AIAA Aeroelastic Prediction Workshop

HIRENASD Test Case

Presented by:

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HIRENASD
funded by DFG

RWTH AACHEN UNIVERSITY

HIRENASD

- 3-D aeroelastic wing with generic fuselage model
- Fixed transition
- Treated as aeroelastic here
  - Relatively weak aeroelastic coupling
- Forced oscillation at 2nd bending mode frequency
- Time history data available
- Data includes
  - Balance loads
  - Mean and fluctuating pressure data
  - Limited set of surface deformation

Known deficiencies:

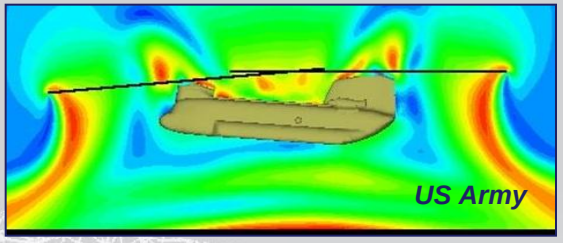
- Limited deflection data
- Only excited at natural frequencies

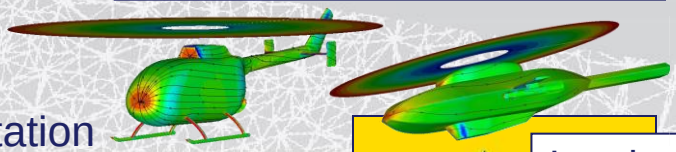
Test medium: Nitrogen
Experiments at matching test conditions:
- Steady Cases
- Dynamic Cases: Oscillations near the natural frequencies

CFD and Aeroelastic Analysis

http://fun3d.larc.nasa.gov/

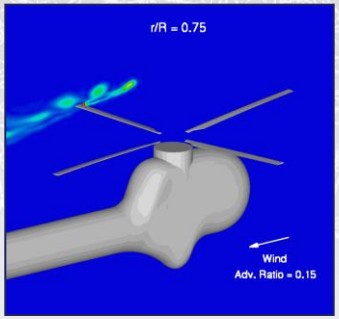
- Solves 2D/3D steady and unsteady Euler and RANS equations on node-based mixed element grids for compressible and incompressible flows
- Supports numerous internal/external efforts across speed range
- General dynamic mesh capability: any combination of rigid/overset/morphing grids, including 6-DOF effects
- Aeroelastic modeling w/ mode shapes, full FEM
- Constrained/multipoint adjoint-based design and mesh adaptation
- Modern software practices including 24/7 testing
- Linear scaling through thousands of cores
- Capabilities fully integrated, very responsive support team, online documentation, training videos, tutorials, etc

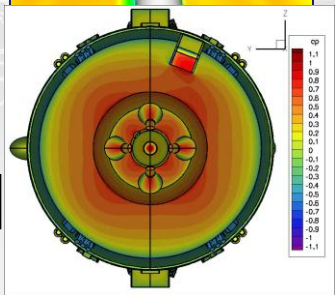


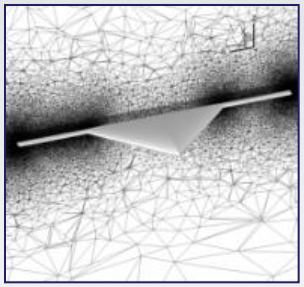


Rotorcraft

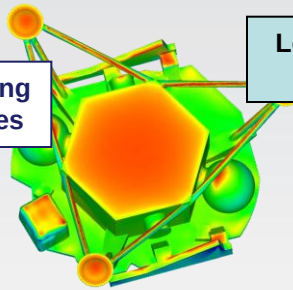
Launch Vehicles



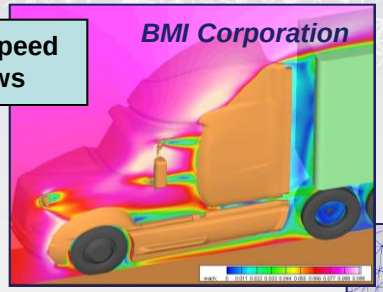




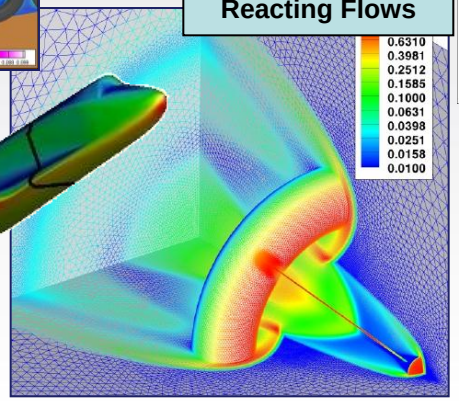
Morphing Vehicles

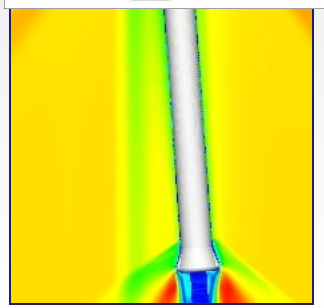


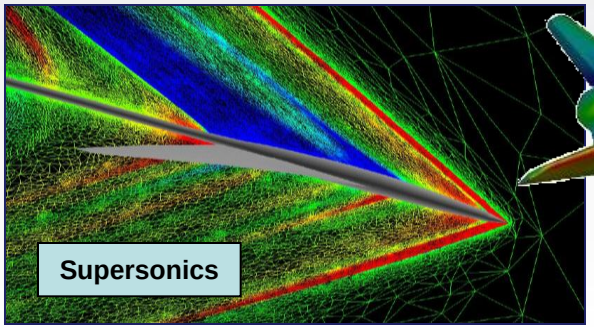
Low-Speed Flows



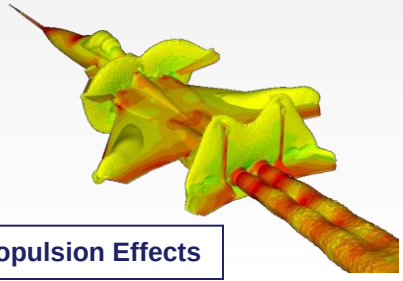
Reacting Flows





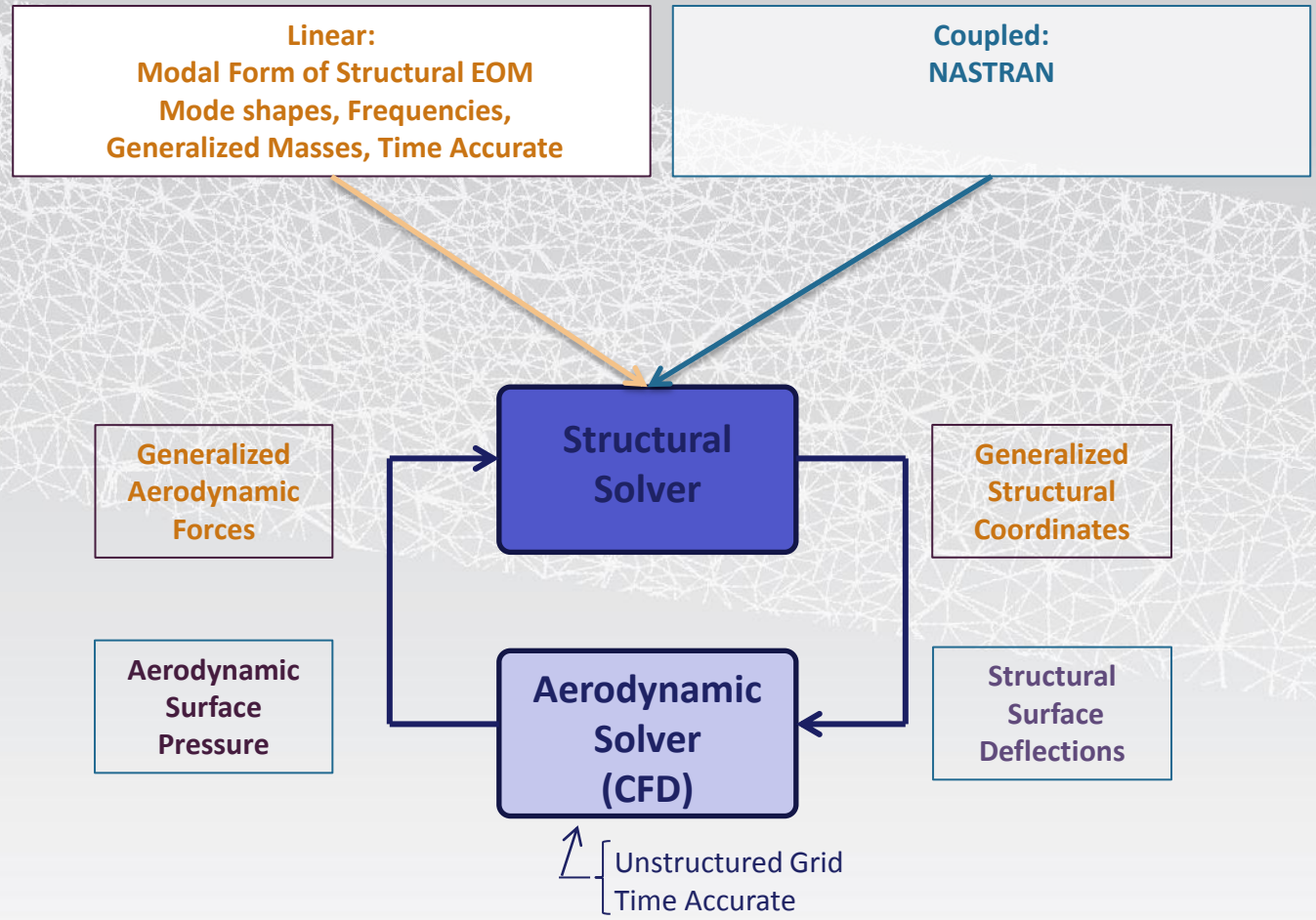


Supersonics



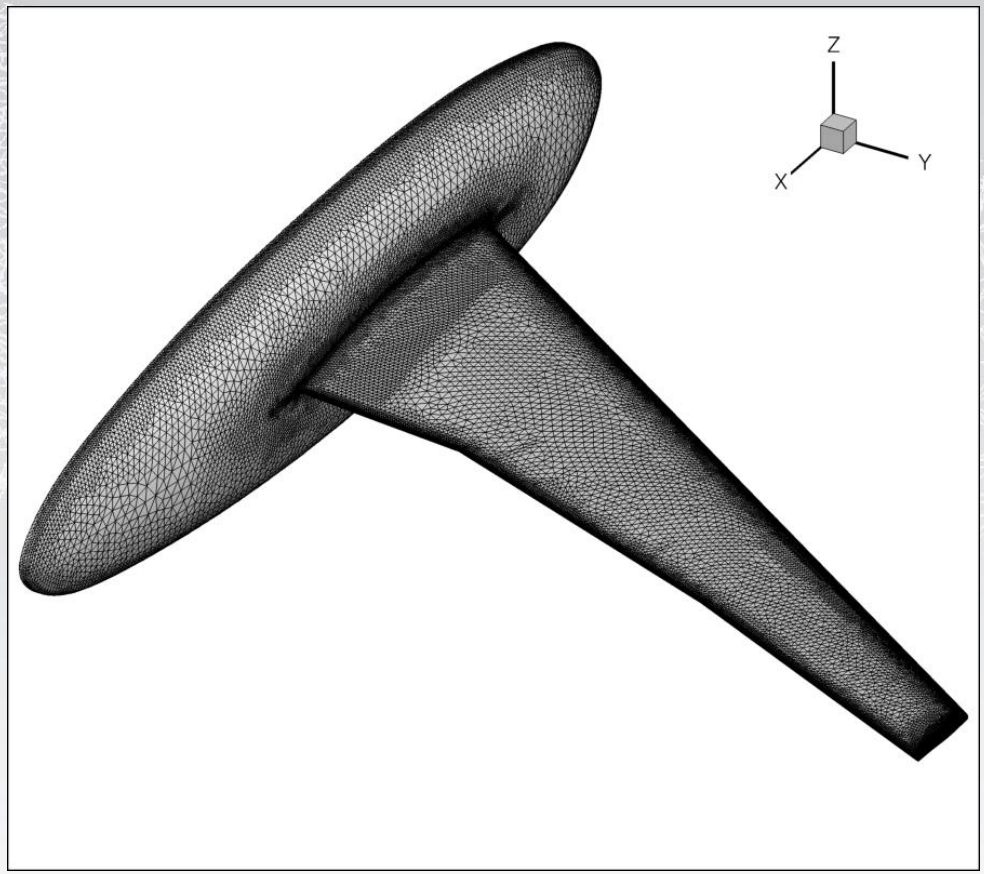
Propulsion Effects

FUN3D Aeroelastic Analysis



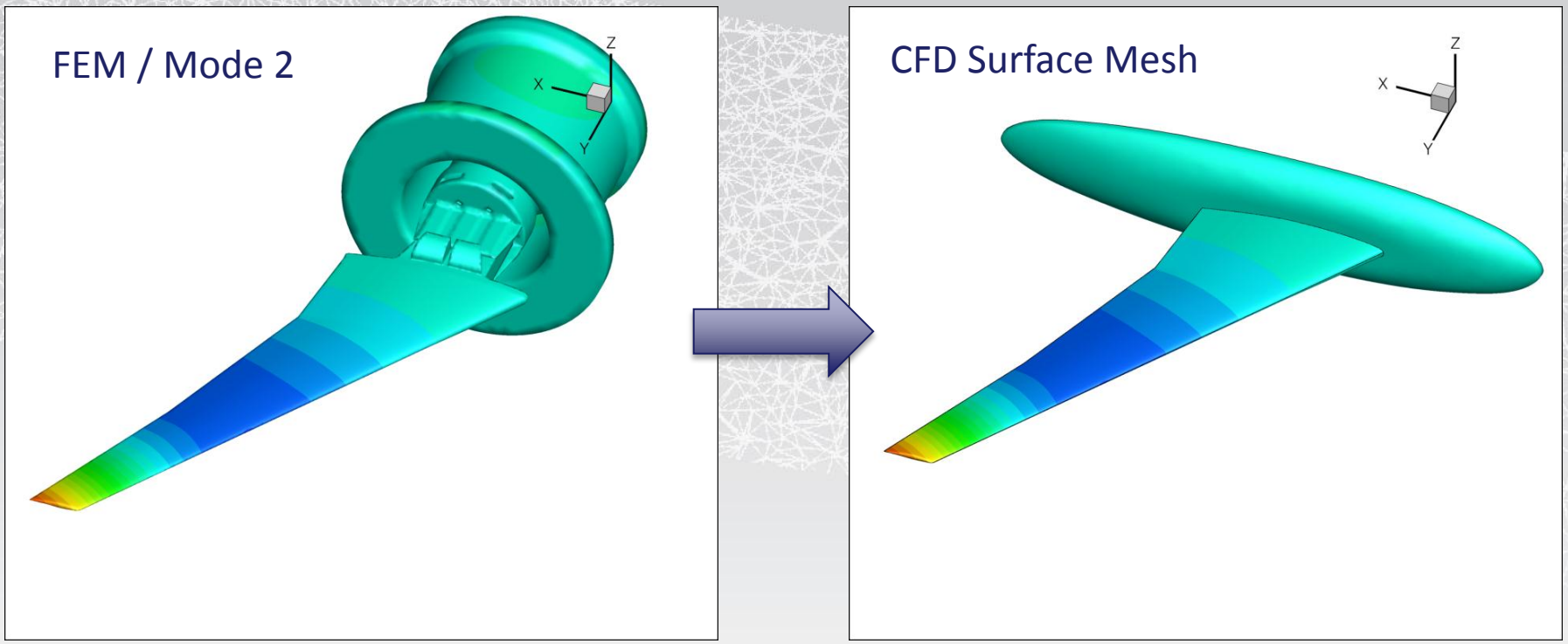
FUN3D Analysis

- FUN3D v.11.6
- Roe scheme
- Venkatakrishnan flux limiter
- SA turbulence model
- Mixed element grids: created by Pawel Chwalowski using VGRID
- 29 modes used in static aeroelastic analysis
- Forced motion $q_n = Asin(\omega t)$



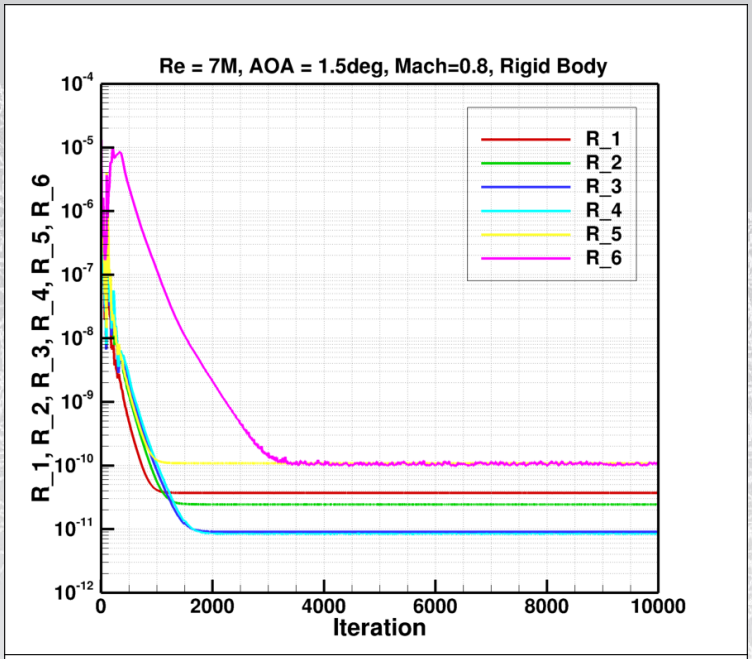
Coarse Grid: 6361743 nodes
Medium Grid: 19061710 nodes
Fine Grid: 56309732 nodes

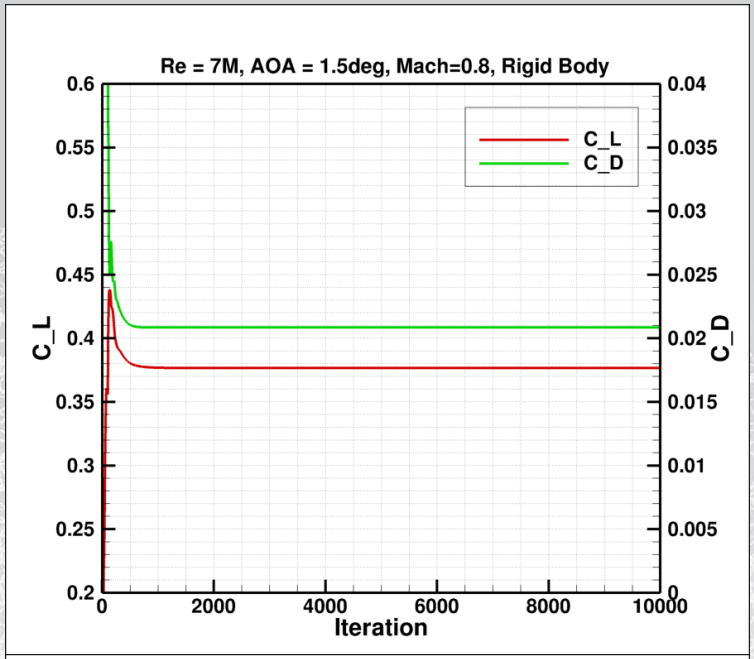
FUN3D Analysis
Mode Shape Interpolation

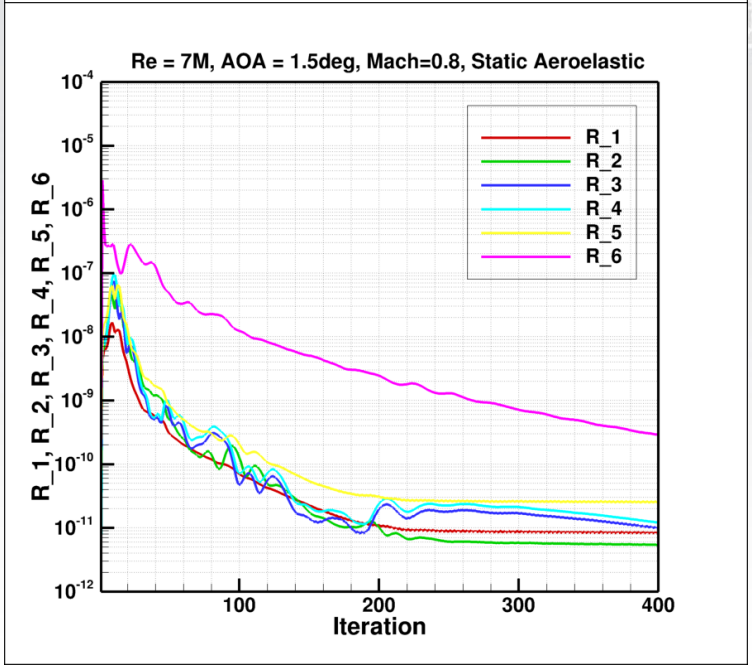


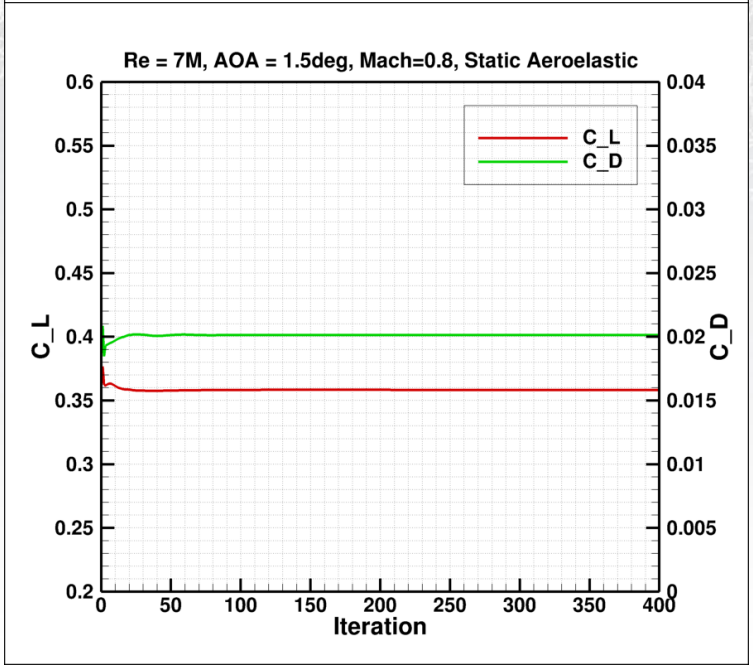
Samareh, J. A., "Discrete Data Transfer Technique for Fluid–Structure Interaction,"
18th AIAA Computational Fluid Dynamics Conference,
AIAA Paper 2007-4309, Miami, FL, June 25-28, 2007.

FUN3D Analysis Convergence

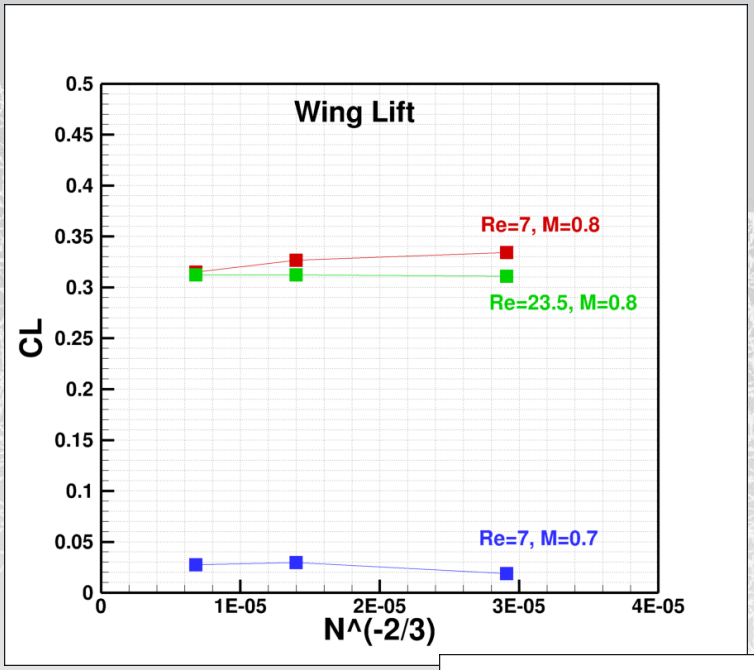


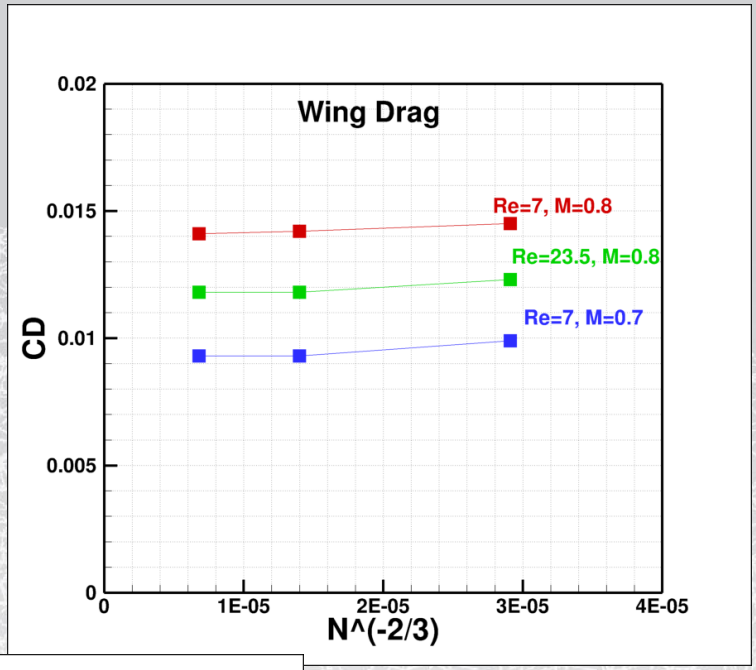


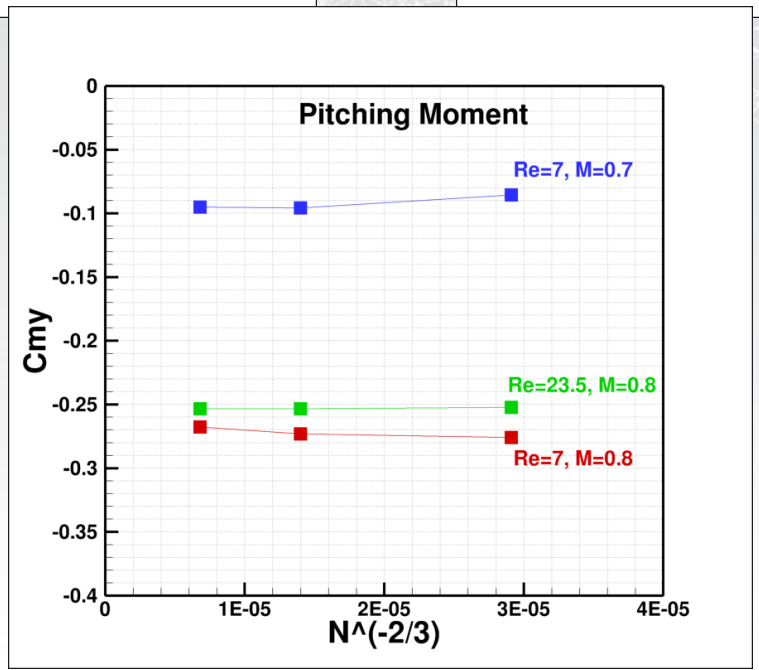




FUN3D Analysis Convergence







HIRENASD Computational Matrix

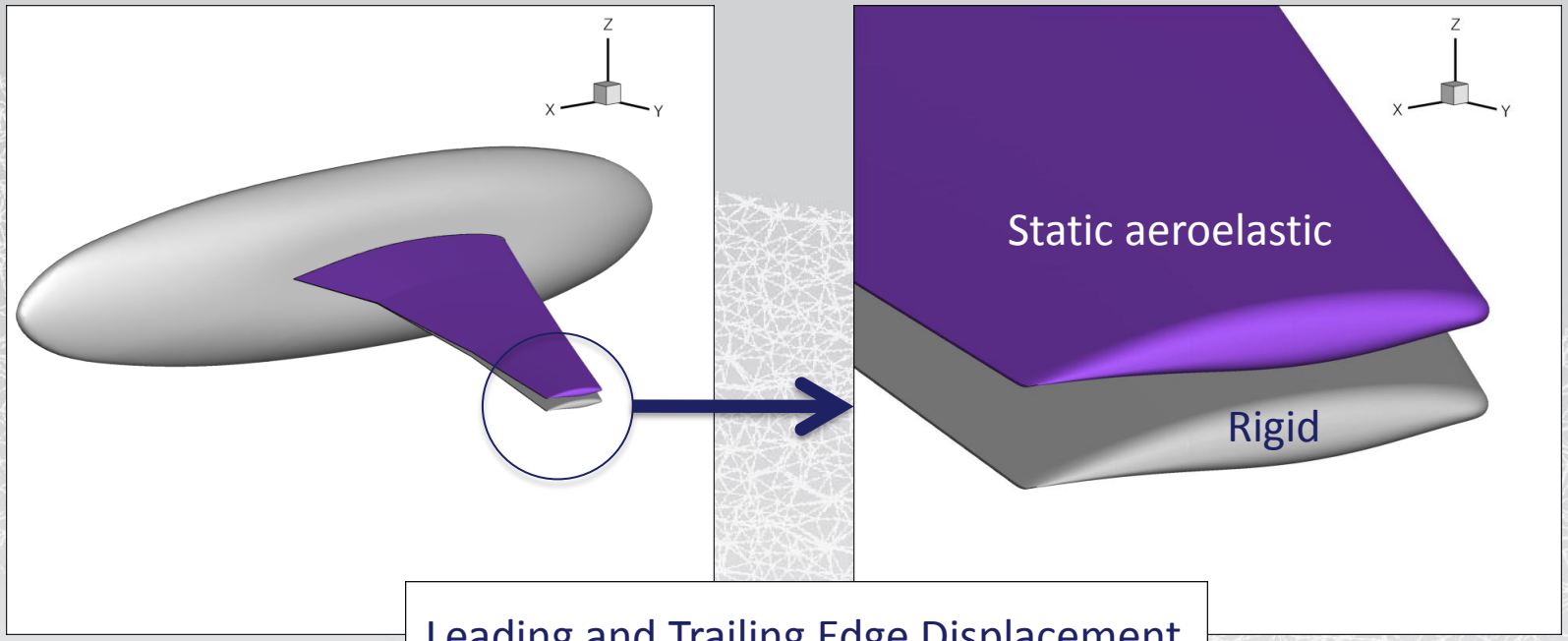
Case \ Grid	Coarse	Medium	Fine
Re_c / Mach	dt / dn / N	dt / dn / N	dt / dn / N
7M / 0.7	0.000197 / 64 / 8	0.000197 / 64 / 4	●
7M / 0.8	0.000198 / 64 / 8	0.000198 / 64 / 8	0.000198 / 64 / 8
		0.00005 / 256 / 3	
23.5M / 0.8	0.000194 / 64 / 8	0.000194 / 64 / 4	0.000194 / 64 / 4

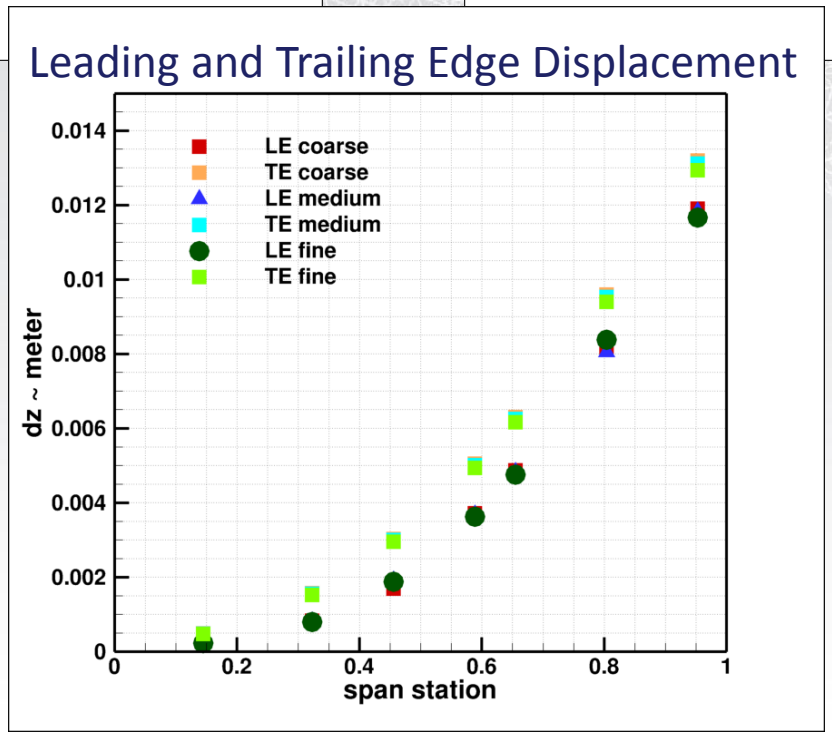
*dt: timestep size (seconds)
dn: # of timesteps per cycle
N: # of cycles

● Analyses not completed

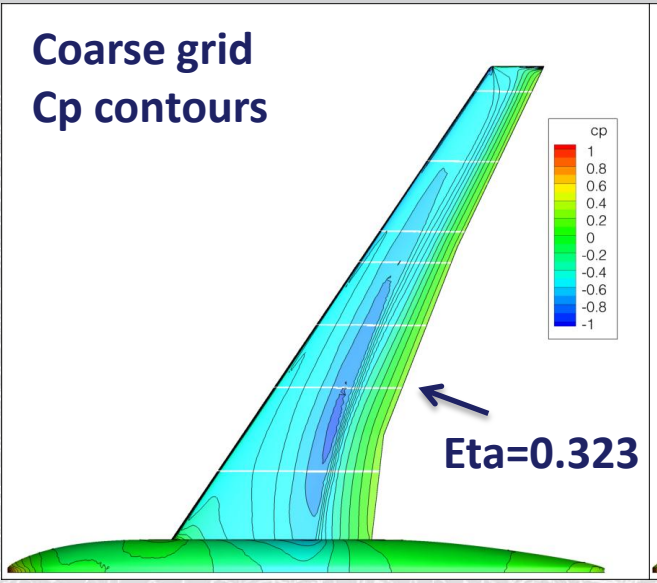
Note: 1. 25 subiterations per time step
2. Solutions were run for 2 cycles before unsteady surface pressure was collected

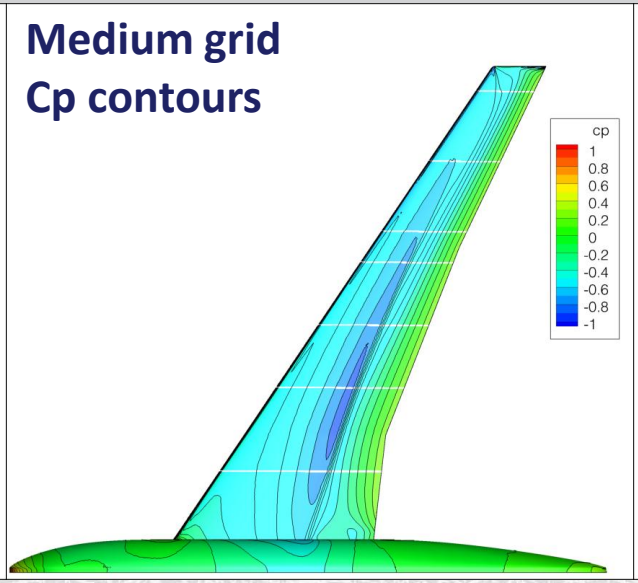
Rigid and Static Aeroelastic Analyses, Mach = 0.8, Re = 7M

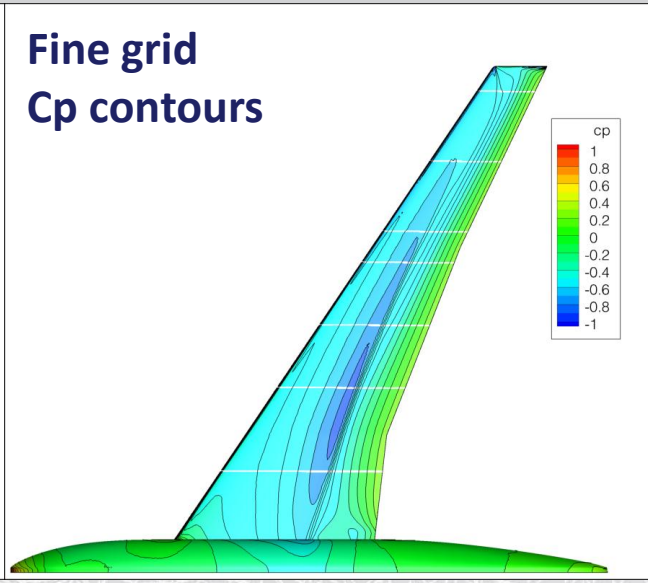


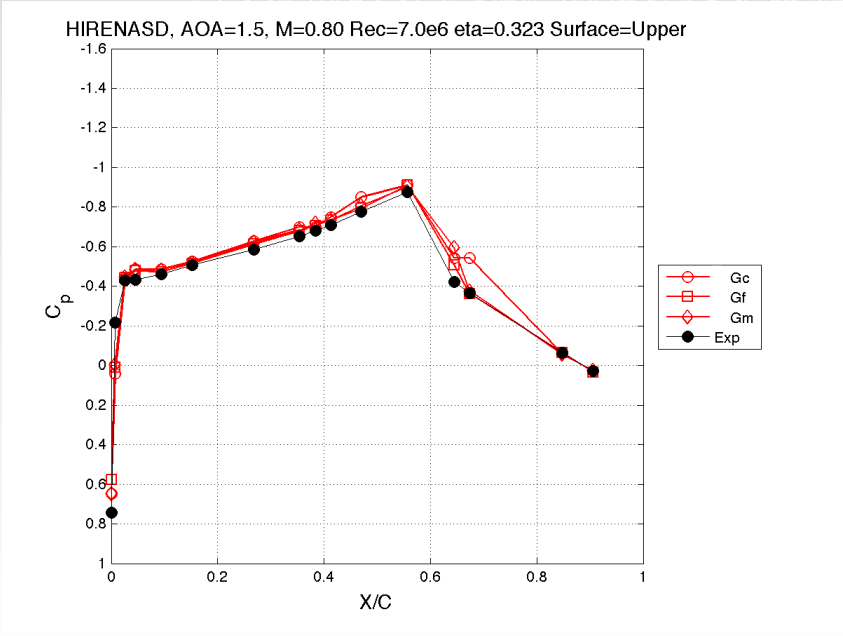


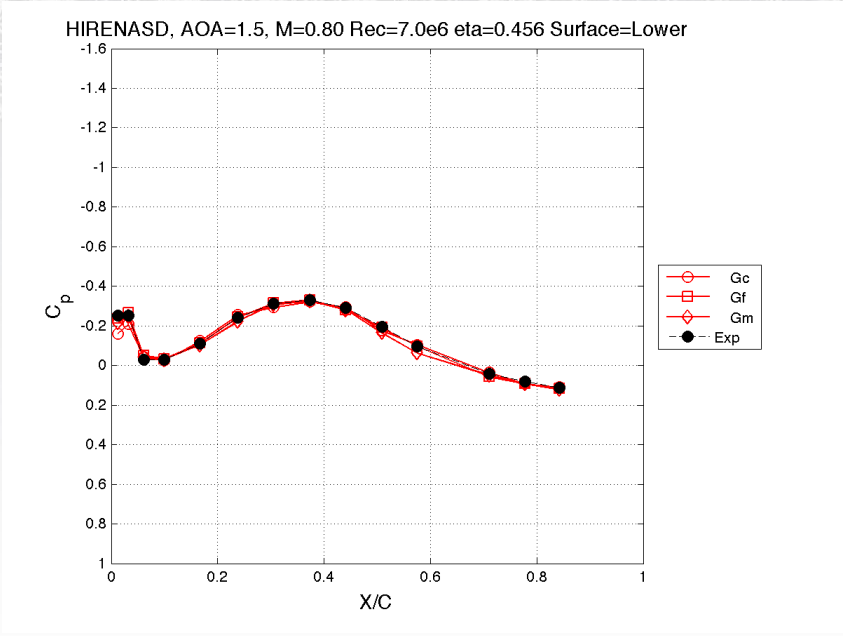
Re_c=7M, Mach=0.8, AoA=1.5deg, Static Aeroelastic







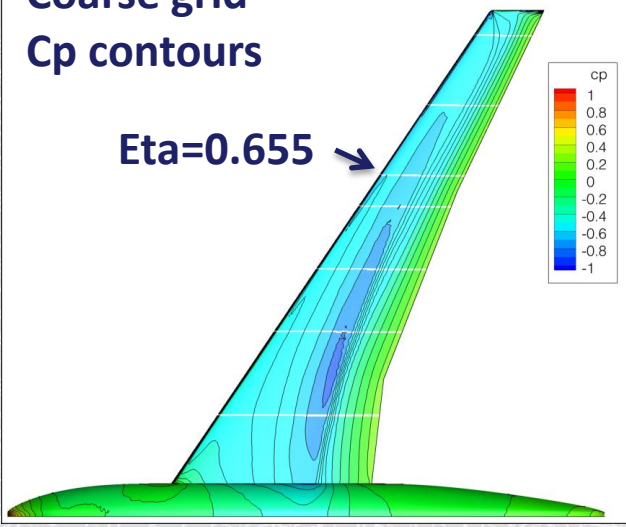




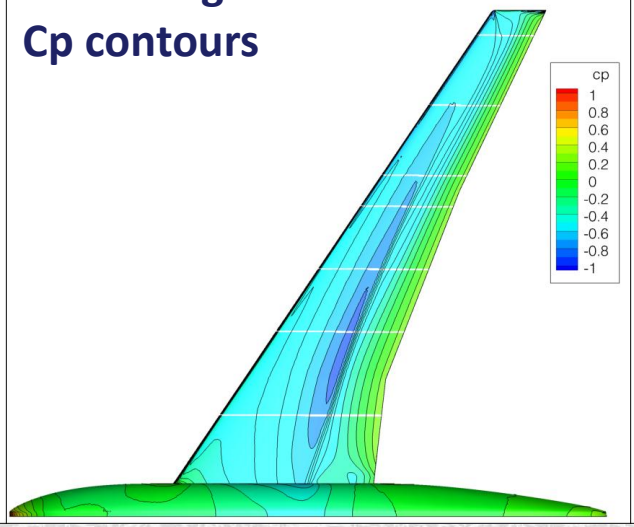
Re_c=7M, Mach=0.8, AoA=1.5deg, Static Aeroelastic

Coarse grid
Cp contours

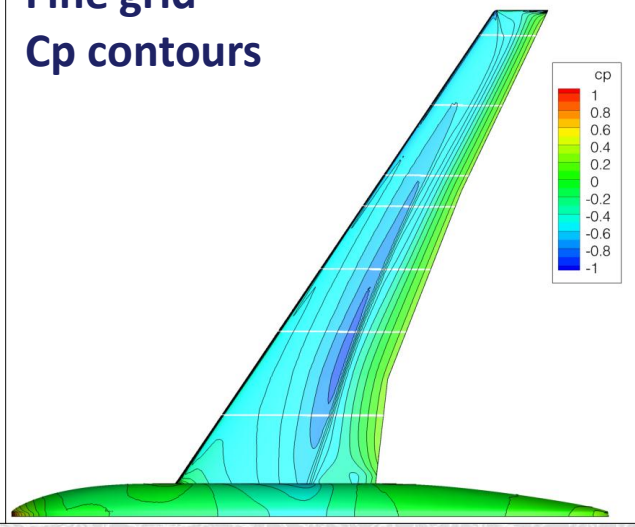
Eta=0.655

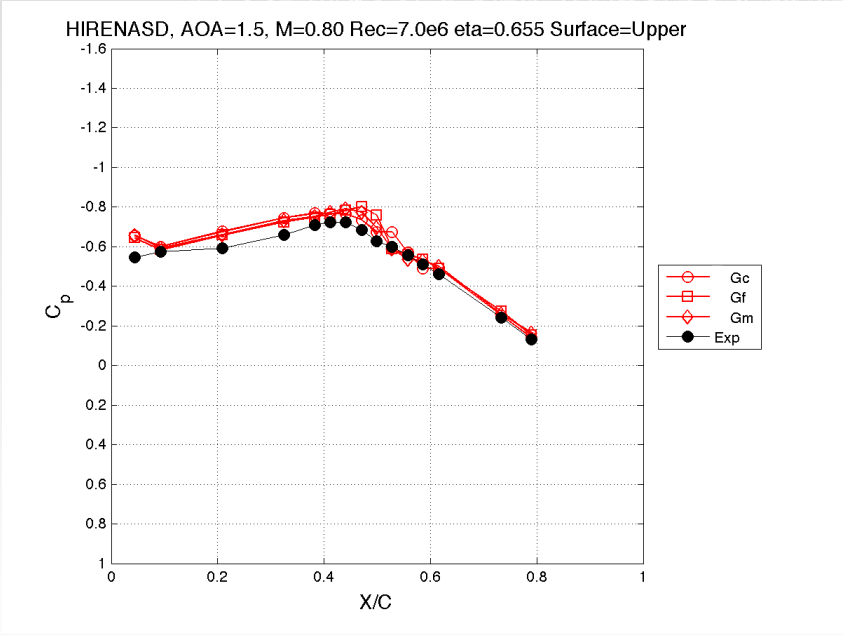


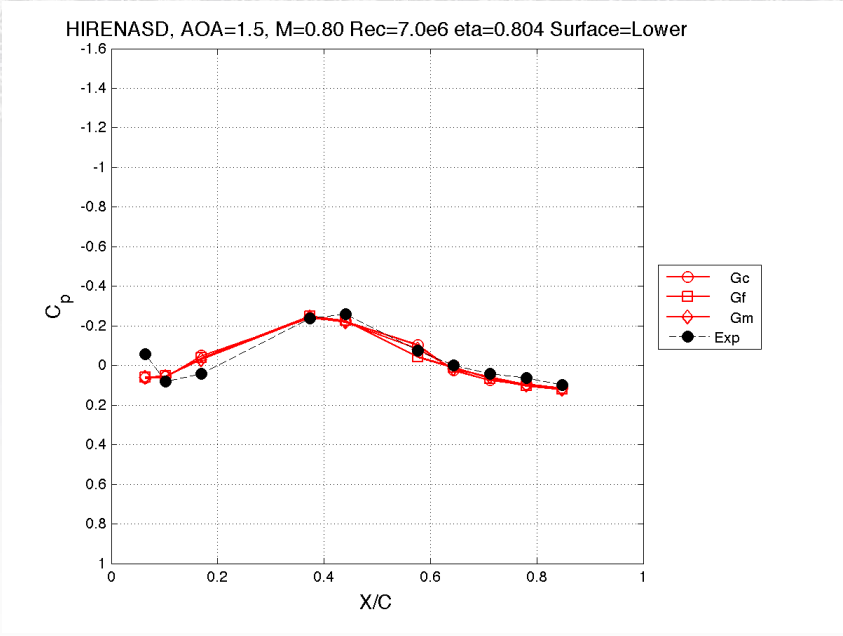
Medium grid
Cp contours



Fine grid
Cp contours

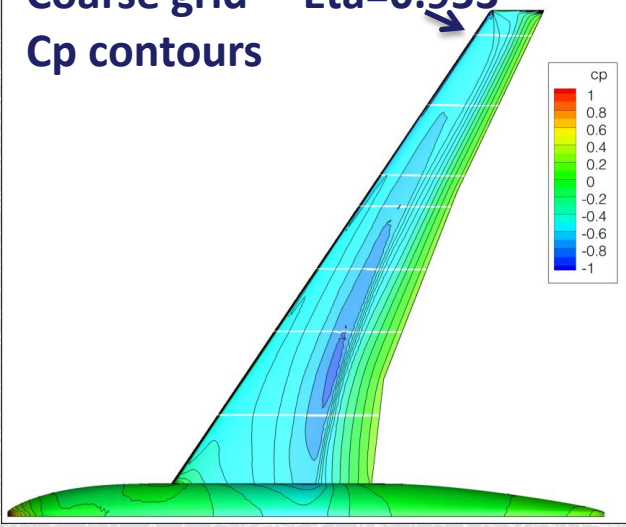




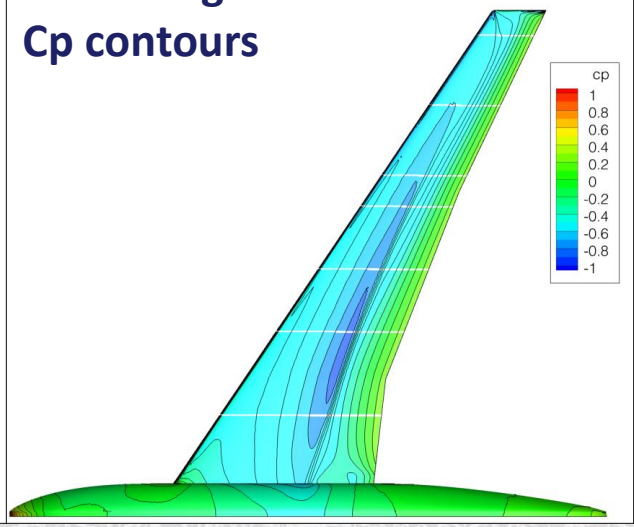


Re_c=7M, Mach=0.8, AoA=1.5deg, Static Aeroelastic

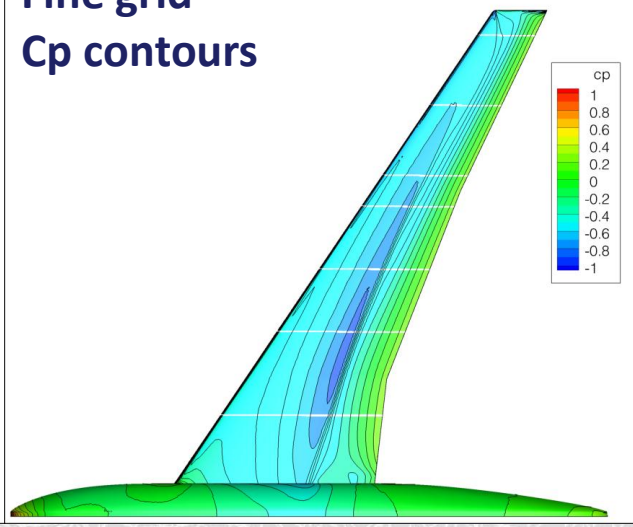
Coarse grid Eta=0.953
Cp contours

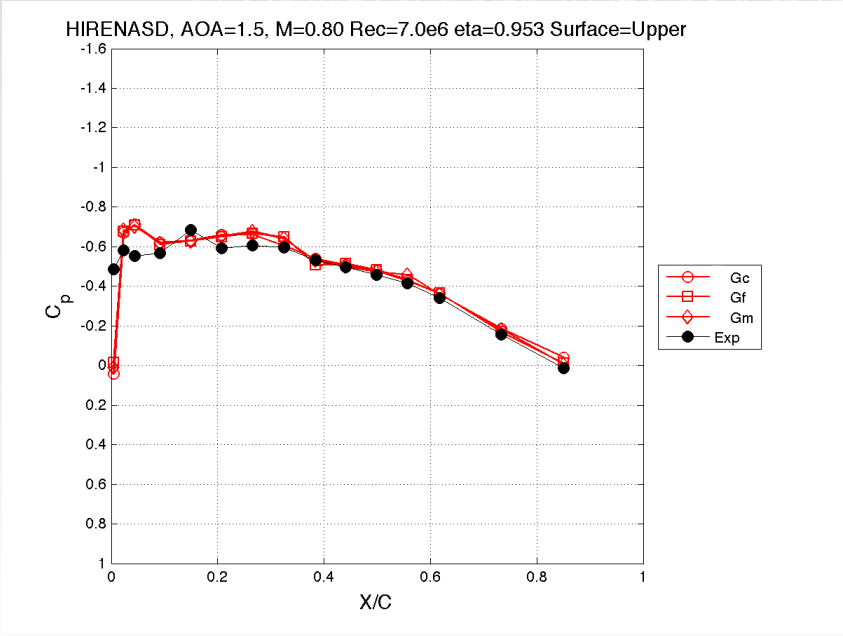


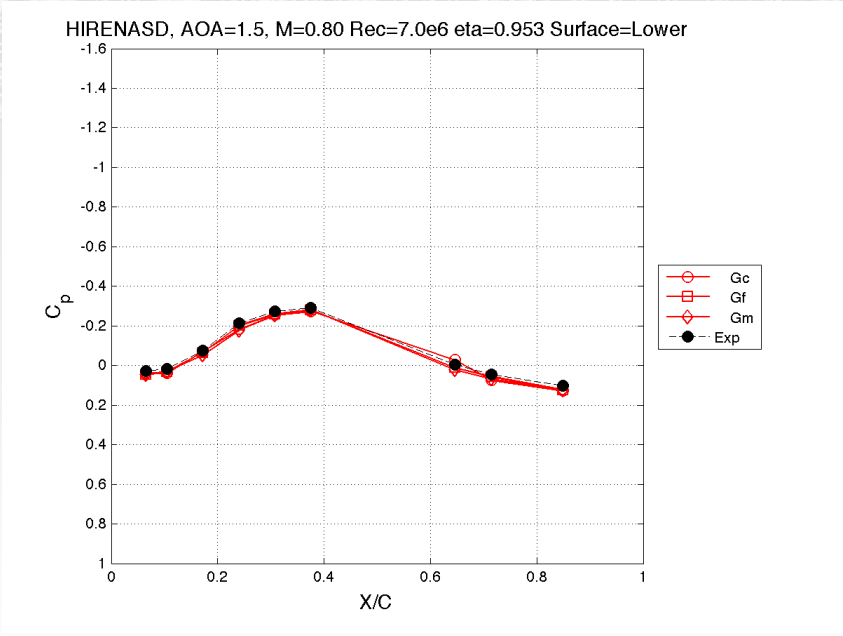
Medium grid
Cp contours



Fine grid
Cp contours

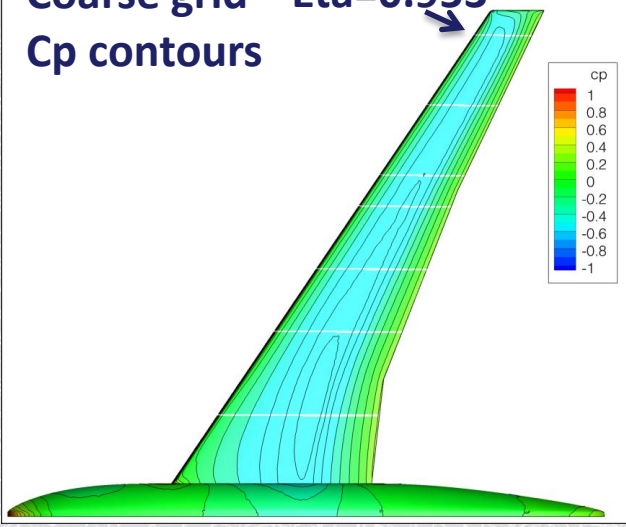




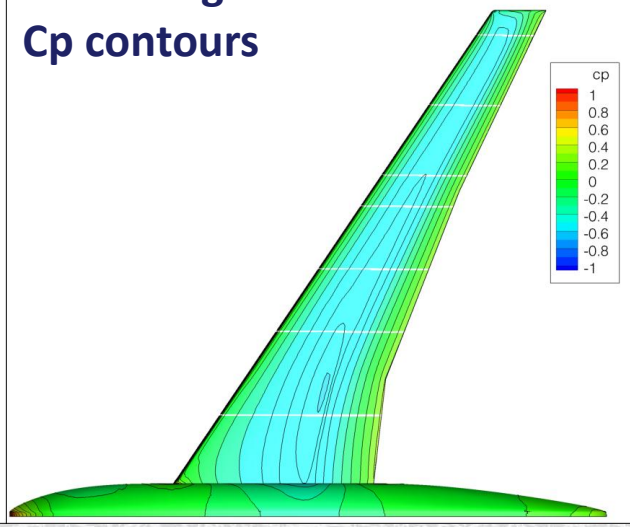


Re_c=23.5M, Mach=0.8, AoA=-1.34deg, Static Aeroelastic

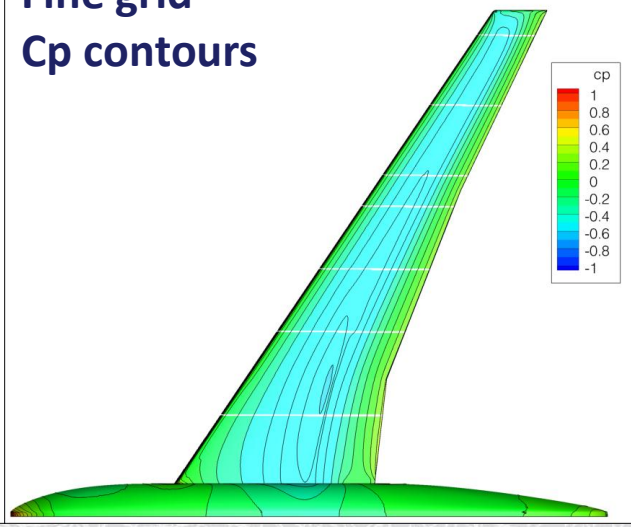
Coarse grid Eta=0.953
Cp contours

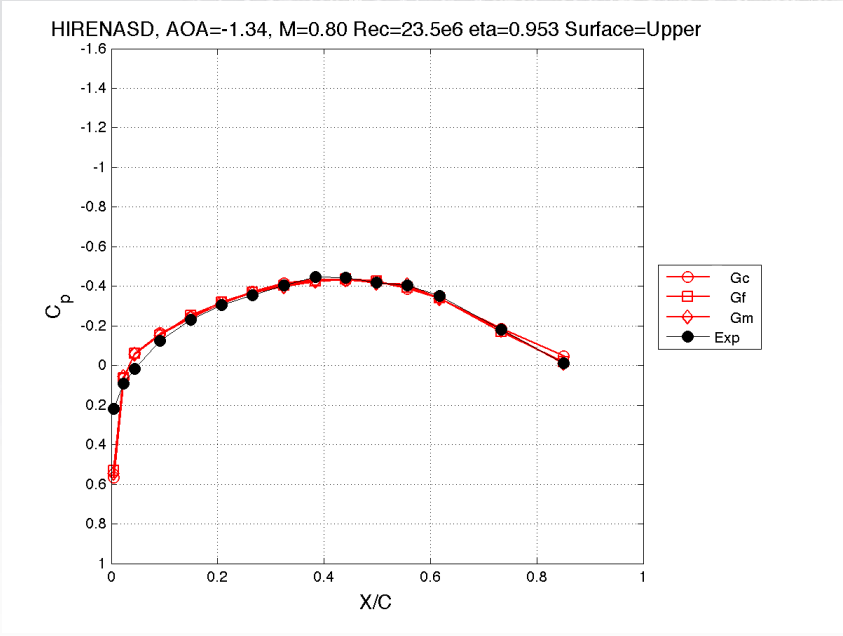


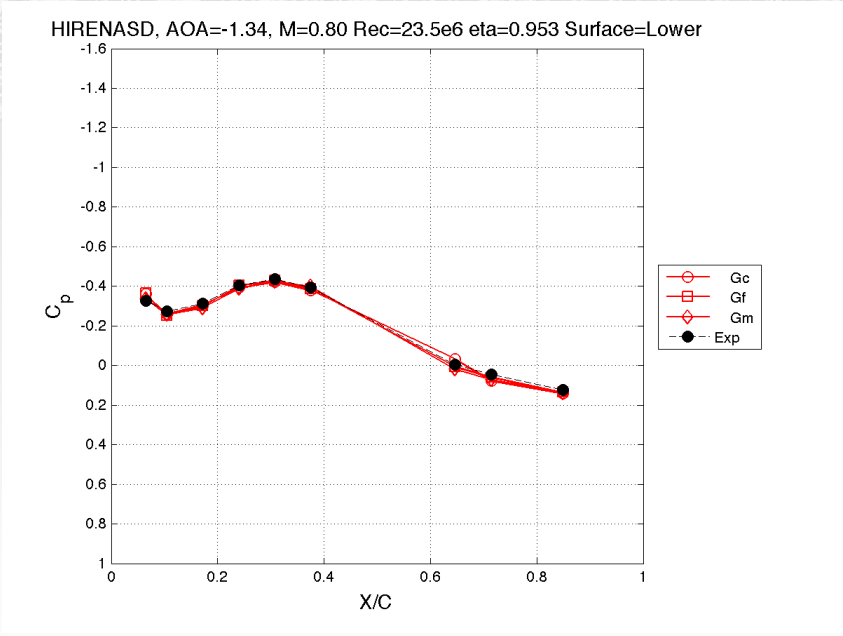
Medium grid
Cp contours



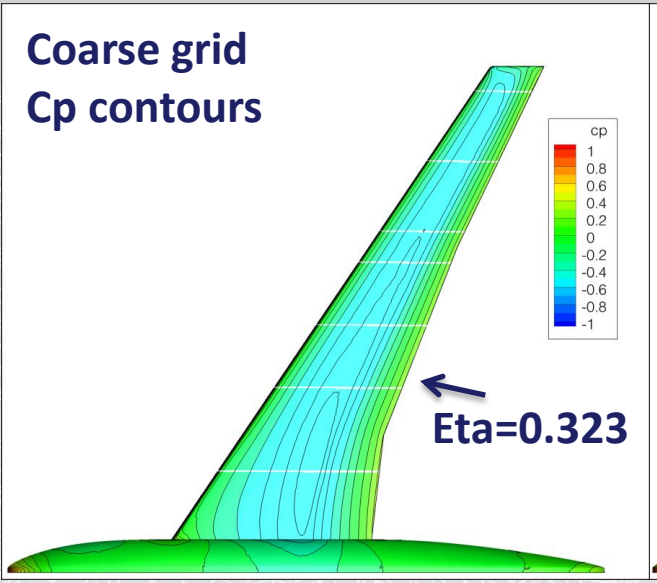
Fine grid
Cp contours

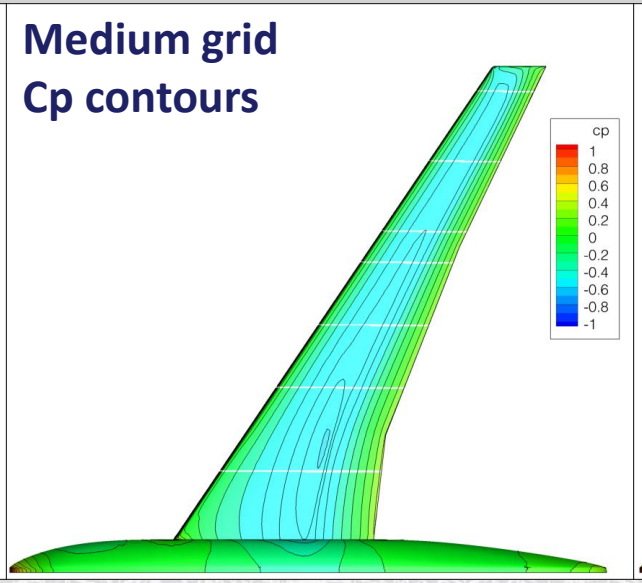


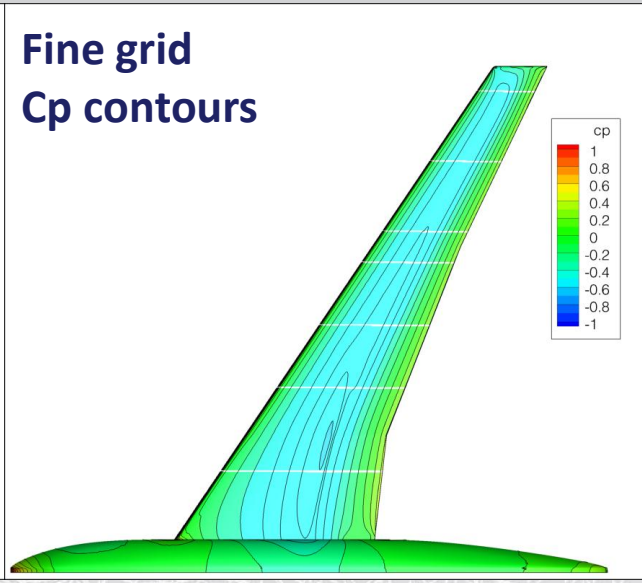


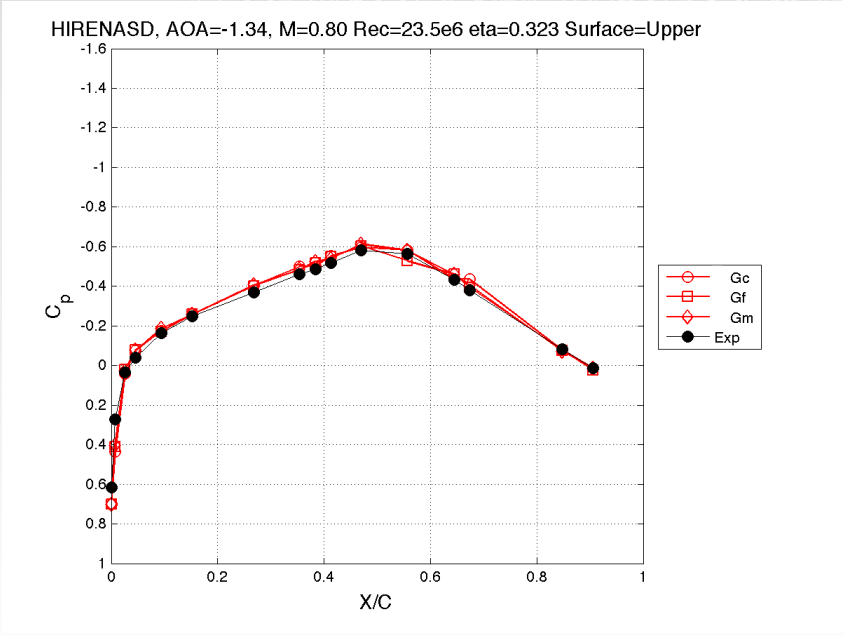


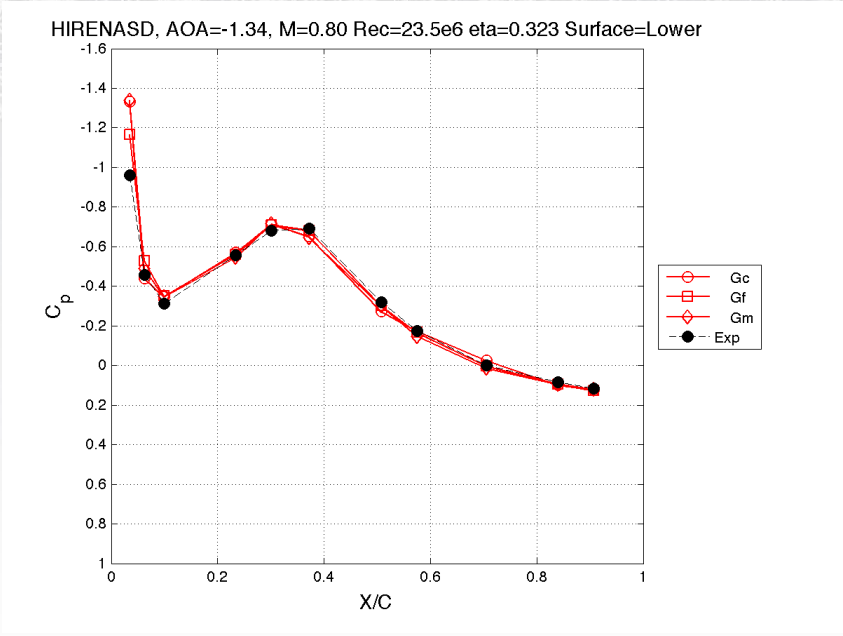
Re_c=23.5M, Mach=0.8, AoA=-1.34deg, Static Aeroelastic



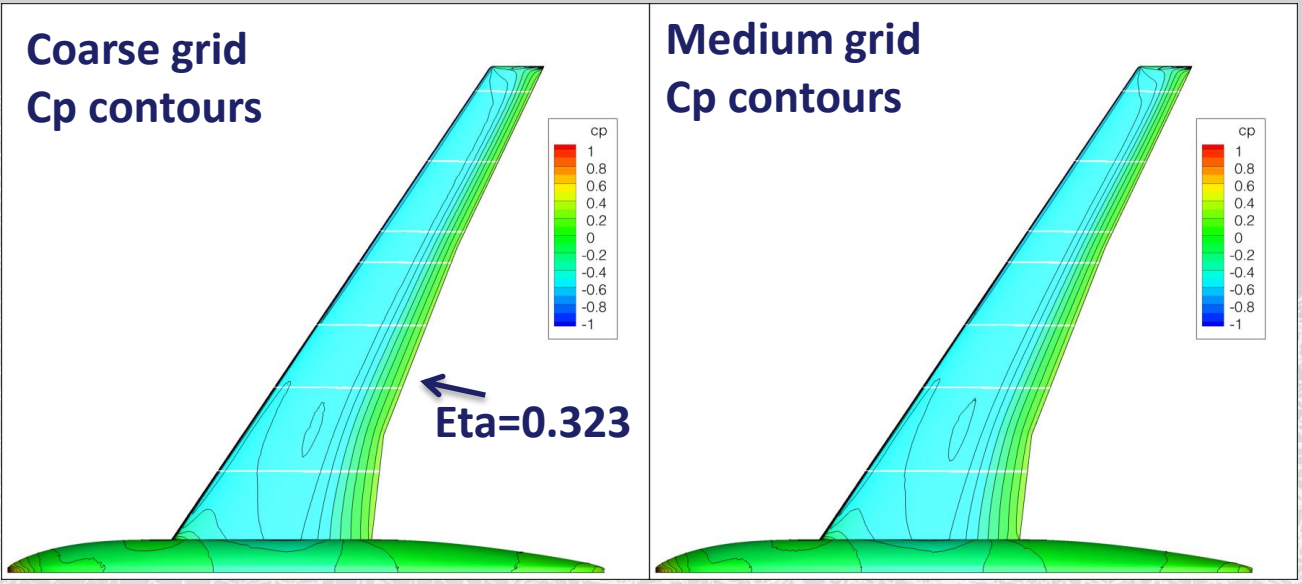


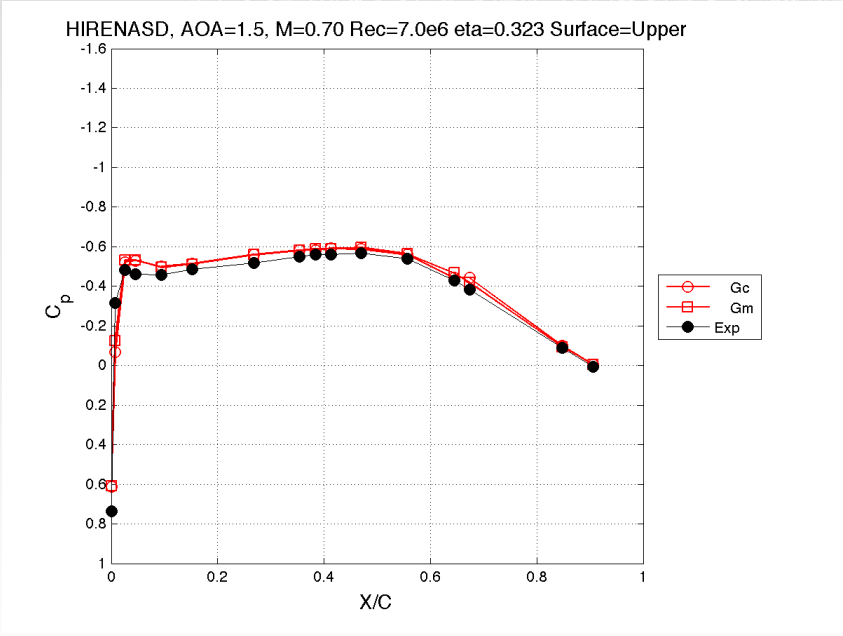


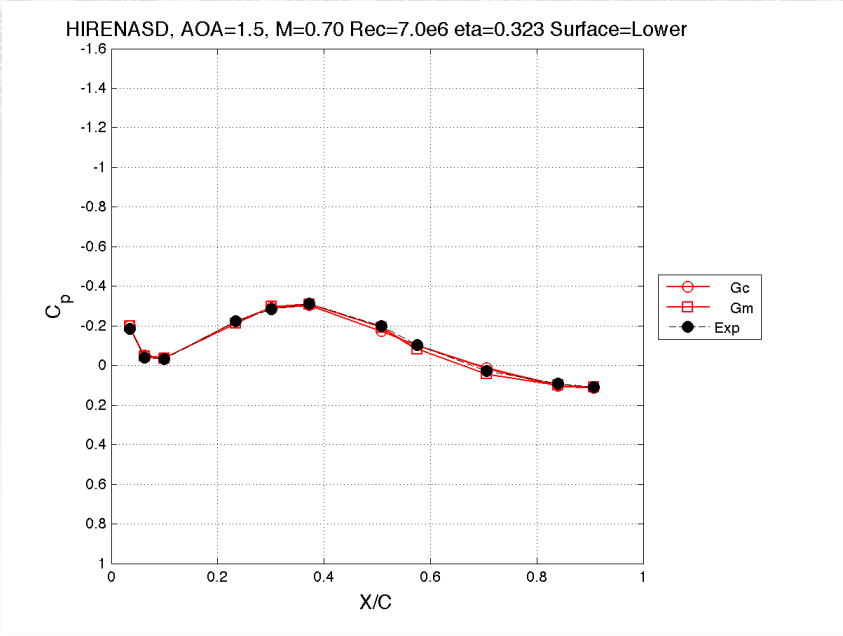




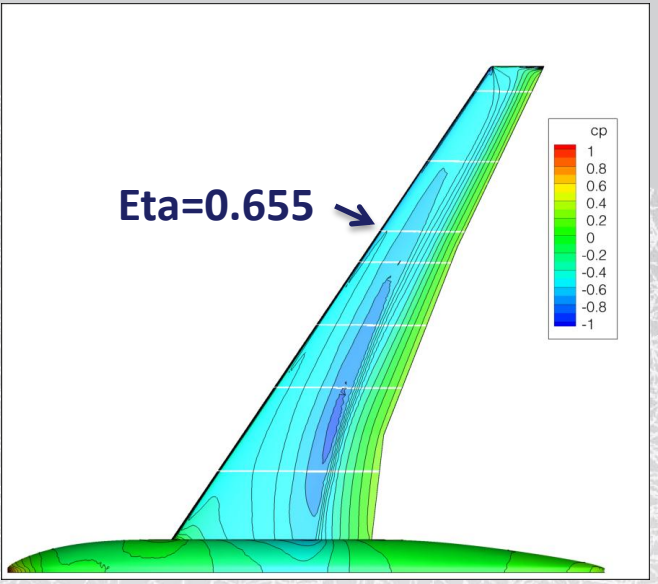
Re_c=7M, Mach=0.7, AoA=1.5deg, Static Aeroelastic

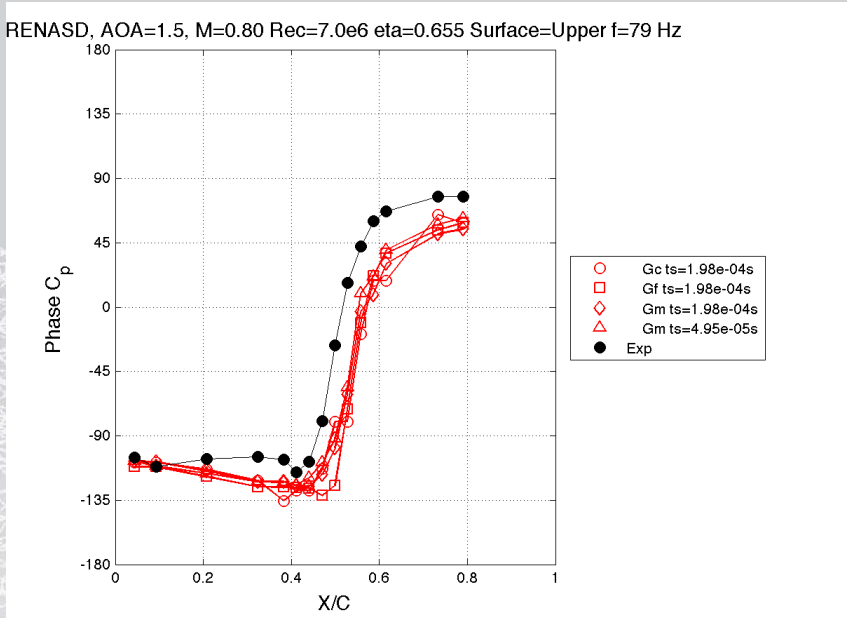


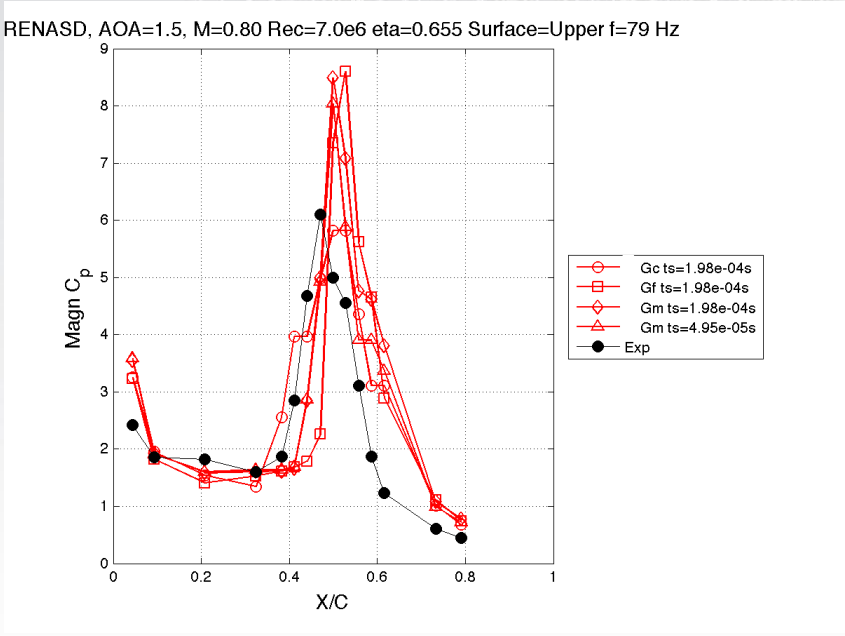


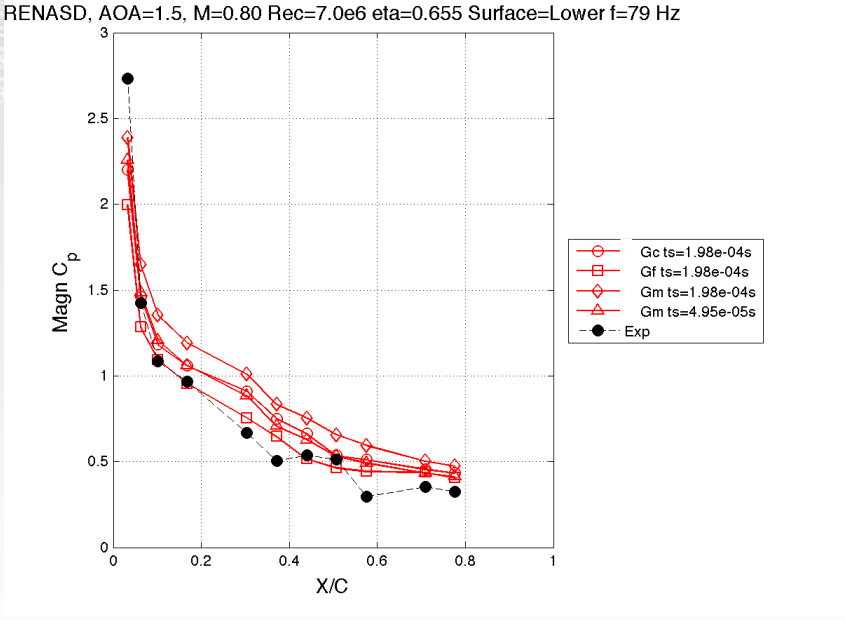


Re_c=7M, Mach=0.8, AoA=1.5deg, Dynamic

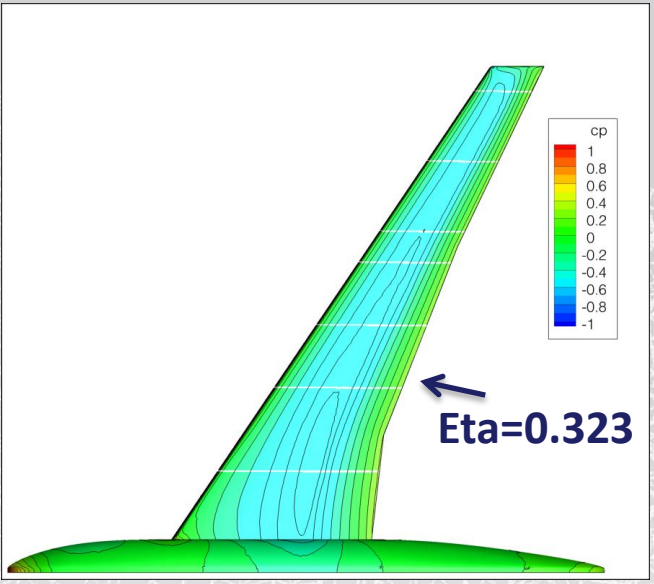


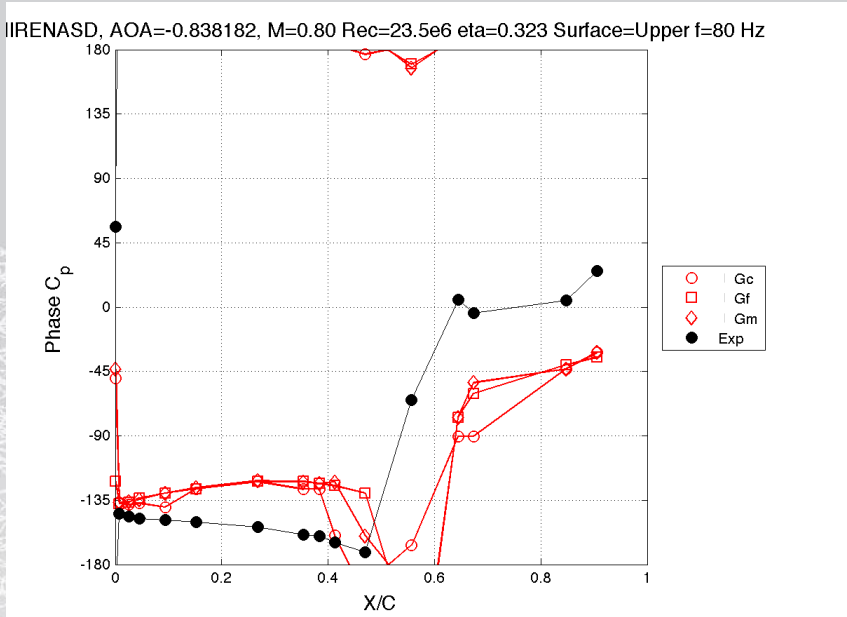


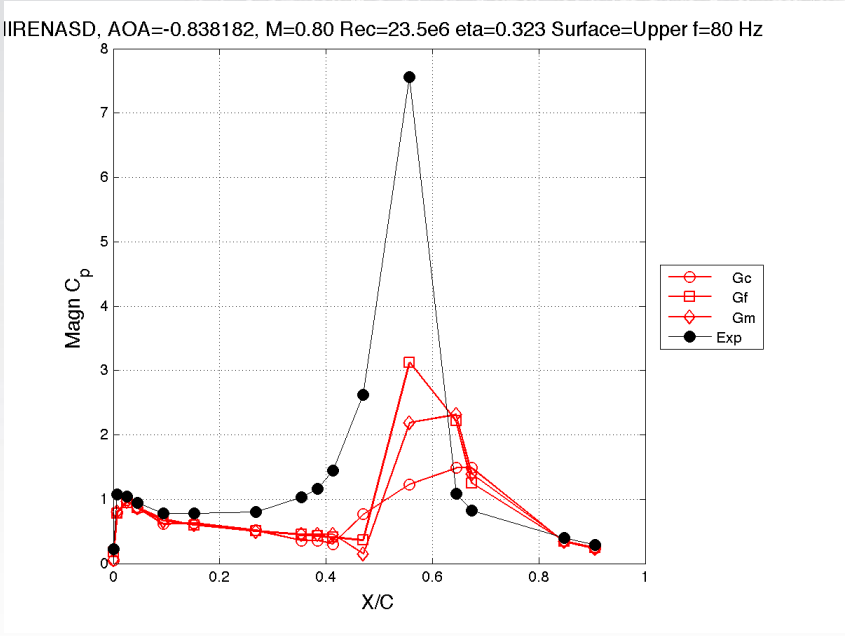


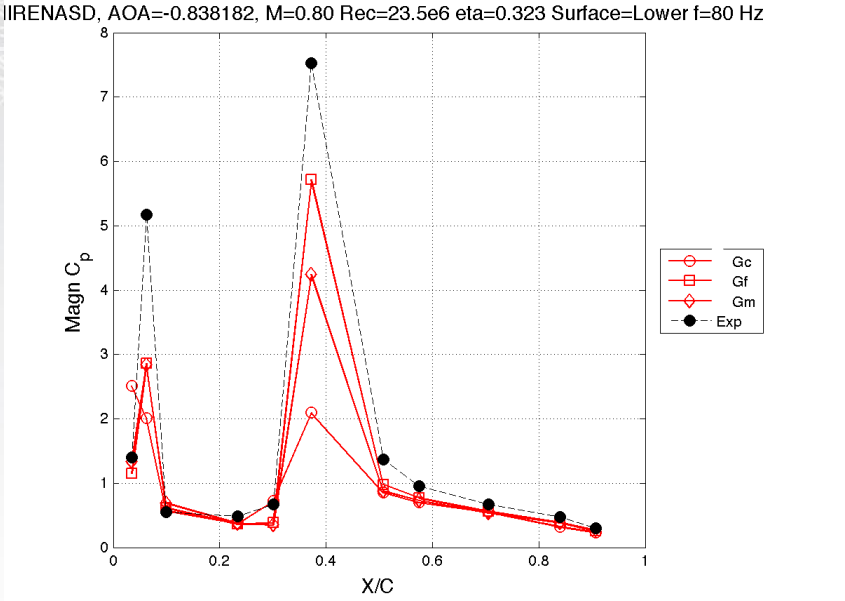


Re_c=23.5M, Mach=0.8, AoA=-1.34deg, Dynamic









Summary

- Computational Cp and FRF compare well with the experimental data
- Fine grids solutions are computationally very expensive
  (~ 4cycles --> 100 hours:1000 processors)
- Subiteration convergence study should be completed
- Turbulence model effects need to be addressed
- Number of modes needed in the static aeroelastic analysis
  needs to be further investigated