

# Airfoil/Flap Example Case\*

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# 1 Introduction

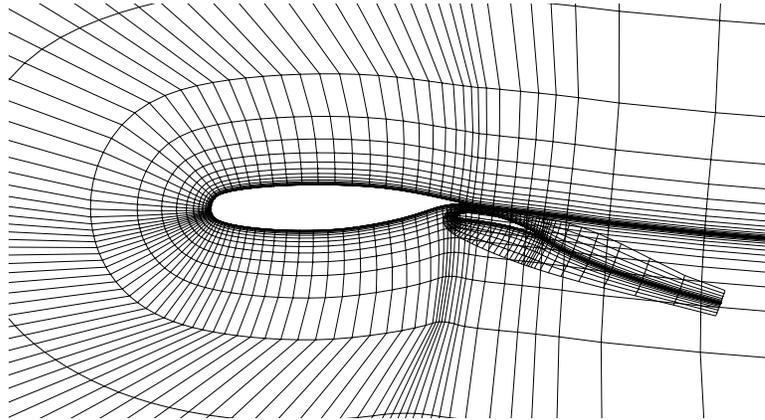
This document describes the use of Wind-US to solve a problem using a Chimera, or overset, grid. It is primarily intended to demonstrate the use of GMAN for Chimera grids.<sup>1</sup>

The geometry is a 2-D airfoil with a flap, shown in [Figure 1](#).



**Figure 1:** Airfoil/flap geometry.

Separate C grids have been created for the airfoil and the flap, with the flap grid overlaying the airfoil grid, as shown in [Figure 2](#).



**Figure 2:** Original airfoil/flap grids.

The outer boundary of the airfoil grid actually extends far beyond the airfoil, but is expanded in [Figure 2](#) to show the details near the surface. The two grids are contained in a multi-zone formatted PLOT3D xyz file. The airfoil grid is zone 1, with  $205 \times 59$  points, and the flap grid is zone 2, with  $179 \times 33$  points. In the figure, every other point in both directions, for both grids, has been omitted.

In the sections that follow:

- The *cfnvt* utility is used to create a common grid (*.cgd*) file from the existing PLOT3D file.
- GMAN is used to cut a hole in the airfoil grid around the flap, define the fringe boundaries for both grids, and set the remaining boundary conditions. This discussion makes up the bulk of the document.
- A Wind-US input data (*.dat*) file is created, and Wind-US is run to solve for the flow field.
- The resulting common flow (*.cfl*) file is used with CFPOST to create PLOT3D xyz and q files, and the results are displayed.

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<sup>1</sup>The various files discussed in this document may be downloaded from the Wind-US documentation WWW site, at <http://www.grc.nasa.gov/WWW/winddocs/gman/example/downloading.html>.



## 2 Creating the *.cgd* File

The PLOT3D xyz file containing the overlaid grids is named *demo.grid*, and is a 3D (although with  $k_{max} = 1$ ), multi-zone, formatted, single-precision file without an IBLANK array. A *.cgd* file named *demo.cgd* was created using *cfcvnt*, as shown in the following runstream. Lines in slanted type were typed by the user.

```
% cfcvnt
*****
* Warning: This software contains technical data whose export is      *
* restricted by the Arms Export Control Act (Title 22, U.S.C., Sec 2751, *
* et seq.) or Executive Order 12470. Violation of these export-control *
* laws is subject to severe criminal penalties. Dissemination of this *
* software is controlled under DoD Directive 5230.25 and AFI 61-204.   *
*****
***** Common File Convert Utilities *****
CFCNVT - Version 1.54 (last changed 2007/02/13 22:47:44)
```

```
0: Exit program
2: Import a Common File
3: Compress a Common File
4: Break Common File into multiple transfer files
5: Combine multiple transfer files into Common File
6: Append one Common File to another
7: Convert Common File binary to a text file
8: Convert Common File text to a binary file
11: Convert PLOT3D/Pegasus file to Common File
12: Convert GASP file to Common File
13: Convert OVERFLOW file to Common File
14: Convert Common File to OVERFLOW file
15: Convert CFPOST GPU file to Common File GPC
16: Convert ascii rake to Common File rake CGF
17: Convert Pegasus 4.0 files to Common File
18: Convert Common File CFL to Plot3d Q
```

Enter the number from one of the above requests

11

PLOT3D file type menu

```
0: Main menu
1: Convert a PLOT3D Grid (.x) file to CFS.
2: Convert a PLOT3D Solution (.q) file to CFS.
3: Convert a PLOT3D Function (.f) file to CFS.
```

Enter the number from one of the above requests

1

PLOT3D Number of Grids menu

```
0: Main menu
```

## Airfoil/Flap Example Case

- 1: PLOT3D Single zone format.
- 2: PLOT3D Multi zone format.

Enter the number from one of the above requests

2

PLOT3D Zone dimension menu

- 0: Main menu
- 1: PLOT3D 2d zone format.
- 2: PLOT3D 3d zone format.

Enter the number from one of the above requests

2

PLOT3D Format menu

- 0: Main menu
- 1: PLOT3D Formatted (ASCII).
- 2: PLOT3D Unformatted (sequential binary).
- 3: PLOT3D Binary (c binary).

Enter the number from one of the above requests

1

PLOT3D Iblank menu

- 0: Main menu
- 1: PLOT3D grid with IBLANK format.
- 2: PLOT3D grid without IBLANK format.

Enter the number from one of the above requests

2

PLOT3D Precision menu

- 0: Main menu
- 1: PLOT3D Single precision format.
- 2: PLOT3D Double precision format.

Enter the number from one of the above requests

1

PLOT3D INTOUT menu

- 0: Main menu
- 1: No INTOUT/XINTOUT file.
- 2: INTOUT file.
- 3: XINTOUT file.

Enter the number from one of the above requests

```

1
  Enter PLOT3D .x file to convert with suffix
demo.grid
  Enter output Common File name with suffix
demo.cgd
  zone, imax,jmax,kmax:          1          205          59          1
  zone, imax,jmax,kmax:          2          205          59          1
  Global maximums set as follows:
  mimax          205
  mjmax          59
  mkmax          1
  mpts:         12095
  recl:         563
  Processing zone ZONE  1
  Writing mesh data
  imax,jmax,kmax:          205          59          1
  Processing zone ZONE  2
  Writing mesh data
  imax,jmax,kmax:          179          33          1

  0: Exit program
  2: Import a Common File
  3: Compress a Common File
  4: Break Common File into multiple transfer files
  5: Combine multiple transfer files into Common File
  6: Append one Common File to another
  7: Convert Common File binary to a text file
  8: Convert Common File text to a binary file
 11: Convert PLOT3D/Pegasus file to Common File
 12: Convert GASP file to Common File
 13: Convert OVERFLOW file to Common File
 14: Convert Common File to OVERFLOW file
 15: Convert CFPOST GPU file to Common File GPC
 16: Convert ascii rake to Common File rake CGF
 17: Convert Pegasus 4.0 files to Common File
 18: Convert Common File CFL to Plot3d Q

  Enter the number from one of the above requests
0

```



### 3 Using GMAN

GMAN was then used in graphics mode to cut a hole in the airfoil grid around the flap, define the fringe boundaries for both grids, and set the remaining boundary conditions. The file *demo.jou* is the journal file created during the interactive GMAN session, with the addition of comments describing the procedure.

The first step, obviously, is to start GMAN.

*gman*

```
***** gman *****
```

```
Select the desired version from the following list.
```

- 0) END
- 1) gman\_pre optimized version

```
Single program automatically selected.
```

```
*****
* Warning: This software contains technical data whose export is      *
* restricted by the Arms Export Control Act (Title 22, U.S.C., Sec 2751, *
* et seq.) or Executive Order 12470. Violation of these export-control *
* laws is subject to severe criminal penalties. Dissemination of this  *
* software is controlled under DoD Directive 5230.25 and AFI 61-204.   *
*****
GMANPRE - Version 6.163 (last changed 2007/02/14 16:35:41)
Creating journal file 'gman.jou'.
```

```
Enter SWITCH or GRAPHICS to change to graphics mode.
```

```
GMAN:
```

At this point, you could type `@demo.jou` to execute the commands stored in the journal file *demo.jou*. You could also enter commands individually at the `GMAN:` prompt. Or, you could enter **SWITCH** or **GRAPHICS** to enter graphics mode.

The following sections describe in detail the use of GMAN for the airfoil/flap configuration. The graphics mode steps are on the left, with the Main Menu steps left-aligned and the Menu Options indented. Most of these are accomplished in GMAN by clicking on the listed menu item using the left mouse button. A few require entering text in the prompt area at the bottom of the screen. (See the “Graphical User Interface Basics” section of the *GMAN User’s Guide* for a description of the various sections of the GMAN screen layout.)

The command line equivalents are shown on the right. Note that, in general, several graphics mode steps become consolidated into a single command. A few of the commands are too long to fit on a single line, and are thus shown with the continued part indented. When using GMAN in command-line mode, however, they should be entered on a single line.

#### 3.1 Opening the File

We first need to tell GMAN the name of the file containing the grid.

## Airfoil/Flap Example Case

### Graphics Mode

Common File  
*enter* demo.cgd

### Command Line Mode

**FILE** demo.cgd

## 3.2 Cutting the Hole

Next, we need to cut a hole in the airfoil grid surrounding the flap.

The first step is to select the zone containing the airfoil grid, and to select the “Overlapping” boundary type. (This boundary type is useful for setting boundary conditions on interior grid points, as well as for Chimera grids.)

### Graphics Mode

BOUNDARY COND.  
1: (*from Zone List*)  
OLAP

### Command Line Mode

**ZONE** 1  
**BOUNDARY** OLAP

We need to tell GMAN the procedure we’re going to use to define the hole. In this case the hole will be defined by grid surfaces that form a closed region around the flap.

### Graphics Mode

MODIFY BNDY  
SHOW OTHER ZONE  
2: (*from Zone List*)  
PICK K-PLANE<sup>2</sup>  
OLAP GENERATION  
GENERATE HOLES  
SET/SHO CUTTER  
CUTTER SURFACE

### Command Line Mode

**CUTTER SURFACE** TYPE

Next, we select the surfaces from the flap grid that specify a closed region around the flap defining the hole.

The  $j = 1$  surface in the flap grid (i.e., the flap surface itself) could be used. However, the flap grid is tightly packed near the flap surface to resolve the boundary layer, while the airfoil grid spacing in this region is much larger. Ideally, the exchange of information between the two grids should occur in regions where the grid cells are similar in size.

Using a grid line farther out, near the outer edge of the flap zone, would result in a hole bigger than the flap grid. Since the boundary conditions around the hole for the solution in the airfoil zone will be computed from the solution in the flap zone, this would be unacceptable.

For these reasons, the  $j = 26$  grid line around the flap is used.

---

<sup>2</sup>At this point, you may want to adjust the view in the window by using the middle and right mouse buttons, or the **Center** choice in the Display Options menu, to enlarge the the view around the flap.

Graphics Mode

```

SET SRF ZON
  enter 2
SET SURF RANGE
  enter 20 26 1
  enter 160 26 1
SET SURF RANGE
  enter 20 1 1
  enter 20 26 1
SET SURF RANGE
  enter 160 1 1
  enter 160 26 1

```

Command Line Mode

```

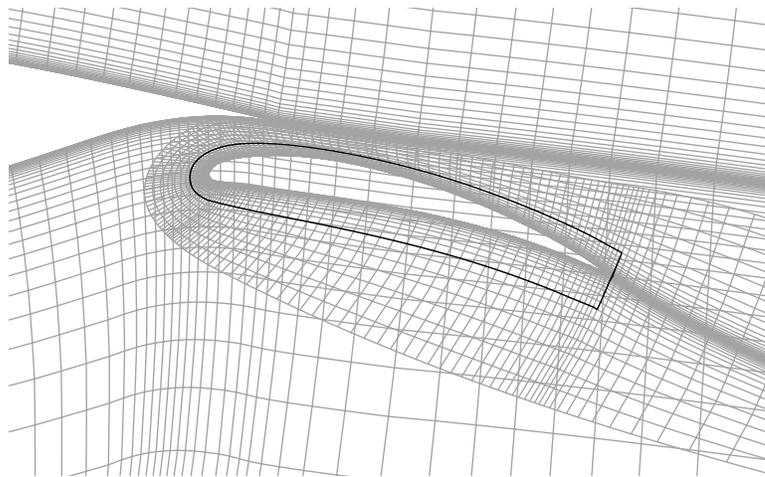
CUTTER SURFACE IN ZONE 2 I20 J26 K1
  TO I160 J26 K1 INCREMENT 1

CUTTER SURFACE IN ZONE 2 I20 J1 K1
  TO I20 J26 K1 INCREMENT 1

CUTTER SURFACE IN ZONE 2 I160 J1 K1
  TO I160 J26 K1 INCREMENT 1

```

The surfaces defining the hole cutter are shown in [Figure 3](#), along with both grids in the region of the flap.



**Figure 3:** Surfaces defining hole cutter.

All overlapping boundaries and holes must have a unique label, greater than six. The Label menu choice is in the Subregion Selection area in the lower-right corner of the GMAN window.

Graphics Mode

```

Label
  enter 7

```

Command Line Mode

```

LABEL 7

```

Finally, we can create the hole.

Graphics Mode

```

GENERATE HOLE

```

Command Line Mode

```

GENERATE HOLE

```

The resulting airfoil grid, with the hole cut into it, is shown in the region of the flap in [Figure 4](#).

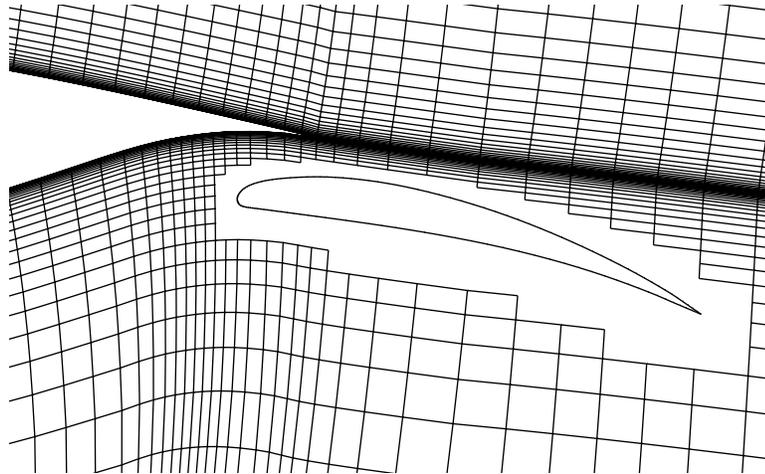


Figure 4: Airfoil grid with hole.

### 3.3 Defining the Fringes

The next step is to define the fringes and set boundary conditions on them. For the airfoil grid, the fringes will be defined as the hole boundary.

#### Graphics Mode

```
OLAP GENERATION
GENERATE FRINGE
  FRG MODE HOLE
GENERATE FRINGE3
OLAP GENERATION
SET FRINGE BND
COUPLE
  2: (from Zone List)
OLAP
COUPLE
BOUNDARY COND.
  YES, SAVE CHANGES
```

#### Command Line Mode

```
FRINGE-MODE HOLE
GENERATE FRINGE

SET FRINGE BOUNDARY COUPLED TO
  ZONE 2 BOUNDARY OLAP

UPDATE
```

The flap grid is completely embedded in the airfoil grid, and the outer boundaries do not overlap any solid boundaries. Cutting a hole is thus not necessary, and we can use the outer boundaries as the fringe.

---

<sup>3</sup>From the Main Menu, not the Menu Trail

Graphics Mode

```
PICK ZONE/BNDY
  2: (from Zone List)
  OLAP
MODIFY BNDY
GENERATE FRINGE
  FRG MODE OUTER
    BOUND I1 ON
    BOUND IMAX ON
    BOUND JMAX ON
Label
  enter 8
GENERATE FRINGE4
OLAP GENERATION
SET FRINGE BND
COUPLE
  1: (from Zone List)
  OLAP
COUPLE
BOUNDARY COND.
  YES, SAVE CHANGES
```

Command Line Mode

```
ZONE 2
BOUNDARY OLAP

FRINGE-MODE OUTER BOUNDARY ON I1
FRINGE-MODE OUTER BOUNDARY ON IMAX
FRINGE-MODE OUTER BOUNDARY ON JMAX
LABEL 8

GENERATE FRINGE

SET FRINGE BOUNDARY COUPLED TO
  ZONE 1 BOUNDARY OLAP

UPDATE
```

### 3.4 Setting the Remaining Boundary Conditions

The remaining boundary conditions that need to be set for the C grid around the airfoil are the downstream outflow boundaries, the outer boundary, the C grid cut line, and the airfoil surface. The downstream and outer boundaries of the flap grid have already been coupled to the airfoil grid, so all that remain are the C grid cut line and the flap surface.

The downstream outflow boundaries for the airfoil grid are at I1 and IMAX, and are defined as **outflow** boundaries.

Graphics Mode

```
PICK ZONE/BNDY
  1: (from Zone List)
  I1
MODIFY BNDY
CHANGE ALL
  OUTFLOW
BOUNDARY COND.
  YES - UPDATE FILE
PICK ZONE/BNDY
  IMAX
MODIFY BNDY
CHANGE ALL
  OUTFLOW
BOUNDARY COND.
  YES - UPDATE FILE
```

Command Line Mode

```
ZONE 1

BOUNDARY I1
OUTFLOW

UPDATE

BOUNDARY IMAX
OUTFLOW

UPDATE
```

---

<sup>4</sup>From the Main Menu, not the Menu Trail

## Airfoil/Flap Example Case

The outer boundary of the airfoil grid is at JMAX, and is defined as a **freestream** boundary.

### Graphics Mode

```
PICK ZONE/BNDY
  JMAX
MODIFY BNDY
CHANGE ALL
  FREESTREAM
BOUNDARY COND.
  YES - UPDATE FILE
```

### Command Line Mode

```
BOUNDARY JMAX
FREESTREAM

UPDATE
```

The C grid cut line and the airfoil surface are both at J1. First, we'll couple the grid to itself, using "point match" coupling. This will define the cut line as a **coupled** boundary, leaving the points on the airfoil surface **undefined**.

### Graphics Mode

```
PICK ZONE/BNDY
  J1
MODIFY BNDY
COUPLE
  1: (from Zone List)
SET COUP MODE
  POINT MTCH ON
SEL OTHER BNDY
  J1:
COUPLE
```

### Command Line Mode

```
BOUNDARY J1
CPMODE POINT MATCH
COUPLED TO ZONE 1 BOUNDARY J1
```

Now, we'll set a **viscous wall** condition at the remaining undefined points, and write the changes to the *.cgd* file.

### Graphics Mode

```
CHANGE BY TYPE
  UNDEFINED
  VISCOUS WALL
BOUNDARY COND.
  YES - UPDATE FILE
```

### Command Line Mode

```
UNDEFINED IS VISCOUS WALL

UPDATE
```

Like the airfoil grid, the cut line and the flap surface in the flap grid are both at J1. The boundary conditions there are set in the same way as in the airfoil grid.

Graphics Mode

```
PICK ZONE/BNDY
  2:  (from Zone List)
  J1
MODIFY BNDY
COUPLE
  2:  (from Zone List)
SEL OTHER BNDY
  J1:
COUPLE
CHANGE BY TYPE
  UNDEFINED
  VISCOUS WALL
BOUNDARY COND.
  YES - UPDATE FILE
```

Command Line Mode

```
ZONE 2
BOUNDARY J1
COUPLED TO ZONE 2 BOUNDARY J1

UNDEFINED IS VISCOUS WALL

UPDATE
```

Finally, it's a good idea to check the boundary conditions to make sure all is OK.<sup>5</sup>

Graphics Mode

```
TOP
CHECK
CHECK BOUNDARY
  PICK ZONE
    ALL (from Zone List)
  RUN BNDY CHKS
```

Command Line Mode

```
ZONE ALL
CHECK BOUNDARY
```

After hitting the **Enter** key to return to graphics mode, we can quit GMAN.

Graphics Mode

```
END
  YES - TERMINATE
```

Command Line Mode

```
EXIT
```

---

<sup>5</sup>This checks regular (non-fringe) boundaries. Fringe boundaries can also be checked, using **RUN FRNG CHKS** in graphics mode, or **CHECK FRINGE** in command line mode. Doing the fringe boundary check for this case yields several messages about volume ratios exceeding the tolerance. This is intended as a warning about differences in the sizes of the grid cells in the two zones in the area of the fringes. As noted earlier, the grid cells in this area should be similar in size. For this case, however, this does not seem to present a problem in the solution.



## 4 Running Wind-US

Listed below is the input data (.dat) file *demo.dat* used for this case.

```
Demo of airfoil/flap Chimera grid
Mach 0.6
First run

/ Inlet conditions
Freestream static 0.6 14.7 520. 0. 0.

/ Boundary conditions
Downstream pressure 14.7 zone 1

/ Viscous terms
Turbulence sst

/ Numerics
Cycles 500

End
```

Two runs were made for a total of 1000 cycles (5000 iterations) On an SGI Octane R10000 system, in serial mode, each run required just over 3200 seconds of CPU time. Genplot files for the maximum and  $L_2$  residuals were generated using *resplt*, as described in the “Tutorial” section of the *Wind-US User’s Guide*.

The residuals are shown in Figure 5(a) and Figure 5(b).

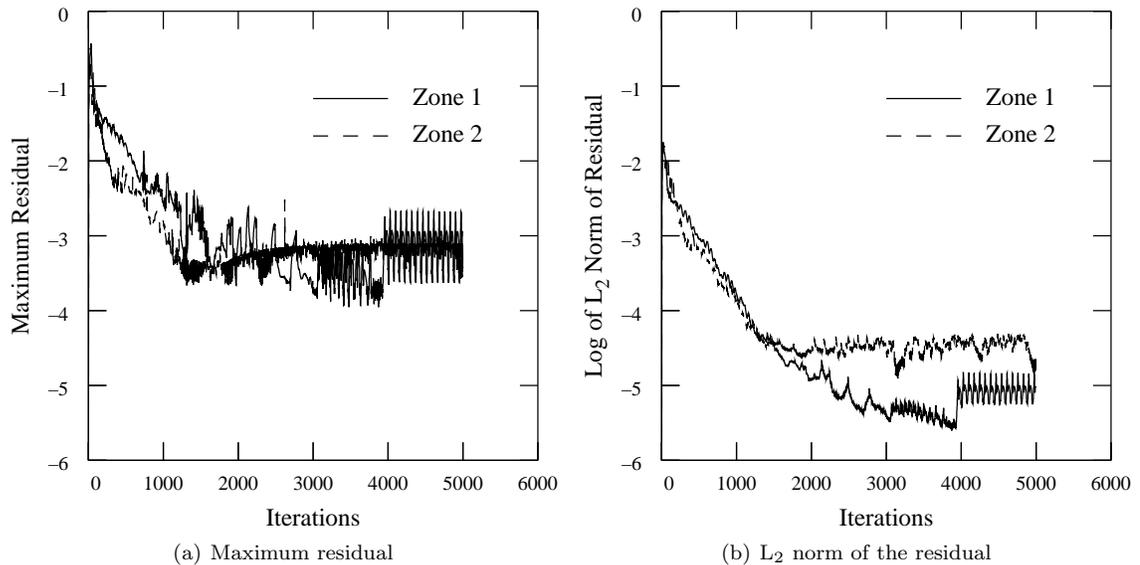


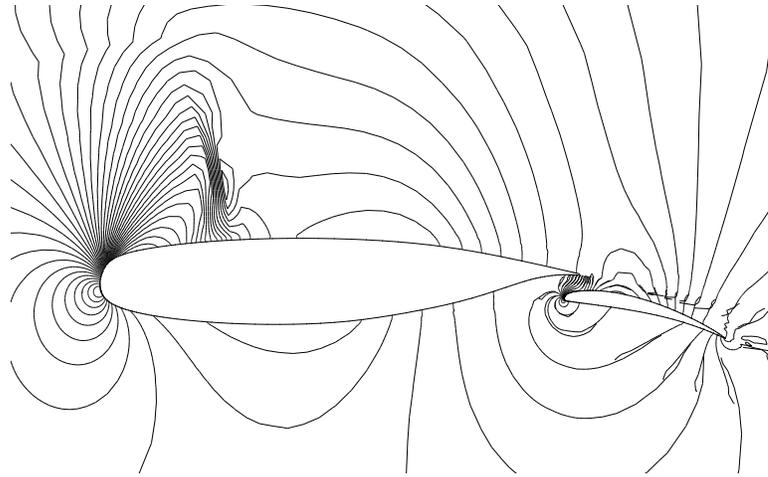
Figure 5: Computed residuals.



## 5 Results

Computed flow field results may be listed and/or plotted using CFPOST, as described in the *CFPOST User's Guide*. CFPOST may also be used to create PLOT3D xyz and q files for use as input to other post-processors, as described under “**Examine the Results**” in the “Tutorial” section of the *Wind-US User's Guide*.

The computed results are shown in [Figure 6](#) in the form of constant static pressure contours.



**Figure 6:** Computed static pressure contours.