FaSTAR Results of Sixth Drag Prediction Workshop

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Summary of FaSTAR results

• Flow Solver: FaSTAR (unstructured-grid solver)

• Results
  • Case 1: Verification Study of 2D NACA0012 airfoil
    • Grid: Family II
    • Turbulence model: SA
    • Discretization: Cell-center/Node-center
  • Case 2: CRM Nacelle-Pylon Drag Increment
    • Grid: unstructured_NASA_GeoLab.REV00
    • Turbulence model: SA-noft2-R-QCR2000
    • Discretization: Node-center
  • Case 3: CRM WB Static Aero-Elastic Effect
    • Grid: unstructured_NASA_GeoLab.REV00
    • Turbulence model: SA-noft2-R-QCR2000
    • Discretization: Node-center
Computational Scheme

- Full compressible Navier-Stokes equations with the Spalart-Allmaras model
- Finite volume method (FVM)
- HLLEW for inviscid flux
- U-MUSCL reconstruction
- GLSQ for gradient computation
- van Leer-type Hishida limiter
- LU-SGS for time integration
- Wall distance code of TAS
FaSTAR can compute aerodynamic forces in 2 minutes with 10M grid and 1024 CPU cores of JSS2. 1024 cores (=32 CPUs) are only 1% of the total system.
Cell center/ Node center

• Both cell-center and node-center discretization methods are supported in FaSTAR
  • Solver is common, but pre/post are different
  • Only neighboring cell information is stored. We switch the discretization method due to the grid type (tetra or hexa)
• Cell-center method was used for DPW5 problems. We validate node-center method for DPW6 problems.
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Grid convergence of $C_D$

FaSTAR (Node center)

FaSTAR (Cell center)

5cnt

sqrt(1/N)
Grid convergence of $C_D$

Pressure drag

Friction drag
Grid convergence of $C_L$ and $C_m$

- Lift
- Pitching moment

FaSTAR (Node center)
FaSTAR (Cell center)
Slope limiter effect

Grid convergence of $C_{Dp}, C_{Df}$

Pressure drag

Friction drag
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Grid convergence of $C_D$

Wing-Body (WB) configuration

$C_D$ vs $1 / \text{GRIDSIZE}^{2/3}$

1cnt

5cnt

DPW5

DPW6

WB(dpw6)

WB(dpw5)
Grid convergence of $C_D$

Wing-Body (WB) configuration

Pressure drag

Friction drag
Grid convergence of WB and WBNP

EXP: NTF data t197R44, t197R79

Drag

Alpha(~Lift)
Grid convergence of WB and WBNP

EXP: NTF data t197R44, t197R79

Pitching moment
Grid convergence of NP interference

**EXP: NTF data t197R44, t197R79**

**ΔDrag**

**ΔAlpha (~Lift)**
Grid convergence of NP interference

EXP: NTF data t197R44, t197R79

$\Delta$ Pitching moment
QCR model effect

Pressure drag

Friction drag

2cnt higher

1cnt lower
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Alpha-sweep (CL and CD)

EXP: NTF data t197R44

CL-alpha

CD-alpha
Alpha-sweep (Cm)

![Graph showing the Alpha-sweep (Cm) with EXP(NTF) and CFD(ETW) data points.]

\[ \Delta C_m = 0.025 - 0.030 \]
Alpha-sweep (CL and CD)

EXP: NTF data t197R44

- \(\Delta C_L \approx 0.05@2.5\text{deg}\)

Support interference is
- \(\Delta C_L \approx 0.024@2\text{deg}, \text{WBT}0\)

Rivers, et al., AIAA2012-3209

Rivers, et al., AIAA2015-1093
Summary

• **Case 1: Verification Study of 2D NACA0012 airfoil**
  • The FaSTAR results agree with the FUN3D, CFL3D, and TAU results
  • The cell center method is close to the CFL3D, whereas the node center method is close to the FUN3D. This difference is caused by the discretization method.

• **Case 2: CRM Nacelle-Pylon Drag Increment**
  • Drag increase with number of grid due to the skin-friction.
  • The nacelle-pylon increment is almost same as the NTF data.

• **Case 3: CRM WB Static Aero-Elastic Effect**
  • Overall trend is same as the NTF experiment.
  • It seems that the difference is caused by the wing deflection and support interference.
Grid type dependency

Grid convergence of $C_L$

- Family I grid
- Family II grid

FaSTAR (Cell center)
Slope limiter effect

Grid convergence of $C_L$, $C_m$

Lift

Pitching moment
SOB (case2)

WB (ExtraFine)

WB (tiny)
Cp contours (case2)

WB (tiny)

WBNP (tiny)
Cp contours (case 2)

WB (tiny)

WBNP (tiny)
Cfx contours

Upper side

Lower side
Nacelle

Cp

Cf

η = 0.35
Nacelle
Wing-pylon interference

\[ C_p \]

\[ C_f \]

\[ \eta = 0.35 \]

Wing

\[ x/c \]
SOB (case3)

Alpha=4.0deg
Cp contours (case3)

Alpha=2.5deg

Alpha=4.0deg
Cp contours (case3)

Alpha=2.5deg

Alpha=4.0deg
Polar curve

![Diagram showing polar curve with markers for CFD and EXP, and annotations for ΔCL and ΔCD.]