Drag Prediction for the DLR-F6 configuration using the TetrUSS Unstructured Grid CFD Software

Chittur (Venkat) Venkatasubban* & Neal Pfeiffer+

*Principal Engineer,  +Principal Engineering Fellow & Manager

Advanced Design
Raytheon Aircraft Company
Wichita, Kansas, USA

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• Acknowledgements to the *TetruSS* team at NASA Langley

  – USM3Dns flow solver
    ▪ *Neal Frink, Paresh Parikh, Mohagna Pandya*

  – GridTool / Vgrid grid generator
    ▪ *Shahyar Pirzadeh, Jamshid Samareh*
### DLR-F6 Configurations

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Grid Class</th>
<th>Tetrahedra</th>
<th>Surface Triangles</th>
<th>Boundary layer cells</th>
<th>No. of cell layers across wing t.e.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DLR-F6 Wing Body</strong></td>
<td>Medium</td>
<td>6,483,682</td>
<td>78,540</td>
<td>z0 = 0.03868 mm (y+ = 50) 8 layers</td>
<td>8</td>
</tr>
<tr>
<td><strong>DLR-F6 Wing Body + FX2B fairing</strong></td>
<td>Coarse</td>
<td>3,142,285</td>
<td>59,660</td>
<td>z0 = 0.03868 mm (y+ = 50) 8 layers</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>6,284,018</td>
<td>80,522</td>
<td>z0 = 0.03868 mm (y+ = 50) 8 layers</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Fine</td>
<td>11,521,175</td>
<td>136,710</td>
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</tr>
</tbody>
</table>
• *Vgrid* grid generator *(Shahyar Pirzadeh et al; NASA Langley)*
  – Unstructured tetrahedra, using advancing front method
  – Element size distribution controlled through field source distributions
• **USM3Dns flow solver** *(Neal Frink et al; NASA Langley)*
  – Cell centered, unstructured tetrahedra
  – Implicit time stepping
  – Spalart Allmaras turbulence model, with wall functions
  – Special boundary conditions on blunt wing trailing edges.
• Computer Hardware

RAC Beowulf Cluster

Front End Node (xw4100)
2GB RAM

48 Port Cisco
10/100MB
Network switch
(Private Network)

NFS / Compute Node
(Itanium 64 bit)

Beowulf Cluster
(15 D510 compute nodes
8 D530 compute nodes)

Company Intranet

User PC or Unix System

D510s

D530s

Each PC (Pentium 4 based) contains 1GB of RAM. Each node has a 100MB network NIC.

Schematic courtesy Everett Schultz, IT Dept., Raytheon Aircraft
DPW - 3

• DLR-F6 + Wing Body
• DLR-F6 + Wing Body

Medium Grid
Tetrahedra = 6,483,682
Triangles = 78,540
DPW - 3

Aircraft Company

• DLR-F6 + Wing Body (Medium Grid)

<table>
<thead>
<tr>
<th></th>
<th>BUB</th>
<th>EYE_B</th>
<th>EYE_W</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS</td>
<td>226.68</td>
<td>238.383</td>
<td>234.11</td>
</tr>
<tr>
<td>BL</td>
<td>-87.57</td>
<td>-66.429</td>
<td>-73.259</td>
</tr>
<tr>
<td>WL</td>
<td>-5.469</td>
<td>-7.801</td>
<td>-9.16</td>
</tr>
</tbody>
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<tr>
<td>FS</td>
<td>222.528</td>
<td>238.968</td>
<td>235.125</td>
</tr>
<tr>
<td>BL</td>
<td>-82.114</td>
<td>-66.705</td>
<td>-72.295</td>
</tr>
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### DLR-F6 + Wing Body (Medium Grid)

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<tr>
<td><strong>BL</strong></td>
<td>-82.114</td>
<td>-66.705</td>
<td>-72.295</td>
</tr>
<tr>
<td><strong>WL</strong></td>
<td>-3.724</td>
<td>-7.326</td>
<td>-9.677</td>
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<tbody>
<tr>
<td><strong>FS</strong></td>
<td>224.785</td>
<td>238.878</td>
<td>236.891</td>
</tr>
<tr>
<td><strong>BL</strong></td>
<td>-76.465</td>
<td>-66.697</td>
<td>-70.147</td>
</tr>
<tr>
<td><strong>WL</strong></td>
<td>-4.279</td>
<td>-7.364</td>
<td>-10.665</td>
</tr>
</tbody>
</table>

AIAA DPW-3 (Drag Prediction Workshop), June 2006

- DLR-F6 Wing Body, without FX2B Farms
- Sref = 145400 mm², cref = 141.2 mm, h/2 = 585.647 mm
- Medium Grid: Tetra, 6,413,662 cells, Surface Triangles = 72,530
- Mach = 0.75, Re = 5 million, Cl = 0.5, CD = 0.026255, alpha = +0.013629
• DLR-F6 + Wing Body (Medium Grid)

**DLR-F6 + Wing Body**

AIAA Drag Prediction Workshop - 3 (June 3-4, 2006)

Mach = 0.75, Re = 5 million, CL = 0.5, alpha = -0.118

Pressure Coefficient (Cp) vs. x/c at various wing spanwise stations

Original Code

+ Limiter

\[
\begin{align*}
Y &= -87.85 \text{ mm} \\
Y &= -139.87 \text{ mm} \\
Y &= -194.53 \text{ mm} \\
Y &= -221.56 \text{ mm} \\
Y &= -240.37 \text{ mm} \\
Y &= -300.09 \text{ mm} \\
Y &= -373.19 \text{ mm} \\
Y &= -496.02 \text{ mm}
\end{align*}
\]
• DLR-F6 + Wing Body (Medium Grid)

Modified Code
No Limiter
• DLR-F6 + Wing Body (Medium Grid)

**DLR-F6 + Wing Body**

*AIAA Drag Prediction Workshop - 3 (June 3-4, 2006)*

Mach = 0.75, Re = 5 million, CL = 0.5

Pressure Coefficient (C_p) vs. x/c at Y = -194.53

\[
\frac{X}{C} = -194.53; \text{Mod; } \alpha = -0.1013
\]

\[
Y = -194.53; \text{Org; } \alpha = +0.0136
\]

\[
"Y = -194.53; \text{Org + Limiter; } \alpha = +0.0136"
\]
DPW - 3

• DLR-F6 + Wing Body (Medium Grid)

Comparisons of Code Variants
• “Modified” Version is preferred to “Original”
  • Limiter is not preferred
• DLR-F6 + Wing Body (Medium Grid)

Comparisons of Code Variants
• "Modified" Version is preferred to "Original"
  • Limiter is not preferred
Aircraft Company

- DLR-F6 + Wing Body + FX2B Fairing

### Coarse
- Tetrahedrons: 3,142,285
- Triangles: 59,660

### Medium
- Tetrahedrons: 6,284,018
- Triangles: 80,522

### Fine
- Tetrahedrons: 11,521,175
- Triangles: 136,710
• DLR-F6 + Wing Body + FX2B Fairing

AIAA DPW-3 (Drag Prediction Workshop), June 2006

DLR-F6 Wing-Body

Tets = 3,142,285
Triangles = 59,660
• DLR-F6 + Wing Body + FX2B Fairing

AIAA DPW-3 (Drag Prediction Workshop), June 2006
DLR-F6 Wing Body, with FX2B Fairing

Tets = 6,284,018
Triangles = 80,522
• DLR-F6 + Wing Body + FX2B Fairing

AIAA DPW-3 (Drag Prediction Workshop), June 2006
DLR-F6 Wing Body, with FX2B Fairing

Tets = 11,521,175
Triangles = 136,710
• DLR-F6 + Wing Body + FX2B Fairing

Coarse

Tets       = 3,142,285
Triangles  = 59,660

Medium

Tets       = 6,284,018
Triangles  = 80,522

Fine

Tets       = 11,521,175
Triangles  = 136,710
• DLR-F6 + Wing Body + FX2B Fairing

Coarse

Tets = 3,142,285
Triangles = 59,660
• DLR-F6 + Wing Body + FX2B Fairing

AIAA DPW-3 (Drag Prediction Workshop), June 2006

DLR-F6 Wing Body, with FX2B Fairing

Tets = 6,284,018
Triangles = 80,522

Medium

C_P
1,200
1,100
1,000
0,900
0,800
0,700
0,600
0,500
0,400
0,300
0,200
0,100
0,000
-0,100
-0,200
-0,300
-0,400
-0,500
-0,600
-0,700
-0,800
-0,900
-1,000
-1,100
-1,200
-1,300
• DLR-F6 + Wing Body + FX2B Fairing

AIAA DPW-3 (Drag Prediction Workshop), June 2006

**DLR-F6 Wing Body, with FX2B Fairing**

- C_P
- Tets = 11,521,175
- Triangles = 136,710

**Fine**
• DLR-F6 + Wing Body + FX2B (Coarse Grid)

**Wing Pressures**

Coarse = 3,142,285 cells
• DLR-F6 + Wing Body + FX2B (Medium Grid)

Wing Pressures

Medium = 6,284,018 cells
• DLR-F6 + Wing Body + FX2B (Fine Grid)

Wing Pressures
Fine = 11,521,175 cells

Pressure Coefficient (Cp) vs. x/c at various wing spanwise stations
• DLR-F6 + Wing Body + FX2B

Grid Convergence

Coarse = 3,142,285 cells
Medium = 6,284,018 cells
Fine = 11,521,175 cells
DPW - 3

• DLR-F6 + Wing Body + FX2B

Comparisons of Code Variants & Grid Convergence
- “Modified” version is preferred to “Original”
- Limiter is not preferred

ΔCD (No Fairing – FX2B); Medium Grid = 1.06 counts
- DLR-F6 + Wing Body + FX2B

Comparisons of Code Variants & Grid Convergence
- “Modified” version is preferred to “Original”
- Limiter is not preferred
• Lift & Moment curves, Drag Polars (with & without FX2B Fairing)

- Slight +ve Alpha shift with FX2B added
- No noticeable change in Drag Polar
- Noticeable decrease in pitch down moment with FX2B added
• Conclusions
  – Bubble detected for DLR-F6 + Wing Body
  – No Bubble detected for DLR-F6 + Wing Body + FX2B
  – Wing trailing edge separation detected with or without FX2B
  – Drag reduction: $\Delta CD$ (No Fairing – FX2B); Medium Grid = 1.06 counts
  – Results obtained under Industrial Conditions!
• **Further work**
  - Solution adaptive grid refinement using *RefineMesh (NASA Langley)*
    - Uses unique hole creation algorithm (*Pirzadeh*)
    - Generates high quality multilevel grid refinement for unstructured tetrahedra
    - Smooth transition between refinement levels
    - Improved estimation of wave drag
    - Useful in production environment, to reduce grid size & computation time
  
  – Plot Skin Friction Coefficients
• Thanks for your attention