NAVIER-STOKES CALCULATION OF TRANSONIC FLOW PAST THE NTF 65-DEGREE DELTA WING

by

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Abstract

This project is a continuation of the research initiated in summer last year. Viscous flow past a wind tunnel model of a 65-degree swept angle Delta wing at transonic speeds is being studied. The model was tested in the 8-foot cryogenic transonic wind tunnel at the National Transonic Facility. Aerodynamic forces and wing surface pressure data were obtained at various angles of attack, Mach numbers and Reynolds' numbers for four different leading edges of the wing. The objectives of the present investigation are:

1. To perform numerical modelling of the flow around the wing.
2. To validate the experimental data with a Navier-Stokes computational fluid dynamics code and vice versa.
3. To investigate the effects of the sting mount of the wing.
4. To evaluate the effects of leading edge radius on the flow.
5. To explain the Reynolds' number effect as indicated by the test data.

Several computer programs were developed to define the surfaces of the wing, the four leading edges and the sting mount. Based on these geometric databases, the surface grids of a single-block computational domain was generated interactively on the IRIS workstation using the GRIDGEN2D module of GRIDGEN. To refine the grids and to avoid excessive loss of grid points due to collapsed edges, a 9-block computational domain containing approximately 750,000 grid points was developed with the GRIDBLOCK module to replace the single-block grid:

<table>
<thead>
<tr>
<th>Block No.</th>
<th>Model Surface Contained</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fore Upper Wing</td>
<td>49x13x65</td>
</tr>
<tr>
<td>2</td>
<td>Leading Edge</td>
<td>49x49x65</td>
</tr>
<tr>
<td>3</td>
<td>Fore Lower Wing</td>
<td>49x13x65</td>
</tr>
<tr>
<td>4</td>
<td>Sting</td>
<td>49x49x65</td>
</tr>
<tr>
<td>5</td>
<td>Wing Apex</td>
<td>25x25x65</td>
</tr>
<tr>
<td>6</td>
<td>Upper Sting Joint</td>
<td>49x25x65</td>
</tr>
<tr>
<td>7</td>
<td>Rear Upper Wing</td>
<td>49x25x65</td>
</tr>
<tr>
<td>8</td>
<td>Rear Lower Wing</td>
<td>49x25x65</td>
</tr>
<tr>
<td>9</td>
<td>Lower Sting Joint</td>
<td>49x25x65</td>
</tr>
</tbody>
</table>
Fig. 1 shows the wing and sting surfaces, and the block edges near the model, while Fig. 2 shows all the blocks in the entire computational domain encompassing a space of 20 chord lengths from the wing in all directions.

The double-precision version of GRIDGEN2D was then used to generate the surface grids of every block. Grid point-clustering was performed on high-curvature portions of the apex, the leading edge, the trailing edge and the sting joint. To facilitate thin-layer Navier-Stokes calculation at high Reynold's numbers, a very tight spacing of 10-6 was specified on the wing surface. Fig. 3 shows some typical surface grids on the model and the plane of symmetry. Figs. 4 and 5 show some typical 2-D grids on block interfaces. Upon minor modification of the blocks containing the wing apex and the leading edge, the surface grids of these two blocks can be generated for other leading edge profiles without disturbing the other blocks.

Job files and input files were created to read the multiple-block surface grids into the GRIDGEN3D module on the Cray supercomputer to generate the internal volume grid of each block. A typical output file summarizing successful generation of satisfactory volume grids is given in Appendix A. The resulting volume grids were finally examined by the GRIDVUE3D module or the FAST software on the IRIS workstation.

The CFL3D computational fluid dynamics code, developed by the Computational Aerodynamics Branch, is to be applied. A typical input file which sets up the code to read the volume grids and specifies the boundary conditions for each block is given in Appendix B. Calculations for both laminar and turbulent flows are being conducted, and preliminary solutions are expected in the immediate future.
Fig. 1  Wing Model and Block Edges – Near Field
Fig. 2  Block Edges - Far Field
Fig. 3  Surface Grids on the Model and Plane of Symmetry
Fig. 4  Surface Grids on Block Interfaces
Fig. 5  Surface Grids on Block Interfaces
GRIDGE N3D Output File

Appendix A

**Input Data**

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**Revision: 8.6.3.4**

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**ALGEBRAIC SOLVER**

INITIAL = 92, TOLER = 1.0E-9, ITSOM = 16, IJAC = 1 &END

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**Grid contains 9 block(s)**

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**Block Data**

**Block 1:** inter2.blk

<table>
<thead>
<tr>
<th>mb</th>
<th>imax</th>
<th>jmax</th>
<th>kmax</th>
<th>name</th>
</tr>
</thead>
<tbody>
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<td>49</td>
<td>65</td>
<td>13</td>
<td>inter2.blk</td>
</tr>
<tr>
<td>2</td>
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</tr>
<tr>
<td>9</td>
<td>49</td>
<td>65</td>
<td>25</td>
<td>inter2.blk</td>
</tr>
</tbody>
</table>

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**Block 2:** inter3.blk

**Block 3:** inter4.blk

**Block 4:** inter7.blk

**Block 5:** inter1.blk

**Block 6:** Upjoint

**Block 7:** Wingup

**Block 8:** Winglo

**Block 9:** Jointlo

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**Jacobian Summary**

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**Block 1:**

- **Number of positive volumes:** 36864 (100.00%)
- **Number of skewed volumes:** 0 (0.00%)
- **Number of negative volumes:** 0 (0.00%)
- **Minimum volume:** 0
- **Maximum volume:** 0

**Block 2:**

- **Number of positive volumes:** 147456 (100.00%)
- **Number of skewed volumes:** 1 (0.00%)
- **Number of negative volumes:** 0 (0.00%)
- **Minimum volume:** 0
- **Maximum volume:** 0

**Block 3:**

- **Number of positive volumes:** 36864 (100.00%)
- **Number of skewed volumes:** 0 (0.00%)
- **Number of negative volumes:** 0 (0.00%)
- **Minimum volume:** 0
- **Maximum volume:** 0

**Block 4:**

- **Number of positive volumes:** 147456 (100.00%)
- **Number of skewed volumes:** 1 (0.00%)
- **Number of negative volumes:** 0 (0.00%)
- **Minimum volume:** 0
- **Maximum volume:** 0

**Block 5:**

- **Number of positive volumes:** 36864 (100.00%)
- **Number of skewed volumes:** 0 (0.00%)
- **Number of negative volumes:** 0 (0.00%)
- **Minimum volume:** 0
- **Maximum volume:** 0

**Block 6:**

- **Number of positive volumes:** 36864 (100.00%)
- **Number of skewed volumes:** 0 (0.00%)
- **Number of negative volumes:** 0 (0.00%)
- **Minimum volume:** 0
- **Maximum volume:** 0

**Block 7:**

- **Number of positive volumes:** 36864 (100.00%)
- **Number of skewed volumes:** 0 (0.00%)
- **Number of negative volumes:** 0 (0.00%)
- **Minimum volume:** 0
- **Maximum volume:** 0

**Block 8:**

- **Number of positive volumes:** 36864 (100.00%)
- **Number of skewed volumes:** 0 (0.00%)
- **Number of negative volumes:** 0 (0.00%)
- **Minimum volume:** 0
- **Maximum volume:** 0

**Block 9:**

- **Number of positive volumes:** 36864 (100.00%)
- **Number of skewed volumes:** 0 (0.00%)
- **Number of negative volumes:** 0 (0.00%)
- **Minimum volume:** 0
- **Maximum volume:** 0

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**Jacobian Summary for Entire Grid**

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**Number of Negative Volumes:** 0 (0.00%)

**Minimum Volume:** 0

**Maximum Volume:** 0

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**Revision Notes:**

- **Revision 8.6.3.4**
- **MDA Engineering, Inc.**

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**Image Description:**

- The image contains a page from a document related to the output of a grid generation algorithm, specifically for 3D grid generation.
- The page includes input data, block data, and Jacobian summaries for different blocks within the grid.
- The output file provides details such as the number of positive, skewed, and negative volumes, minimum and maximum volumes, and Jacobian values for each block.

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**Further Information:**

- The grid generation process is likely used in computational fluid dynamics (CFD) simulations, where accurate grid representation is crucial for accurate simulation results.
- The Jacobian information helps in understanding the geometry and connectivity of the grid, which is essential for solving partial differential equations numerically.

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**Technical Details:**

- **Input Data Format:** The input data includes various parameters such as block names, dimensions, and volume information.
- **Output File Structure:** The output file is structured to provide comprehensive information about the grid, including volume statistics and Jacobian data for each block.

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**Technical Questions:**

- **Understanding Grid Geometry:** How does the grid geometry affect the accuracy of CFD simulations?
- **Volume Analysis:** What does the number of positive, skewed, and negative volumes indicate in the context of grid generation?
- **Jacobian Importance:** Why is the Jacobian calculation important for grid generation?