Simulation of Shock Boundary Layer and Shear Layer Interaction

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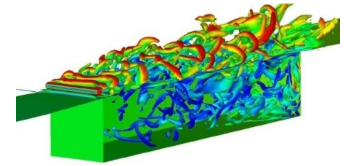
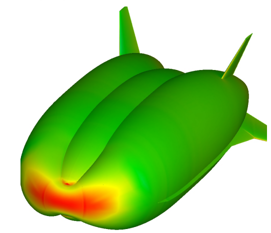
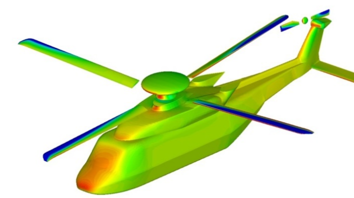
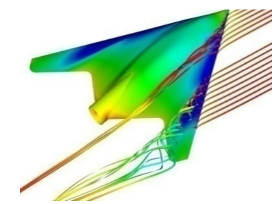
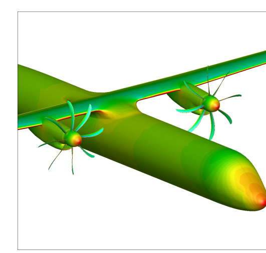
CFD Solver – Core HMB2 Features



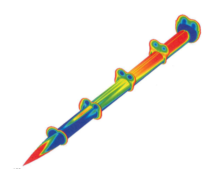


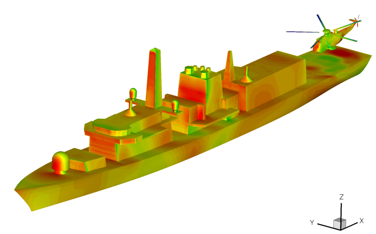




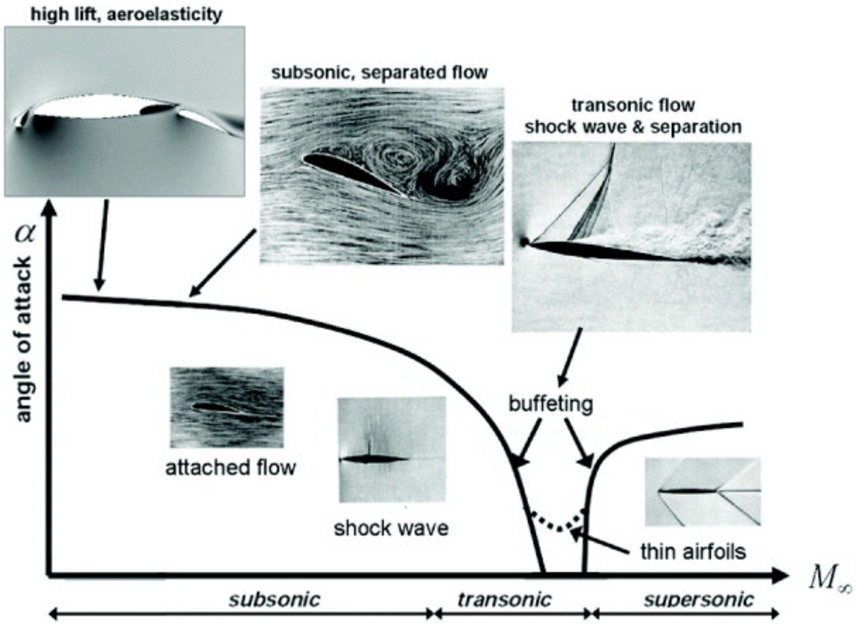


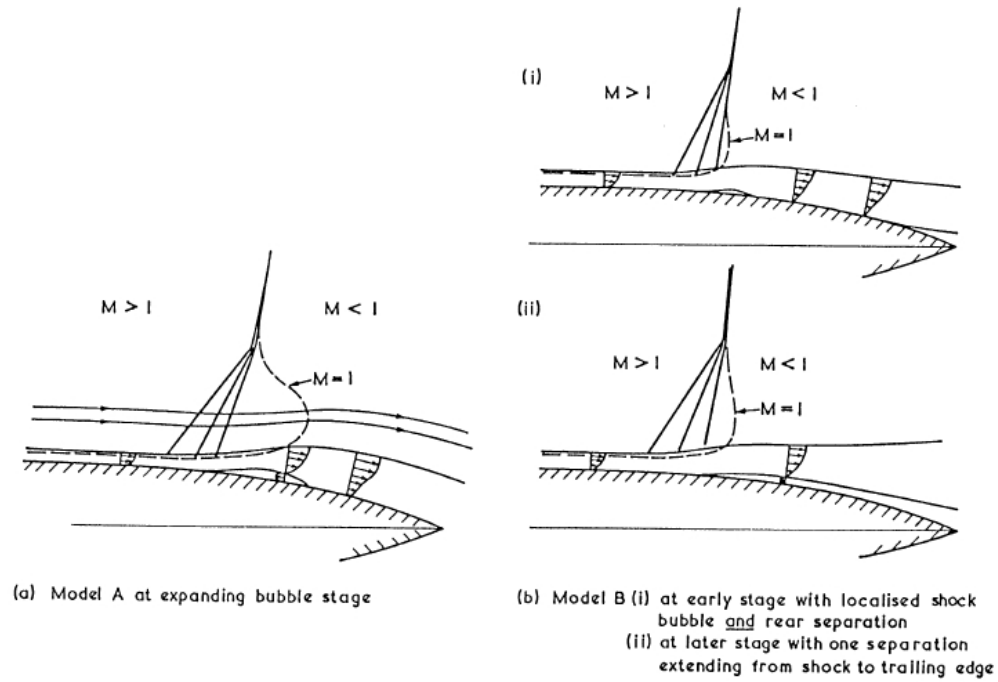
- Control volume method
- Parallel - Shared and Distributed memory
- Multi-block structured grids
- Moving grids, sliding planes, overset grids
- URANS - Variety of turbulence & transition models LES/DES/SAS
- Implicit time marching
- Time and Frequency domain solver
- Osher, All Mach Roe, AUSM for convective fluxes
- MUSCL scheme – nominal 3rd order
- Central differences for viscous fluxes
- Hover formulation, rotor trimming, blade actuation
- Flight mechanics module
- Aeroelastic method

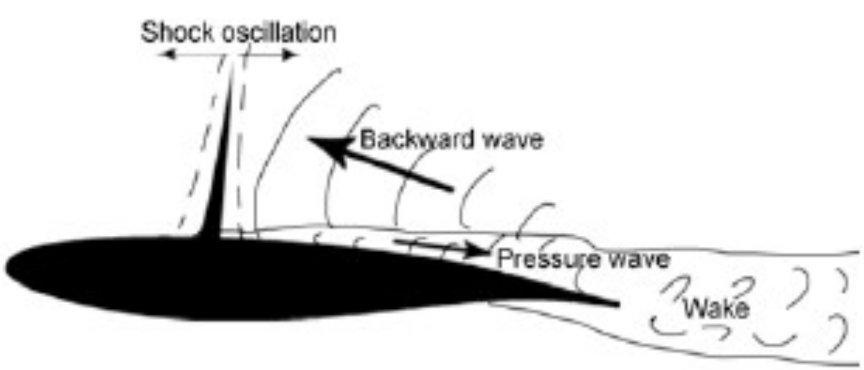




Shock Boundary Layer Interaction and Buffet





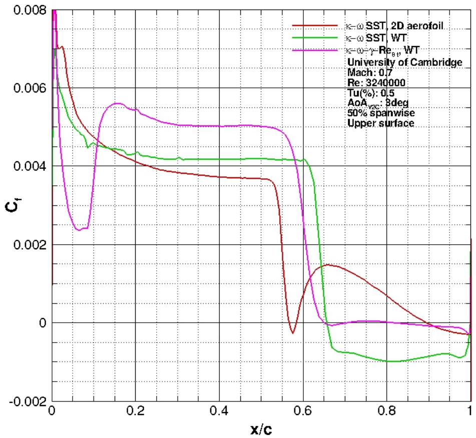


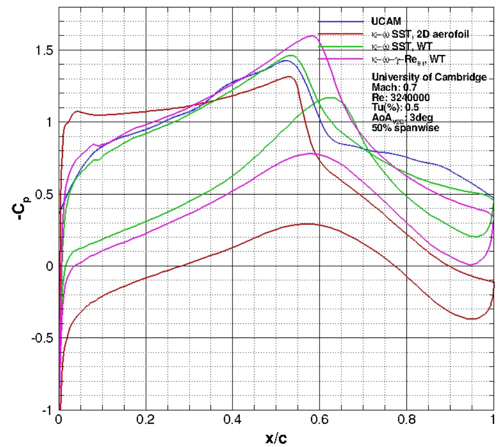
Sketch of shock boundary layer interaction with (a) bubble separation and (b) bubble and rear separation [1]

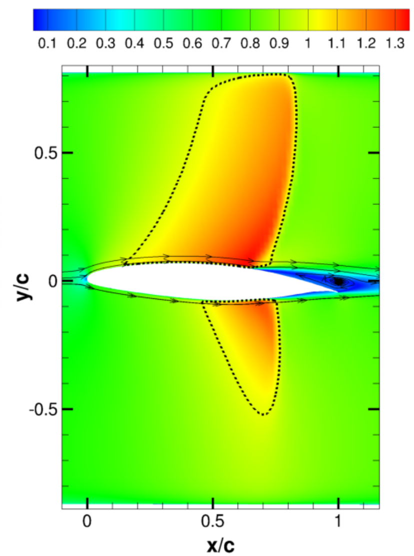
Interplay between shock wave, BL and TL pressure leads to Buffet feeding mechanism

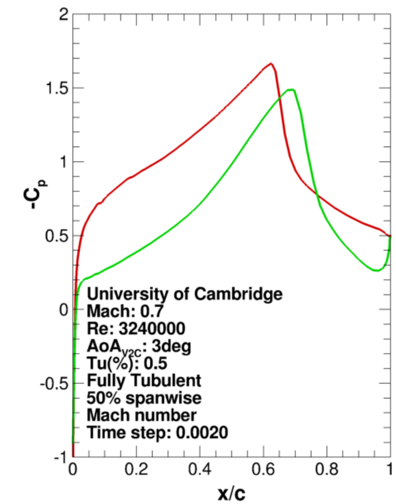
[1] Pearcey, Osborne and Haines (1968)

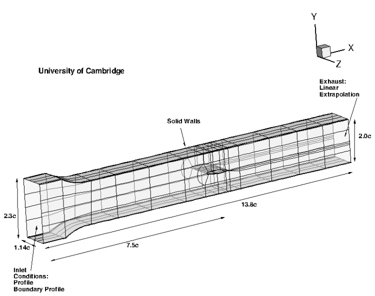
V2C aerofoil - With and without WT wall
$\kappa-\omega$ and $\kappa-\omega-\gamma-Re_{\theta t}$
M_∞ 0.7 Re_c 3.24×10^6 a:3deg





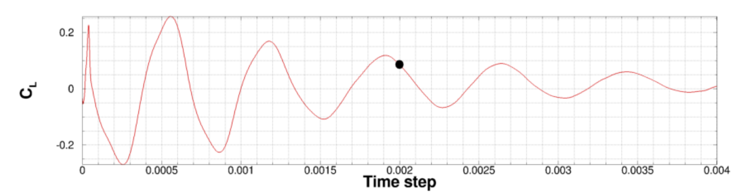




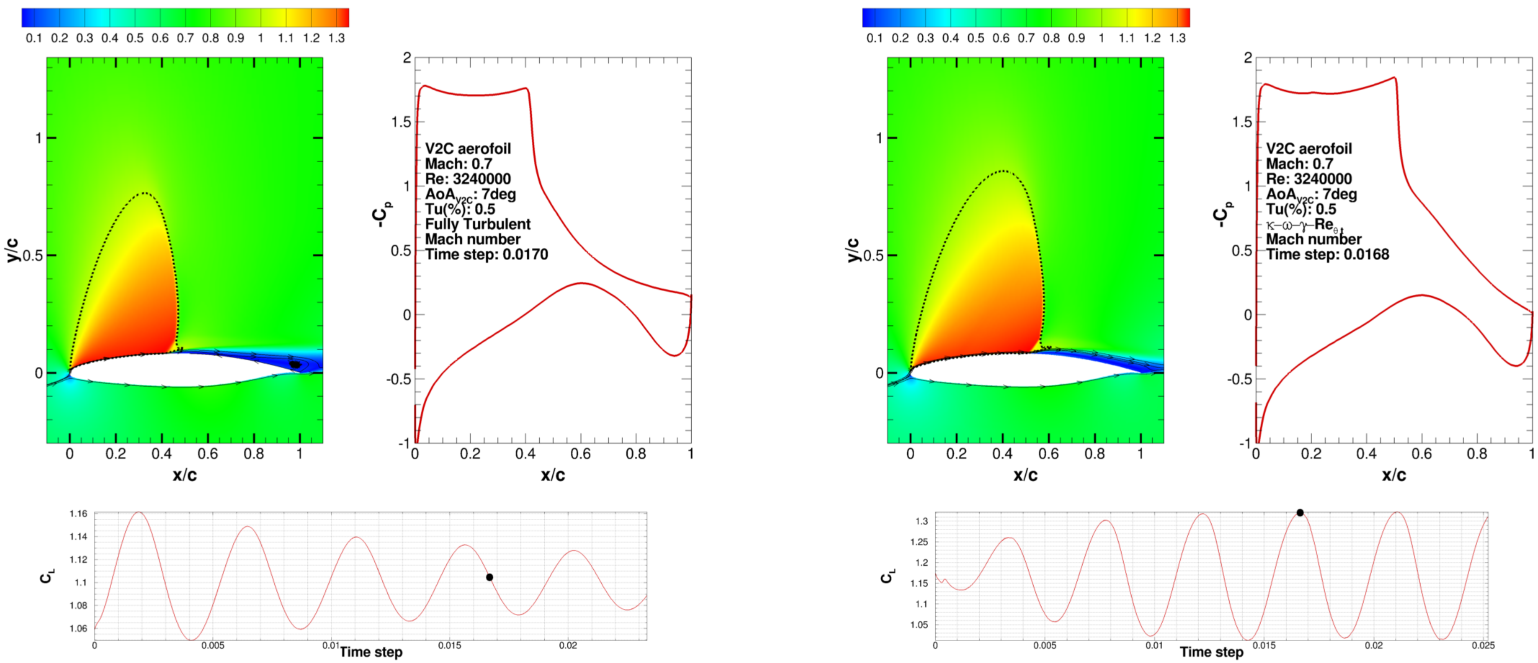


Surface skin friction(left) and pressure distribution(right) for $\kappa-\omega$ SST model and $\kappa-\omega-\gamma-Re_{\theta t}$ model. Comparison with measurements from UCAM

M_∞ 0.7, Re_c 3.24x10^6, a=3deg, Tu(%)= 0.5



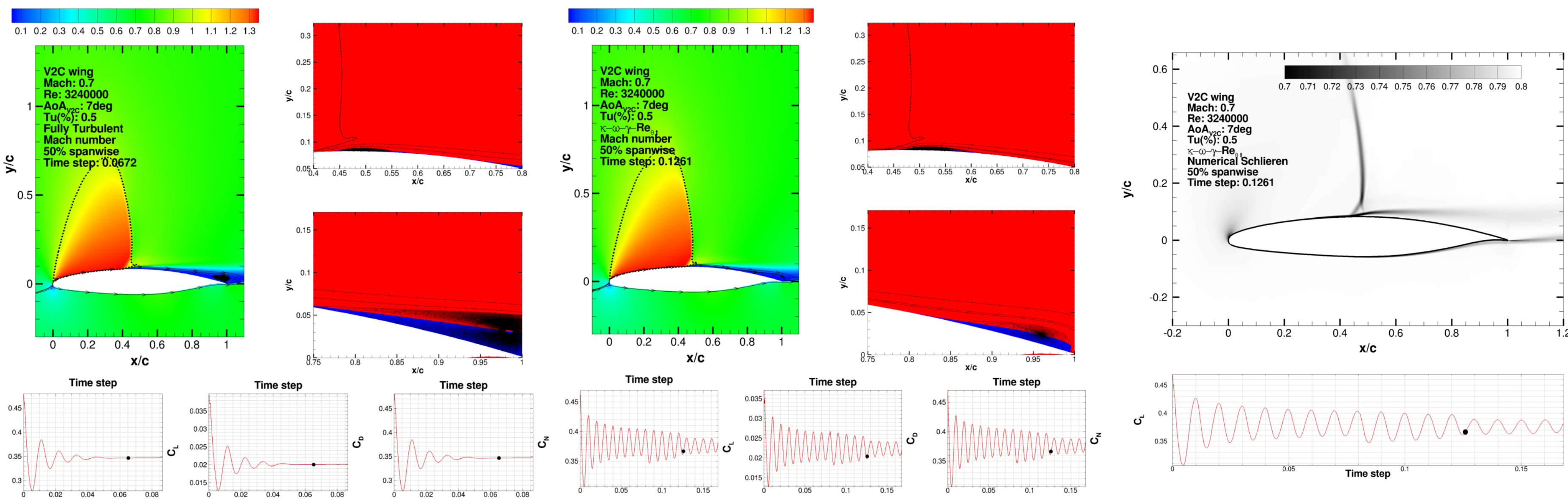
V2C aerofoil - Unsteady Calculations
$\kappa-\omega$ and $\kappa-\omega-\gamma-Re_{\theta t}$
M_∞ 0.7 Re_c 3.24×10^6 a:7deg



Mach number visualisation and surface pressure distribution mid-span of the section for $\kappa-\omega$ SST model and $\kappa-\omega-\gamma-Re_{\theta t}$ model

M_∞ 0.7, Re_c 3.24×10^6, a=7deg, Tu(%)= 0.5

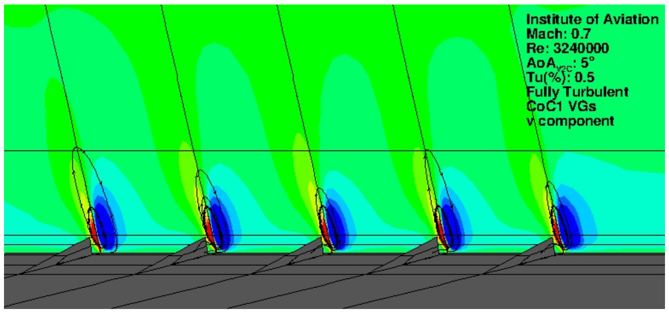
V2C 3D aerofoil - Unsteady Calculations
$\kappa-\omega$ and $\kappa-\omega-\gamma-Re_{\theta t}$
M_∞ 0.7 Re_c 3.24×10^6 a:7deg



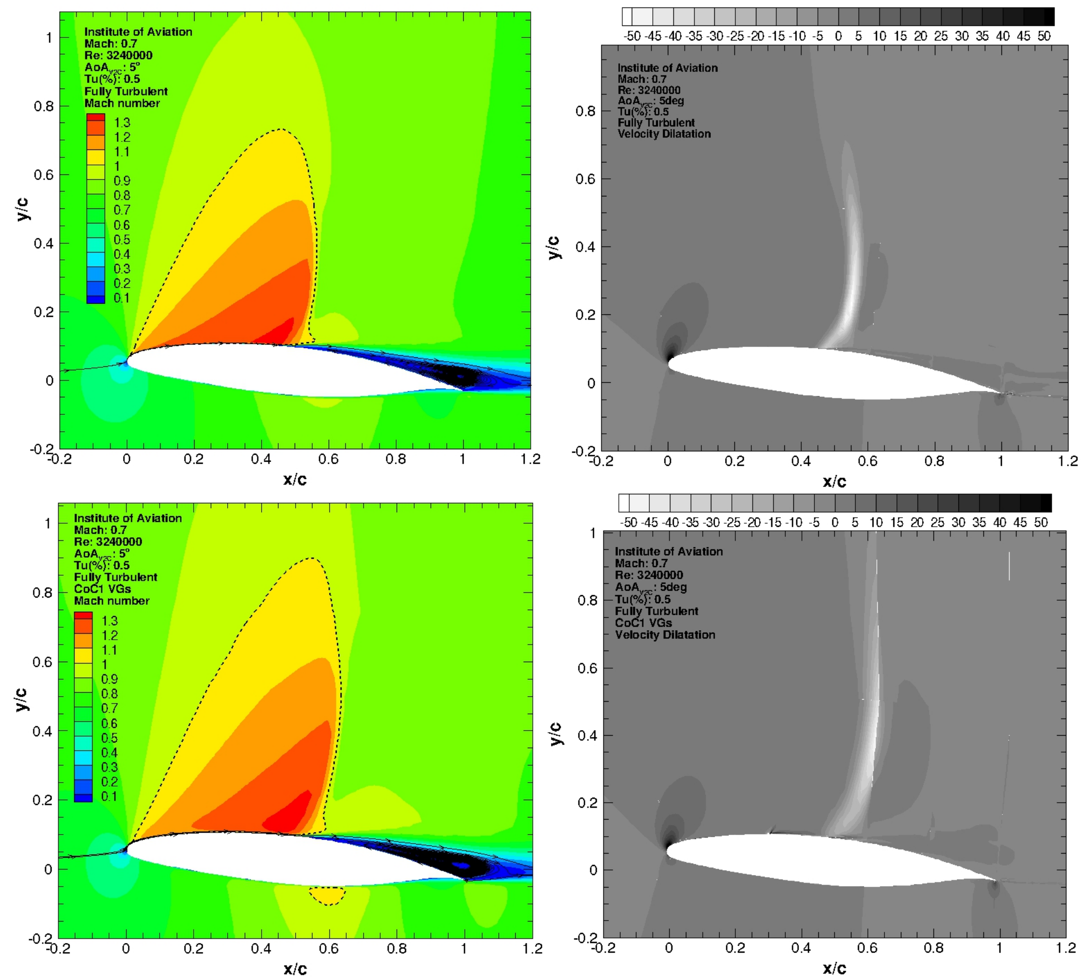
Mach number visualisation and numerical schlieren, mid-span of the section for $\kappa-\omega$ SST and $\kappa-\omega-\gamma-Re_{\theta t}$ models

M_∞ 0.7, Re_c $3.24\text{x}10^6$, a=7deg, Tu(%)= 0.5

V2C - CoC1 VGs
IoA WT - κ−ω SST
M_∞ 0.7 Re_c 3.24×10^6 a:5deg



v component of velocity using 5 CoC1 VGs.



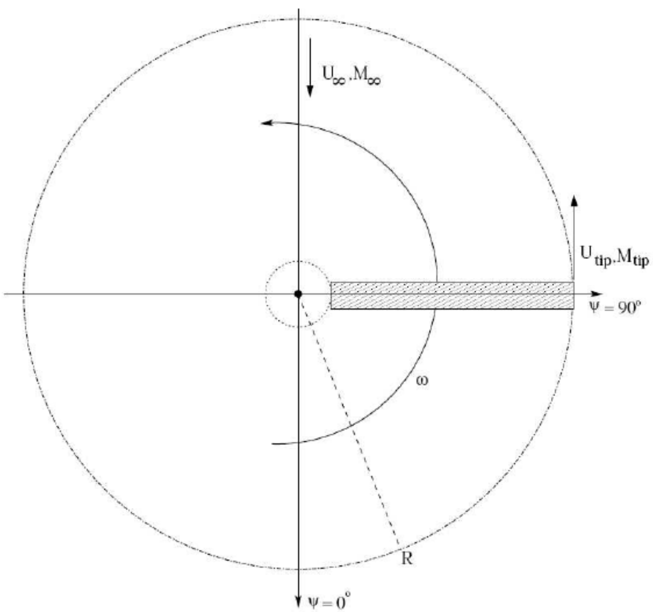
Comparison of Mach number and Velocity dilatation without (upper) and with (lower) VGs.

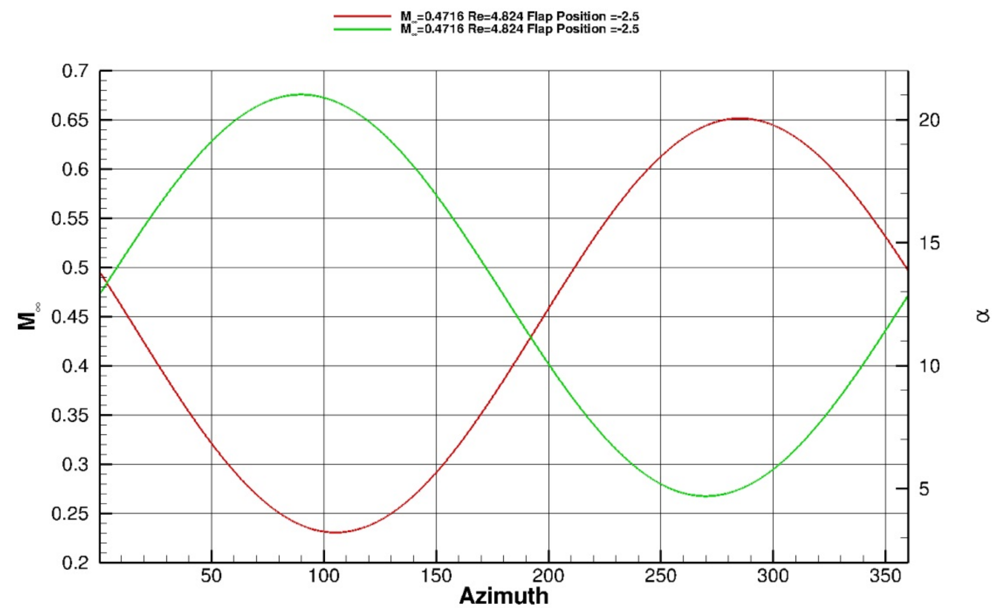
M_∞ 0.7, Re_c 3.24×10^6, a=5deg, Tu(%)= 0.5

dMdt Computations

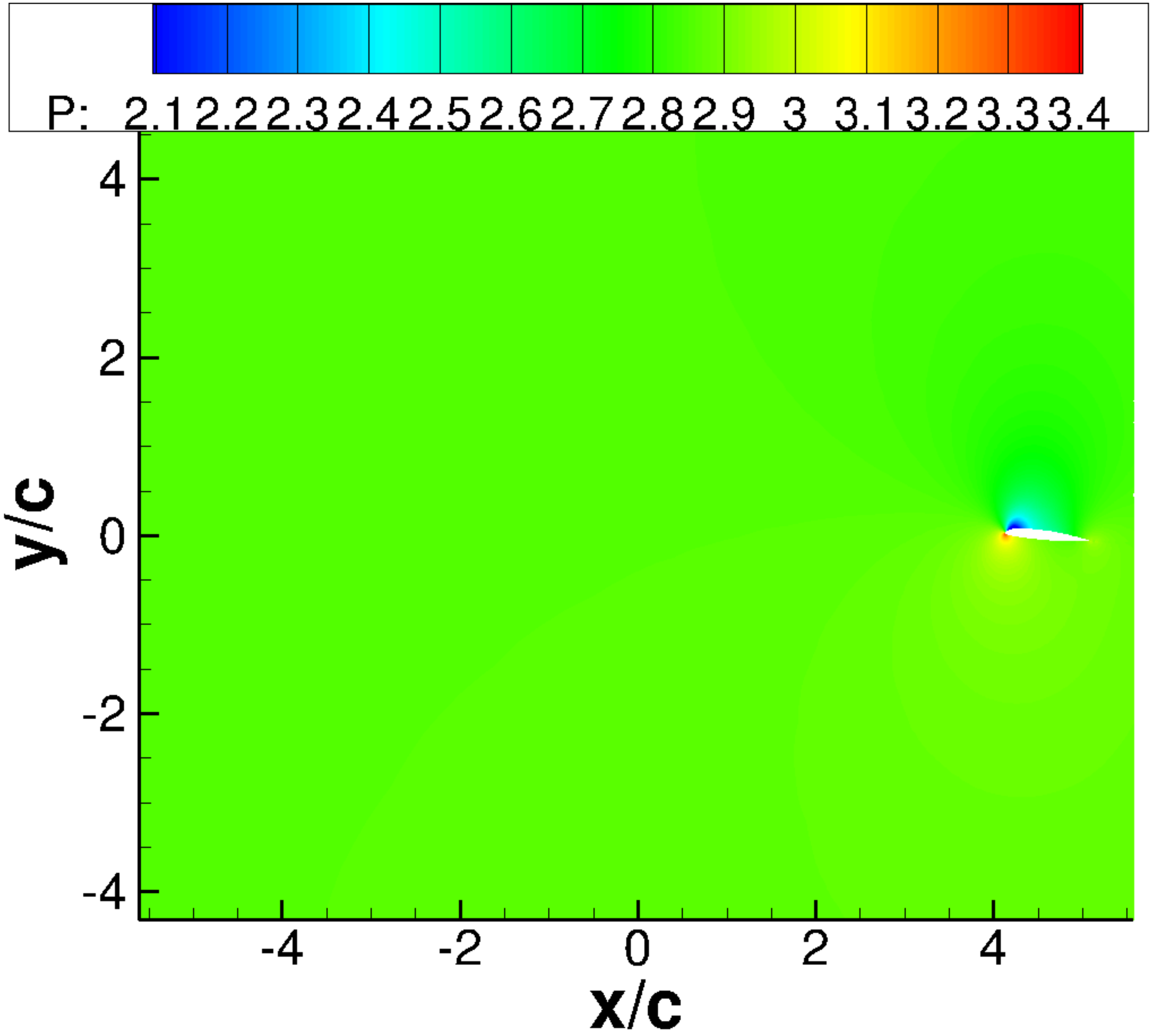
$$x = x_0 + \sum_{i=1}^{N_h} x_s \sin(2kit) + x_c \cos(2kit)$$

$$U = U_{tip}\frac{r}{R} + U_\infty \sin(\omega t)$$

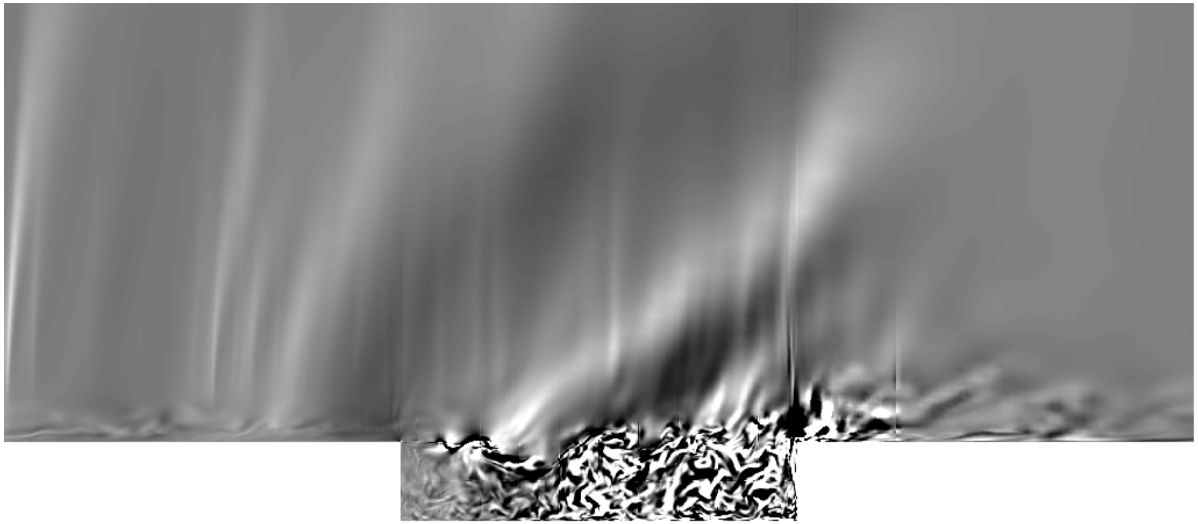




- AUM 11,500 kg
- Forward Speed 135 kts
- Inboard Station
- Fundamental question on the relationship between aerodynamic coefficeints and dMdt


P: 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 3 3.1 3.2 3.3 3.4
4
2
0
-2
-4
y/c
-4
-2
0
2
4
x/c

Transonic Cavity
Shock/Shear Layer Interactions



- Transonic Cavity Flow – LES simulation M_{∞}=0.85
- Acoustic waves and shock-waves interacting with cavity shear layer
- Earlier shear layer breakdown

Current Areas of Research

- Unsteady, Transitional SWBLI
  - Helicopter flows
  - Validation
  - Flow control
    - Vortex generators, acoustic forcing/modulation
    - Morphing of lifting surfaces
- CFD methods and models
  - SAS, DES, IDDES, LES
  - Stability of NS – Buffet onset
  - Frequency domain solver
    - Solve for large-amplitude modes only
- dMdt effects
  - Flows out of equilibrium
  - Forced unsteadiness
  - Low/high frequency de-coupling
- Transonic flows over cavities
  - Acoustics
  - Flow Dynamics
  - Control
    - Selective resonance

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