Assessment of an Unstructured Grid Navier-Stokes Code for Predicting Aircraft Performance

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Introduction

• Purpose
  – Assess LMAS tools drag prediction capabilities.
  – Assess influence of select grid parameters on drag prediction.

• Outline
  – CFD tools description.
  – Grid description.
  – Convergence criteria.
  – Code performance / computer description.
  – CFD results.

• Summary / Conclusions
Aerodynamics Tools Description

• Grid Generator - GRIDTOOL / VGRID3D
  - *NASA LaRC developed*
  - *Tetrahedral based unstructured grids*
    • Advancing layers to resolve boundary layer
    • Minimizes grid generation time

• Flow Solver - USM3Dns
  - *NASA LaRC developed*
  - *Euler and Navier-Stokes*
    • Cell based
    • Implicit
    - *Spalart-Allmaras turbulence model*
      • Wall function
    - *Fully turbulent*

• LM Previous Experience
  - *Extensively utilized - main CFD code for over 3 years*
  - *Excellent correlation with wind tunnel and flight data*
Grids Description

- **Baseline FV** (Full Viscous) - Workshop Provided
  - Solutions generated but not reported
  - USM3D bug with force/moment calculation (FV only)
- **Baseline WF** (Wall Function) - NASA LaRC Provided
- **MOD 1 WF** - LMAC Developed
  - Similar to Baseline WF
- **MOD 2 WF** - LMAC Developed
  - Refined wing LE and fuselage nose
  - Otherwise same as MOD 1 WF
- **MOD 3 WF** - LMAC Developed
  - Same as MOD 2 WF with reduced y+

<table>
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<th>Number of Cells</th>
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Convergence Criteria

Alpha=0 degrees, M=0.75, Re=3.0x10^6

MOD 1 GRID
Code Performance / Beowulf Cluster

**Code Performance**

- Baseline WF Grid (5,000 iters)
  - $2.39 \times 10^6$ Cells
- 40 processors / 20 nodes
- CPU Time: 720 hours
- Wall Clock Time: 20.0 hours
- Memory Requirements: 168 words/cell

**Cluster Description**

- 64 Node Cluster
  - Dual Intel PIII 850 Mhz Processors
  - 128 Total Processors
  - 768 MB PC100 ECC RAM / Node
- 2 Clusters
USM3D Predictions on the DLR-F4 Wing/Body Configuration

\[ M=0.75, \ Re=3.0 \times 10^6 \]
USM3D Predictions on the DLR-F4 Wing/Body Configuration

$M=0.75, \ Re=3.0 \times 10^6$
USM3D Predictions on the DLR-F4 Wing/Body Configuration

$M=0.75, \; Re=3.0\times10^6$
USM3D Predicted Wing Surface Pressures on the DLR-F4 Wing/Body Configuration

η = 23.8%

C_p

0.0 0.2 0.4 0.6 0.8 1.0

0.0 0.2 0.4 0.6 0.8 1.0

η = 33.1%

C_p

0.0 0.2 0.4 0.6 0.8 1.0

η = 40.9%

C_p

0.0 0.2 0.4 0.6 0.8 1.0

η = 84.4%

C_p

0.0 0.2 0.4 0.6 0.8 1.0

η = 63.6%

C_p

0.0 0.2 0.4 0.6 0.8 1.0

USM3Dns - with wall fxns
α = 0.25°, M = 0.75, Re = 3.0x10^6
fully turb, C_l = 0.5945

DRA - 8'x8', trans fixed
M = 0.75, Re = 3.0x10^6, C_l = 0.57

η = 18.5%

C_p

0.0 0.2 0.4 0.6 0.8 1.0

η = 51.2%

C_p

0.0 0.2 0.4 0.6 0.8 1.0

η = 84.4%

C_p

0.0 0.2 0.4 0.6 0.8 1.0

η = 63.6%

C_p

0.0 0.2 0.4 0.6 0.8 1.0

η = 51.2%

C_p

0.0 0.2 0.4 0.6 0.8 1.0

X/C

X/C
Summary / Conclusions

• Assessed USM3Dns drag prediction capabilities
  – *Evaluated baseline wall function grid*
  – *Evaluated 3 LMAS generated grids*
    • Investigated wing leading edge and fuselage nose grid refinement effects
    • Investigated initial viscous grid spacing effects
    • Not considered optimal or drag converged grids
  – *Not able to report on full viscous drag results*

• Grid refinement effects
  – *Minimal CL impact*
  – *~5% drag reduction*
    • Not drag converged
  – *Slight CM impact*

• Initial viscous grid spacing effects
  – *Minimal CL and CD impact*
  – *Slight CM impact*
  – *y+ of 40 or 50 sufficient for wall function results with ~8 cells across BL*

• Future work
  – *Evaluate latest USM3Dns recommendations from NASA LaRC*