities in the supersonic aerodynamic influence coefficient computation.

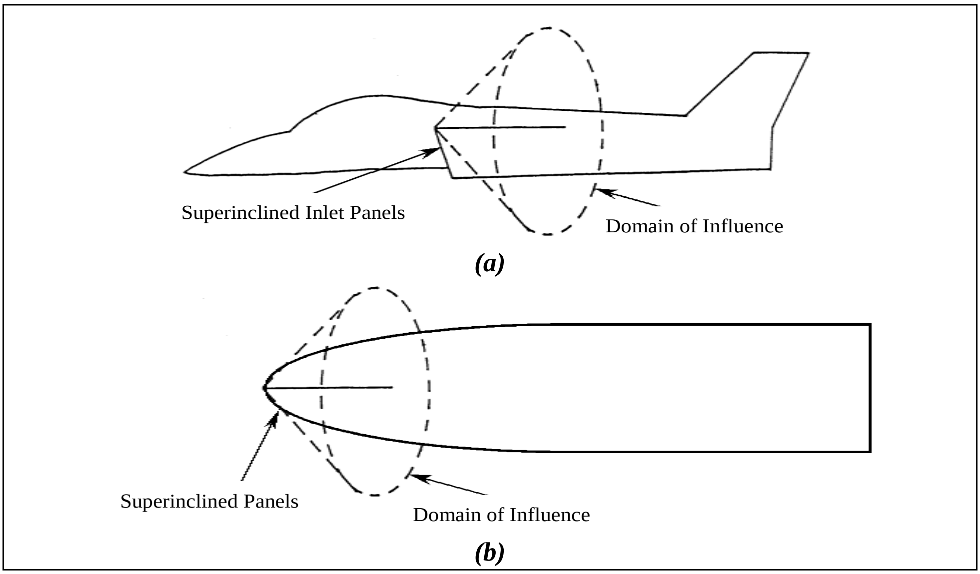


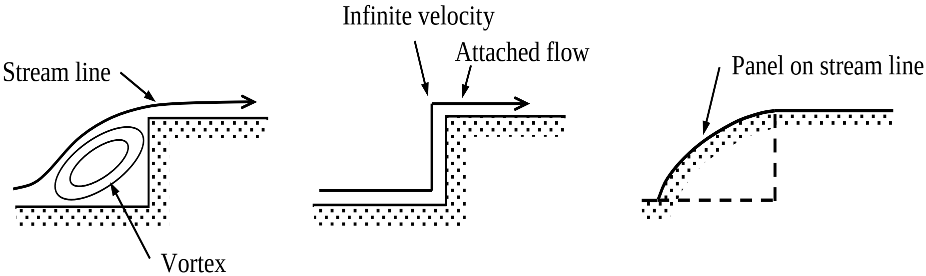
Figure 5.21 Superinclined Panels (a) on Engine Inlet (b) on Thick Body

To circumvent this numerical singularity problem that is associated with super-inclined boxes in supersonic flow, we introduce a special treatment for the aerodynamic influence coefficient computation in ZONAIR. This engineering treatment adopts the corresponding oblique shock angle for a cone (based on the Exact Euler Conical-Flow Solutions) to compute the Mach wave angle. The local cone angle for each superinclined box is measured by the angle between the freestream and the slope of the panel. The corresponding oblique shock angle is used as a modified Mach wave angle to position a "Mach Wave" slightly ahead of the super-inclined panels. It is this modified Mach angle that determines the region of influence of the super-inclined panels.

However, for superinclined panels at the wing leading edge, it is highly recommended to use CAERO7 to model the wing instead of using CQUAD4/CTRIA3 to model the physical wing shape.

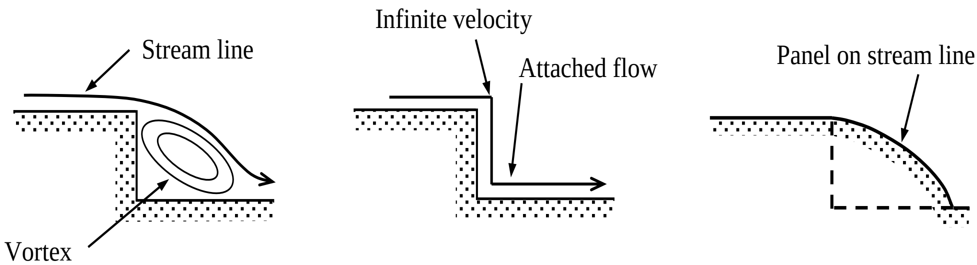
5.8 MODELING OF THE REAL FLOW USING THE POTENTIAL FLOW THEORY

Unlike the Computational Fluid Dynamics (CFD) methodology that "simulates" the flow, the panel method solves the potential flow equation that can only be used to "model" the flow. This is to say that in order to establish a good panel model that can capture most of the physics of the flow, the user must understand the overall flow structure. Due to the attached flow assumption of potential flow theory, the best panel model is one in which all panels are placed on the closest streamlines of the flow to the body surface; not on the exact surface of the configuration. For instance, the flow velocity predicted by the potential flow passing a sharp corner would be infinite at the corner in order to keep the flow attached. Shown in Figure 5.22(a) is a flow passing a forward facing step where a vortex is developed and trapped at the corner, and a streamline is developed over the trapped vortex. If the surface of the step is modeled exactly by aerodynamic panels (Figure 5.22(b)), an infinite velocity will be predicted by the panel method which obviously is incorrect. The recommended panel modeled is shown in Figure 5.22(c) where the panels are placed on the streamline to form a smooth panel model. In so doing, the flow velocity on this smooth panel model can remain finite. In fact, ZONAIR does not allow any panel whose inclination angle with respect to the flow direction to be greater than 90° to avoid such an infinite flow velocity prediction such as the one shown in Figure 5.22(b). Similarly, the correct panel model for a flow passing a backward facing step is shown in Figure 5.23(c).



(a) Real Flow *(b) Incorrect Panel Model* *(c) Correct Panel Model*

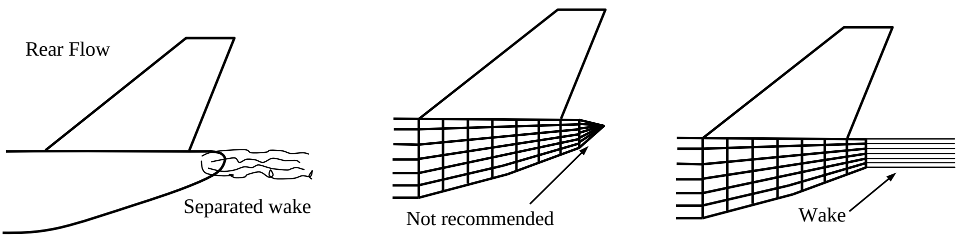
Figure 5.22 Modeling of Flow Passing a Forward Facing Step



(a) Real Flow *(b) Incorrect Panel Model* *(c) Correct Panel Model*

Figure 5.23 Modeling of Flow Passing a Backward Facing Step

Another example showing how to use the wake surface to model separated flow on an aft body is illustrated in Figure 5.24. In the real flow, the fluid does not stagnate at a point at the aft end of the body, but rather separates into a trailing wake. It is recommended that the aft body be truncated at the separation line and use the wake surface to model the streamline outside the separated flow (Figure 5.24(c)). Although the exact separation line may not be known, it is likely that the error incurred will be less than if the flow is forced to remain attached and stagnated (Figure 5.24(b)). The closed aft end model usually yields a solution with a poor lift and may also wrongly influence nearby lifting surfaces. The preferred modeled for the open trailing wake is shown in Figure 5.24(c). The body itself is modeled by the surface panels but with a wake surface attached to the truncated-end of the body at the presumed separation line. This will assure that the flow departs the body smoothly along the specified wake surface.



(a) Real Flow *(b) Incorrect Panel Model* *(c) Recommended Model*

Figure 5.24 Modeling of Aft Body

5.9 COMPUTATIONAL TIME AND DISK SPACE REQUIREMENT

Figure 5.25 gives ZONAIR computational time and disk space requirements as a function of the number of panels on a 2.4 GHz PC computer. It can be seen that the CPU time and disk space increase exponentially as the number of panels increase. At 10,000 panels, the disk space could require 20 GB and the CPU time could reach 800 minutes. Therefore, in order to keep the CPU time and disk space requirement on a reasonable level, it is recommended that the number of panels be kept below 5,000. In fact, numerical experience shows that a model with 5,000 panels is usually sufficient to model a complex configuration such as whole aircraft with external stores. Beyond 5,000 panels the gain in accuracy may not be significant.

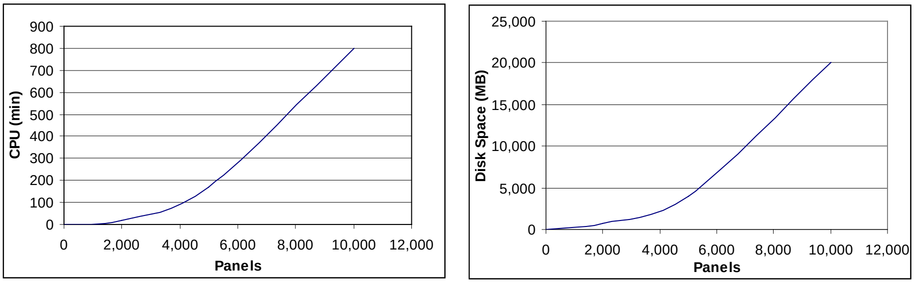


Figure 5.25 CPU Time and Disk Space Versus Number of Panels

Chapter 6

MODELING GUIDELINES OF SPLINE FOR FLEXIBLE LOADS

To compute the flexible loads due to the structural deformation, it is required the coupling between the aerodynamics and structures. Since the requirements to generate the discretized models for the structural analysis and the aerodynamic analysis are subject to different engineering considerations, the grid point locations of these two models may be considerably different. This gives rise to the problem of transferring the displacements and forces between these two grid systems. Four spline methods are incorporated, in the spline module of ZONAIR, which generate spline matrices to perform the displacement and force transferal between the structural finite element model and the ZONAIR aerodynamic model. These four spline methods are:

- Infinite Plate Spline (IPS) Method by the **SPLINE1** bulk data card
- Beam Spline Method by the **SPLINE2** bulk data card
- Thin Plate Spline (TPS) Method by the **SPLINE3** bulk data card
- Rigid Body Attachment by the **ATTACH** bulk data card

The generation of the spline matrix is performed on a component-by-component basis. The selection of the spline method for a given component depends on the type of component in the ZONAIR model (i.e., wing-like or body-like component) and the type of elements (i.e., beam or plate element) used in the finite element model. For instance, if a body-like component is modeled in the ZONAIR model and if beam-type elements are used for the finite element model, then the beam spline method should be employed. If wing-like components are modeled in the ZONAIR model and plate-type elements are used for the finite element model, then the IPS method should be used. The TPS method is a 3-D spline method that can link a set of finite element grid points in 3-D space to either a wing-like or body-like component. The **ATTACH** bulk data card handles the special case in which a component is absent in the finite element model but is present in the ZONAIR model. A typical example of such a special case is an underwing store that is represented by a concentrated mass at a single finite element grid point but is completely modeled in the ZONAIR model.

Experience has shown that most of the errors in performing flexible loads analysis are introduced in the spline procedure. The following modeling guidelines present several situations in which inaccurate spline results are easily introduced due to incorrect input set-up.

6.1 ILL-CONDITIONED SPLINE MATRIX DUE TO COINCIDENT FINITE ELEMENT GRID POINT LOCATIONS

The selection of the finite element grid points that are to be linked to an aerodynamic component is completely at the user's discretion. These grid points are defined by **SET1** or **SET2** bulk data cards. Should two of the selected finite element grid points be located within a small tolerance of one another (tolerance set by EPS defined in the **SPLINE1** and **SPLINE3** bulk data cards), the resultant spline matrix is either singular or ill-conditioned. This input error is automatically detected by the ZONAIR spline module. However, certain scenarios exist in which this kind of input error may not be detected by the spline module.

As an example of such a scenario, Figure 6.1 shows the cross-section of a wing-like component in which the solid circles represent the finite element grid points on the upper and the lower skins and the line represents the side view of a **CAERO7** macroelement. All finite element grid points appear to be well separated. If the IPS method is selected as the spline method, the spline module projects the finite element grid points onto the plane of the **CAERO7** macroelement (Figure 6.1(b)). This plane is called the "spline plane."

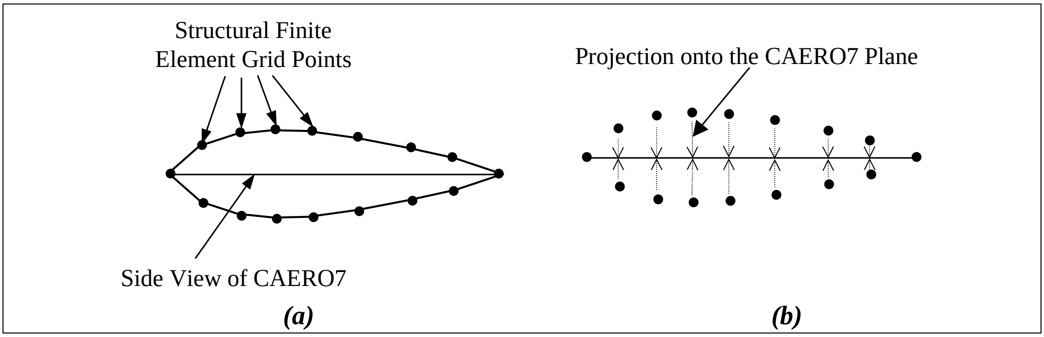


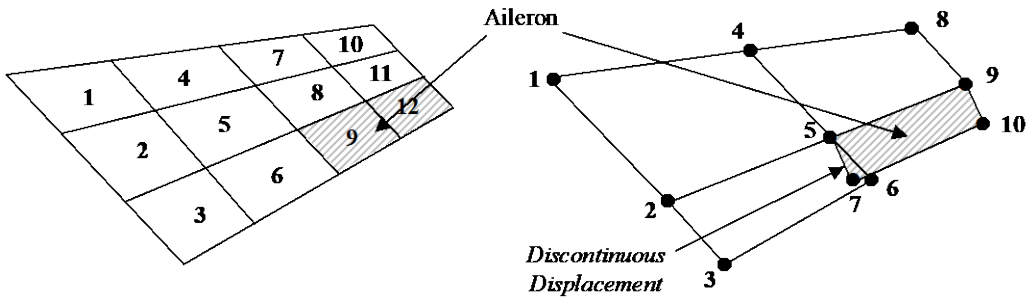
Figure 6.1 Cross-Section of a Wing-Like Component

If the projection of two grid points on the spline plane are too close to one another, an ill-conditioned spline matrix results. In this situation, the error condition may not be detected by the spline module. To avoid this input error, it is recommended that either the upper or the lower grid points, but not both, be included in the **SET1** bulk data card.

The spline case illustrated in Figure 6.1(a) is an ideal case for the TPS method. Since TPS is a 3-D spline method, there is no requirement to define a spline plane for grid point projection. Therefore, all upper and lower grid points can be included in the spline. However, this is true only for a thick wing-like component. As described in the remarks of the **SPLINE3** bulk data card, the structural points used by the TPS method can not be located close to or within the same plane. Otherwise, an ill-conditioned spline matrix may result. For such a case, where the wing-like component thickness is very thin, the IPS method is recommended, but only with the selection of either the upper skin or the lower skin grid points.

6.2 SPLINE FOR DISCONTINUOUS STRUCTURE

A typical case of a discontinuous structure is a control surface. The control surface creates discontinuous displacements between its side edges and the main wing as well as discontinuous slopes along the hinge line, which may have a large impact on the aeroelastic response. For this reason, it becomes important to accurately transfer these discontinuous displacements and slopes from the finite element grid points to the aerodynamic model.



(a) CAERO7 Macroelement *(b) Structural Finite Element Model*

Figure 6.2 Spline of Discontinuous Structure Due to a Control Surface

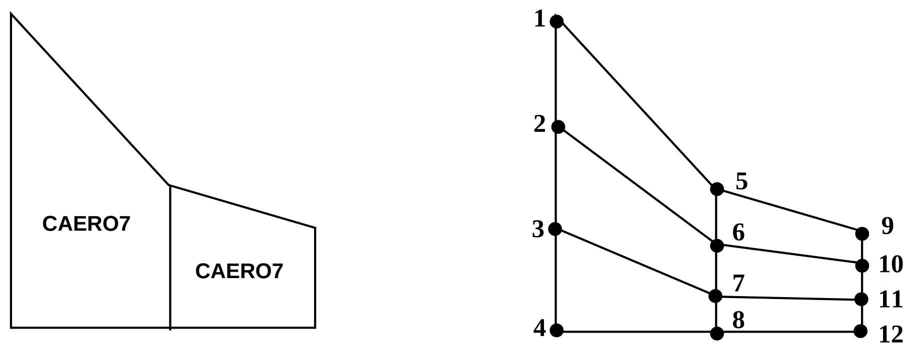
Figure 6.2(a) presents a wing with aileron configuration modeled by a **CAERO7** macroelement that includes 12 wing boxes, denoted as box 1 through box 12. The shaded area represents the aileron and its corresponding wing boxes are box 9 and box 12. The finite element model shown in Figure 6.2(b) consists of 4 plate-type elements generated by the connection of the ten grid points (represented by the solid circles and denoted as grid points 1 through 10). Discontinuous displacement occurs between the inboard edge of the aileron and the main wing due to the discontinuous structure (between grid points 6 and 7). Because the finite element model exclusively employs plate type elements, the IPS method should be selected for this case.

Since the IPS method is formulated based on the structural equation of an infinite plate, the continuity of displacement is inherently imposed. This indicates that if all of the finite element grid points shown in Figure 6.2(b) are included in the spline, the resultant displacement on the **CAERO7** macroelement are continuous. In this case, failure to transfer discontinuous displacement due to the aileron will lead to incorrect aeroelastic results.

The correct technique to be used in this spline case is to apply the IPS method on the main wing and on the aileron separately by specifying two **SPLINE1** bulk data cards. The first **SPLINE1** established for the main wing should include the wing boxes (boxes 1 - 6 plus 7, 8, 10, and 11) and finite element grid points corresponding to the main wing only (grid points 1 – 6 plus 8 and 9). Likewise, the second **SPLINE1** established for the aileron should include only those wing boxes (boxes 9 and 12) and finite element grid points (5, 7, 9, and 10) associated with the aileron.

6.3 ENSURING CONTINUOUS STRUCTURE ACROSS TWO ADJACENT CAERO7 MACROELEMENTS

One of the modeling restrictions of the **CAERO7** macroelement is that it can only represent trapezoidal types of surfaces, i.e., the inboard and outboard edges must be parallel to the x-axis of the aerodynamic coordinates. Therefore, to model a non-trapezoidal type of wing-like component may require more than one **CAERO7**. Figure 6.3(a) presents a cranked wing planform that is modeled by two **CAERO7** macroelements; one for the inboard region and one for the outboard region. The plate-type finite element model shown in Figure 6.3(b) has 12 grid points, denoted as grid point 1 through grid point 12.



(a) Aerodynamic Model *(b) Structural Finite Element Model*

Figure 6.3 Spline for a Cranked Wing Planform

Two **SPLINE1** bulk data cards are required to spline the two **CAERO7** macroelements to the structure. The structural finite element model by itself is a continuous structure and should not incur any discontinuous slopes. Discontinuous slopes across the two **CAERO7** macroelements result if the inboard **CAERO7** only refers to the finite element grid points located in the inboard region (grid points 1 through 8) and the outboard **CAERO7** only refers to the finite grid points located in the outboard region (grid points 5 through 12). Such discontinuous slopes across the two **CAERO7** macroelements are incorrect and will lead to incorrect aeroelastic results.

The correct technique for this spline case is to use the IPS method and to ensure that the inboard and outboard **CAERO7** macroelements refer to <u>all</u> the grid points in the finite element model (grid points 1 through 12). The infinite plates generated by the IPS method for these two **CAERO7** macroelements are then identical, leading to continuous displacements and slopes across these two wing components.

6.4 ACCURATE ROTATIONAL STRUCTURAL DISPLACEMENT FOR BEAM SPLINE METHOD

Unlike the IPS and TPS methods, which adopt only the translational displacements at the structural grid points, the beam spline method requires both the translational and rotational displacements.

Often in structural finite element analysis, the translational displacements are included as the analysis set (i.e., A-set) degrees-of-freedom. Since the modal analyses of finite element methods only assure accurate modal displacements for the A-set degrees of freedom, exclusion of the rotational displacement for A-set degrees-of-freedom in the beam spline method leads to inaccurate spline results on the aerodynamic model.

6.5 INACCURATE SPLINE RESULTS DUE TO EXTRAPOLATION

Since structural grid points are usually placed at major load carrying components, the structural finite element model may appear to be “shorter” than the aerodynamic model. A typical case where this can occur is in modeling the structural wing torque box of a wing component. A finite element wing model that does not fully extend to the leading and trailing edges of the wing may result an inaccurate spline result due to extrapolation. Another typical case is the beam-type element model of a fuselage component. Since the nose section of a fuselage is often considered a non-structural part and, therefore, requires no structural modeling, the beam model may end up shorter than the actual length of the fuselage.

Extrapolation is performed for the spline of aerodynamic panels located outside the domain of the structural finite element grid points. Both of the plate spline methods (IPS and TPS) and the beam spline method incorporated within the spline module of ZONAIR provide a purely linear extrapolation only if the aerodynamic panel is located far away from the finite element model. Otherwise, distortions and oscillations may occur in the extrapolation regions. For this reason, extrapolation should be avoided.

To circumvent the extrapolation problem, it is recommended that extra grid points located at the leading and trailing edges of the wing or at the nose of the fuselage be added in the structural finite element model. These grid points can then be connected by rigid elements to their adjacent grid points. Thus, the problem associated with extrapolation can be avoided.

As a final note, graphical display of the displacements on the aerodynamic model for spline verification is highly recommended. It is for this reason that ZONAIR provides an option to generate output files containing the aerodynamic panel and corresponding displacement data using the **PLTMODE** bulk data card. Visual inspection of the displacements for both the aerodynamic and the finite element models would minimize errors caused by incorrect implementation of the spline.

Chapter 7

PLOT FILES

This section describes the ZONAIR output files generated for plotting purposes. Output plot files are generated by the existence of any of the following bulk data cards within the bulk data input section: **PLTAERO**, **PLTCP**, **PLTMODE**, and **PLTTRIM**. Table 2.1 presents the output plot file capability of the ZONAIR software system.

Category	Associated Bulk Data Card	Description	Software Compatibility
Aerodynamic Model	**PLTAERO**	Generates an ASCII text file for plotting the aerodynamic model.	- PATRAN - TECPLOT - I-DEAS - FEMAP - ANSYS - NASTRAN
Pressures	**PLTCP**	Generates an ASCII text file for plotting the pressure coefficients.	- PATRAN - TECPLOT - I-DEAS - FEMAP - ANSYS - NASTRAN - PEGASUS
Interpolated Structural Modes	**PLTMODE**	Generates an ASCII text file for plotting the interpolated structural mode on the aerodynamic model.	- PATRAN - TECPLOT - I-DEAS - FEMAP - ANSYS - NASTRAN
Static Aeroelastic / Trim Analysis Results	**PLTTRIM**	Generates an ASCII text file for the post-processing of the static aeroelastic/trim analysis.	- PATRAN - TECPLOT - I-DEAS - FEMAP - ANSYS - NASTRAN - PEGASUS

All output plot files are saved in ASCII text format and can be directly read in by the graphical software programs listed in the above table (or any equivalent software packages that can process the same data format). The PATRAN output is a combination of neutral file (containing the aerodynamic model) and results file (containing the displacement or pressure results) output. **Note that for the PATRAN output option, the aerodynamic models generated by the PLTxxxx bulk data cards (all stored in neutral file format) are all different from one another and cannot be used interchangeably.** This restriction is due to the necessity of duplicating grid points in some of the output plot files to allow for viewing (or animation) of discontinuous components (e.g., a flapping control surface in a modal analysis). In addition, some plot files (like **PLTMODE**) require displaying of both sides of the model even though only half of the model may have been specified in the input. For this reason, the user must take extra care when requesting multiple plot files in PATRAN format to ensure that the aerodynamic model names are unique (or they will be overwritten). The TECPLOT output is in Tecplot's finite element zone input format. The I-DEAS output is in universal data file format. The FEMAP output is in FEMAP neutral file format. The ANSYS format is identical to the FEMAP neutral file output format and can be read into ANSYS via a translator developed by PADT Inc. in Tempe, Arizona. **Note that the ANSYS option description is not included in this Chapter since it is identical to the FEMAP output option.** Excel output is in column format and can be read in by virtually any spreadsheet application. Finally, the NASTRAN supported output is in bulk data format and can be plotted by any graphical software package capable of reading in and displaying NASTRAN bulk data input (e.g., ARIES, FEMAP, etc.)

The following sections describe each of the output plot files listed above. Samples of each output file taken from the cropped wing and trim forward swept wing demonstration test cases are presented along with descriptions of the output file contents.

7.1 AERODYNAMIC MODEL (PLTAERO)

An output data file of the aerodynamic model can be generated with the **PLTAERO** bulk data card (see Figure 7.1). Viewing the aerodynamic model is extremely useful in determining if the aerodynamic configuration is modeled properly. Often times numeric typos are entered in the bulk data input that can go undetected in the analysis. For example, an aerodynamic coordinate system that is referred to by an underwing store may be located in the wrong place due to a typo in the **ACOORD** bulk data card. In this case, the store would be located somewhere other than its intended position. This error in the aerodynamic configuration can quickly be detected by viewing the aerodynamic model.

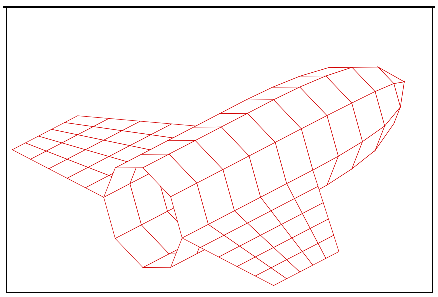


Figure 7.1 Plot of the Aerodynamic Model

The **PLTAERO** output plot file contains the aerodynamic panel corner grid points along with the aerodynamic panel connectivity information. The data for this output file is generated based on the **GRID**, **CQUAD4**, **CTRIA3**, **CBAR**, …etc., specified in the bulk data section of the input deck.

PATRAN Compatible Output

The PATRAN compatible output is saved in neutral file format. A sample of the NASTRAN compatible output is shown in the following figure and is described below:

```
25       0       0       1       0       0       0       0       0
ZONAIR AERODYNAMIC MODEL
26       0       0       1      91      65       1       1       0
  08/22/200015:31:31         2.5
 1     201       0       2       0       0       0       0       0
-0.100000000E+03 0.000000000E+00 0.000000000E+00
0G       6       0       0000000
 1     202       0       2       0       0       0       0       0
-0.100000000E+03 0.000000000E+00 0.000000000E+00
0G       6       0       0000000                   Aerodynamic
                       .                           Grid Points
                       .
                       .

2     201       4       2       0       0       0       0       0
       4           0           1           0  0.000000000E+00  0.000000000E+00
0.000000000E+00
     202     207     206     201
 2     202       4       2       0       0       0       0       0
       4           0           1           0  0.000000000E+00  0.000000000E+00
0.000000000E+00
     203     208     207     202
 2     203       4       2       0       0       0       0       0
       4           0           1           0  0.000000000E+00  0.000000000E+00
0.000000000E+00
     204     209     208     203                       Quadrilateral
                       .                               Elements
                       .
                       .

31   10101       0       1       0       0       0       0       0
 0.300000000E+02 0.000000000E+00 0.000000000E+00
31   10102       0       1       0       0       0       0       0
 0.300000000E+02 0.333330002E+02 0.000000000E+00
31   10103       0       1       0       0       0       0       0
 0.300000000E+02 0.666669998E+02 0.000000000E+00
                       .                           Structural FEM
                       .                           Grid Points
                       .

99       0       0       1       0       0       0       0       0
```

Data Packets 1 (Node Data) and 2 (Element Data) are used to output the aerodynamic grid points and aerodynamic panels, respectively. Data Packet 31 (Grid Data) is used to output the structural grid points if requested in the **PLTAERO** bulk data card (i.e., FEMGRID=YES).

Steps within PATRAN to View the Aerodynamic Model
*(ZONAIR output file generated by the **PLTAERO** bulk data card)*

- Open a new PATRAN database.

- Read in the geometry file. Select File-Import from the Radio buttons. Object-Model Source-Neutral select the appropriate geometry neutral file and click Apply.

- *Tecplot Compatible Output*

A sample of the Tecplot compatible output is shown as follows:

```
TITLE ="AERO MODEL WITH     91 AERO GRIDS &     17 FEM GRIDS. AERO PANELS=
65"
VARIABLE = X, Y, Z, EXTID
ZONE I=     108 J=      65 F=FEPOINT
 -1.0000E+02  0.0000E+00  0.0000E+00     201
 -1.0000E+02  0.0000E+00  0.0000E+00     202
 -1.0000E+02  0.0000E+00  0.0000E+00     203
 -1.0000E+02  0.0000E+00  0.0000E+00     204
              .
              .
              .

       2       7       6       1
       3       8       7       2
       4       9       8       3
       5      10       9       4
       7      12      11       6
              .
              .
              .
```

Grid Point Identification Numbers

Aerodynamic Grid Points (X,Y,Z)

Aerodynamic Connectivity Information (aero panels)
e.g., the first line connects the 2nd, 7th, 6th and 1st aero grid points listed above

TITLE	lists the number of aerodynamic grids, structural finite element grids and aerodynamic panels
VARIABLE	defines the variable names associated with the column data
X	X-coordinate of the aerodynamic grid point
Y	Y-coordinate of the aerodynamic grid point
Z	Z-coordinate of the aerodynamic grid point
EXTID	External grid point identification number

ZONE	specifies information for the current zone (the Tecplot input can be broken up into multiple zones; only one ZONE is used to define the aerodynamic model)
I	number of aerodynamic grid points listed in the plot file
J	number of aerodynamic panels listed in the plot file
F=FEPOINT	finite-element zone specification

- *I-DEAS Compatible Output*

The I-DEAS compatible output is saved in the universal file format. Data set 781 is used to output the aerodynamic as well as structural (if requested in the **PLTAERO** bulk data card) grid points. Data set 780 is used to output the aerodynamic panels. A sample of the I-DEAS compatible output is shown in the following figure.

```
    -1
   781
       201          0          0         11
  -1.0000000000000000D+02   0.0000000000000000D+00   0.0000000000000000D+00
       202          0          0         11
  -1.0000000000000000D+02   0.0000000000000000D+00   0.0000000000000000D+00
       203          0          0         11
  -1.0000000000000000D+02   0.0000000000000000D+00   0.0000000000000000D+00
       204          0          0         11
  -1.0000000000000000D+02   0.0000000000000000D+00   0.0000000000000000D+00
                                                  .
                                                  .                 Aerodynamic
                                                                    Grid Points
101          0          0         11
   0.0000000000000000D+00   3.0000000000000000D+01   0.0000000000000000D+00
       102          0          0         11
   2.0000000000000000D+01   3.0000000000000000D+01   0.0000000000000000D+00
       103          0          0         11
   4.0000000000000000D+01   3.0000000000000000D+01   0.0000000000000000D+00
                                                  .
                                                  .                   Structural FEM
                                                                      Grid Points
    -1
   780
       201         94          1     100000         1         1         1         4
       202        207        206        201
       202         94          1     100000         1         1         1         4
       203        208        207        202
       203         94          1     100000         1         1         1         4
       204        209        208        203
       204         94          1     100000         1         1         1         4
                                                  .
                                                  .                 Quadrilateral
                                                  .                 Elements
```

- *FEMAP Compatible Output*

The FEMAP compatible output is saved in the FEMAP (Version 7.0) neutral file format. Data Blocks 403 and 404 are used to output the aerodynamic grids and panels, respectively. Data Block 570 is used to output the structural grid points (if requested in the **PLTAERO** bulk data card). A sample of the FEMAP compatible output is shown in the following figure.

```
-1
   100
<NULL>
        7.
   -1
-1
                                            .
                                            .

403
       201,          0,          0,          1,         46,     0,     0,     0,     0,     0,
0,    -1.0000000000000000D+02,      0.0000000000000000D+00,      0.0000000000000000D+00,
0,
       202,          0,          0,          1,         46,     0,     0,     0,     0,     0,
0,    -1.0000000000000000D+02,      0.0000000000000000D+00,      0.0000000000000000D+00,
0,
       203,          0,          0,          1,         46,     0,     0,     0,     0,     0,
0,    -1.0000000000000000D+02,      0.0000000000000000D+00,      0.0000000000000000D+00,
0,
       204,          0,          0,          1,         46,     0,     0,     0,     0,     0,
0,  -1.0000000000000000D+02,   0.0000000000000000D+00,
                                            .
                                            .
-1
   570
     10101,              0,              0,              0,              2,              4,
0.0000000000000000D+00,         0,
   0.0000000000000000D+00,   3.0000000000000000D+01,   0.0000000000000000D+00,
     10102,              0,              0,              0,              2,              4,
0.0000000000000000D+00,         0,
   3.3333000183105469D+01,   3.0000000000000000D+01,   0.0000000000000000D+00,
     10103,              0,              0,              0,              2,              4,
0.0000000000000000D+00,         0,
   6.6666999816894531D+01,   3.0000000000000000D+01,   0.0000000000000000D+00,
     10104,              0,              0,              0,              2,              4,
0.0000000000000000D+00,         0,
   1.0000000000000000D+02,   3.0000000000000000D+01,   0.0000000000000000D+00,

-1
   404
       201,       124,         1,        17,         4,         1,         0,         0,
0,         0,         0,         0,
       202,       207,       206,       201,         0,         0,         0,         0,
0,         0,
         0,         0,         0,         0,         0,         0,         0,         0,
0,         0,
   0.0000000000000000D+00,   0.0000000000000000D+00,   0.0000000000000000D+00,
   0.0000000000000000D+00,   0.0000000000000000D+00,   0.0000000000000000D+00,
   0.0000000000000000D+00,   0.0000000000000000D+00,   0.0000000000000000D+00,
    0,     0,     0,     0,     0,     0,     0,     0,     0,     0,     0,     0,         0,
0,         0,         0,
                                            .
                                            .
                                            .
```

Neutral File Header followed by other required Data Blocks

Aerodynamic Grid Points

Structural FEM Grid Points

Quadrilateral Elements

Steps within FEMAP to View the Aerodynamic Model
*(ZONAIR output file generated by the **PLTAERO** bulk data card)*

- Open (via File/Import/FEMAP Neutral) the ZONAIR output neutral file of the aerodynamic model (select View/Redraw if the image does not appear after loading)
- Aerodynamic grids (nodes) are displayed as green x's
- Structural FEM grids (points) are displayed as red +'s
- Aerodynamic panels (elements) are displayed as white quadrilaterals
- Rotate, pan or autocenter the model with the Dynamic Rotate function (top left button on the toolbar)
- Node, Point and Element features (such as id's) can be set in the View/Options window

- *NASTRAN Compatible Output*

The NASTRAN compatible output is saved in standard NASTRAN bulk data format. A sample of the NASTRAN compatible output is shown in the following figure and is described below:

```
BEGIN BULK
$ AERO MODEL BY       91 GRIDS AND       65 CQUAD4
$ WHERE THE PSHELL ENTRES OF CQUAD4 ARE CAERO7 AND BODY7 IDENTIFICATION NUMBERS
$ ADDITIONAL      17 FEM GRIDS ARE DISPLAYED
GRID         201        -1.00+020.000+000.000+00
GRID         202        -1.00+020.000+000.000+00      Aerodynamic
GRID         203        -1.00+020.000+000.000+00      Grid Points
GRID         204        -1.00+020.000+000.000+00
GRID         205        -1.00+020.000+000.000+00
GRID         206        -8.00+010.000+00-1.70+01
                          .
                          .
                          .

CQUAD4       201     201     202     207     206     201
CQUAD4       202     201     203     208     207     202
CQUAD4       203     201     204     209     208     203      Quadrilateral
CQUAD4       204     201     205     210     209     204      Elements
CQUAD4       205     201     207     212     211     206
CQUAD4       206     201     208     213     212     207
                          .
                          .
                          .

$$$THE FOLLOWING GRIDS ARE THE FEM GRIDS IN THE AERODYNAMIC COORDNATES.
$$$IDS ARE OFFSET BY        0
$$$BASIC ON ACSID IN THE AEROZ BULK DATA ENTRY
GRID       10101        0.000+003.000+010.000+00      Structural FEM
GRID       10102        3.333+013.000+010.000+00      Grid Points
GRID       10103        6.666+013.000+010.000+00
GRID       10104        1.000+023.000+010.000+00
GRID       10201        1.666+015.333+010.000+00
                          .
                          .
                          .

ENDDATA
```

The first three comment cards (initiated with a **$**) list the number of aerodynamic grid points (**GRID**) and quadrilateral (**CQUAD4**) elements listed in the file. If the FEMGRID entry of the **PLTAERO** bulk data card is set to 'YES', then the number of structural grid points read in from the finite element input to the ZONAIR software system is also displayed and printed in this file.

7.2 PRESSURE COEFFICIENTS (PLTCP)

An output data file of the pressure coefficients for all aerodynamic panels in the model can be generated with the **PLTCP** bulk data card (see Figure 7.2).

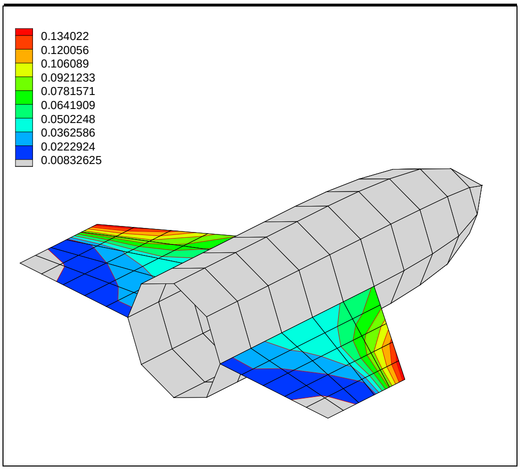


Figure 7.2 Plot of Pressure Coefficient (M=0.8, k=0.2, 1st mode, Re(C_P))

The pressure coefficients and local Mach numbers for a specified flight condition specified by an **AEROGEN** bulk data card are generated. For detailed descriptions of these options, please see the **PLTCP** bulk data card description presented in Chapter 4.

The **PLTCP** output plot file contains the aerodynamic pressures and local Mach numbers on each aerodynamic panel (for the PATRAN, I-DEAS, FEMAP and NASTRAN output cases) or at each aerodynamic grid point (for the TECPLOT output case).

- *PATRAN Compatible Output*

The PATRAN compatible output to display the pressure and local Mach number results are saved in two separate files. The aerodynamic model is saved in the neutral file format while the pressure and local Mach number results are saved in a results file. Both files will need to be imported into PATRAN to display the results. A sample of the PATRAN compatible output files are shown in the following figures and are described below:

Neutral File of the Aerodynamic Model

```
25       0       0       1       0       0       0       0       0
ZONAIR AERODYNAMIC MODEL - PATRAN NEUTRAL FILE OUTPUT
26       0       0       1      91      65       1       1       0
  08/22/200016:11:23         2.5
 1     201       0       2       0       0       0       0       0
-0.100000000E+03 0.000000000E+00 0.000000000E+00
0G       6       0       0000000
 1     202       0       2       0       0       0       0       0
-0.100000000E+03 0.000000000E+00 0.000000000E+00
0G       6       0       0000000                      Aerodynamic
                          .                           Grid Points
                          .
                          .
2     201       4       2       0       0       0       0       0
      4       0       1       0 0.000000000E+00 0.000000000E+00 0.000000000E+00
     202     207     206     201
 2     202       4       2       0       0       0       0       0
       4       0       1       0 0.000000000E+00 0.000000000E+00 0.000000000E+00
     203     208     207     202
                          .                            Aerodynamic
                          .                            Panels
                          .
```

Data Packets 1 (Node Data) and 2 (Element Data) are used to output the aerodynamic grid points and aerodynamic panels, respectively.

Results File of the Pressure (Element Results)

```
ZONAIR STEADY CP AND MACH NU       1, FLEX=NO      , M=    0.60, Q=    0.00
    2
RESULT QUANTITIES:MACH NUMBER

       1       3
0.2690387E+000.5080803E+00
       2       3
0.2867234E+000.5015833E+00
       3       3
0.3232428E+000.4879461E+00
       4       3
0.3735698E+000.4686236E+00
       5       3
0.4271863E+000.4472803E+00
       6       3
0.4615177E+000.4331503E+00
......................
......................
......................
```

The Element Results File is used with four data quantities specified.

<u>Steps within PATRAN to View the Aerodynamic Model with Pressure and Local Mach Numbers</u>

(ZONAIR output file generated by ***PLTCP*** *bulk data card)*

- Open a new PATRAN database.

- Read in the geometry file first. Select File-Import from the Radio buttons; Object-Model Source-Neutral select the appropriate geometry neutral file and click Apply.

- Read in the pressure results file next. Select File-Import from the Radio buttons, Object-Results Source-Patran2.els. After selecting the Patran2.els, locate the ZONAIR pressure results file in whatever directory it has been stored in. Select the appropriate pressure results file and click Apply.

- Verify that the import/read was successful in the Dialog Box. Select Results from the Radio buttons, Action-Create, Object-Quickplot.

- The Fringe results list should show up results that were read in. Select the desired pressure quantity and click Apply.

The following PATRAN results template can be used to load the pressures from ZONAIR.

```
/* ZONAIR_pres.res_tmpl */
/* PATRAN 2.5 results file template for ZONAIR *.els files */

KEYLOC = 0

TYPE = scalar
COLUMN = 1
PRI = Pressure Coefficient
SEC = Real

TYPE = scalar
COLUMN = 2
PRI = Local_Mach
SEC = Imag.

TYPE = END
```

- *Tecplot Compatible Output*

A sample of the Tecplot output is shown in the following figure and is described below:

```
TITLE ="UNSTEADY CP: PLTCP=    3000 MODE=       1 MACH=   .8000 K=   .2000"
VARIABLE = X, Y, Z, RE(CP), IM(CP) EXTID
ZONE I=      91 J=      65 F=FEPOINT
  -.1000E+03   .0000E+00   .0000E+00  -.7643E-04   .2361E-03     201
  -.1000E+03   .0000E+00   .0000E+00  -.5331E-04   .1644E-03     202
  -.1000E+03   .0000E+00   .0000E+00   .2541E-05   .3619E-05     203
  -.1000E+03   .0000E+00   .0000E+00   .5529E-04   .1649E-03     204
  -.1000E+03   .0000E+00   .0000E+00   .7531E-04   .2300E-03     205
                     .
                     .
                     .
```

Aerodynamic Grid Points (X,Y,Z)

CP

Local Mach

Grid Point Identification Numbers

```
       2       7       6       1
       3       8       7       2
       4       9       8       3
       5      10       9       4
       7      12      11       6
                     .
                     .
                     .
```

Aerodynamic Connectivity Information (aero paneles)
e.g. the first line connects the 2nd, 7th, 6th and 1st aero grid points listed above

TITLE lists the **PLTCP** bulk data card identification number

VARIABLE	defines the variable names associated with the column data
X	X-coordinate of the aerodynamic grid point
Y	Y-coordinate of the aerodynamic grid point
Z	Z-coordinate of the aerodynamic grid point
RE(CP)	Real component of the pressure result
IM(CP)	Imaginary component of the pressure result
EXTID	External grid point identification number

ZONE	specifies information of the current zone (the Tecplot input can be broken up into multiple zones; only one zone is used to define the pressure output)
I	number of aerodynamic grid points listed in the plot file
J	number of aerodynamic panels listed in the plot file
F=FEPOINT	finite-element zone specification

- *I-DEAS Compatible Output*

The I-DEAS compatible output is saved in the universal file format. Data sets 781 and 780 are used to output the aerodynamic grid points and panels, respectively. Data set 56 is used to output the pressure and is output four times for displaying the real, imaginary, magnitude and phase angle of the pressure. The first five ID lines of each data set 56 list the following information:

Line 1:	Pressure component of the current data set
Line 2:	**PLTCP** Bulk Data Card identification number
Line 3:	The number of aerodynamic grid points in the model
Line 4:	The number of aerodynamic panels in the model

Line 5: The pressure component of the current data set (i.e., real, imaginary, magnitude, or phase angle) – repeated from Line 1 but more descriptive.

A sample of the I-DEAS compatible output is shown in the following figure:

```
    -1
   781
       201         0         0        11
  -1.0000000000000000D+02   0.0000000000000000D+00   0.0000000000000000D+00
       202         0         0        11
  -1.0000000000000000D+02   0.0000000000000000D+00   0.0000000000000000D+00
       203         0         0        11
  -1.0000000000000000D+02   0.0000000000000000D+00   0.0000000000000000D+00
       204         0         0        11
  -1.0000000000000000D+02   0.0000000000000000D+00   0.0000000000000000D+00
                                                .
                                                .          Aerodynamic
    -1                                                     Grid Points
   780
       201        94         1    100000         1         1         1         4
       202       207       206       201
       202        94         1    100000         1         1         1         4
       203       208       207       202
       203        94         1    100000         1         1         1         4
       204       209       208       203
       204        94         1    100000         1         1         1         4
                                                .          Quadrilateral
                                                .          Elements
    -1
    56
ZONAIR PRESSURE - MODE=    1 MACH NO.=  1.2000 K=  0.2000 CP(REAL)
PRESSURE FOR PLTCP BULK DATA CARD WITH ID:       25
NUMBER OF AERODYNAMIC GRID POINTS IN MODEL =           91
NUMBER OF AERODYNAMIC BOXES IN MODEL =           65
REAL COMPONENT OF PRESSURE - CP(RE)
         1         1         1        18         2         1
         1         1         1
  0.00000E+00
       201         1
  0.00000E+00
       202         1
  0.00000E+00
       203         1
  0.00000E+00                          Pressures
         .
         .
```

- *FEMAP Compatible Output*

The FEMAP compatible output is saved in the FEMAP (Version 7.0) neutral file format. Data Blocks 403 and 404 are used to output the aerodynamic grids and panels, respectively. Data Block 450 is used to output the pressure, and local Mach number output set definition. Data Block 451 is used to output two data vectors to display the results. A sample of the FEMAP compatible output is shown in the following figure.

```
-1
   100
<NULL>
        7.
   -1
-1
                                              .
                                              .
```

Neutral File Header followed by other required Data Blocks

```
403
       201,          0,          0,          1,         46,     0,     0,     0,     0,     0,     0,  -
1.0000000000000000D+02,   0.0000000000000000D+00,   0.0000000000000000D+00,         0,
       202,          0,          0,          1,         46,     0,     0,     0,     0,     0,     0,  -
1.0000000000000000D+02,   0.0000000000000000D+00,   0.0000000000000000D+00,         0,
       203,          0,          0,          1,         46,     0,     0,     0,     0,     0,     0,  -
1.0000000000000000D+02,   0.0000000000000000D+00,   0.0000000000000000D+00,         0,
       204,          0,          0,          1,         46,     0,     0,     0,     0,     0,     0,  -
1.0000000000000000D+02,   0.0000000000000000D+00,
                                              .
                                              .
```

Aerodynamic Grid Points

```
-1
   404
       201,        124,          1,          17,          4,          1,          0,          0,
0,          0,          0,          0,
       202,        207,        206,         201,          0,          0,          0,          0,
0,          0,
         0,          0,          0,           0,          0,          0,          0,          0,
0,          0,
   0.0000000000000000D+00,   0.0000000000000000D+00,   0.0000000000000000D+00,
   0.0000000000000000D+00,   0.0000000000000000D+00,   0.0000000000000000D+00,
   0.0000000000000000D+00,   0.0000000000000000D+00,   0.0000000000000000D+00,
    0,     0,     0,     0,     0,     0,     0,     0,     0,     0,     0,     0,          0,          0,
0,          0,
                                              .
                                              .
                                              .
```

Quadrilateral Elements

```
-1
   450
   1,
ZONAIR Pressure
   0,   0
   2.0000000298023224D-01,
   1,
 <NULL>
   -1
   -1
   451
   1,   1,   1,
CPRE Mode   1M= 0.8k= 0.2
   0.,   0.,   0.,
  0,  0,  1,  0,  0,  0,  0,  0,  0,  0,
  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
  0,  0,  3,  8,
  0,  1,  1,
       201,  -1.7237762222066522D-04,
       202,  -7.4403775215614587D-05,
       203,   7.4400115408934653D-05,
       204,   1.7237753490917385D-04,
                                              .
                                              .
```

Pressure Output Set Definition

Pressure Output Data Vector Definition

Steps within FEMAP to View the Aerodynamic Model with Pressure
*(ZONAIR output file generated by **PLTCP** bulk data card)*

- Open (via File/Import/FEMAP Neutral) the ZONAIR output neutral file of the aerodynamic model with pressure (select View/Redraw if the image does not appear after loading)
- Aerodynamic grids (nodes) are displayed as green x's
- Aerodynamic panels (elements) are displayed as white quadrilaterals
- Rotate, pan or autocenter the model with the Dynamic Rotate function (top left button on the toolbar)
- Node, Point and Element features (such as id's) can be set in the View/Options window
- Open the View/Select Window
- From the Contour Style section, click on the Contour button
- Click on the Deformed and Contour Data button bar
- In the window that opens, under Output Vectors/Contour, select either CP_VALUE or LACAL_MACH to be displayed
- Click on OK for both windows

- *NASTRAN Compatible Output*

The NASTRAN compatible output is saved in standard NASTRAN bulk data format. A sample is shown in the following figure and is described below:

```
GRID           1       0.0000000.0000000.000000
GRID           2       0.2000000.0000000.092000
GRID           3       0.2000000.0460000.080000
GRID           4       0.2000000.0800000.046000
GRID           5       0.2000000.0920000.000000
GRID           6       0.2000000.080000-0.04600
GRID           7       0.2000000.046000-0.08000

PSHELL         1       1
MAT1           1    1.00             0.
CTRIA3         1       1       1       2       3
CTRIA3         2       1       1       3       4
CQUAD4         7       1       2       9      10       3
CQUAD4         8       1       3      10      11       4
CQUAD4         9       1       4      11      12       5
CQUAD4        10       1       5      12      13       6
CQUAD4        11       1       6      13      14       7

PLOAD4         1       12.690-01
PLOAD4         1       22.867-01
PLOAD4         1       33.232-01
PLOAD4         1       43.735-01
PLOAD4         1       54.271-01
PLOAD4         1       64.615-01
```

Aerodynamic Grid Points

Quadrilateral Elements

Pressures

The comment title cards (**$**) list the identification number of the current **PLTCP** bulk data card. Standard **PLOAD4** bulk data cards are used for the pressure output. The **PLOAD4** bulk data card SID entry is used to delineate the real from imaginary components of the pressure. The number of aerodynamic grid points (**GRID**), quadrilateral (**CQUAD4**) elements and **PLOAD4** bulk data cards within the plot file are also provided.

7.3 INTERPOLATED STRUCTURAL MODE SHAPE (PLTMODE)

An output data file of the interpolated structural mode shapes on the aerodynamic model can be generated with the **PLTMODE** bulk data card (see Figure 7.3). Viewing the interpolated structural modes is very useful in determining whether or not the aerodynamic model is properly splined to the structure. Experience has shown that most errors in aeroelastic analysis are a result of incorrect spline input. Therefore, viewing the interpolated structural mode shapes should always be performed for verification purposes whenever the spline input (i.e., **SPLINE1**, **SPLINE2, SPLINE3,** an **ATTACH** bulk data cards) is modified.

The maximum displacement of the interpolated structural mode shape is controlled by the MAXDISP entry of the **PLTMODE** bulk data card. MAXDISP is a fraction (i.e., 0.0 – 1.0) of the reference chord length (REFC entry) specified in the **AEROZ** bulk data card.

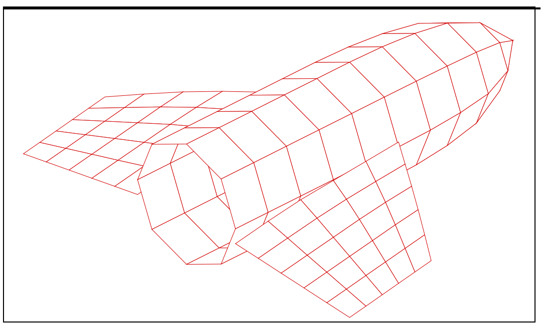


Figure 7.3 Plot of an Interpolated Mode Shape on the Aerodynamic Model (Mode 1)

The **PLTMODE** output plot file contains the deformed aerodynamic model for a specified structural mode. All aerodynamic panel corner grid points and connectivity information of the aerodynamic model (i.e., a deformed aerodynamic model) is generated. The magnitude of the displacement is scaled by the SCALE entry of the **PLTMODE** bulk data card. The data for this output file is generated by the spline (**SPLINE**) module.

- *PATRAN Compatible Output*

The PATRAN compatible output to display the interpolated mode shape is saved in two separate files. The aerodynamic model is saved in the neutral file format while the interpolated mode shape nodal displacements are saved in a results file. Both files will need to be imported into PATRAN to display the interpolated mode shape results. A sample of the PATRAN compatible output files are shown described in the following figures:

.

Neutral File of the Aerodynamic Model

```
25       0       0       1       0       0       0       0       0
ZONAIR AERODYNAMIC MODEL - PATRAN NEUTRAL FILE OUTPUT
26       0       0       1     260      65       1       1       0
  08/23/200009:09:28         2.5
 1       1       0       2       0       0       0       0       0
-0.100000000E+03 0.000000000E+00 0.000000000E+00
0G       6       0       0000000
 1       2       0       2       0       0       0       0       0
-0.800000000E+02 0.120208158E+02-0.120208149E+02
0G       6       0       0000000
                          .
                          .
                          .

2       1       4       2       0       0       0       0       0
       4       0       1       0 0.000000000E+00 0.000000000E+00 0.000000000E+00
       1       2       3       4
 2       2       4       2       0       0       0       0       0
       4       0       1       0 0.000000000E+00 0.000000000E+00 0.000000000E+00
       5       6       7       8
                          .
                          .
                          .
```

Aerodynamic Grid Points

Aerodynamic Panels

Results File of the Interpolated Mode Shape (Displacement Results)

```
ZONAIR MODE SHAPE: PLTMODE ID=      10, MODE=       1, FREQ=   4.613 HZ
      260      260   0.300000E+02      259        3
FOR THREE DEGREES OF FREEDOM DX DY DZ
SUBTITLE 2
       10.0000000E+000.0000000E+000.0000000E+00
       20.0000000E+000.0000000E+000.0000000E+00
       30.0000000E+000.0000000E+000.0000000E+00
       40.0000000E+000.0000000E+000.0000000E+00
```

Aero Grid Id's

DX, DY, DZ

Displacements at aero grids

<u>Steps within PATRAN to View the Deformed or Animated interpolated Mode Shape</u>
(ZONAIR output file generated by PLTMODE bulk data card)

- Open a new PATRAN database.

- Read in the geometry file first. Select File-Import from the Radio buttons; Object-Model Source-Neutral select the appropriate geometry neutral file and click Apply.

- Read in the displacement results file next. Select File-Import from the Radio buttons, Object-Results Source-Patran2.dis. After selecting the Patran2.dis, locate the ZONAIR interpolated mode shape displacement results file in whatever directory it has been stored in. Select the appropriate displacement results file and click Apply.

- Verify that the import/read was successful in the Dialog Box. Select Results from the Radio buttons, Action-Create, Object-Quickplot.
- The Fringe results list should show up results that were read in.

The following PATRAN results template can be used to load the displacements from ZONAIR.

```
/* ZONAIR_dis.res_tmpl */
/* PATRAN 2.5 results file template for ZONAIR .dis files */

KEYLOC = 0

TYPE = vector
COLUMN = 1, 2, 3
PRI = Displacements
SEC = Translational
CTYPE = nodal

TYPE = END
```

- *Tecplot Compatible Output*

A sample of the Tecplot compatible output is shown in the following figure and is described below.

```
TITLE ="THE    1TH MODE ON AERO MODEL FROM FILE sample.fre"
VARIABLE = X, Y, Z, EXTID
ZONE I=     260 J=      65 F=FEPOINT
 -1.0000E+02  0.0000E+00  0.0000E+00     202
 -8.0000E+01  1.2021E+01 -1.2021E+01     207     <-- Grid Point
 -8.0000E+01  0.0000E+00 -1.7000E+01     206         Identification Numbers
 -1.0000E+02  0.0000E+00  0.0000E+00     201
 -1.0000E+02  0.0000E+00  0.0000E+00     203
              .
              .                  Aerodynamic
              .                  Grid Points (X,Y,Z)

      1       2       3       4   Aerodynamic Connectivity
      5       6       7       8   Information (aero panels)
      9      10      11      12   e.g., the first line connects the 1st, 2nd, 3rd and 4th
     13      14      15      16   aero grid points listed above
     17      18      19      20
```

TITLE — lists the requested structural mode index, and the name of the structural finite element output file from which the structural finite element modes are read in (i.e., file assigned by the **ASSIGN** Executive Control Command in the **ASSIGN** Executive Command Section)

VARIABLE	defines the variable names associated with the column data
X	X-coordinate of the aerodynamic grid point
Y	Y-coordinate of the aerodynamic grid point
Z	Z-coordinate of the aerodynamic grid point
EXTID	External grid point identification number
ZONE	specifies information for the current zone
I	number of aerodynamic grid points listed in the plot file
J	number of aerodynamic panels listed in the plot file
F=FEPOINT	finite-element zone specification

- *I-DEAS Compatible Output*

The I-DEAS compatible output is saved in the universal file format. Data sets 781 and 780 are used to output the aerodynamic grid points and panels, respectively. Data set 55 is used to output the displacements at the aerodynamic grid points. The first five ID lines of data set 55 list the following information:

Line 1: Structural input data mode shape number
Line 2: Structural input data filename
Line 3: NONE
Line 4: NONE
Line 5: NONE

A sample of the I-DEAS compatible output is shown in the following figure:

```
    -1
   781
         1         0         0        11
  -1.0000000000000000D+02   0.0000000000000000D+00   0.0000000000000000D+00
         2         0         0        11
  -8.0000000000000000D+01   1.2020814895629883D+01  -1.2020814895629883D+01
         3         0         0        11
  -8.0000000000000000D+01   0.0000000000000000D+00  -1.7000000000000000D+01
         4         0         0        11
  -1.0000000000000000D+02   0.0000000000000000D+00   0.0000000000000000D+00
                                            .
    -1
   780
         1        94         1    100000         1       201         1         4
         1         2         3         4
         2        94         1    100000         1       201         1         4
         5         6         7         8
         3        94         1    100000         1       201         1         4
         9        10        11        12
         4        94         1    100000         1       201         1         4
        13        14        15        16
                                            .
    -1
    55
ZONAIR MODE SHAPE OUTPUT, MODE=        1
FROM FILE: crop.f06
NONE
NONE
NONE
         1         2         3         8         2         6
         1         1         1
  0.00000E+00
         1
```

Aerodynamic Grid Points

Quadrilateral Elements

```
  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         2
  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         3
  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         4
  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
                                         .          Displacements on Aerodynamic Grids
                                         .
```

- *FEMAP Compatible Output*

The FEMAP compatible output is saved in the FEMAP (ver 7.0) neutral file format. Data Blocks 403 and 404 are used to output the aerodynamic grids and panels, respectively. Data Block 450 is used to output the flutter mode output set definition. Data Block 451 is used to output four data vectors to display the interpolated mode shape (TOTAL Translation), X-axis translation (T1), Y-axis translation (T2) and Z-axis translation (T3). A sample of the FEMAP compatible output is shown in the following figure.

```
-1
   100                          Neutral File Header
<NULL>                          followed by other
        7.                      required Data Blocks
   -1
-1
                                                     .
                                                     .

403
       201,         0,         0,         1,        46,    0,    0,    0,    0,    0,    0,  -
1.0000000000000000D+02,   0.0000000000000000D+00,   0.0000000000000000D+00,         0,
       202,         0,         0,         1,        46,    0,    0,    0,    0,    0,    0,  -
1.0000000000000000D+02,   0.0000000000000000D+00,   0.0000000000000000D+00,         0,
       203,         0,         0,         1,        46,    0,    0,    0,    0,    0,    0,  -
1.0000000000000000D+02,   0.0000000000000000D+00,   0.0000000000000000D+00,         0,
       204,         0,         0,         1,        46,    0,    0,    0,    0,    0,    0,  -
1.0000000000000000D+02,   0.0000000000000000D+00,
                                                     .
                                                     .          Aerodynamic
                                                                Grid Points
-1
   404
       201,       124,         1,        17,         4,         1,         0,         0,
0,         0,         0,         0,
       202,       207,       206,       201,         0,         0,         0,         0,
0,         0,
         0,         0,         0,         0,         0,         0,         0,         0,
0,         0,
   0.0000000000000000D+00,   0.0000000000000000D+00,   0.0000000000000000D+00,
   0.0000000000000000D+00,   0.0000000000000000D+00,   0.0000000000000000D+00,
   0.0000000000000000D+00,   0.0000000000000000D+00,   0.0000000000000000D+00,
    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,         0,         0,
0,         0,
                                                     .                    Quadrant
                                                     .                    Elements
                                                     .
```

```
-1
   450
   1,
Mode     1    4.613 Hz
   0,   2
   4.6127114295959473D+00,
   1,
 <NULL>
   -1
   -1
   451
   1,   1,   1,
ZONAIR Total Translation
   0.,   0.,   0.,
  2,  3,  4,  0,  0,  0,  0,  0,  0,  0,
  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,
  0,  0,  1,  7,
  1,  1,  1,
        1,   0.0000000000000000D+00,
        2,   0.0000000000000000D+00,
        3,   0.0000000000000000D+00,
        4,   0.0000000000000000D+00,
```

Interpolated Mode
Output Set
Definition

<u>Steps within FEMAP to View the Deformed or Animated Interpolated Mode Shape</u>
(ZONAIR output file generated by PLTMODE bulk data card)

- Open (via File/Import/FEMAP Neutral) the ZONAIR output neutral file of the aerodynamic model with interpolated mode deformation (select View/Redraw if the image does not appear after loading).
- Aerodynamic grids (nodes) are displayed as green x's.
- Aerodynamic panels (elements) are displayed as white quadrilaterals.
- Rotate, pan or autocenter the model with the Dynamic Rotate function (top left button on the toolbar).
- Node, Point and Element features (such as id's) can be set in the View/Options window.
- Open the View/Select Window.
- To <u>animate</u> the flutter mode, from the Deformed Style section, click on the Animate button.
- To <u>statically view</u> the flutter mode, from the Deformed Style section, click on the Deform button.
- Click on the Deformed and Contour Data button bar.
- In the window that opens, under Output Vectors/Deformation, select either TOTAL, T1, T2, or T3 to be displayed. TOTAL is the complete flutter mode shape. The modal natural frequency is displayed in the Output Set panel and will also show on the lower left-hand side of the screen during animation.
- Click on OK for both windows.
- FEMAP, by default, animates or deforms the model based on a percentage of the model length. To view the actual displacement based on the ZONAIR output (set by the MAXDISP entry of the **PLTMODE** bulk data card), open the View/Options window, select the PostProcessing category, select Deformed Style in the Options menu and uncheck the % of Model (Actual) checkbox.
- The number of frames and display times of the animation sequence can be set by the View/Options/PostProcessing/Animation/Frames and Delay input options.

- *NASTRAN Compatible Output*

The NASTRAN compatible output is saved in standard NASTRAN bulk data format. A sample is shown in the following figure and is described below.

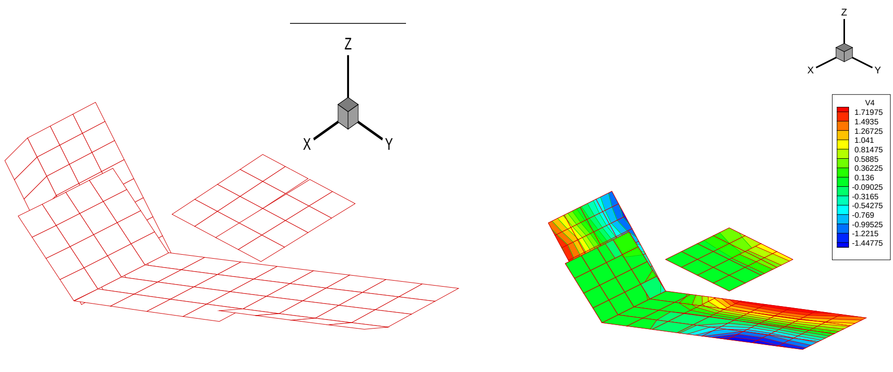
```
BEGIN BULK
$ DEFORMED AERO MODEL OF THE    2TH MODE (REPRESENTED BY GRID & CQUAD4) FROM FILE:
$      sample.fre
GRID           1        -1.00+020.000+000.000+00
GRID           2        -8.00+011.202+01-1.20+01
GRID           3        -8.00+010.000+00-1.70+01    Aerodynamic
GRID           4        -1.00+020.000+000.000+00    Grid Points
GRID           5        -1.00+020.000+000.000+00
                          .
                          .
                          .

CQUAD4         1      201       1       2       3       4
CQUAD4         2      201       5       6       7       8
CQUAD4         3      201       9      10      11      12
CQUAD4         4      201      13      14      15      16    Quadrilateral
CQUAD4         5      201      17      18      19      20    Elements
                          .
                          .
                          .
ENDDATA
```

The comment title card (**$**) list the index of the structural mode shape and the name of the structural finite element output file from which the structural finite element modes are read in (i.e., file assigned by the **ASSIGN** Executive Command in the **ASSIGN** Executive Command Section).

7.4 Static Aeroelastic/Trim Analysis Results (PLTTRIM)

An output data file of the static aeroelastic/trim results can be generated with the **PLTTRIM** bulk data card. Two types of output plot files and one ASCII text file can be generated through the use of the **PLTTRIM** bulk data card. The plot files can be used to display the deformed aerodynamic model under flight loads (e.g., Figure 7.4(a)) and/or the resulting steady pressure distribution (e.g., Figure 7.4(b)). An ASCII text file can also be output that contains the NASTRAN or I-DEAS **FORCE** and **MOMENT** bulk data cards at the structural finite element grid points. This output can be inserted into the NASTRAN or I-DEAS model input deck to perform a detailed stress analysis using static structural analysis.



(a)　　　　*(b)*

Figure 7.4 Sample Output Plot Files of the PLTTRIM Bulk Data Card, (a) Deformed Aero Model and (b) Steady Pressure Distribution

The output format for the deformed aerodynamic model is identical to that of the **PLTMODE** bulk data card (please see Section 7.3 for a description of this output format), except that both sides of the deformed aerodynamic model are included. The output format for the steady pressure distribution is identical to the **PLTCP** bulk data card except that the imaginary component of the pressure result will always be zero while the real component will reflect the steady pressure (please see Section 7.2 for a description of this output format).

NASTRAN Compatible FORCE/MOMENT Output

The output format of the ASCII text file containing the NASTRAN **FORCE** and **MOMENT** bulk data cards is shown in the following figure.

```
$FORCES & MOMENTS AT FEM GRIDS RESULTING FROM TRIM =     100 FOR FLEXIBLE MODEL
$ MACH =  0.9000 DYNAMIC PRESSURE= 0.12000E+04
$FORCES & MOMENTS IN TERMS OF NASTRAN FORCE AND MOMENT BULK DATA CARDS
$FOR TWO SIDES OF THE MODEL
$WHERE LOAD SET=      100 REFERS TO THE GRIDS ON THE RIGHT HAND SIDE OF THE MODEL
$      LOAD SET =     101 REFERS TO THE GRIDS ON THE LEFT HAND SIDE OF THE MODEL
$ THE USER CAN INSERT THIS FILE BACK TO THE FEM MODEL
$ FOR SUBSEQUENT STATIC ANALYSIS AND STRESS CALCULATIONS.
FORCE        100     90       00.000+00   1.000   0.000   0.000
FORCE        100     90       00.000+00   0.000   1.000   0.000
FORCE        100     90       01.665+04   0.000   0.000   1.000
MOMENT       100     90       04.083+04   1.000   0.000   0.000
MOMENT       100     90       04.859+04   0.000   1.000   0.000
MOMENT       100     90       00.000+00   0.000   0.000   1.000
FORCE        100     97       0-2.93-10   1.000   0.000   0.000
FORCE        100     97       0-7.39-13   0.000   1.000   0.000
FORCE        100     97       0-7.20+03   0.000   0.000   1.000
MOMENT       100     97       00.000+00   1.000   0.000   0.000
MOMENT       100     97       00.000+00   0.000   1.000   0.000
MOMENT       100     97       00.000+00   0.000   0.000   1.000

                                .
                                .
```

Eight title lines are output, each beginning with a NASTRAN comment (**$**) card, that list the **TRIM** bulk data card ID number, Mach number, dynamic pressure, and LOAD SET ID's within the current file that indicate whether the entries refer to the right-hand or left-hand sides of the model.

- *I-DEAS Compatible FORCE/MOMENT Output*

The output format of the ASCII text file containing I-DEAS output of **FORCE** and **MOMENT** stored in universal dataset 782 for both Left-Hand-Side (LHS) and Right-Hand-Side (RHS) load sets is shown in the following figure.

```
-1
    782
       100         1
RIGHT-HAND-SIDE OF FLEXIBLE MODEL
        90         4 1 1 1 1 1 1
  0.00000E+00  0.00000E+00  1.66503E+04  4.08355E+04  4.85924E+04  0.00000E+00
        97         4 1 1 1 1 1 1
 -2.93787E-10 -7.39602E-13 -7.20023E+03  0.00000E+00  0.00000E+00  0.00000E+00

                                 .
                                 .
-1
    782
       101         1
LEFT-HAND-SIDE OF FLEXIBLE MODEL
        90         4 1 1 1 1 1 1
  0.00000E+00  0.00000E+00  1.14435E+04  2.51545E+04  3.56345E+04  0.00000E+00
        97         4 1 1 1 1 1 1
 -2.93787E-10 -7.39602E-13 -7.20023E+03  0.00000E+00  0.00000E+00  0.00000E+00
```

ZONA Technology, Inc.
9489 E. Ironwood Square Drive
Scottsdale, AZ 85258
Tel (480) 945-9988
Fax (480) 945-6588
info@zonatech.com
www.zonatech.com

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