DLR F6/FX2B Summary

Edward N. Tinoco
Grid Convergence – All Solutions

F6 Wing-Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50
Grid Convergence – Structured Grid Solutions

1 CFL3D – SST – Structured-B
2 CFL3D – SA – Structured-B
7 UPACS – SA – Structured-I
9 SLIM – SA – Structured-I
0 SLIM – V2F – Structured-I
B PAB1D – SZL – Structured-B
C PAB1D – KE – Structured-B
D PAB1D – Girimaji – Structured-B
E STAR-CCM+ – Structured

STRUCTURED GRIDS
- Boeing Grids
- ICEM Grids
- SAUNA Grids

F6 Wing-Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50

CD-CL*2/(P+AR) vs GRIDFACTOR = 1/(GRID SIZE)^2/3

5 Counts
31.6M 11.2M 6.1M 3.9M 2.8M

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Grid Convergence – Unstructured Grid Solutions

F6 Wing-Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50

UNSTRUCTURED GRID
- VGRID Grids
- AFRL Grids
- ANSYS CFX Grids
- Other Grids

GRID FAC = 1/(GRID SIZE)^2/3
Grid Convergence – Overset Grid Solutions

5 OVERFLOW SA – Overset
H CFLID/TNS Mentor SST – Overset
J CFLID/TLNS Mentor SST – Overset
K OVERFLOW Mentor SST – Overset

F6 Wing-Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50

Grid Face = 1/(Grid Size)^2/3
“Drag” Polars – Structured Grid Solutions

<table>
<thead>
<tr>
<th>Model</th>
<th>Method</th>
<th>Grid Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFL3D</td>
<td>SST</td>
<td>Structured-B</td>
</tr>
<tr>
<td>CFL3D</td>
<td>SA</td>
<td>Structured-B</td>
</tr>
<tr>
<td>UPACS</td>
<td>SA</td>
<td>Structured-I</td>
</tr>
<tr>
<td>S1mb</td>
<td>SA</td>
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</tr>
<tr>
<td>S1mb</td>
<td>V2F</td>
<td>Structured-I</td>
</tr>
<tr>
<td>PAB3D</td>
<td>SZL</td>
<td>Structured-B</td>
</tr>
<tr>
<td>PAB3D</td>
<td>KE</td>
<td>Structured-B</td>
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<tr>
<td>PAB3D</td>
<td>Girimaji</td>
<td>Structured-B</td>
</tr>
<tr>
<td>STAR-CCM+</td>
<td></td>
<td>Structured</td>
</tr>
</tbody>
</table>

STRUCTURED GRIDS
- Boeing Grids
- ICEM Grids
- SAUNA Grids

F6 Wing-Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50

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“Drag” Polars – Unstructured Grid Solutions

F6 Wing-Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50

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“Drag” Polars – Overset Grid Solutions

F6 Wing-Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50

5 OVERFLOW SA – Overset
H CFL3D/NSG Mentor SST – Overset
J CFL3D/TLNS Mentor SST – Overset
K OVERFLOW Mentor SST – Overset

CD-CL^2/(P*I*AR)
Skin Friction – Structured Grid Solutions

1 CFL3D - SST - Structured-B
2 CFL3D - SA - Structured-B
7 UPACS - SA - Structured-I
9 Slmb - SA - Structured-I
0 Slmb - V2F - Structured-I
B PABID - SZL - Structured-B
C PABID - KE - Structured:B
D PABID - Gliirmaj - Structured-B
E STAR-CCM+ - Structured

Structured Grids
- Boeing Grids
- ICEM Grids
- SAUNA Grids

F6 Wing-Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50

CD Skin Friction

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Skin Friction – Unstructured Grid Solutions

![Diagram of skin friction with unstructured grid solutions](image)

**F6 Wing-Body w/wo FX2, MACH = 0.75**

Re = 5 Million, Fixed CL=0.50

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Skin Friction – Overset Grid Solutions

F6 Wing-Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50

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Skin Friction – SA Turbulence Model Solutions

SA TURBULENCE MODEL
- Structured Grids
- Unstructured Grids
- Overset Grids

F6 Wing-Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50

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Skin Friction – SST Turbulence Model Solutions

![Graph showing skin friction results for structured and unstructured grids. The graph compares different turbulence models and grid types, highlighting the differences in skin friction coefficients for two configurations: F6 Wing-Body w/o FX2 and F6 Wing-Body w/ FX2. The Mach number is 0.75, and the Reynolds number is 5 Million, with a fixed Cl=0.50.]
Skin Friction – Other Turbulence Model Solutions

3rd CFD Drag Prediction Workshop
San Francisco, California – June 2006

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Skin Friction – Grid Type

The diagram illustrates the skin friction coefficients for different grid types. The plots compare structured grids, unstructured grids, and overset grids for a F6 Wing-Body configuration without FX2, with a Mach number of 0.75, Reynolds number of 5 million, and a fixed lift coefficient of 0.50. The grid size effect is shown with different grid resolutions: 31.8M, 11.2M, 6.1M, 3.9M, and 2.8M. The CD (drag coefficient) is plotted against a normalized grid size factor (GRIDFACTOR = 1/(GRID SIZE)^2/3).
Skin Friction – Turbulence Model

- SA Turbulence Model
- SST Turbulence Model
- Other Turbulence Models

F6 Wing-Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50

3rd CFD Drag Prediction Workshop
San Francisco, California – June 2006
Drag Increment – Grid Type

F6 Wing-Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50

Structured Grids
1 CFL3D - SST
2 CFL3D - SA
7 UPACS - SA
9 Sihmb - SA
0 Sihmb - V2F
B PAB3D - ZL
C PAB3D - KE
D PAB3D - Gitamaji
E STAR-CCM+ K-omega

Delta CD (WB - WB w/FX2)
3 EDGE - K-MeOmega
4 ANSYS - SST
6 FUN3D - SA
8 TASM - SA
A BCFD - SA
P CFD++ - SA
G NSU3D - SA
N TAU - SA
N Fluent - KE

Overset Grids
5 OVERFLOW SA
H CFL3D,TNS SST
J CFL3D,TNS SST

5 Counts

31.6M
11.2M
3.9M

GRID FAC = 1/(GRID SIZE)^2/3

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Drag Increment – Turbulence Models

![Graphs showing drag increment for various turbulence models.](image-url)
F6 WB Separation Bubble on Wing

 Overlay of Computed Streamlines, SST Turbulence Model, Re=5M

 Wind Tunnel Oil Flow Photo, Re=3M

Edge of Separation Bubble on Wing
Separation Bubble Size – Grid Type
Drag Increment – Filtered by Bubble Size

F6 Wing–Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50

Edge of Separation Bubble

Del*ta CD (WB – WB w/FX2)

GRID FAC = 1/(GRID SIZE)^2/3

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Pressure Distributions – Wing Section 1

Mach = 0.75, CL=0.50, Re=5M

WING SECTION 1

F6 – Wing-Body

F6 – Wing-Body W/FX2

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Drag Increment
Filtered by Bubble Size and Pressure Distribution

F6 Wing-Body w/wo FX2, MACH = 0.75
Re = 5 Million, Fixed CL=0.50

Pressure Distribution - Section 1

Delta CD (WB - WB w/FX2)

1 CFL3D - SST
2 CFL3D - SA
3 EDGE - K-Omega
4 TAS_FLOW - SA
5 PAB3D - SL
6 PAB3D - KE
7 STAR-CCM+ K-Omega
8 NSU3D - SA
9 M TAU - SA

2 Counts

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OBSERVATIONS

• Disappointing!!
• Inboard separation bubble continues to be a major source of difficulty
• No major trends based on grid type or turbulence model
• Grid convergence characteristics suggest difficulty in generating consistent sets of grids
• Some sets had obvious problems with convergence, matching CL
• Good news
  • Just about all solution sets showed the fairing to reduce drag
  • Skin friction predictions well behaved, relatively tight groupings
BACKUP / EXTRA