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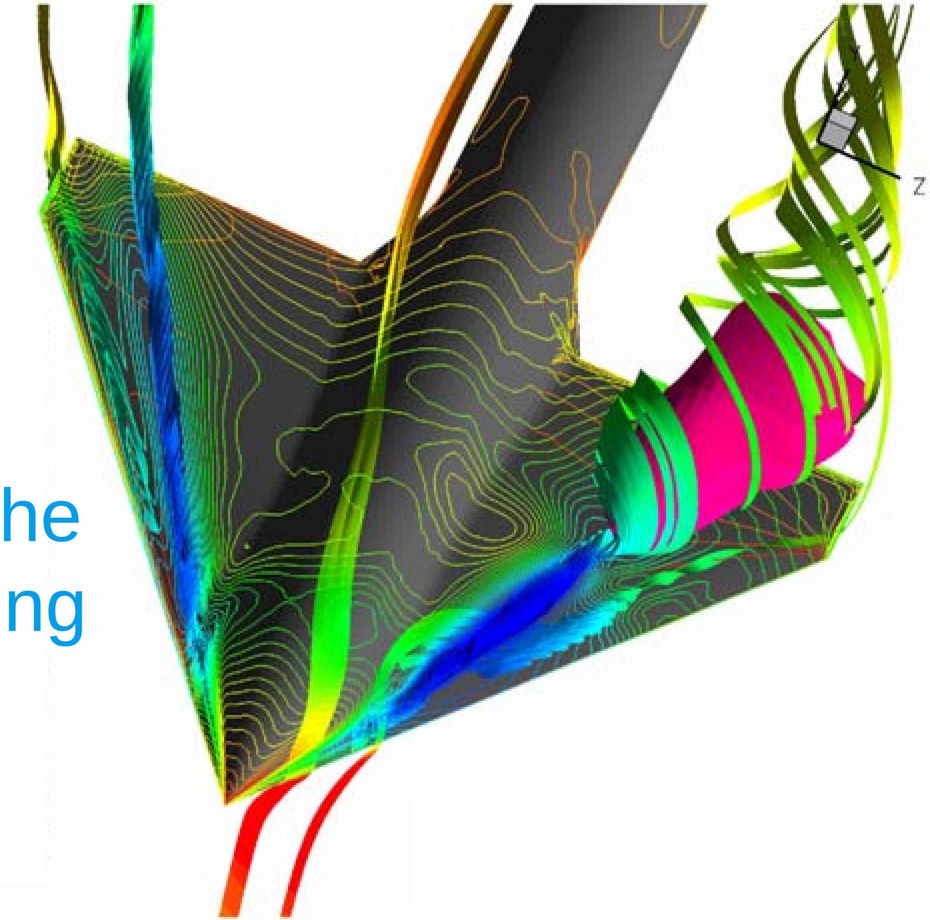
The impact of vortical flow on the free rolling motion of a delta wing aircraft



M.T. Arthur

Integrating CFD and Experiments
University of Glasgow, 8th - 9th September, 2003

Conference held in honour of Professor Bryan Richards

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Acknowledgements

Study undertaken by the Western European Armaments Group as THALES Joint Programme 12.15 and formerly TA15

Participants:

- UK: M.T. Arthur (QinetiQ) and M. Allan, M. Woodgate and K.J. Badcock (University of Glasgow)
- Germany: W. Fritz (EADS(M)) and J. Kompenhans (DLR)
- The Netherlands: O.J. Boelens and B.B. Prananta (NLR)
- Italy: N. Ceresola (Alenia)

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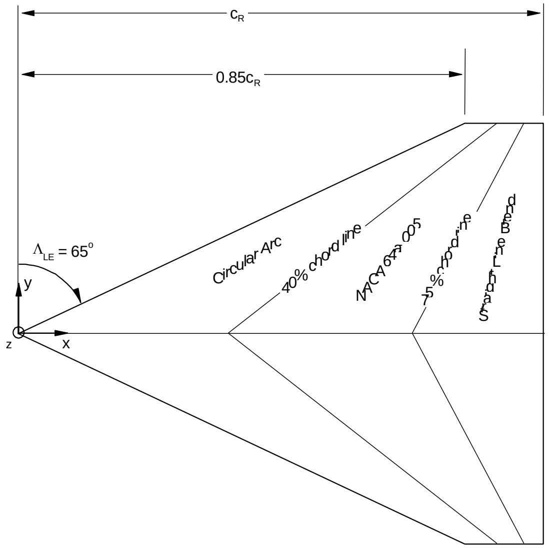
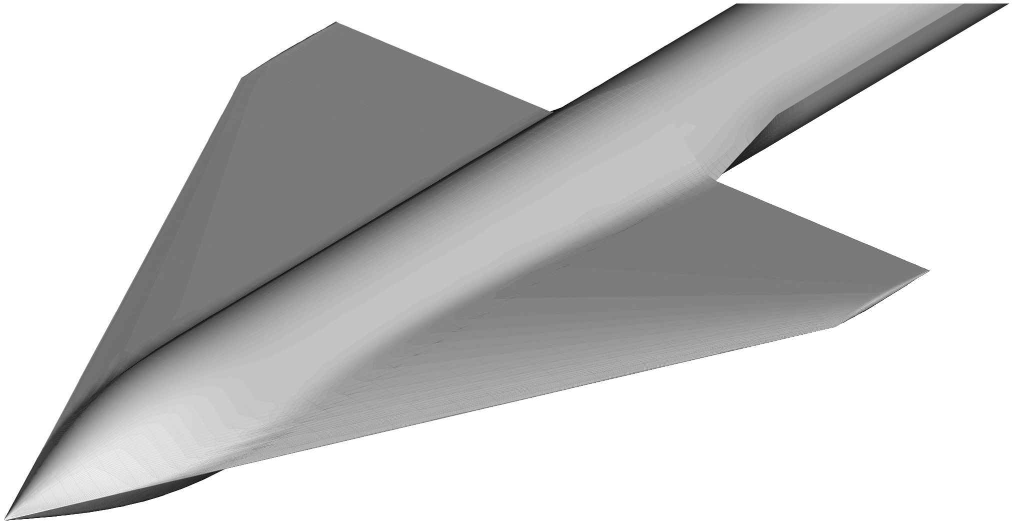
The objectives of JP12.15

- The development of methods for the prediction of vortical flows
- More precisely:
  - demonstrate feasibility of coupling unsteady Navier-Stokes solver with flight mechanics model;
  - investigate performance and robustness of methodology;
  - demonstrate initial capability for examining damping characteristics of a delta wing configuration manoeuvring in roll;
  - investigate unsteady flow field above the delta wing model by means of PIV in order to provide experimental data for validation.

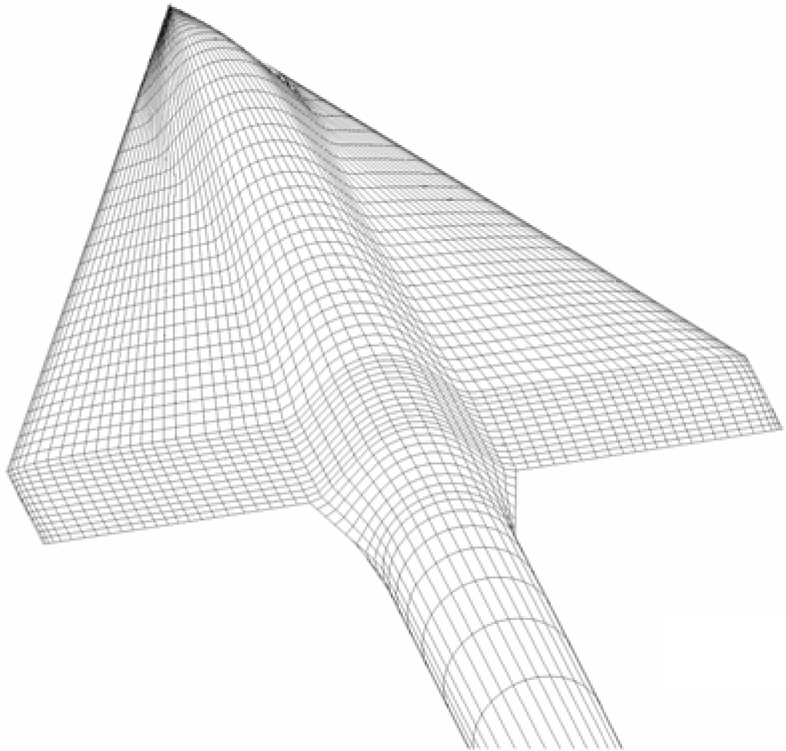
Geometry of the configuration

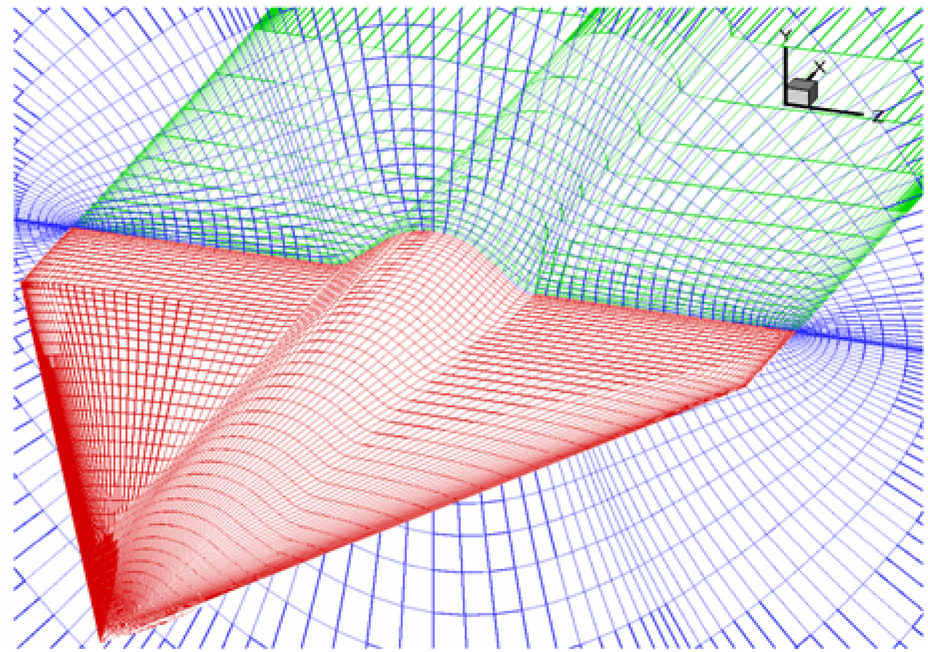
- Same delta wing planform as used in the earlier exercises of WEAG TA15 and THALES JP12.15





Configuration and computational grid





144 intervals streamwise from apex,
320 circumferential and 64 normal

2,949,120 cells in total

Results

Definition of example 1

Flow conditions:

M_∞=0.85, α=9°, Re_{CR}=4.9X10^6, U_∞=281.79 m/s,

ρ_∞=0.6354 kg/m^3

Initial condition:

ϕ_o=+40° (port wing down)

Coefficient of mechanical friction:

C_{lf}= 0

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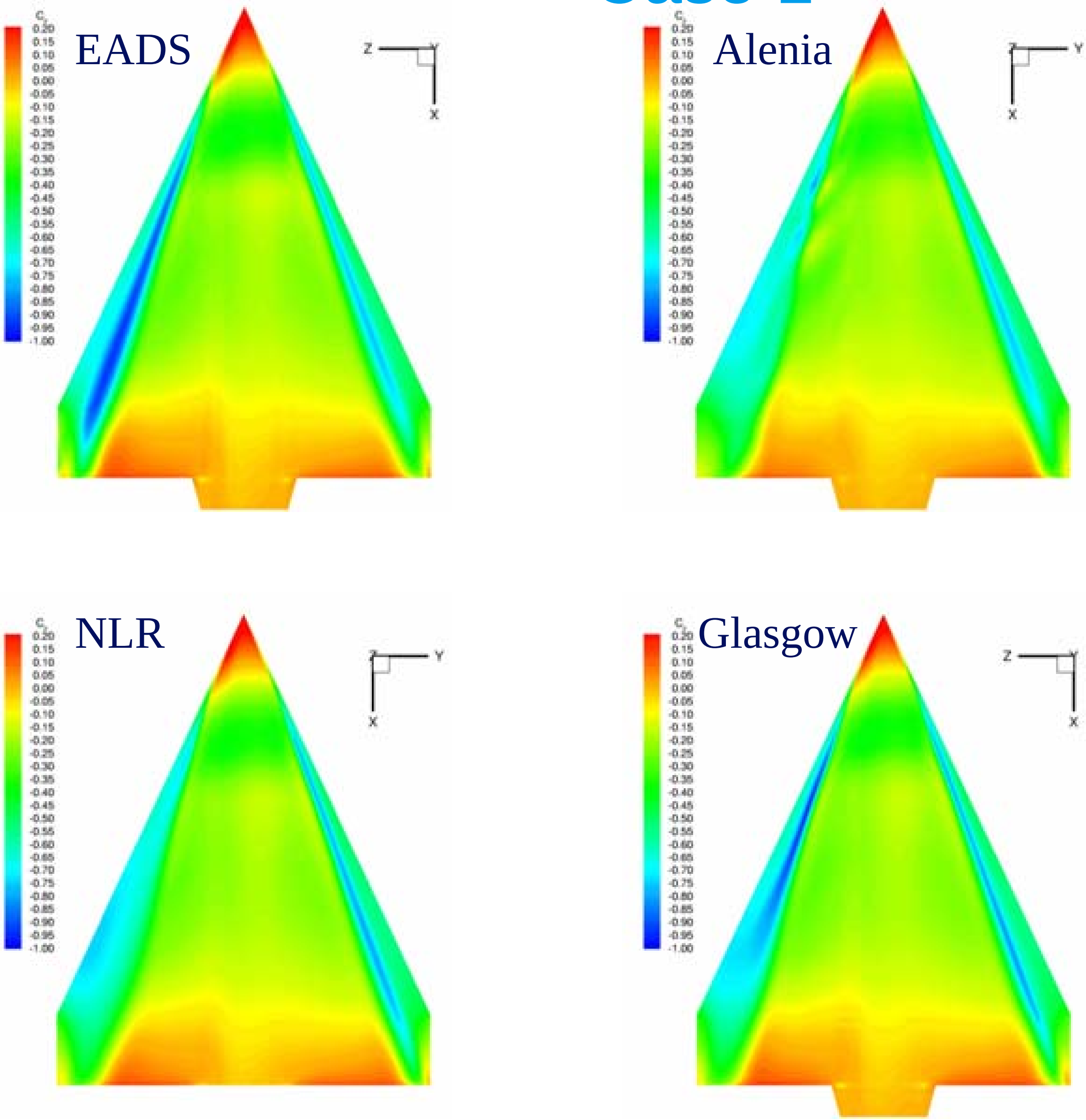
Upper surface pressure distributions at start of motion

Case 1



$M_\infty=0.85$

$\alpha=9^o$

$Re_{CR}=4.9X10^6$

$\phi_o=40^o$

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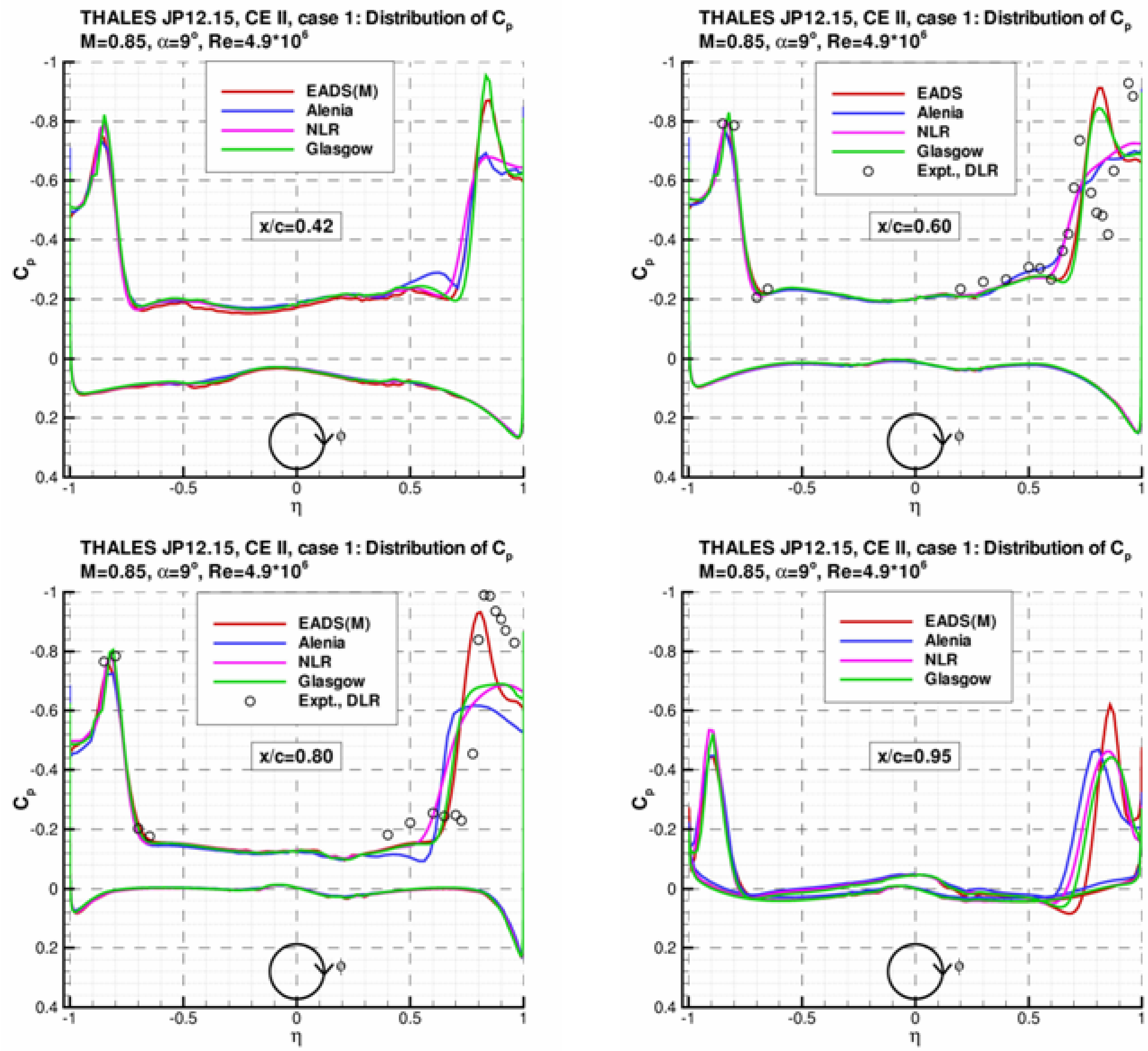
Spanwise distributions of pressure - case 1



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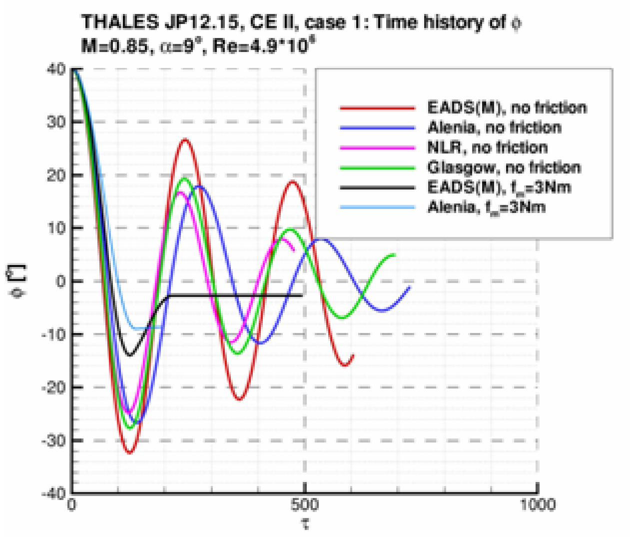
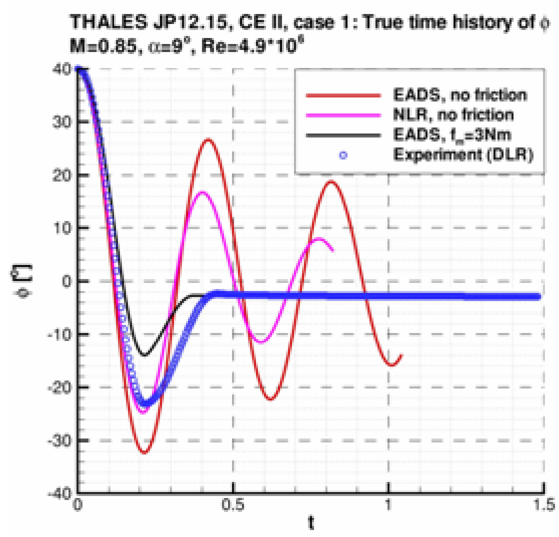
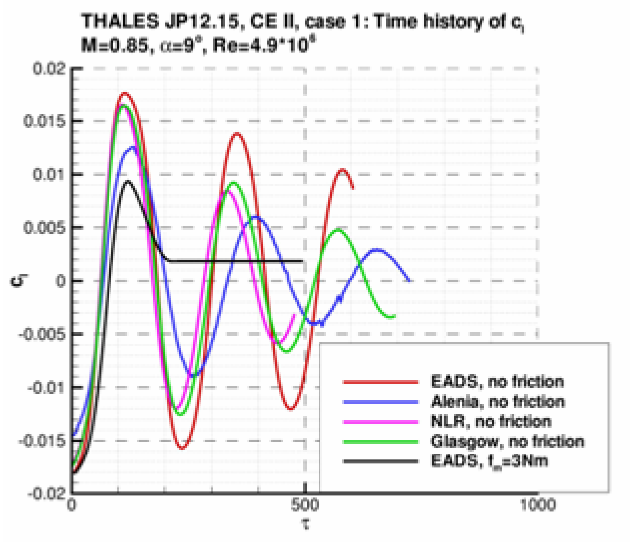
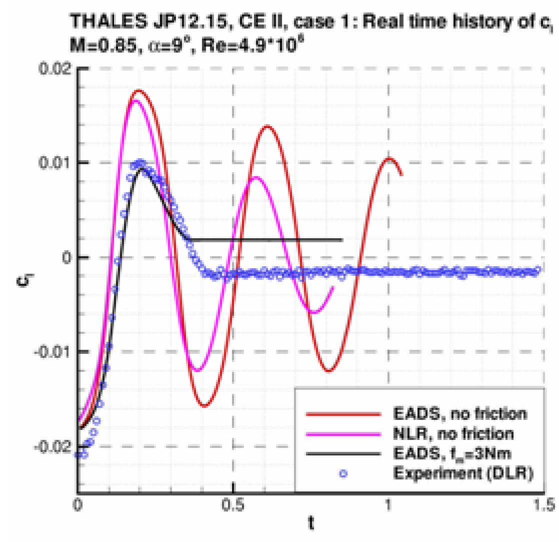
Time histories, case 1

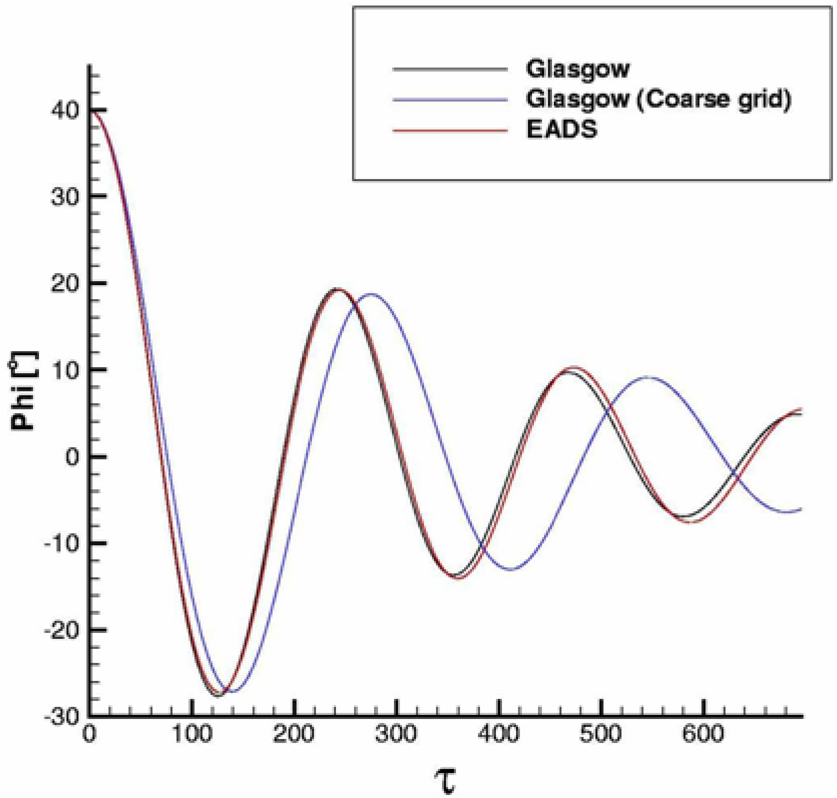


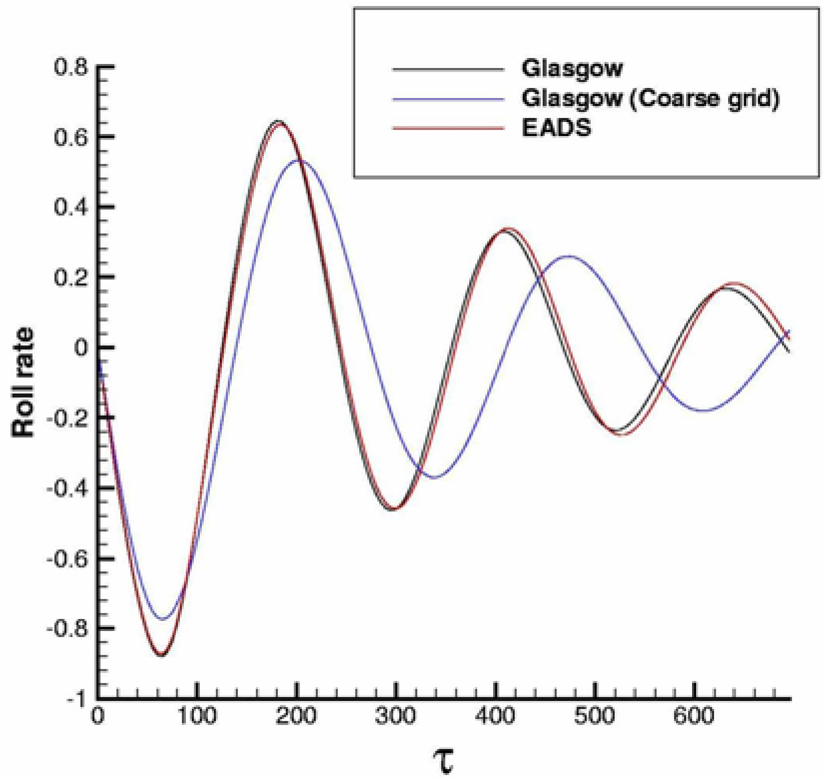






Effect of grid refinement





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Definition of example 2

Flow conditions:

M_∞=0.85, α=17^o, Re_{CR}=4.9X10^6, U_∞ =281.79 m/s, ρ_∞=0.6354 kg/m^3

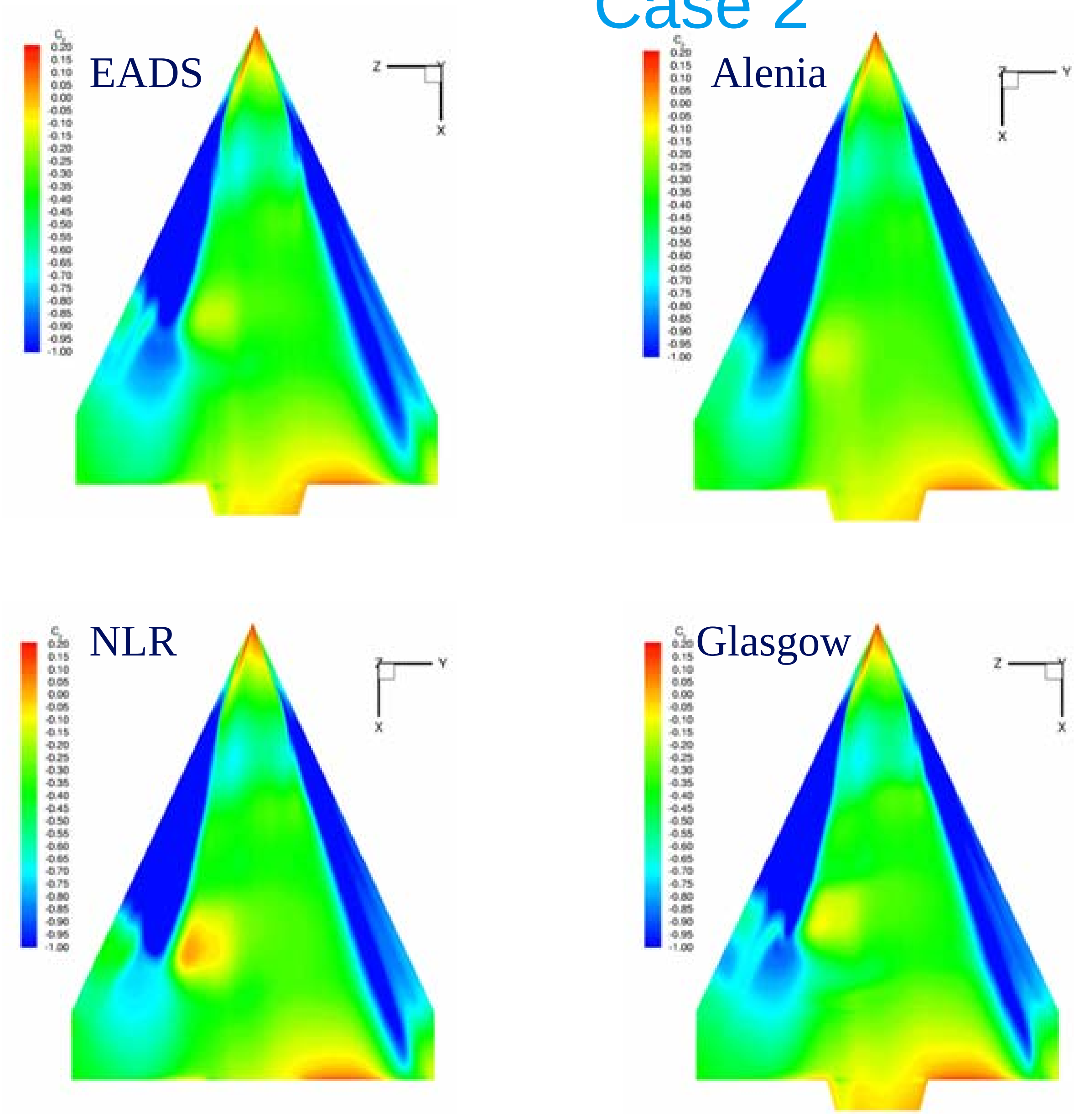
Initial condition:

ϕ_o=+30^o

Coefficient of mechanical friction:

C_{lf}= 0.00578 (i.e. a constant, adverse rolling moment of 3Nm)

Upper surface pressure distributions at start of motion
Case 2



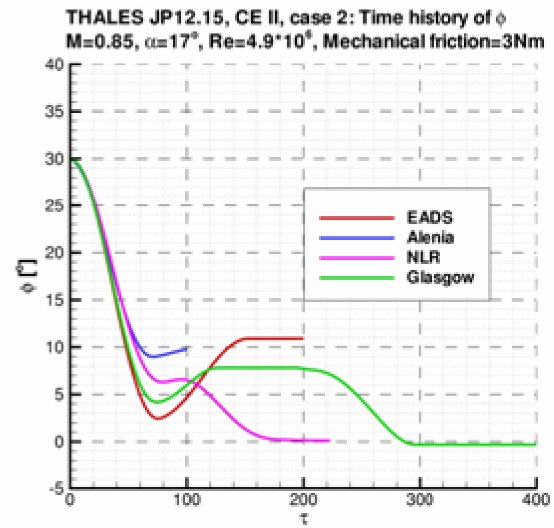
$M_\infty=0.85$

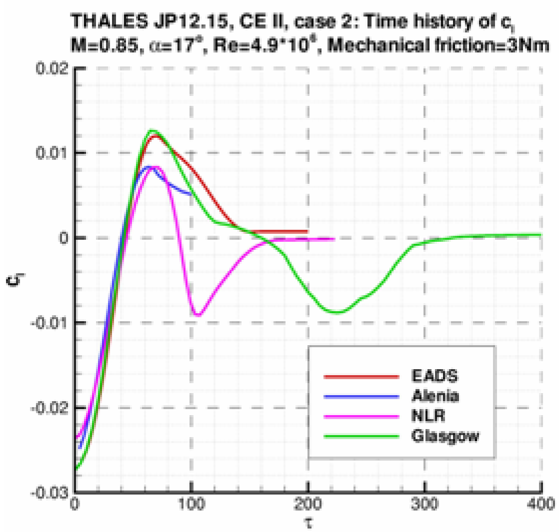
$\alpha=17^o$

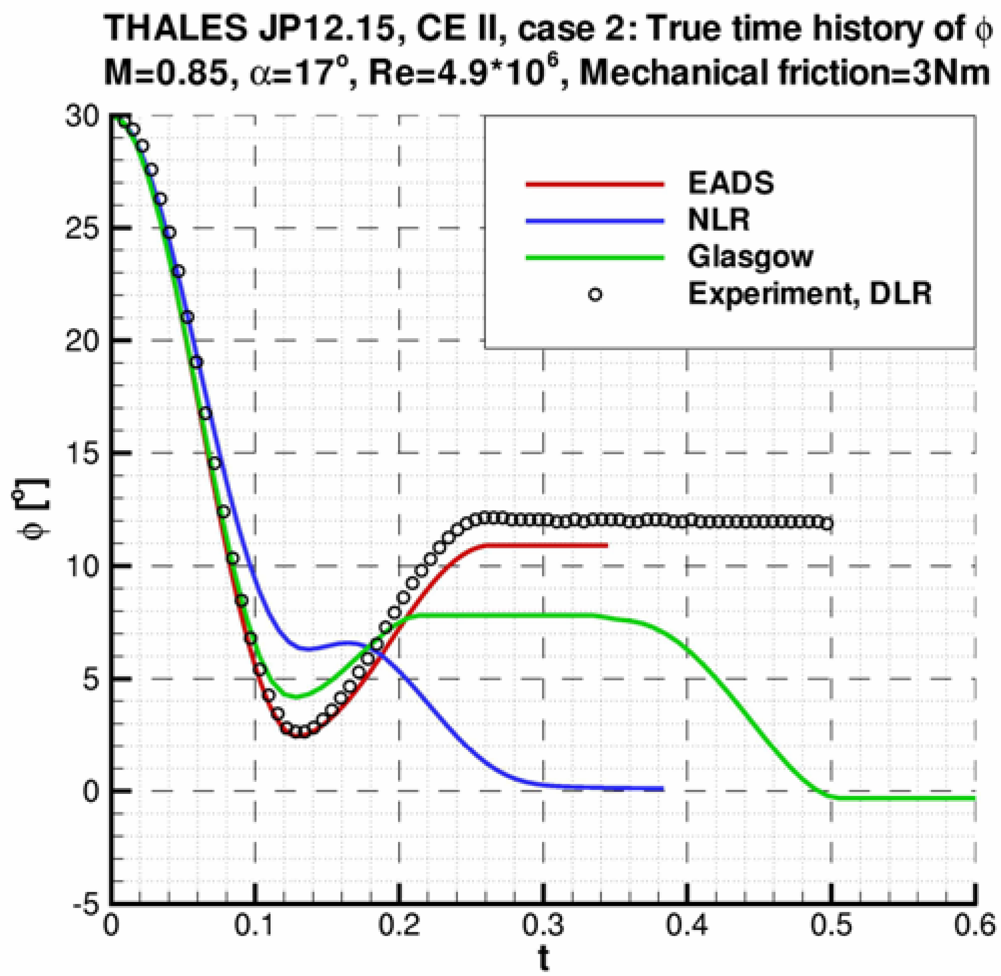
$Re_{CR}=4.9X10^6$

$\phi_o=30^o$

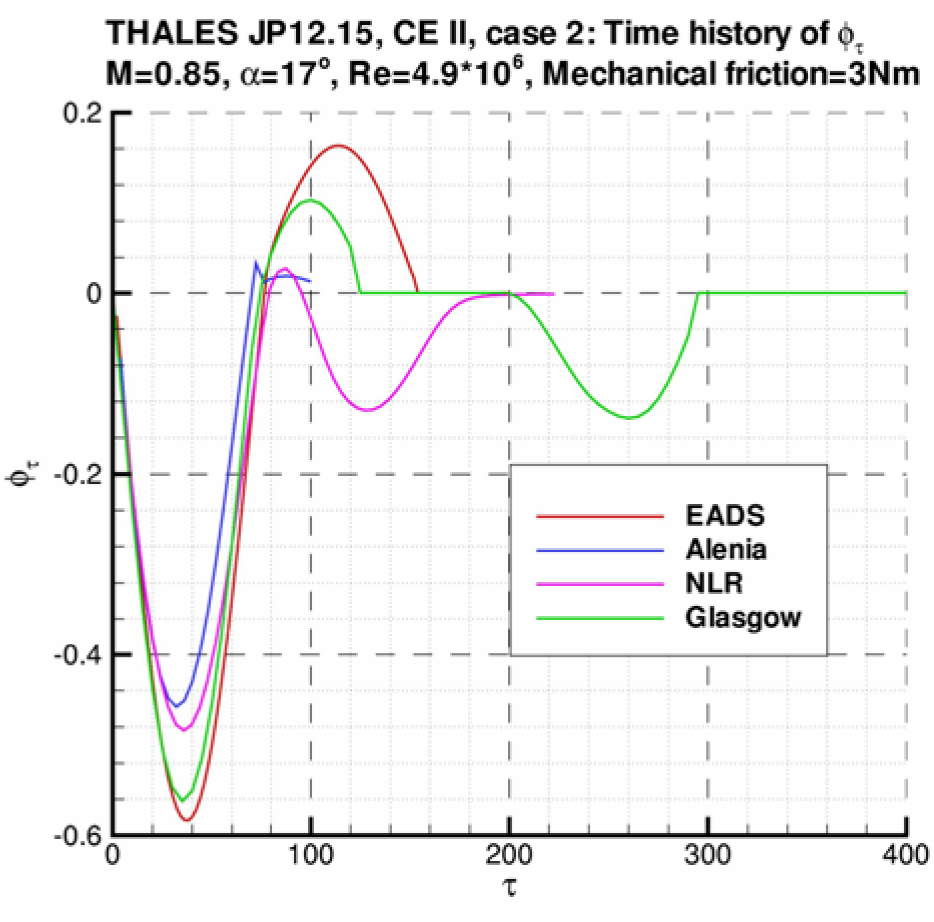
Time variation of ϕ, case 2

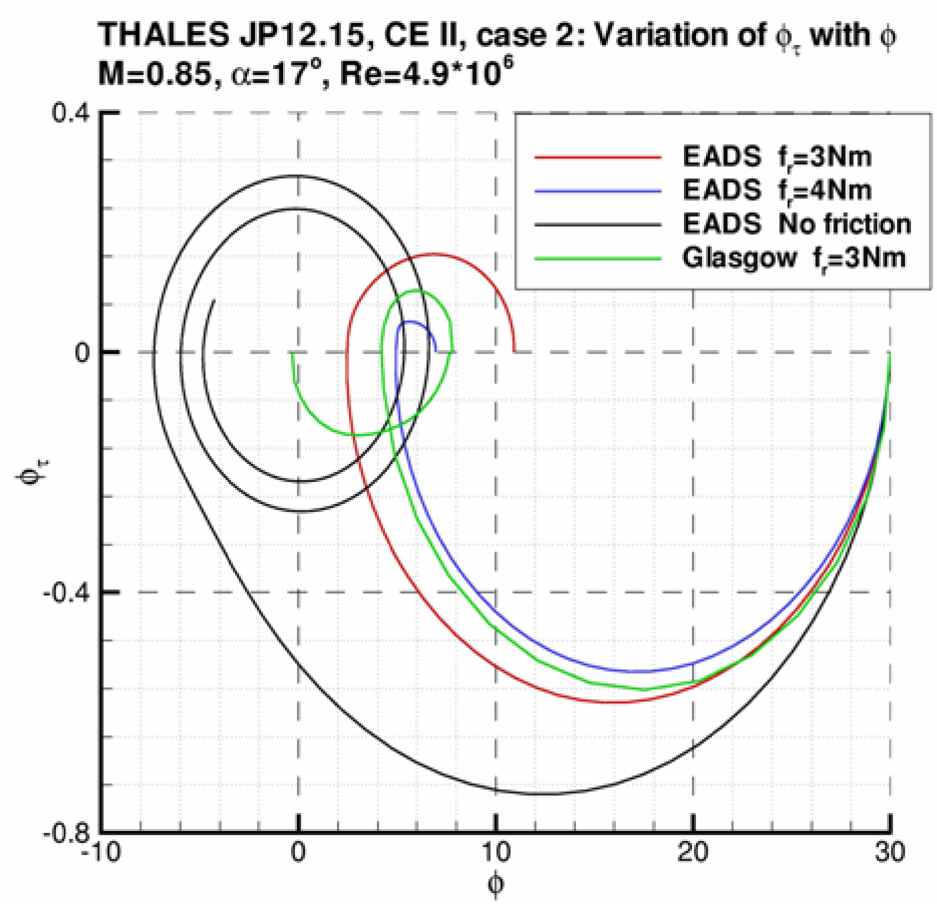






Time variations of ϕ_τ and c_l, case 2





Definition of example 3

Flow conditions:

M_∞=0.85, α=17°, Re_{CR}=4.8X10^6, U_∞ =281.79 m/s,

ρ_∞=0.6354 kg/m^3

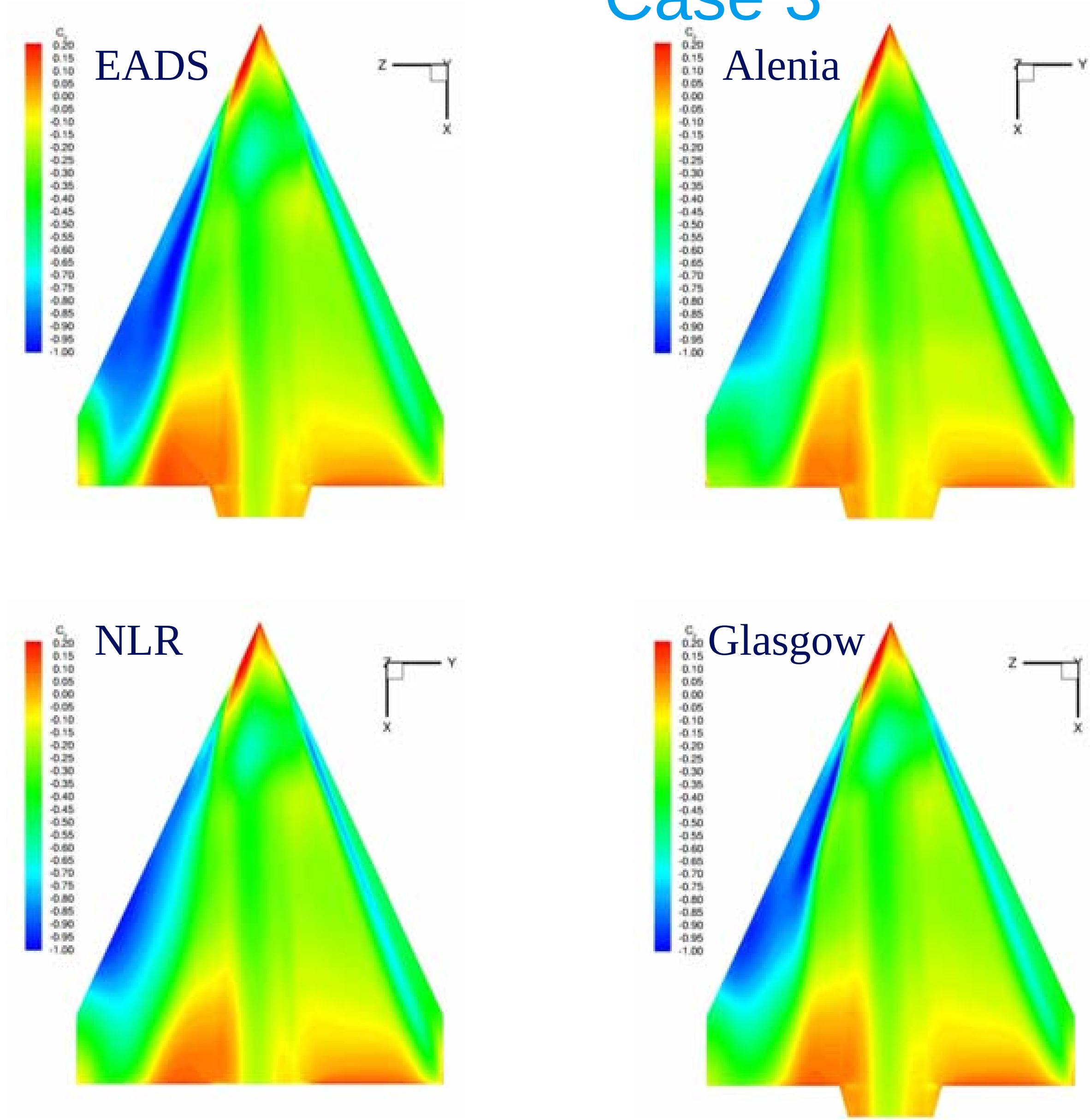
Initial condition:

ϕ_o=+60°

Coefficient of mechanical friction:

C_{lf}= 0.00578

Upper surface pressure distributions at start of motion
Case 3



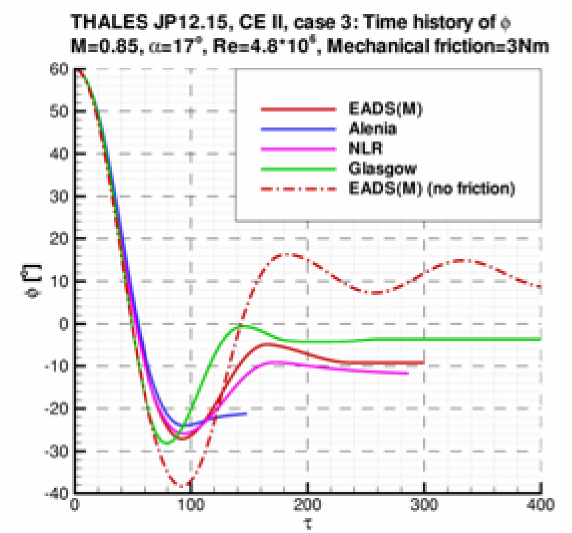
$M_{\infty}=0.85$

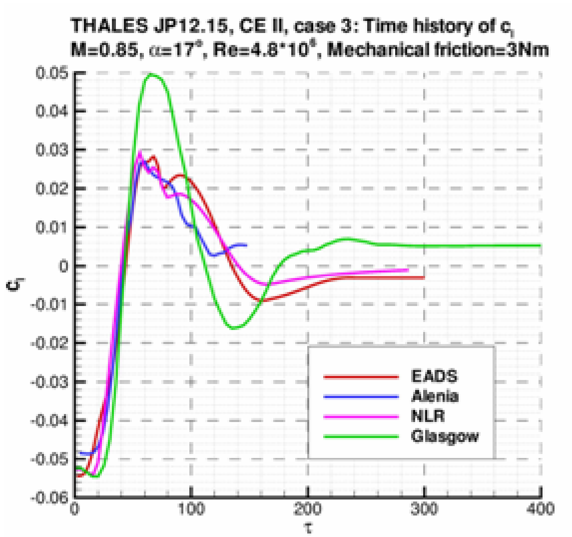
$\alpha=17^{o}$

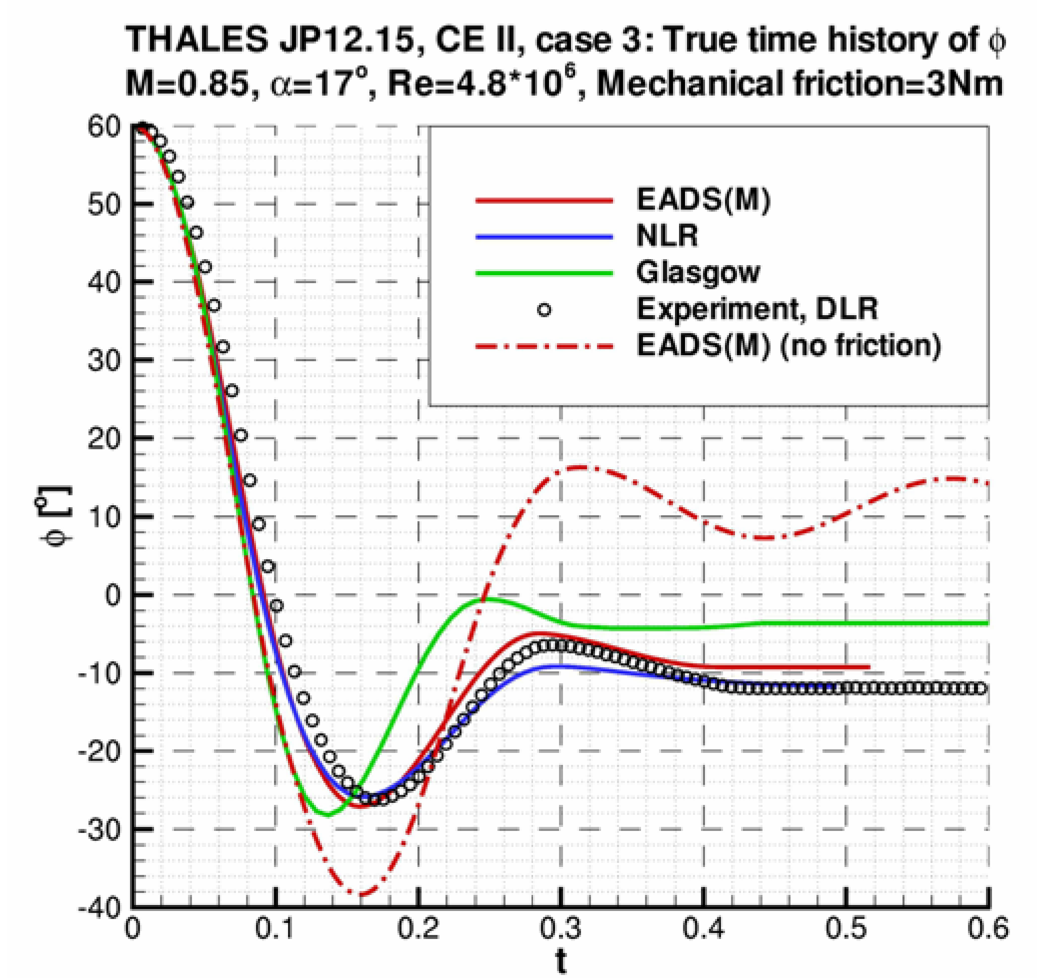
$Re_{CR}=4.8X10^{6}$

$\phi_{o}=60^{o}$

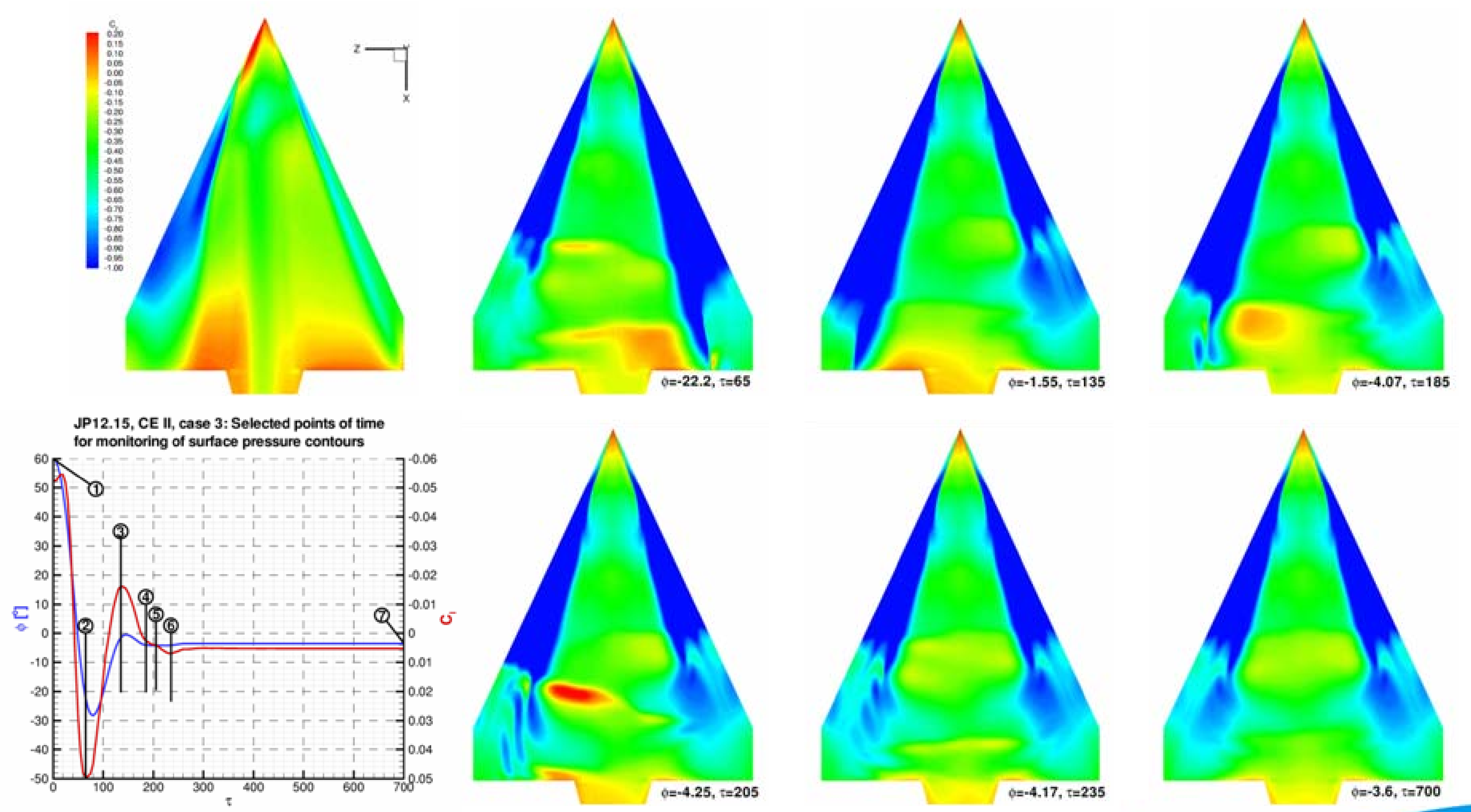
Time variation of ϕ and c_l, case 3







Surface pressure contours at selected points in time: Glasgow



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Conclusions

- The (computational) objectives of the exercise have been met
  - Navier-Stokes solvers have been coupled with a simple flight mechanics model
  - completion of a range of calculations has demonstrated that the methodology is robust
  - a complete calculation typically takes well under one day (wall clock time)
  - some of the damping characteristics of a delta wing configuration manoeuvring in roll have been explored

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Conclusions - continued

- Successful first step in the exploitation of CFD for the simulation of aircraft manoeuvre demonstrated
- Has the potential to
  – bridge the gap between wind tunnel and free flight
  – enable the exploration of manoeuvres difficult to perform in a wind tunnel
  – enable the exploration of manoeuvres dangerous to perform in flight
  – allow control surface operation to be incorporated

Conclusions - continued

- Marks one step in the development of a complete capability for the assessment of aircraft characteristics, taking into account aerodynamics, flight mechanics, control surface deployment, structural dynamics and power settings.