FOI Result for Benchmark Super-Critical Wing Case 1-3

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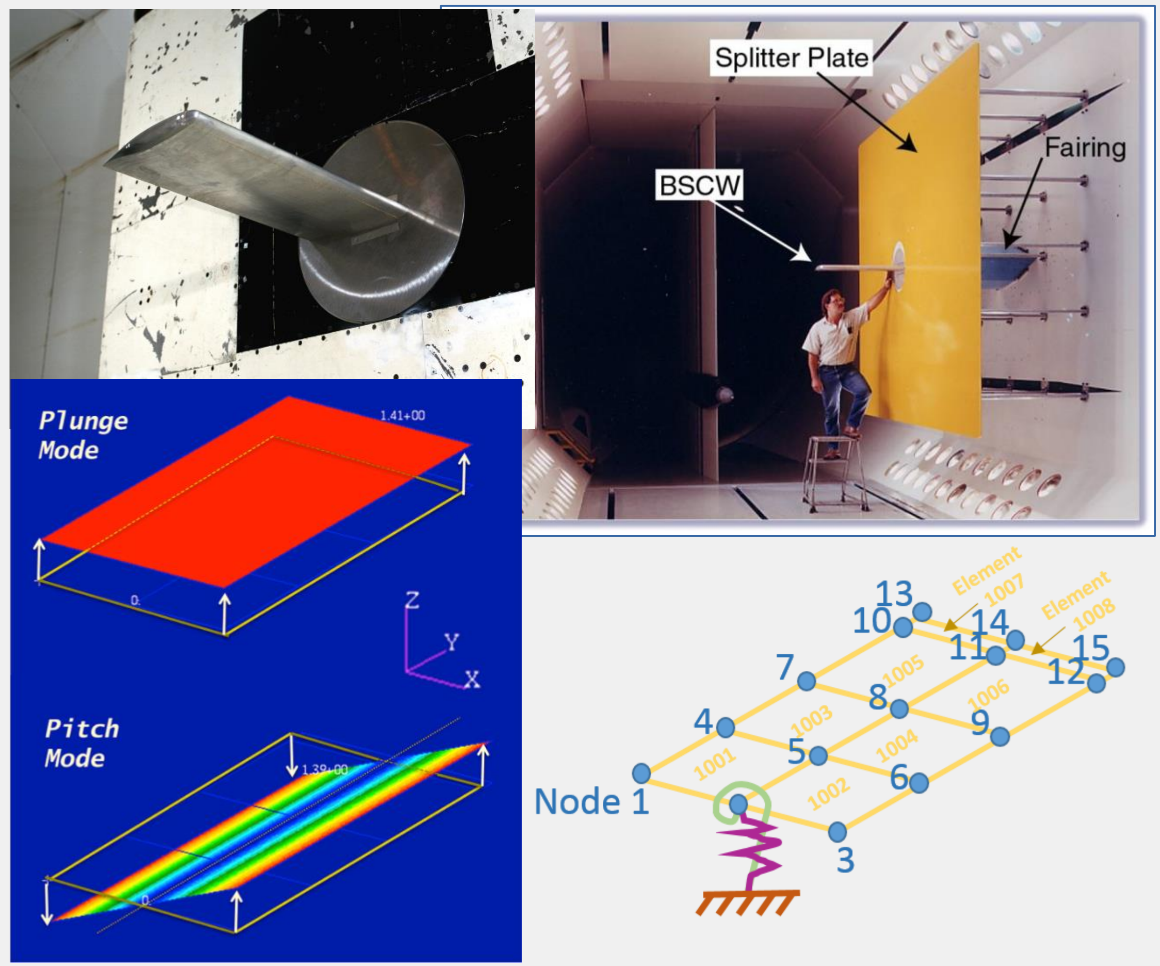
The Benchmark Super-Critical Wing

- Tested in the NASA-TDT facility
- The NASA pitch and plunging apparatus (PAPA) was used for the aeroelastic test
- A linear structural FE model was provided by NASA (AePW) with frequencies matched to WT modal data: 5.20 Hz (pitching) and 3.33 Hz (plunging)



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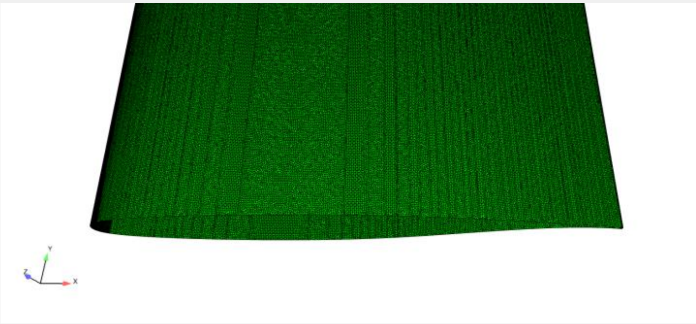
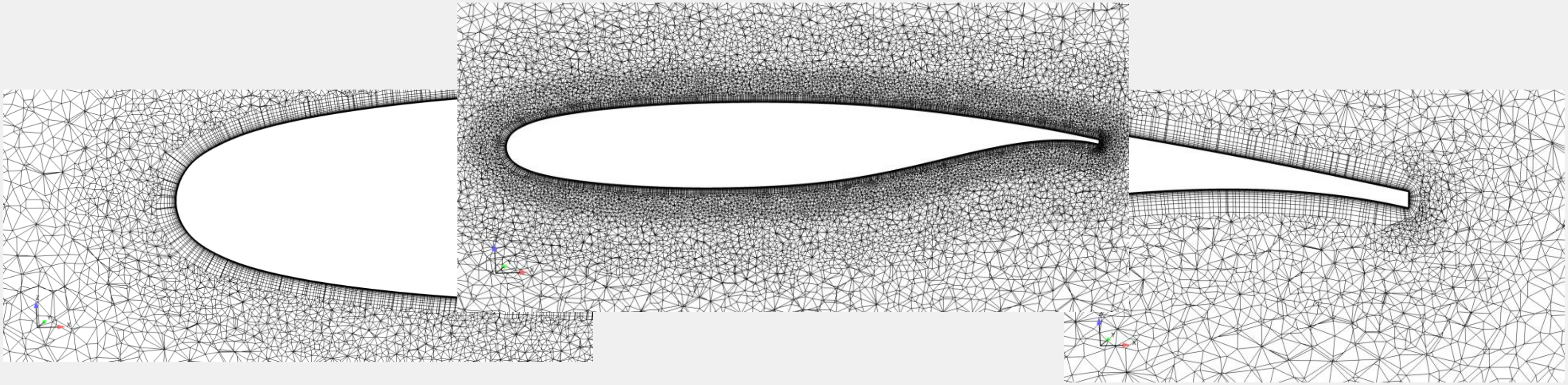
The CFD Mesh

- CFD mesh made according to the meshing guide from AePW-I
  - The mesh used here is a medium, size unstructured mesh having about ~13 mil points





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Mesh Motion vs. Mesh Deformation

Forced/Prescribed pitch motion (Case 1):

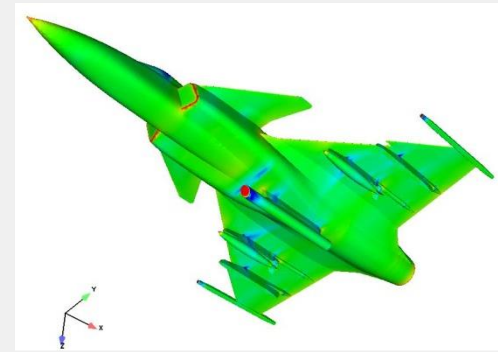
- CFD mesh is considered as rigid and it is rotated
- The pitch angle is prescribed w.r.t. time

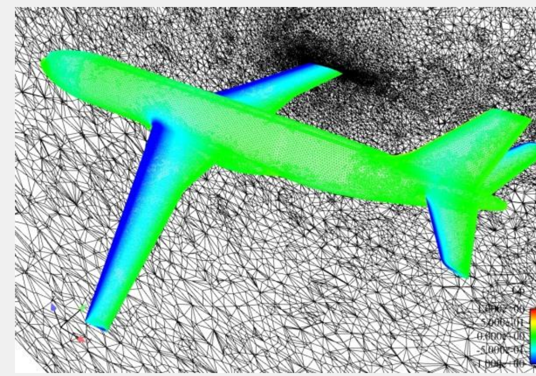
Aeroelastic motion (Case 2 and 3)

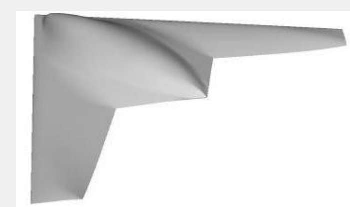
- Two degrees-of-freedom motion – pitch and plunge mode
- CFD mesh can be therefore considered as rigid and instead of deforming, it can be moved
  - The pitch and plunge is determined using modal coordinates
  - Save time by avoiding mesh deformation

Edge – a CFD code for unstructured grids

- Independent in-house code, developed since 1997 at FOI (and former FFA)
- State-of-art flow solver for the compressible Euler and Navier-Stokes equations
- Steady-state and time dependent solutions on unstructured grids
- Fully parallel, scalable, no size limit. High efficiency
- Developed in collaboration with selected external partners. Used also in teaching and for research at different universities
- Saab Aerosystems main CFD tool

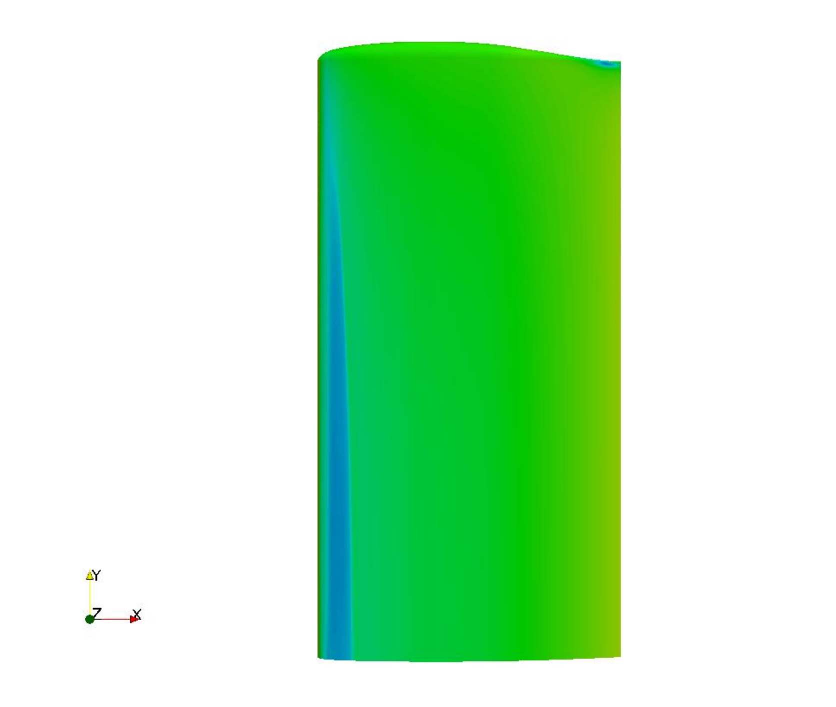




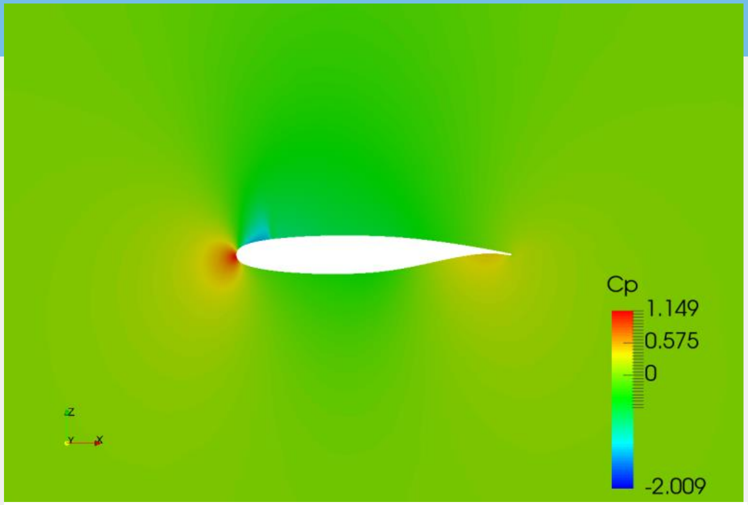


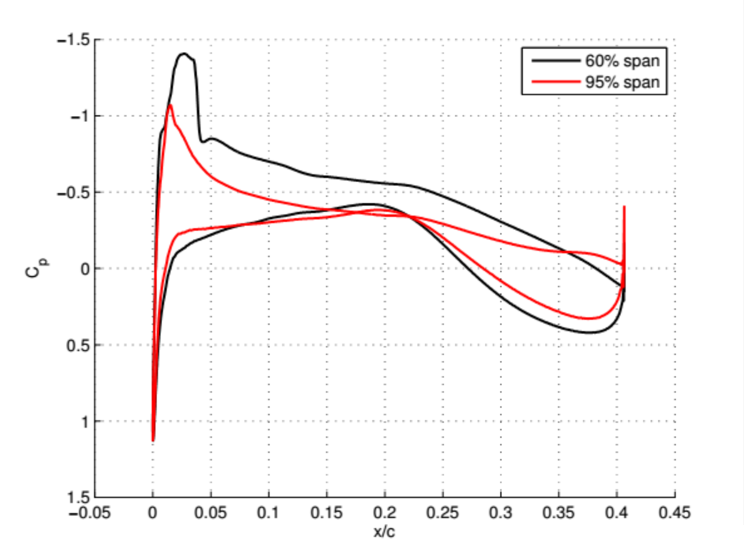
BSCW Case 1: Mach 0.7 and $\alpha = 3^o$

- Near transonic flow
  - SA model



Results of unforced steady case





Integral Coefficients

- Calculated 7 oscillation cycles
- CFD time step = 10^{-4}

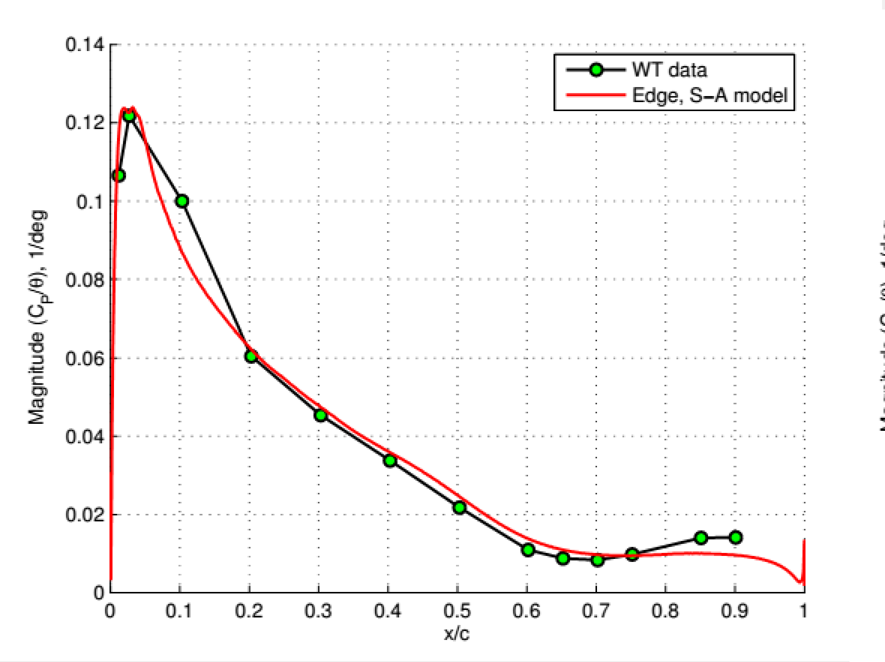
	C_L mean value	C_m mean value	C_D mean value
Wing	0,431650	-0,01585	0,02725
60% span section	0,440046	-0,01194	-
95% span section	0,289877	-0,00541	-

Frequency response function

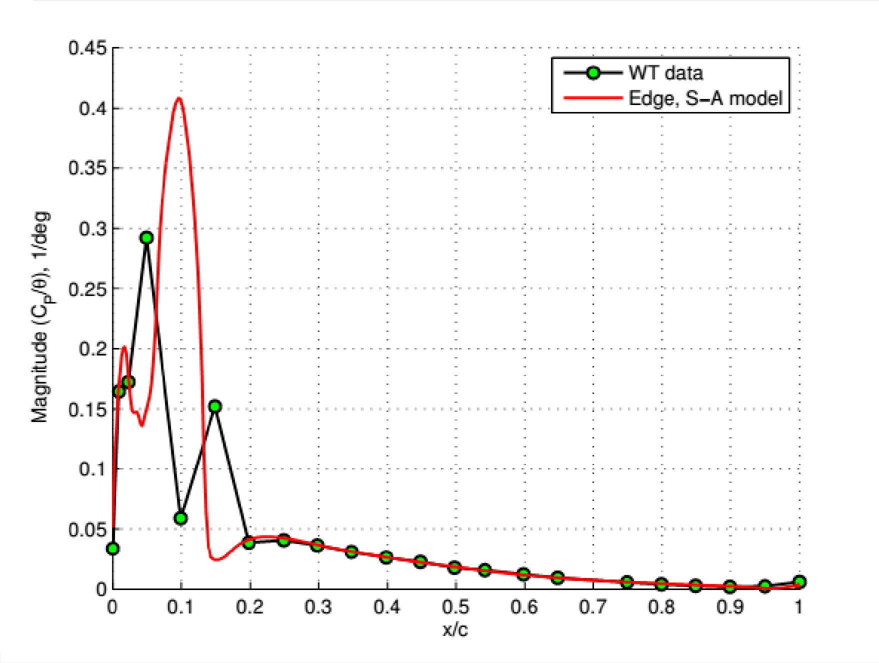
- Calculated between pressure coefficient and pitch angle
- At 60% wing span position
- Forced oscillations – $|\theta| = 1°$
- Processing frequency: 10Hz

Frequency Response Function

- Magnitude



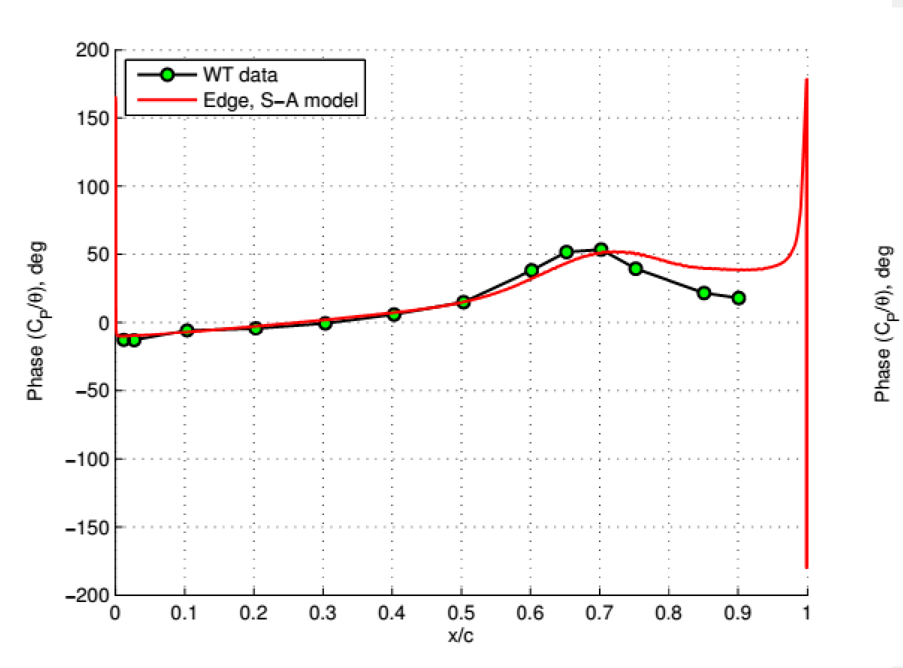
Lower surface



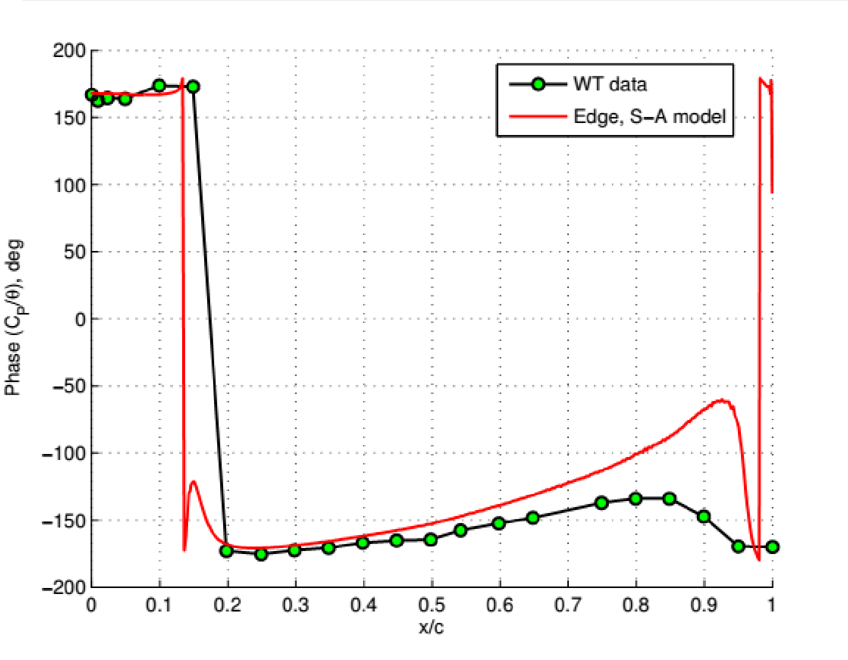
Upper surface

Frequency Response Function

- Phase



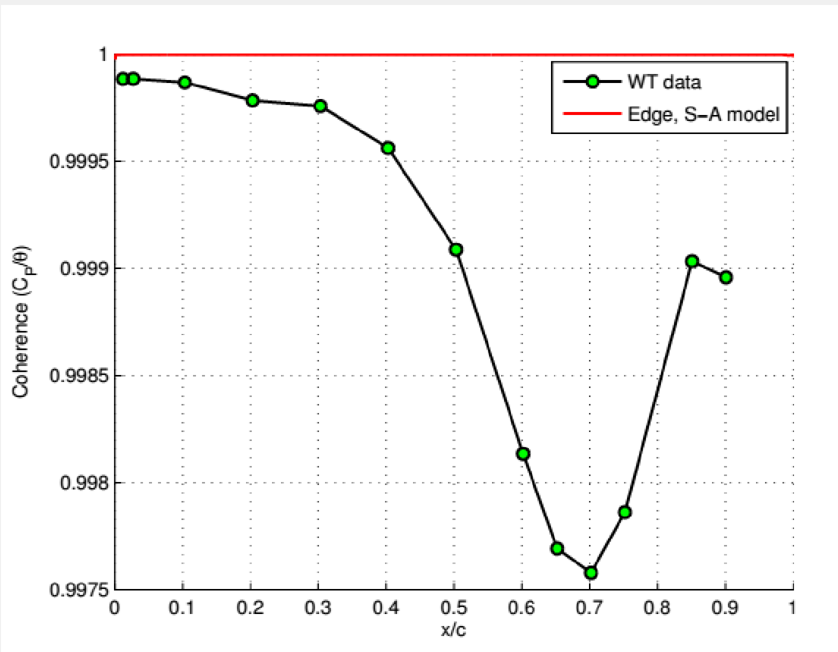
Lower surface



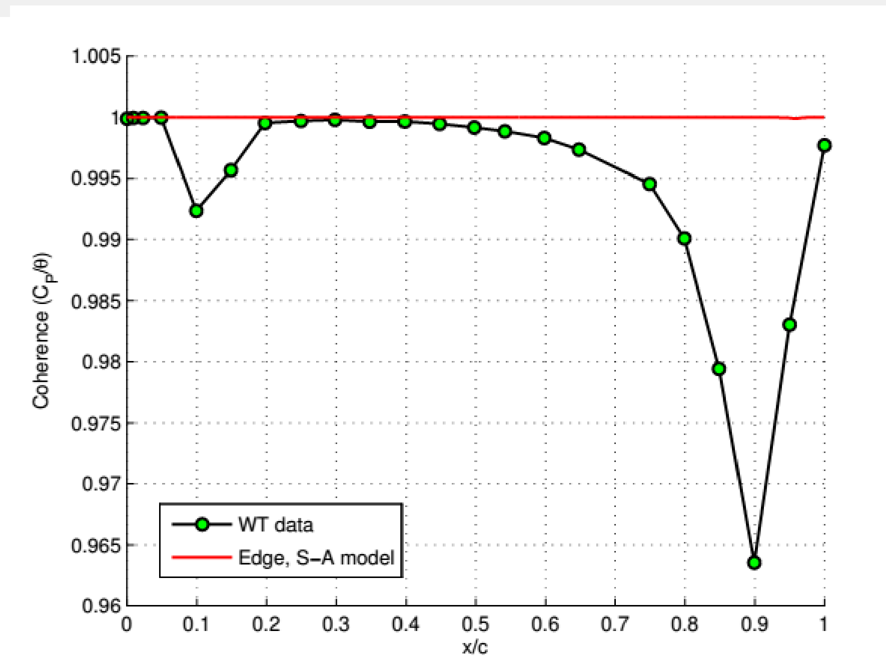
Upper surface

Frequency Response Function

- Coherence



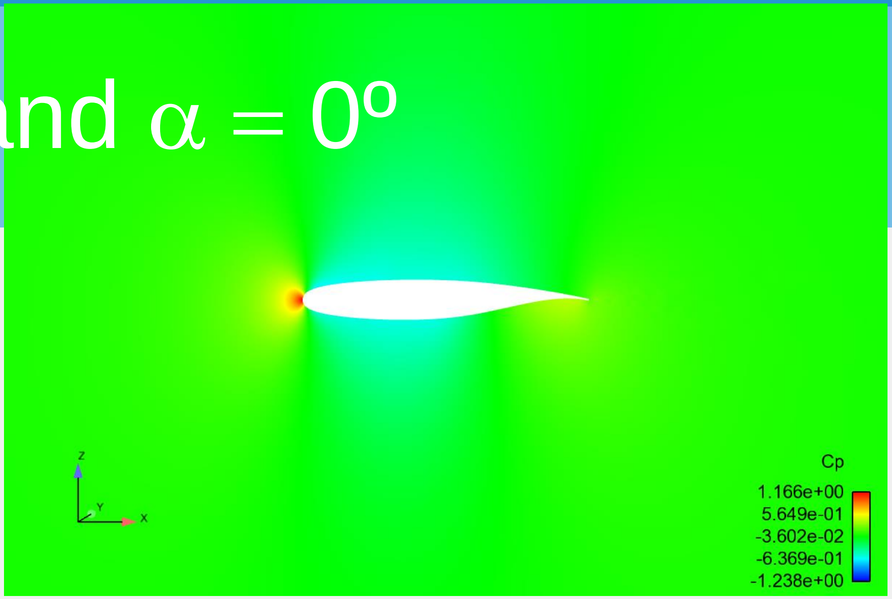
Lower surface

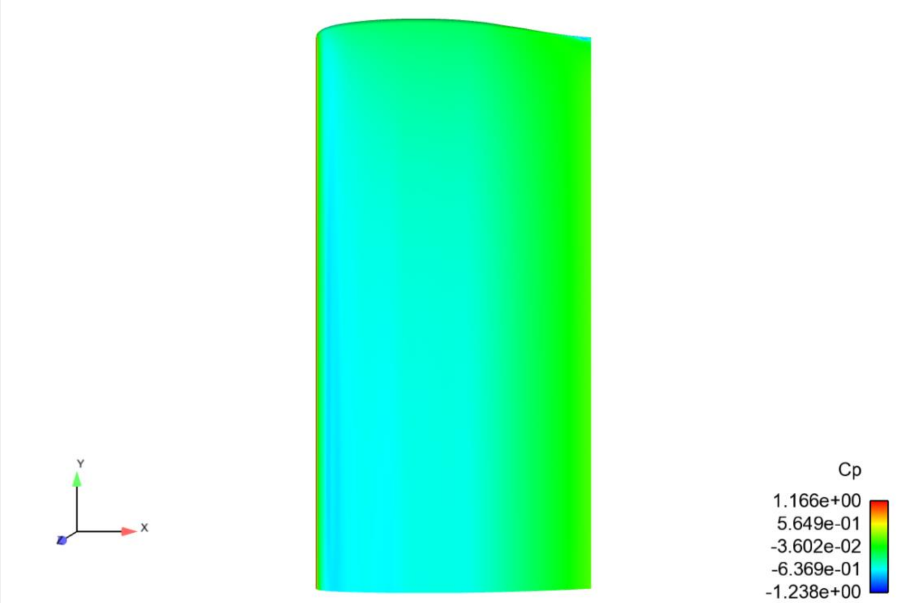


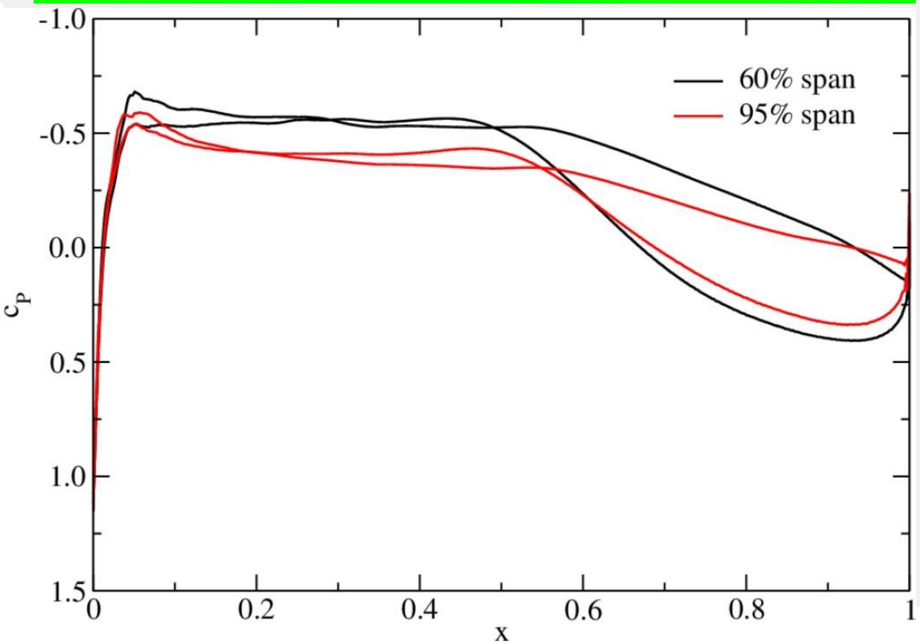
Upper surface

Case 2: Mach 0.74 and $\alpha = 0^o$

- Subsonic inflow conditions
- "Strongly coupled scheme" at sub-iteration level
- T=10 sec and Δt = 0.002 sec







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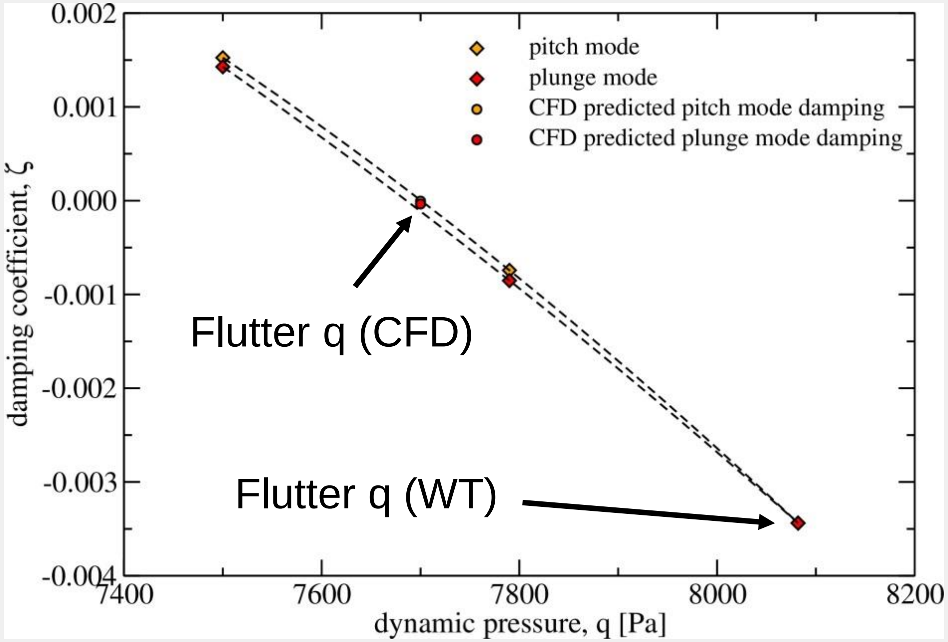
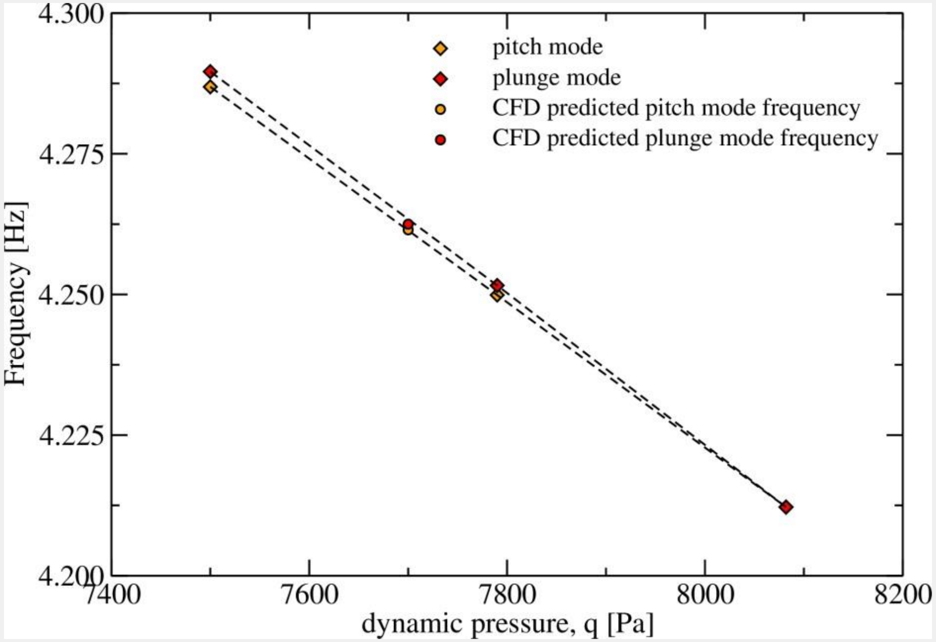
Estimated Flutter Dynamic Pressure

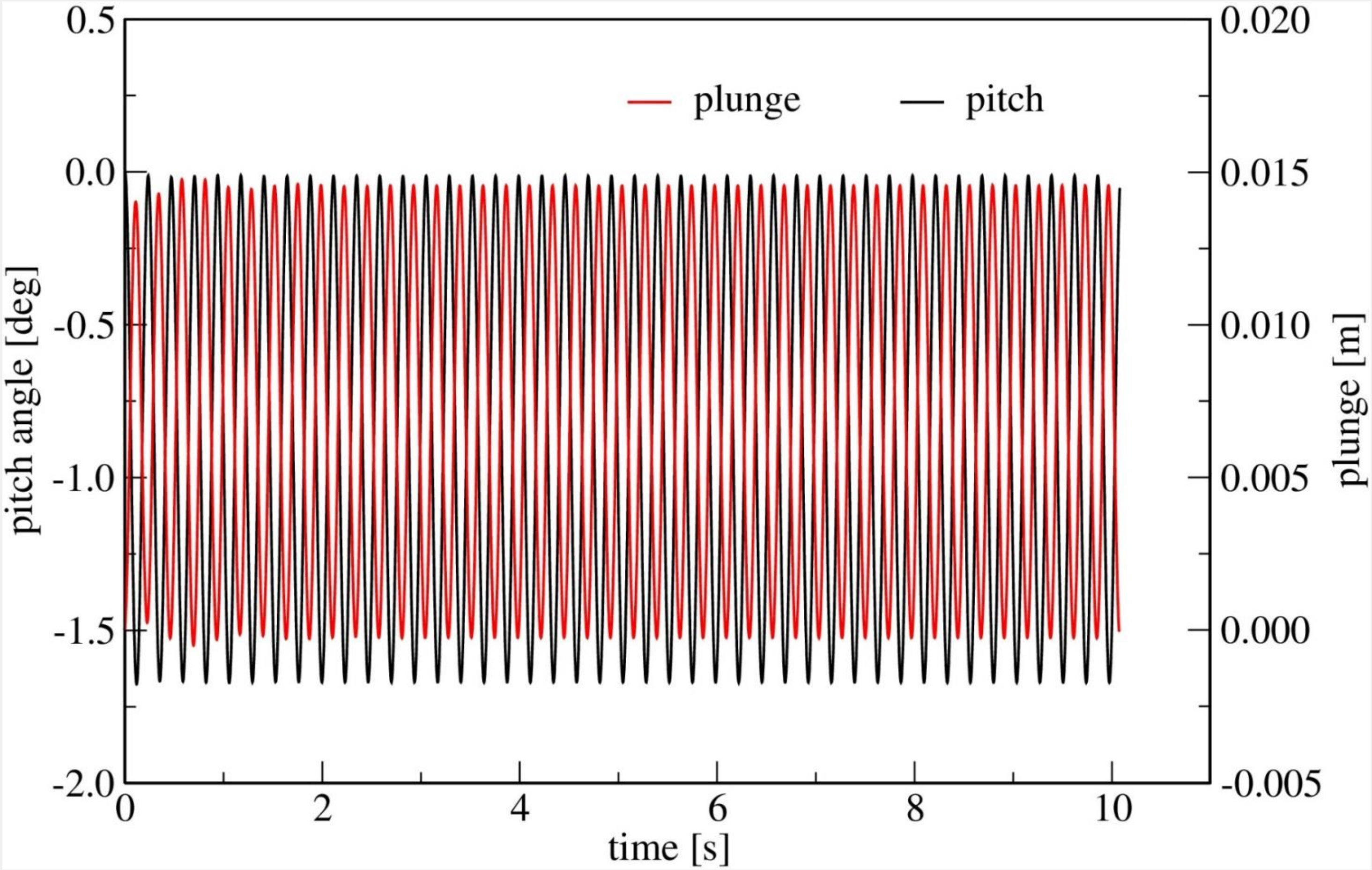




Three different dynamic pressures calculated

- The estimated CFD flutter dynamic pressure is 7700 Pa
- WT flutter dynamic pressure is estimated at 8082 Pa
- With WT measured flutter frequency at 4.3 Hz and for CFD 4.26 Hz

Modal Coordinates at Flutter Dynamic Pressure



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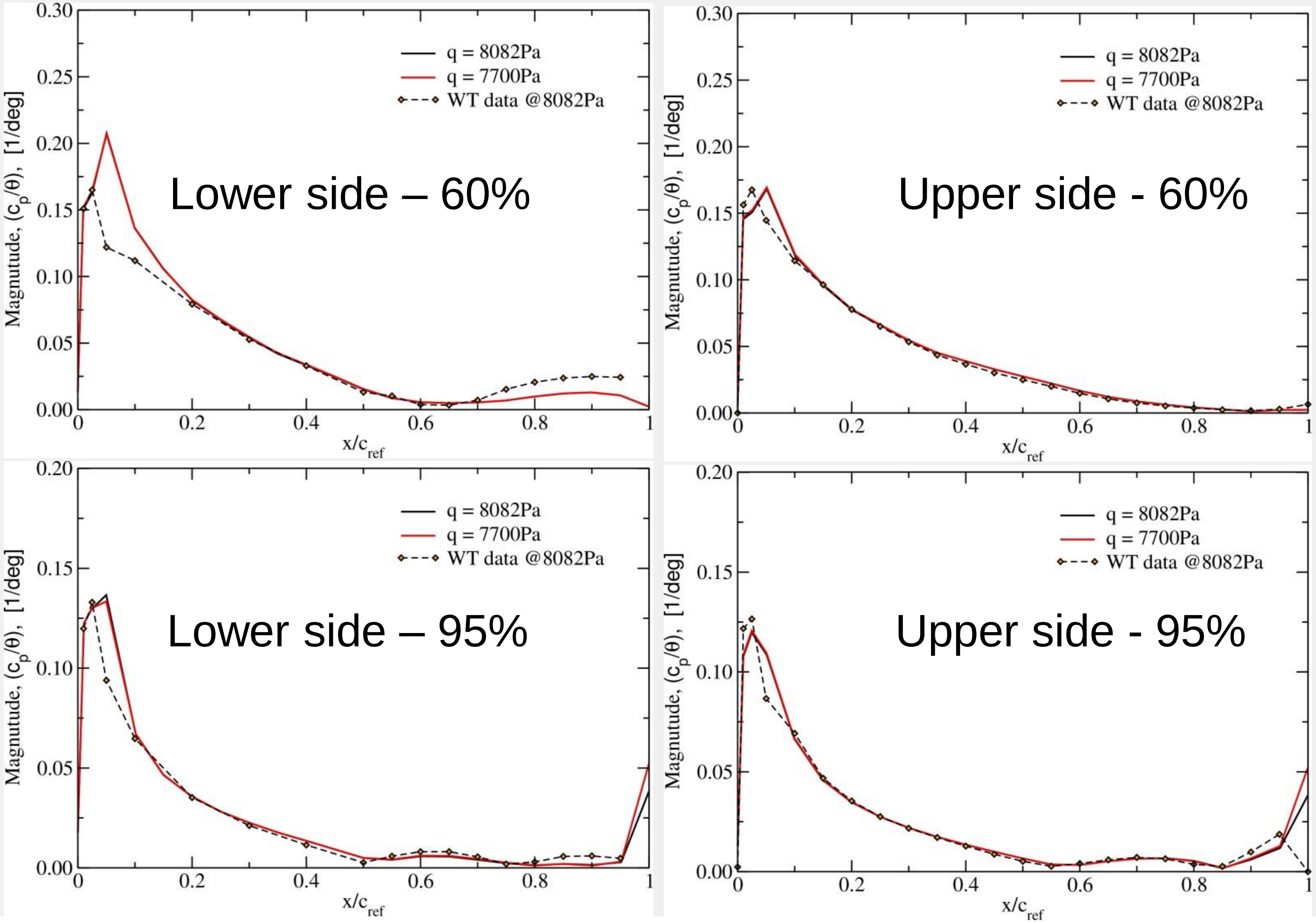
FRF Magnitude Comparison



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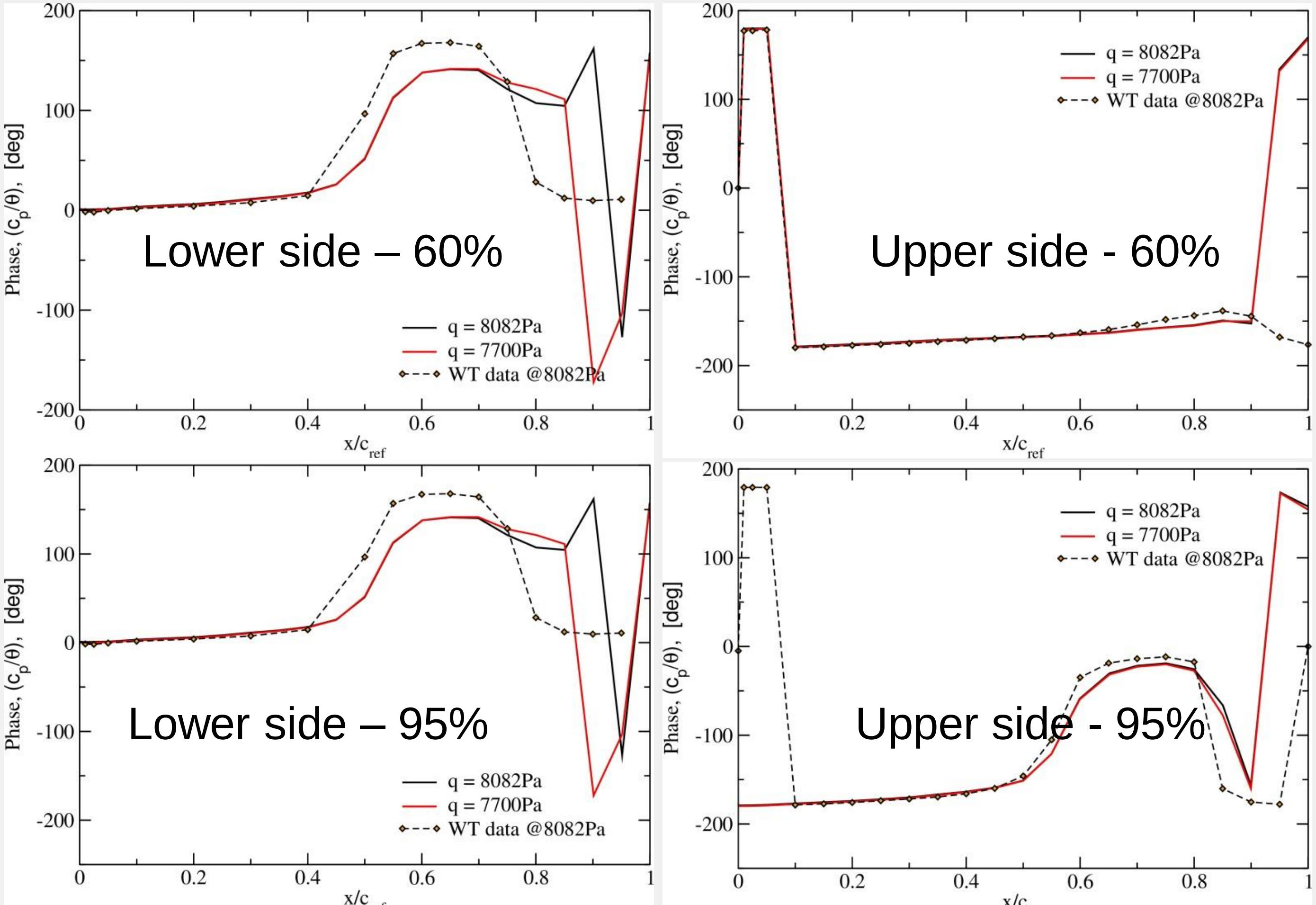
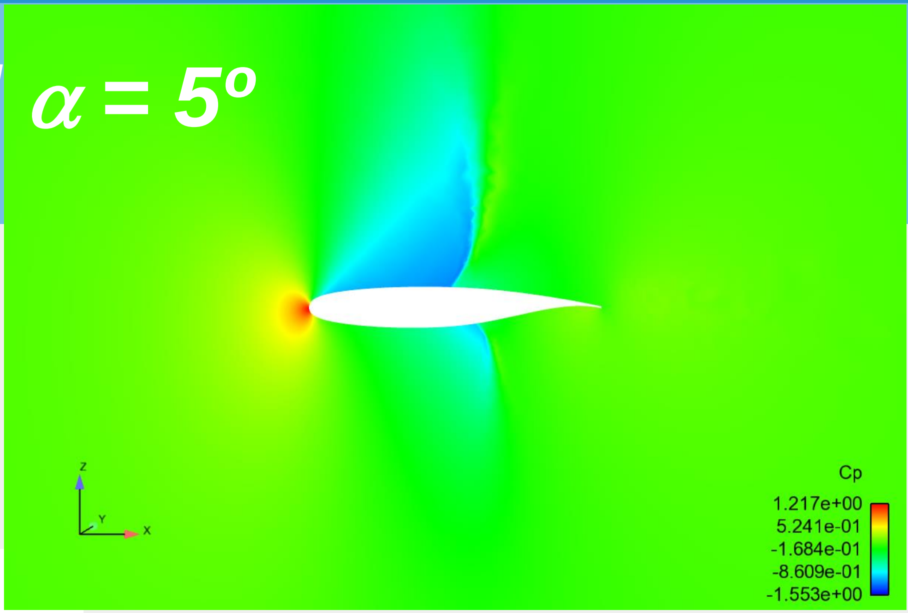
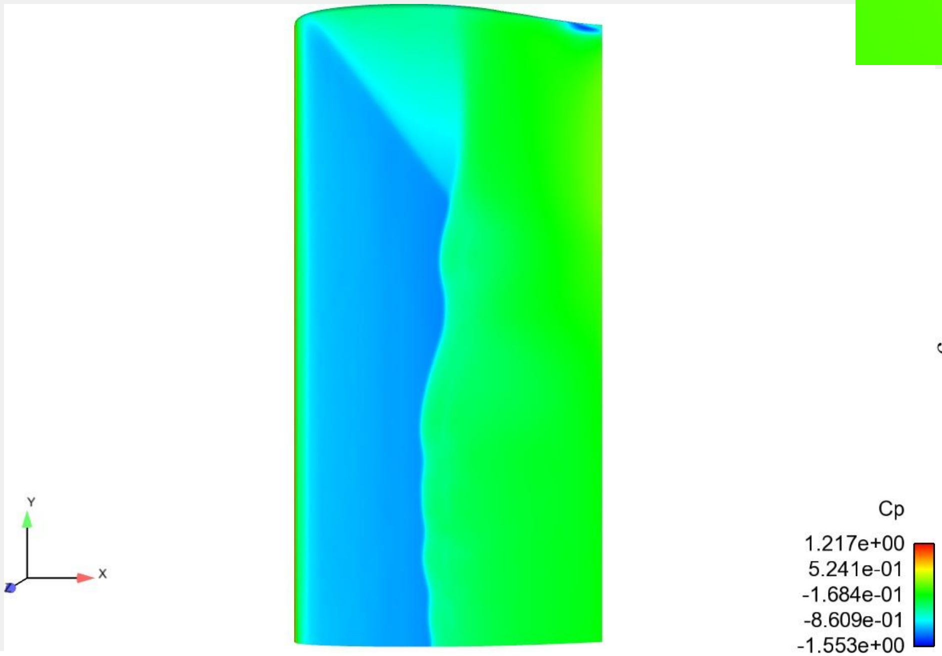
FRF Phase Comparison

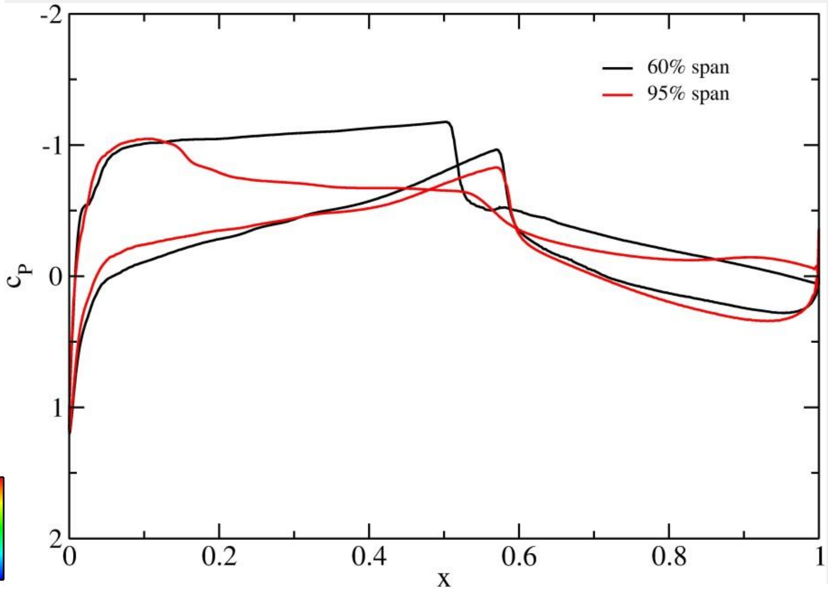


Case 3: Mach 0.85 and $\alpha = 5^o$

- Transonic flow
  - SA model
  - Do not see any large separation

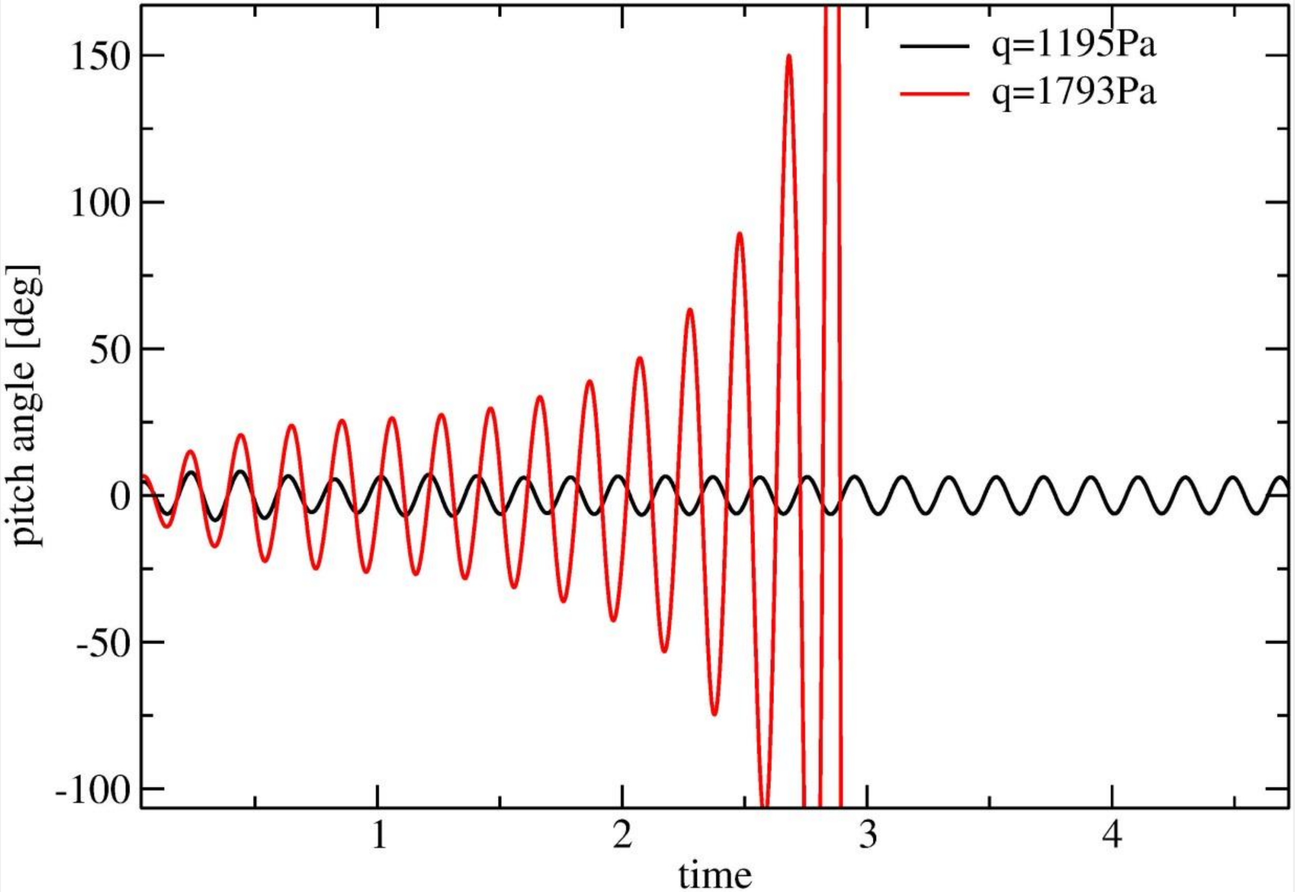






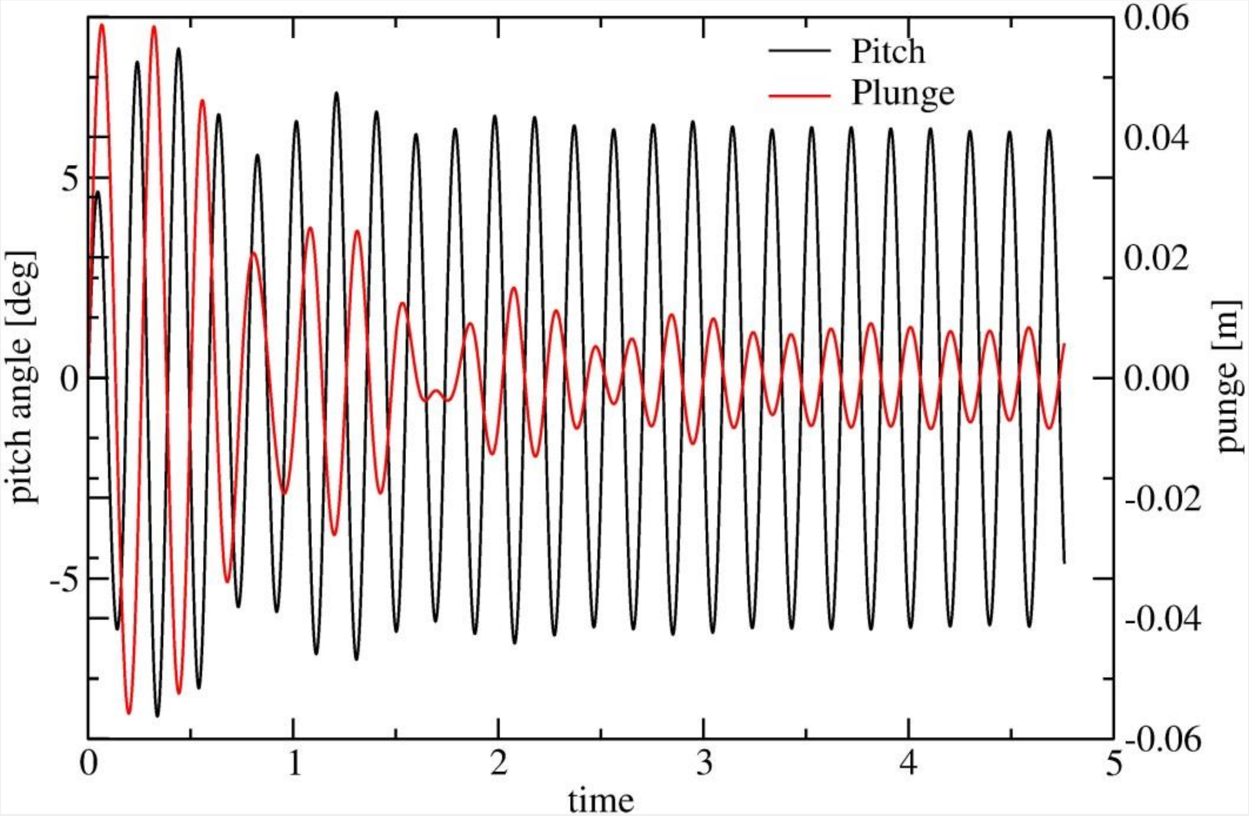
Different Dynamic Pressures

- Calculated at five different dynamic pressures
  - The flutter dynamic pressure ~25psf



Pitch and plunge @ flutter pressure

- Damping coefficients and frequency
  - Initial 3 seconds - transient
  - Pitching mode: ζ=0.00031, f=5.18Hz
  - Plunging mode: ζ=0.00017, f=5.18Hz



Conclusion

- The dominant effect for this case is coupling
  - There is no flow separation, the flow is linear of weakly non-linear
  - Structure is linear
  - Allow for larger time steps
    - Provided the time integration of coupled system is of sufficient accuracy (second order)
- The above conclusion does not have to be necessarily valid for separated flow where the time scale is then determined by the flow separation modeling