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A member of the Russell Group

Aeroelastic Prediction Workshop
AePW-1

Rectangular Supercritical Wing

Sebastian Timme

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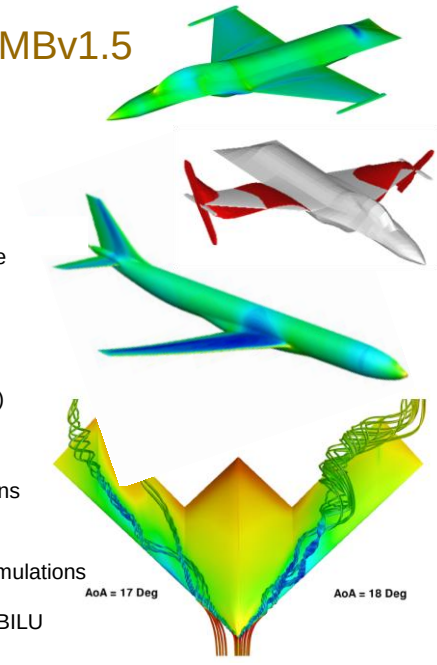
Flow Solver Overview – PMBv1.5



- Parallel Multiblock (PMB) structured solver developed since 1996
- Solving 2D/3D steady/unsteady compressible Euler/Navier-Stokes equations
- Various turbulence models (SAE, k-ω, etc.)
- Cell-centred finite-volume scheme
- Euler fluxes via Riemann solver (Roe, Osher)
- Higher-order spatial accuracy using MUSCL
- Viscous fluxes using Green-Gauss theorem
- Two halo layers to impose boundary conditions
- Fully-implicit time marching
- 2nd-order dual-time stepping for unsteady simulations
- Krylov subspace sparse iterative solver with BILU preconditioning for solving linear systems

RSW Grids Overview

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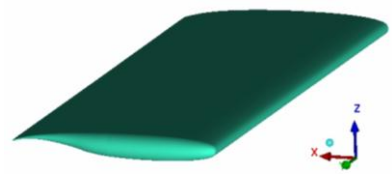
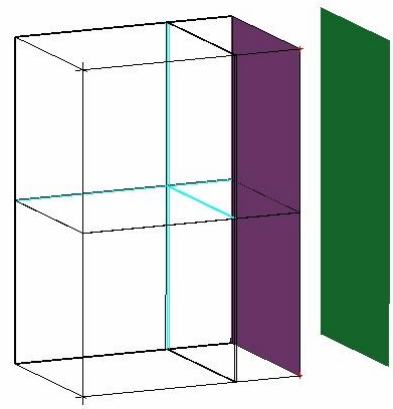
- Inflow boundary location is 1000 inch ahead of LE
- 55 inch span
- no splitter plate
- viscous wind tunnel wall

	Grid points	Grid cells
Coarse	2,321,200	2,028,800
Medium	6,597,984	6,003,264
Fine	18,632,712	17,432,544



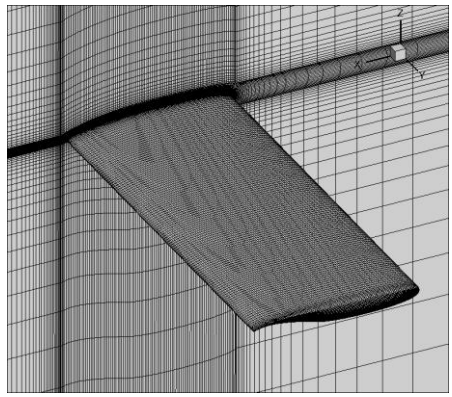


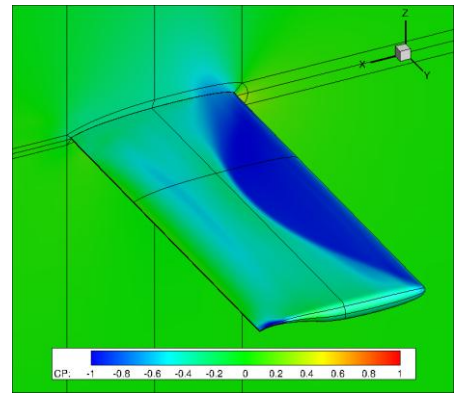
Modified inflow boundary

Geometry and blocking files provided by Thorsten Hansen (ANSYS).

RSW Grids Overview

- Surface mesh and typical surface pressure distribution for fine grid





176 blocks overall

Simulated Cases

Steady

- cases 6E23 and 6E24
- coarse, medium and fine grids (SAE model)
- coarse and medium grids (SST model)

Unsteady

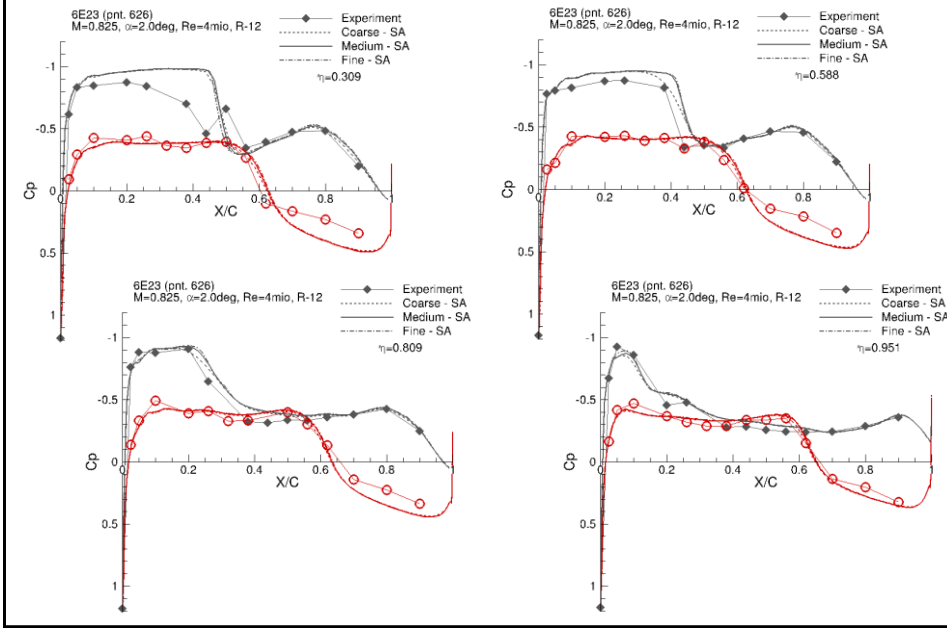
- cases 6E54 and 6E56
- coarse and medium grids (SAE model)

Steady Simulations Overview

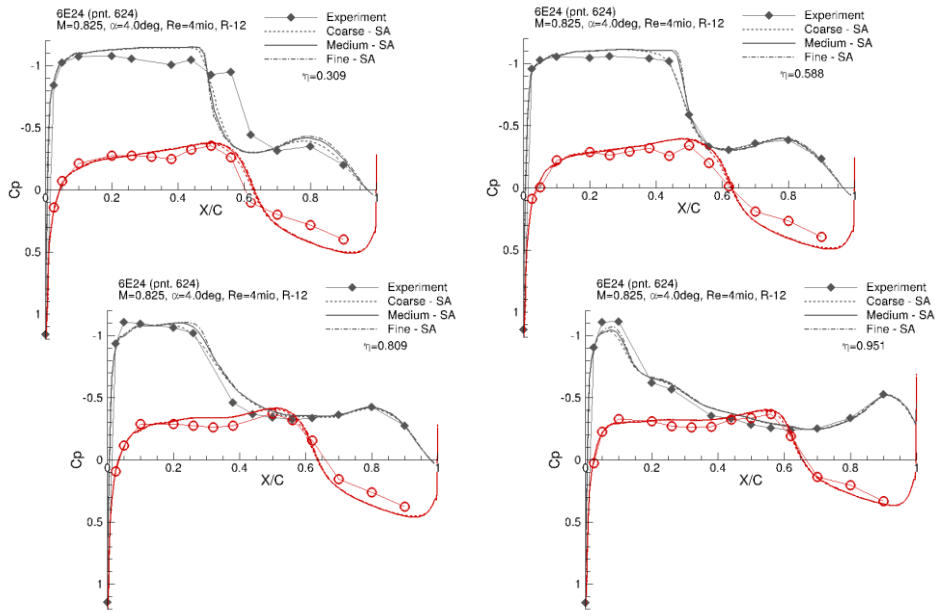
- Osher's Riemann solver for Euler fluxes
- Turbulence model used is compressible form of Spalart-Allmaras model with Edwards' modifications (SAE), also SST model for comparison
- Run fully turbulent

- Moment centre at x/c=0.46
- Reference area for integrated loads is 24 inch x 48 inch
- CL,CD,CM include pressure and friction contributions

Steady Results



Steady Results



Steady Results

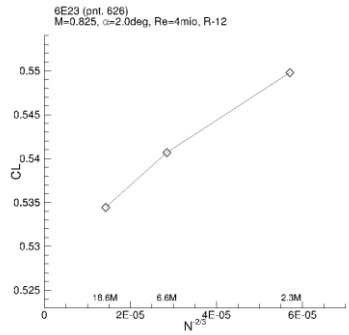
- Integrated forces and moment (CL,CM,CD)

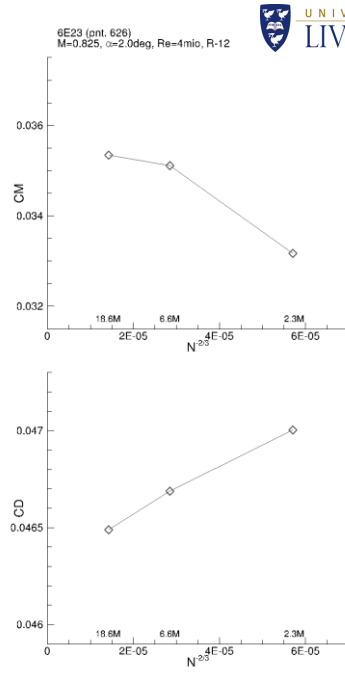
6E23	Lift	Drag	Moment
Coarse	0.549797	0.047004	0.033167
Medium	0.540689	0.046688	0.035106
Fine	0.534424	0.046488	0.035346

6E24	Lift	Drag	Moment
Coarse	0.688156	0.075762	-0.000897
Medium	0.684095	0.075505	0.001103
Fine	0.679196	0.075321	0.001602

Steady Results

- CL,CM,CD vs. $N^{-2/3}$





Steady Results

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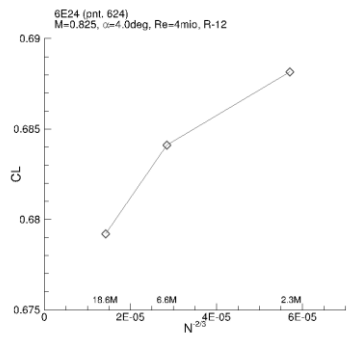
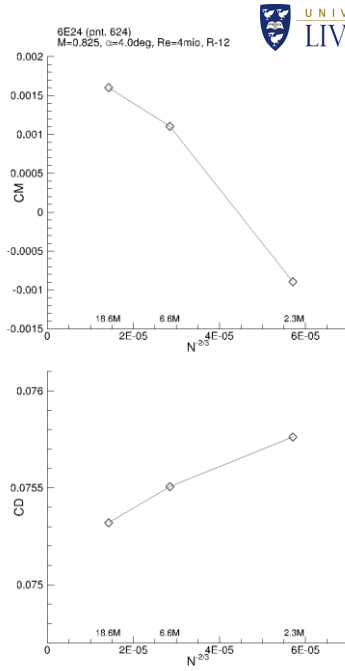
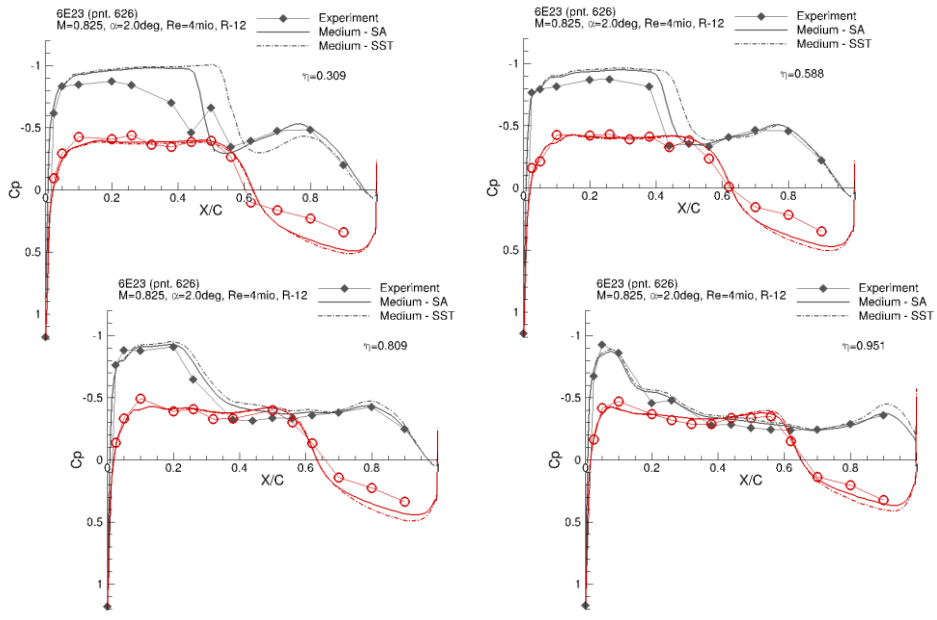




Steady Results – SA vs. SST



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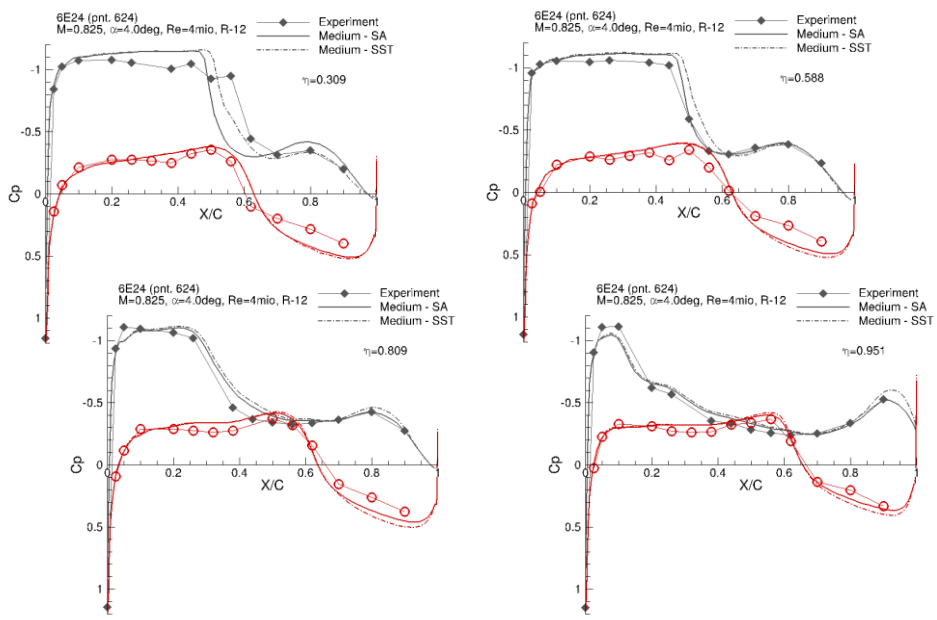
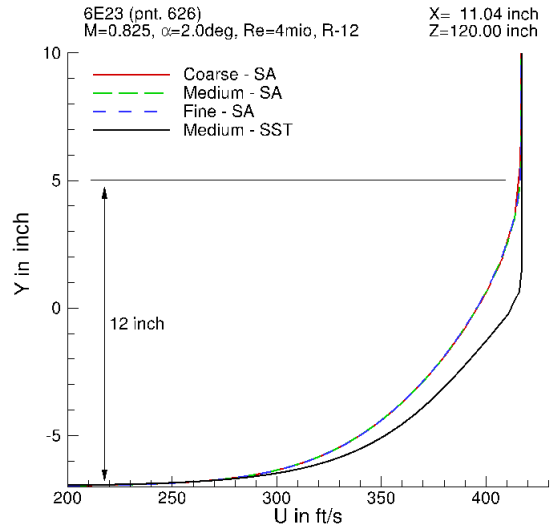


Steady Results – SA vs. SST

- Boundary layer velocity profile

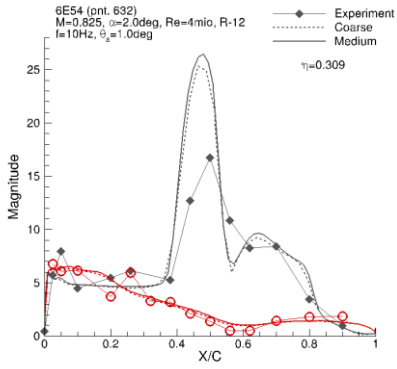


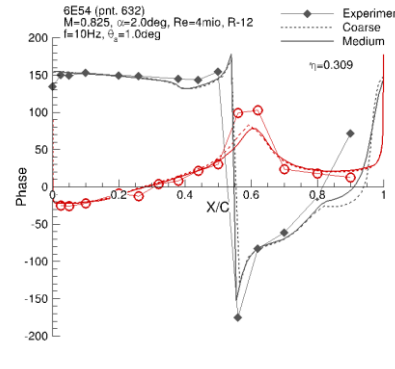
Unsteady Simulations Overview

- Unsteady runs started from converged steady case 6E23
- Forced pitching motion about x/c=0.46 at 10 Hz (6E54) and 20 Hz (6E56) with 2 degrees mean incidence and pitching amplitude of 1 degree
- Pitching motion applied via a rigid rotation of computational domain
  - –influence on wind tunnel wall boundary layer?
- Simulation of 8 cycles with 64 steps per cycle
- max. 50 pseudo steps per real time step
  - –target convergence in pseudo time is 3 orders of magnitude
  - –criterion: update in pseudo time scaled by change in real time
- Signal used for Fourier analysis starting from 3rd cycle (remove transients!)

Unsteady Results

- Magnitude and phase of CP vs. x/c at excitation frequency (10 Hz)





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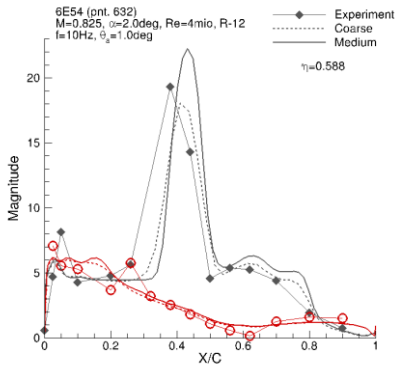

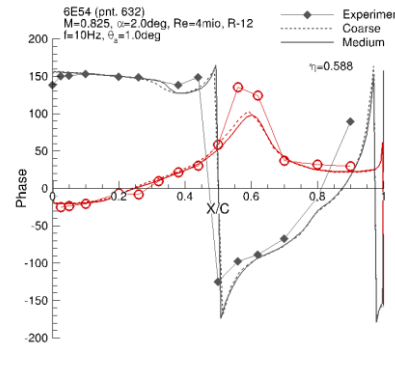

Unsteady Results

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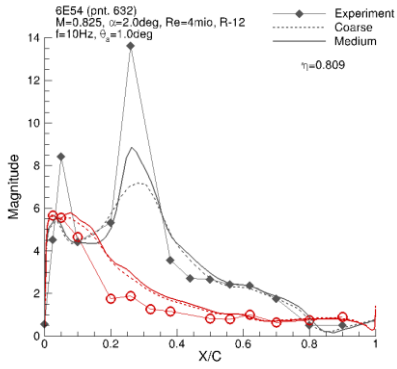

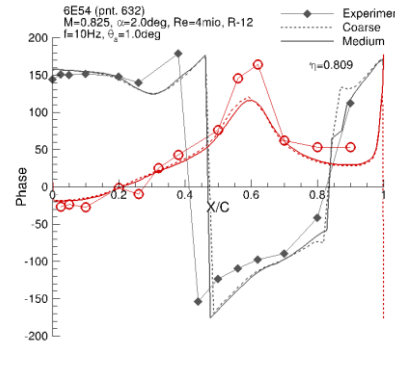

Unsteady Results

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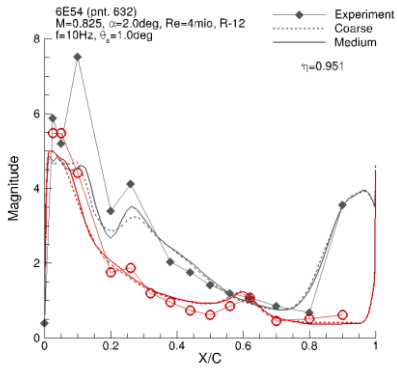
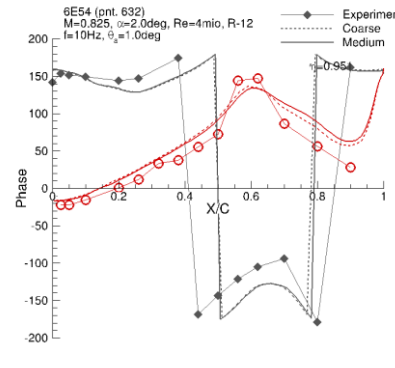
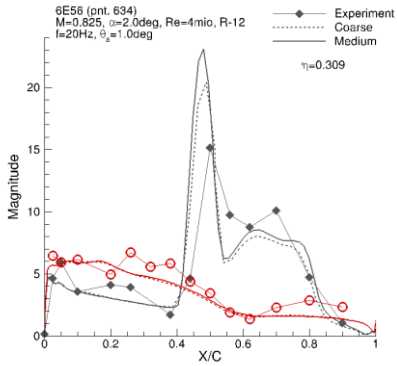
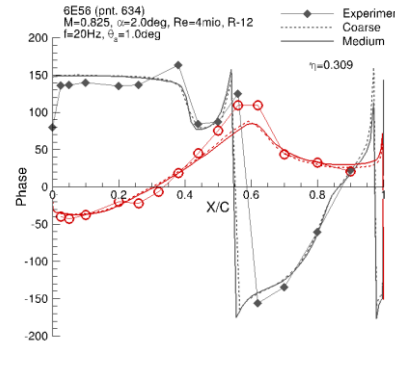




Unsteady Results

- Magnitude and phase of CP vs. x/c at excitation frequency (20 Hz)





Unsteady Results

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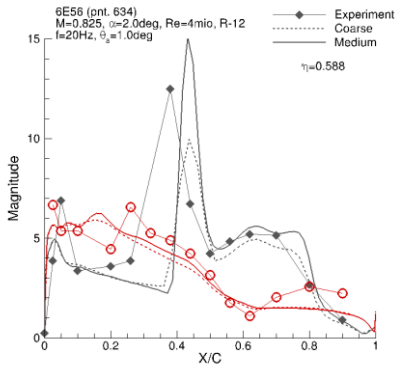

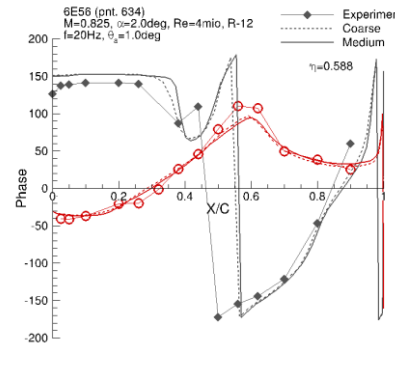

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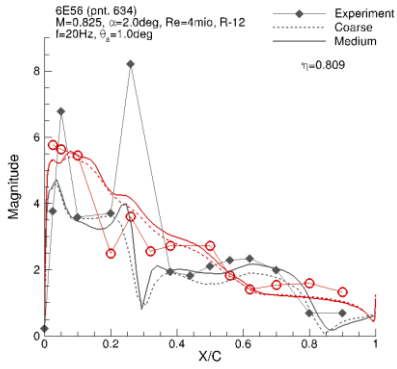

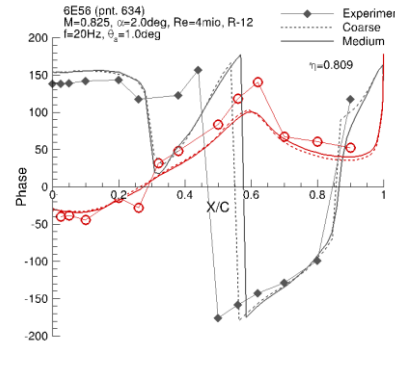

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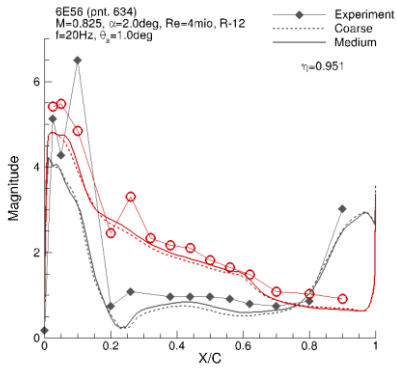

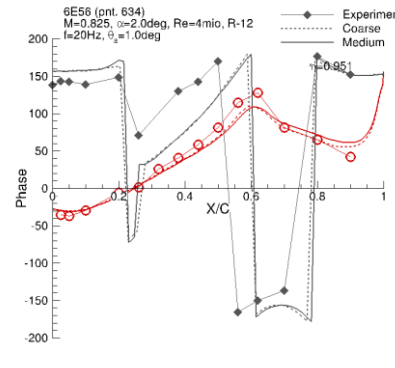

Unsteady Results

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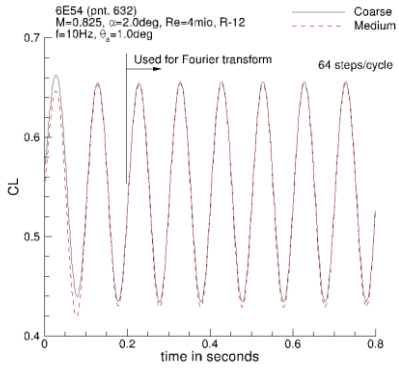
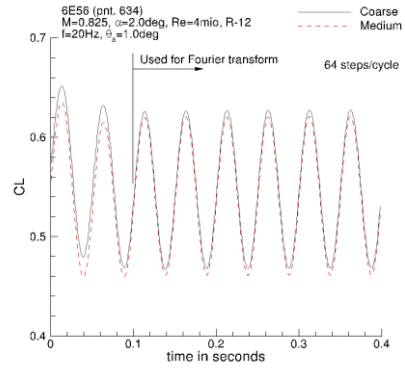
- Time history of lift coefficient





Unsteady Results

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- Real and imaginary parts of CD,CM,CD

6E54 (10 Hz)	Lift		Drag		Moment	
	Real	Imag	Real	Imag	Real	Imag
Coarse	6.1936	-1.3162	0.7310	0.0176	-0.9866	0.7812
Medium	6.3108	-1.2777	0.7269	0.0098	-1.0097	0.7789
Fine	--		--		--	

6E56 (20 Hz)	Lift		Drag		Moment	
	Real	Imag	Real	Imag	Real	Imag
Coarse	4.4496	-0.9961	0.7401	-0.1056	-0.5701	0.7957
Medium	4.4607	-0.9918	0.7306	-0.1033	-0.5816	0.8258
Fine	--		--		--	

Future Work

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- Understand differences between SAE and SST turbulence models when simulating boundary layer on wind tunnel wall.
  - → Does a more similar boundary layer “correct” steady shock location differences?

- For temporal convergence, double number of real time steps per cycle.