BCFD Predictions for the 3rd AIAA Drag Prediction Workshop (DPW3)

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• Cell-centered, finite-volume approach
• HLLE flux calculation with second-order spatial reconstruction
  • Linear preserving gradient calculation
• Fully implicit time integration
• Turbulence models
  • Spallart-Allmaras
  • SST
• Additional capabilities: Time accurate LES, real gas effects, hybrid structured/unstructured solver, additional flux formulations available
Grid Details

- Unstructured grids
  - Mixed tetrahedra and prisms (boundary layer)
  - Surface grids generated with MADCAP
  - Volume grids generated with AFLR3
  - Available on NASA FTP site

- Running on 64 bit Linux clusters
  - Typical execution time: 24 hours on fine grid (33M cells)
    running on 33 processors
F6 Wing/Body Grids

Coarse (~4M cells)

Medium (~8M cells)

Fine (~33M cells)
F6 Wing Root Region Grid

Coarse (~4M cells)

Medium (~8M cells)

Fine (~33M cells)
F6 + FX2B Wing Root Region Grid

Coarse (~4M cells)

Medium (~8M cells)

Fine (~33M cells)
• Separation seen on the F6 geometry wing root

• No separation seen on the F6+FX2B geometry wing root
Drag Polars

Drag Polars

- Error bars represent magnitude of oscillations of CL in the F6 solution
- F6+FX2B solutions saw little oscillation
- SST model seen to predict ~10 counts less drag than the S-A model
- FX2B fairing seen to reduce drag regardless of turbulence model
Skin friction behavior

Lower SST drag comes from reduced viscous drag contribution
• SST results seen to extrapolate to a lower drag value when compared to S-A for the FX2B configuration
Crinkle cut, F6+FX2B, S-A, Mach contours at BL=200mm

Isotropic tetrahedra quickly dissipate wake
Wing Cp contours, F6+FX2B, S-A model

Top View

Bottom View

AoA = -3, -1, 0, 1.5
Comparison of Cp between turbulence models
CL=0.5, fine grid

\( \alpha_{SA} = 0.119^\circ \)
\( \alpha_{SST} = 0.166^\circ \)

Shock moves forward in S-A solution

\((Cp_{Spalart} - Cp_{SST})\)

Cp cut at BL=240.37mm
Comparison of skin friction between turbulence models

(Cf_Spalart / Cf_SST)

$\alpha_{S-A} = 0.119^\circ$

$\alpha_{SST} = 0.166^\circ$

• Localized regions of higher skin friction using S-A when compared to SST
• Strong need for best-practices in unstructured grid generation – both surface and volume gridding

• Refine wake region using localized source nodes in volume grid generation

• Difficulty converging F6 cases (without fairing) for both turbulence models

• Turbulence model + grid dependencies
  • ~10 counts drag difference predicted between S-A and SST models
  • Refine grid further to remove any grid dependency on turbulence model

• Future plans
  • Alternate grids – highly resolved and selectively resolved grids, other DPW3 grids
  • Unsteady simulations
  • Cross-code solution comparisons