2nd AIAA CFD High Lift Prediction Workshop
High Lift Prediction using the Edge solver

by
Peter Eliasson, Shia-Hui Peng

Swedish Defence Research Agency (FOI)

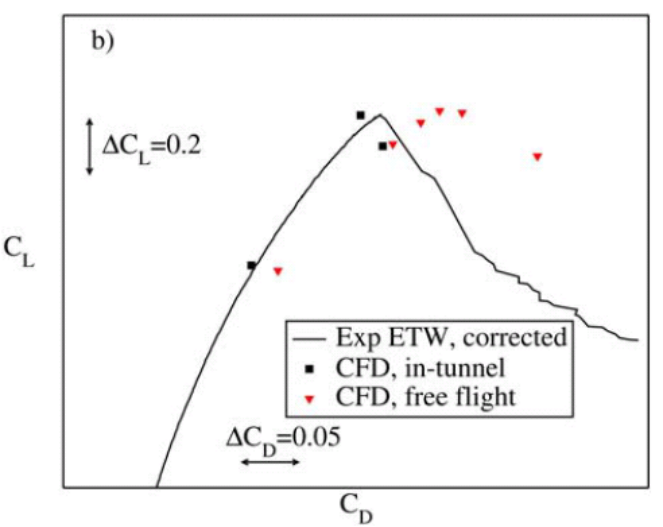
Contribution

- Case 1, Configuration 2
  - Grid convergence studies using DLR hybrid Solar grids (B_uns_mix_Case1Config2_v1)
  - Steady state RANS calculations with two turbulence models
    - ✓ Required angles
    - ✓ EARSM, submitted
    - ✓ SA, submitted except fine grid results
- Case 2a,2b Configuration 4
  - Grid convergence studies using DLR hybrid Solar grids (high/lowRe_medium/B_uns_mix_Case2Config4_v1)
  - Steady state RANS calculations with two turbulence models
    - ✓ Required angles
    - ✓ EARSM + SA, submitted

FOI

Background

- Familiar test case from EUROLIFT I, II and DESIREH
- Test cases used a lot in the past
- Example from EUROLIFT II
  - Investigation of installation effects on a take-off configuration
  - Wall/peniche caused some inboard effects
    - ✓ Leading to reduced drag
  - AIAA 2007-262; AIAA Journal 2008, Vol. 45, no. 1



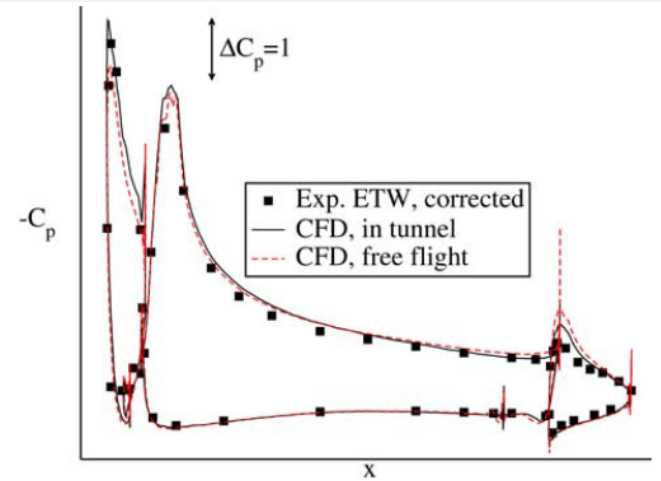


Figure 15. Pressure distributions, tunnel results corrected to free flight. *Angle at maximum lift α_2, 15% span.*

Grids from DLR

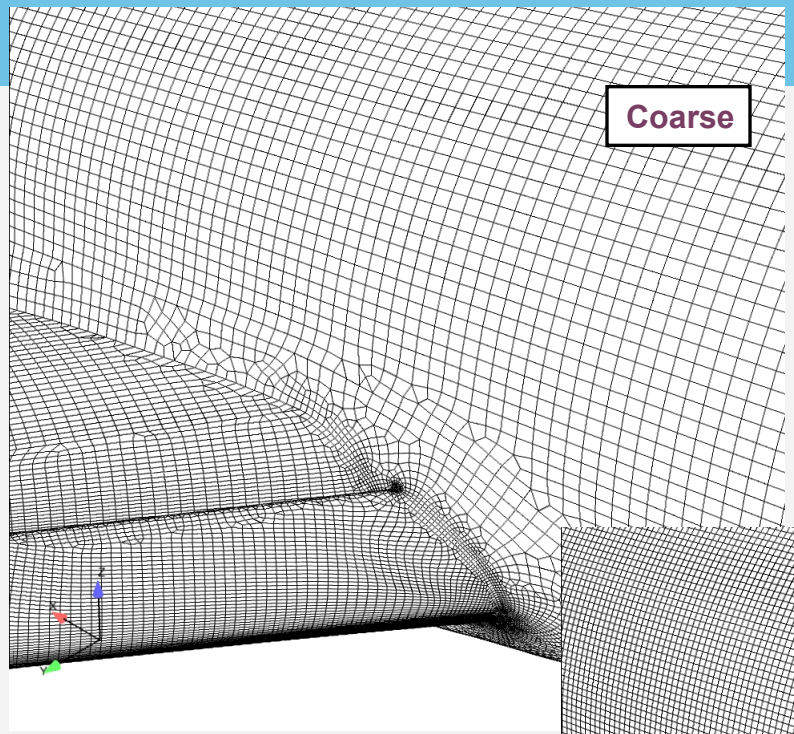
- Case1

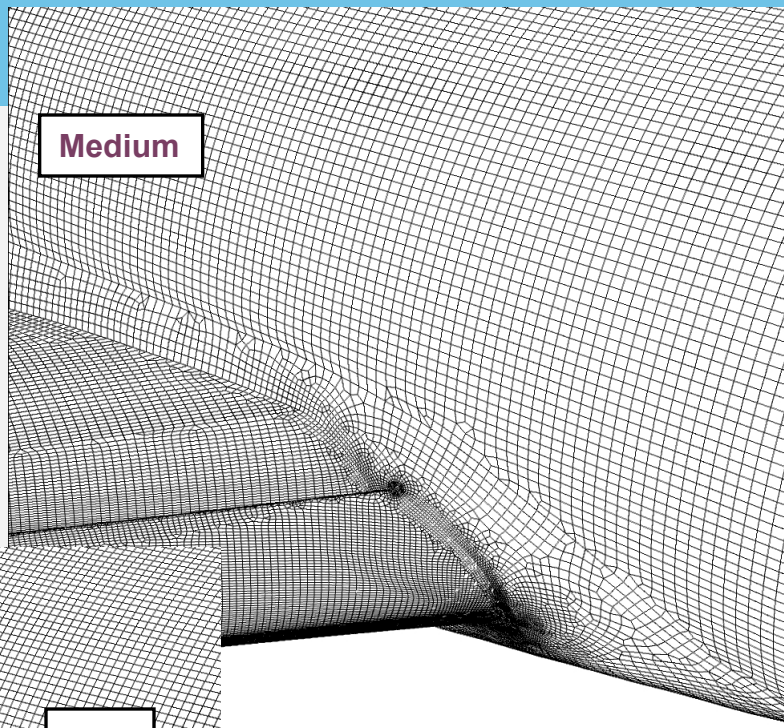
DLR grids, Config 1	Coarse	Medium	Fine
# nodes	9.2×10^6	25.6×10^6	73.4×10^6
# boundary nodes	409×10^3	848×10^3	1770×10^3
# hexahedral elements	6.5×10^6	18.6×10^6	55.0×10^6
# prisms	34×10^3	96×10^3	195×10^3
# tetrahedral elements	14×10^6	39.5×10^6	108×10^6

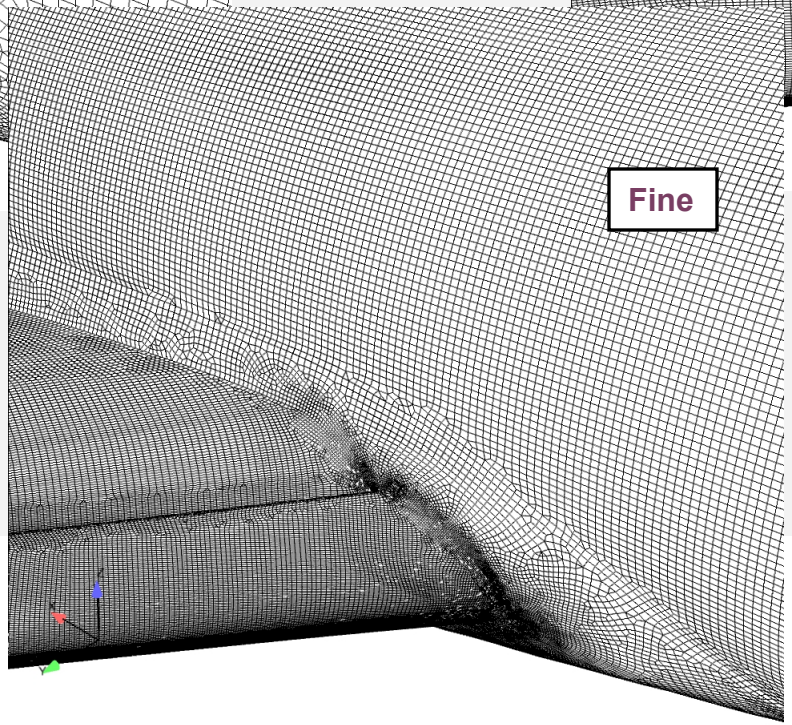
- Case2
  - Low Re 3bout 35 m nodes
    - About 37.3 m nodes
  - High Re
    - About 32.4 m nodes

FOI

Grid pictures







Edge flow solver

- Finite volume, node centered, edge-based
- 3-4 level W-cycles, full multigrid
  - Semi coarsening, 1:4
- 3-stage Runge-Kutta scheme, CFL=1.25
- Line-implicit time integration in regions with stretched grids
- Central scheme with artificial dissipation for mean flow and turbulence
- Full NS, compact discretization of normal derivatives
- Weak boundary conditions on all variables including no-slip velocity

- All solutions started from free stream
- Linux cluster used, up to 128 processors
  - Computing time up to 10 day for finest grids and 40.000 iterations

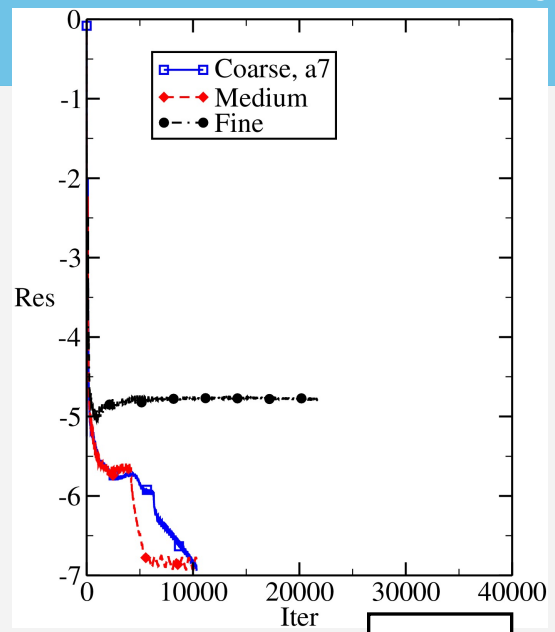
FOI

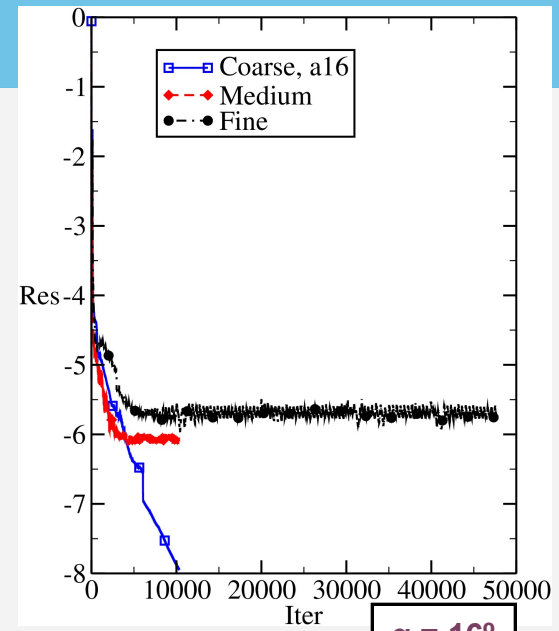
Turbulence models

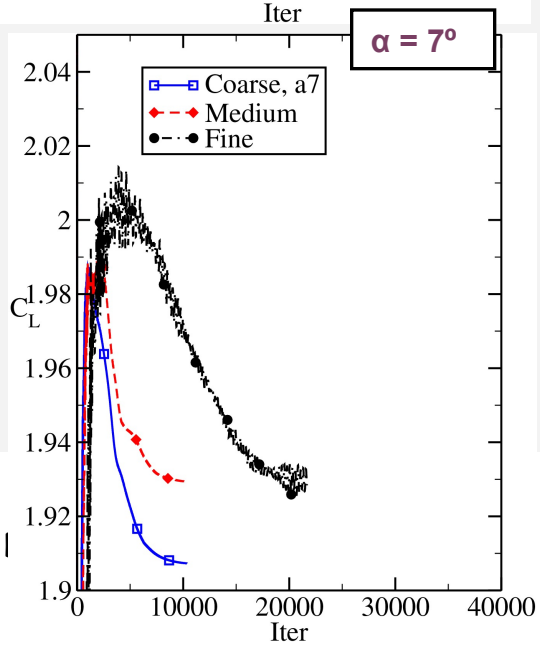
- Explicit Algebraic Reynolds Stress Model (EARSM)
  - Wallin, S., Johansson, A. V., "An Explicit Algebraic Reynolds Stress Model for Incompressible and Compressible Turbulent Flows," Journal of Fluid Mechanics, Vol. 403, 2000, pp. 89-132
  - Hellsten, A., "New Advanced k-ω Turbulence Model for High Lift Aerodynamics," AIAA Journal, Vol. 43, No. 9, 2005, pp. 1857-1869
  - Standard implementation
- Spalart-Allmaras model
  - Spalart, P. R., and Allmaras, S. R., "A One-Equation Turbulence Model for Aerodynamic Flows", AIAA Paper 92-0439, 1992.
  - Standard implementation but cross diffusion written as diffusive and anti-diffusive term

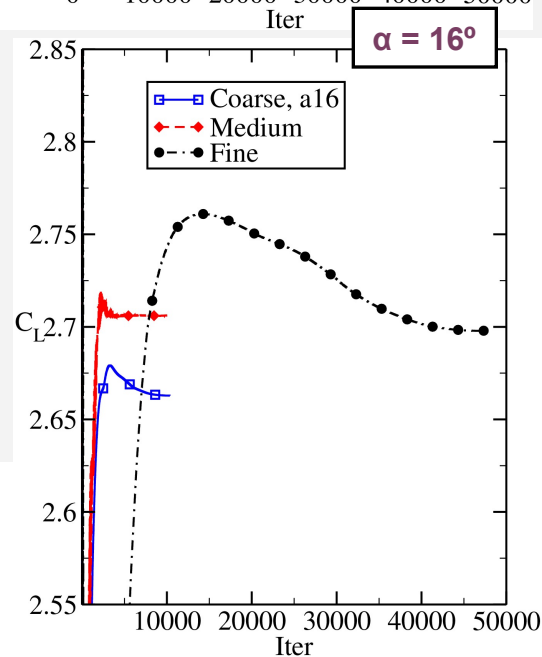
Case1, grid refinement study

- Steady state convergence rates
  - SA
  - EARSM similar or worse





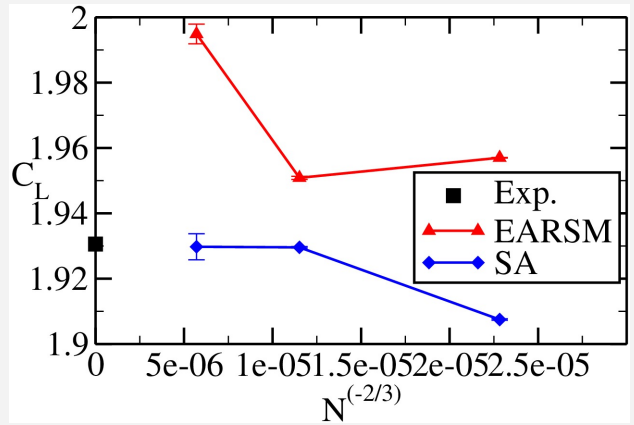




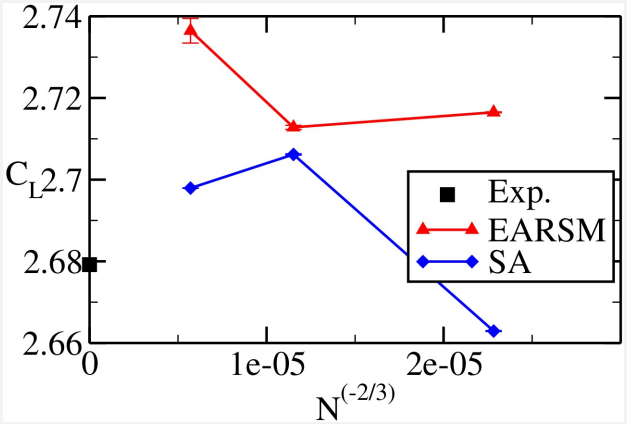
San I

Case1, grid convergence of forces

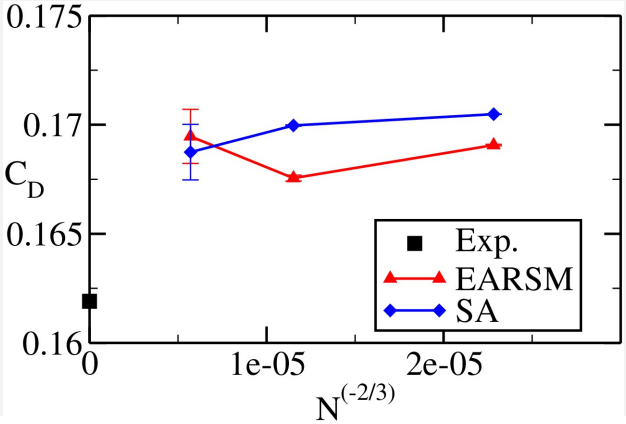
- Observations
  - Minor oscillations at finer grids
  - High fine grid C_L with EARSM

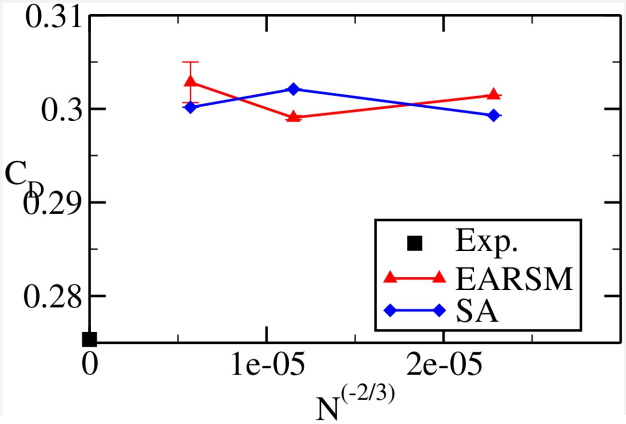


α = 7°



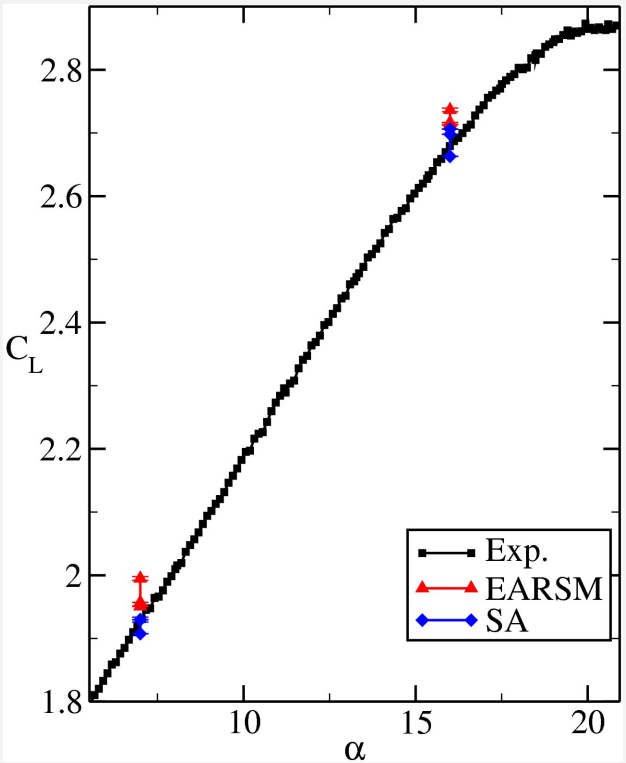
α = 16°

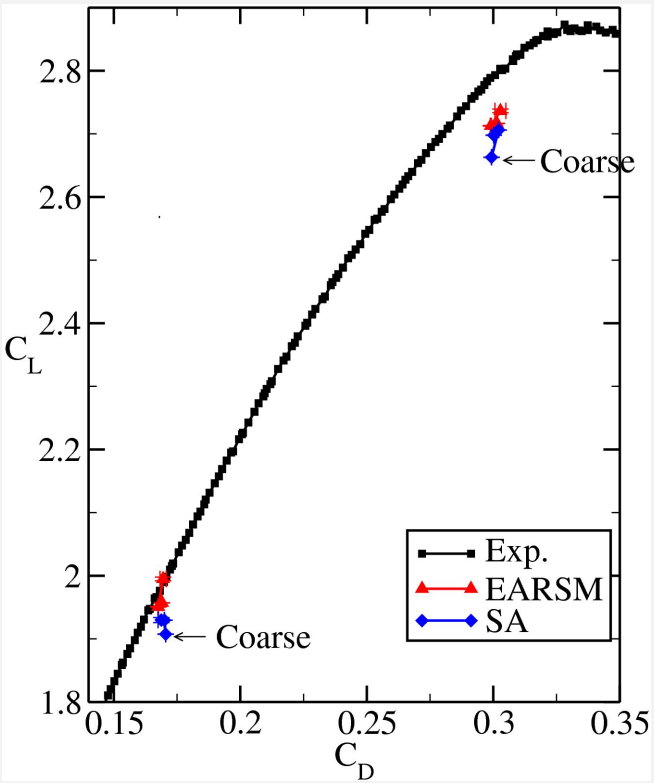




Case1, grid convergence of forces

- Over prediction of C_D

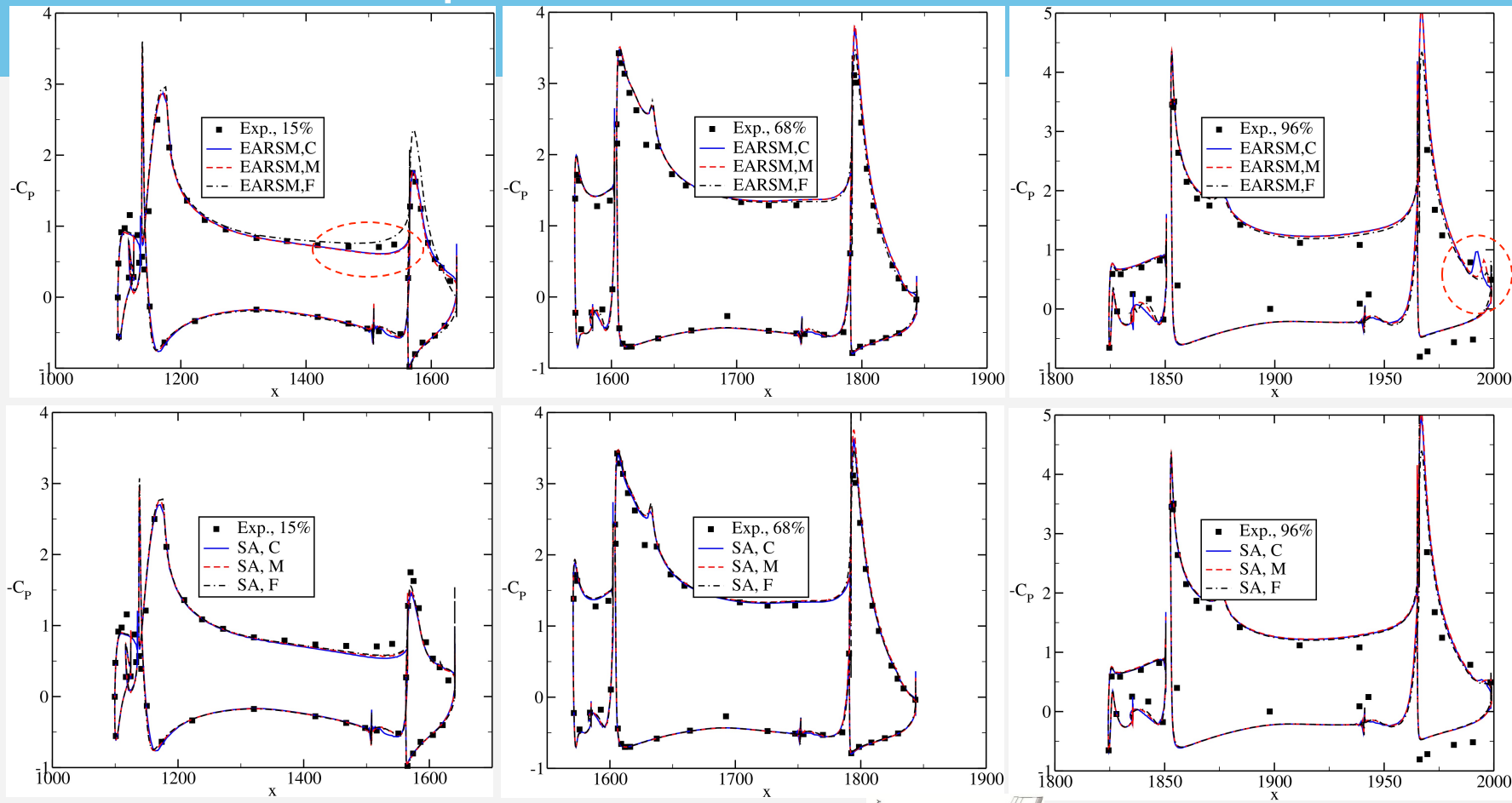


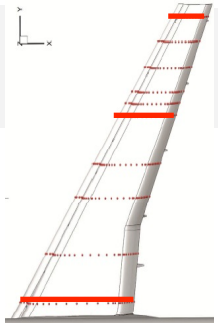


Case1, Cp, alfa 7

EARSM

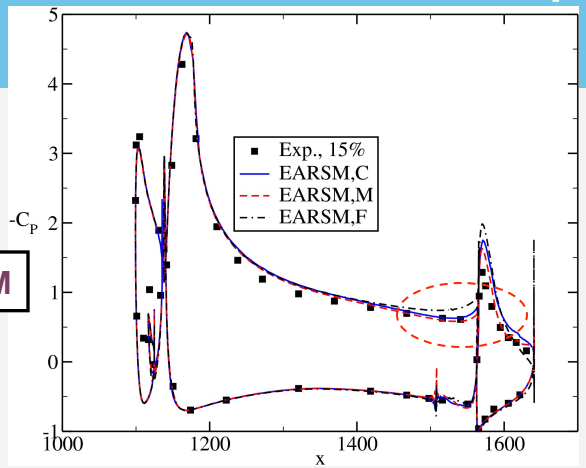
SA

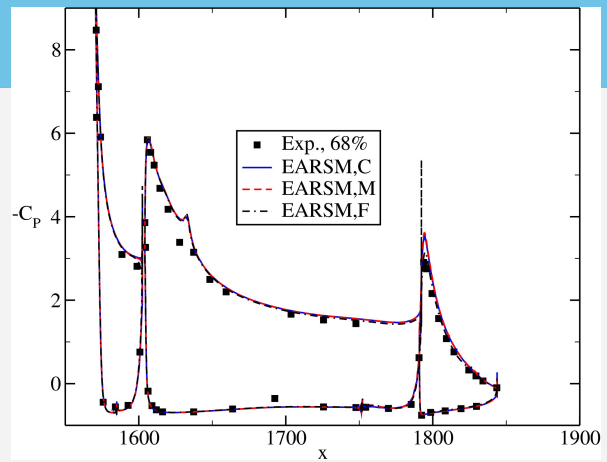


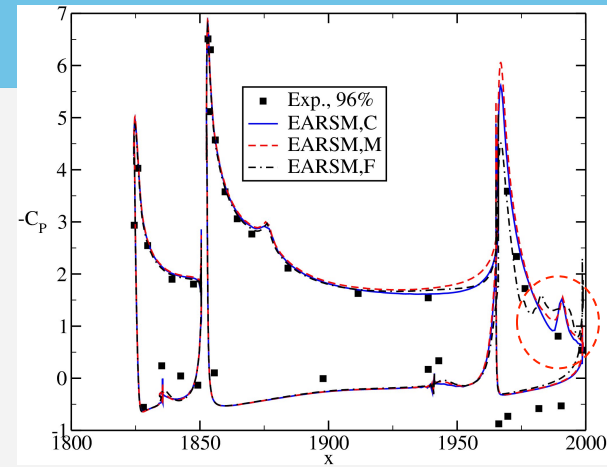


Case1, Cp, alfa 16

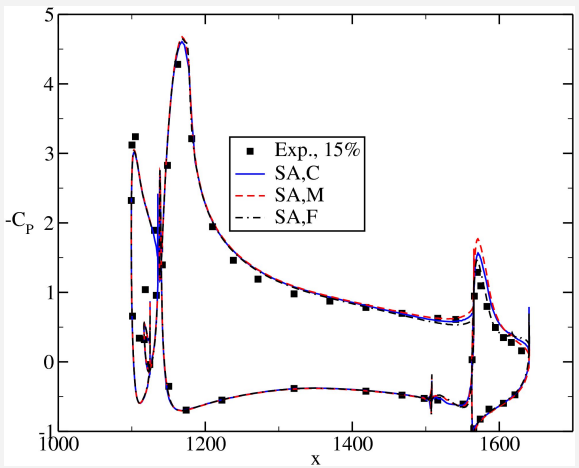
EARSM

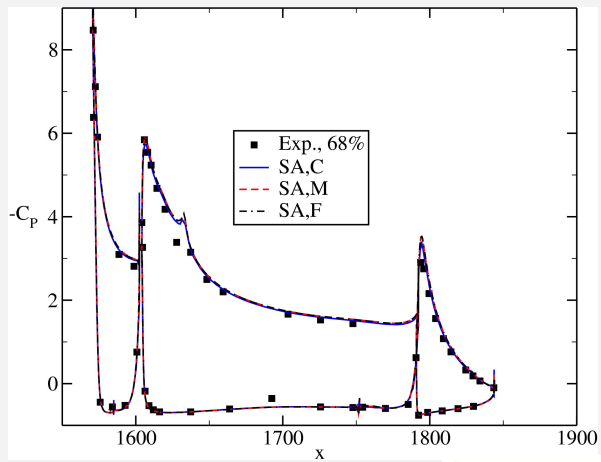


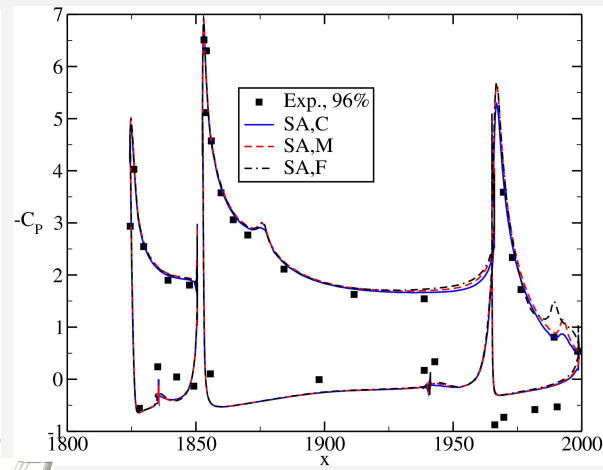


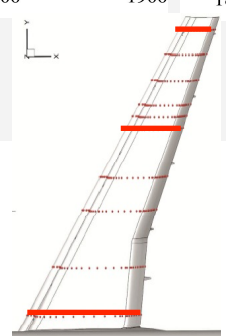


SA

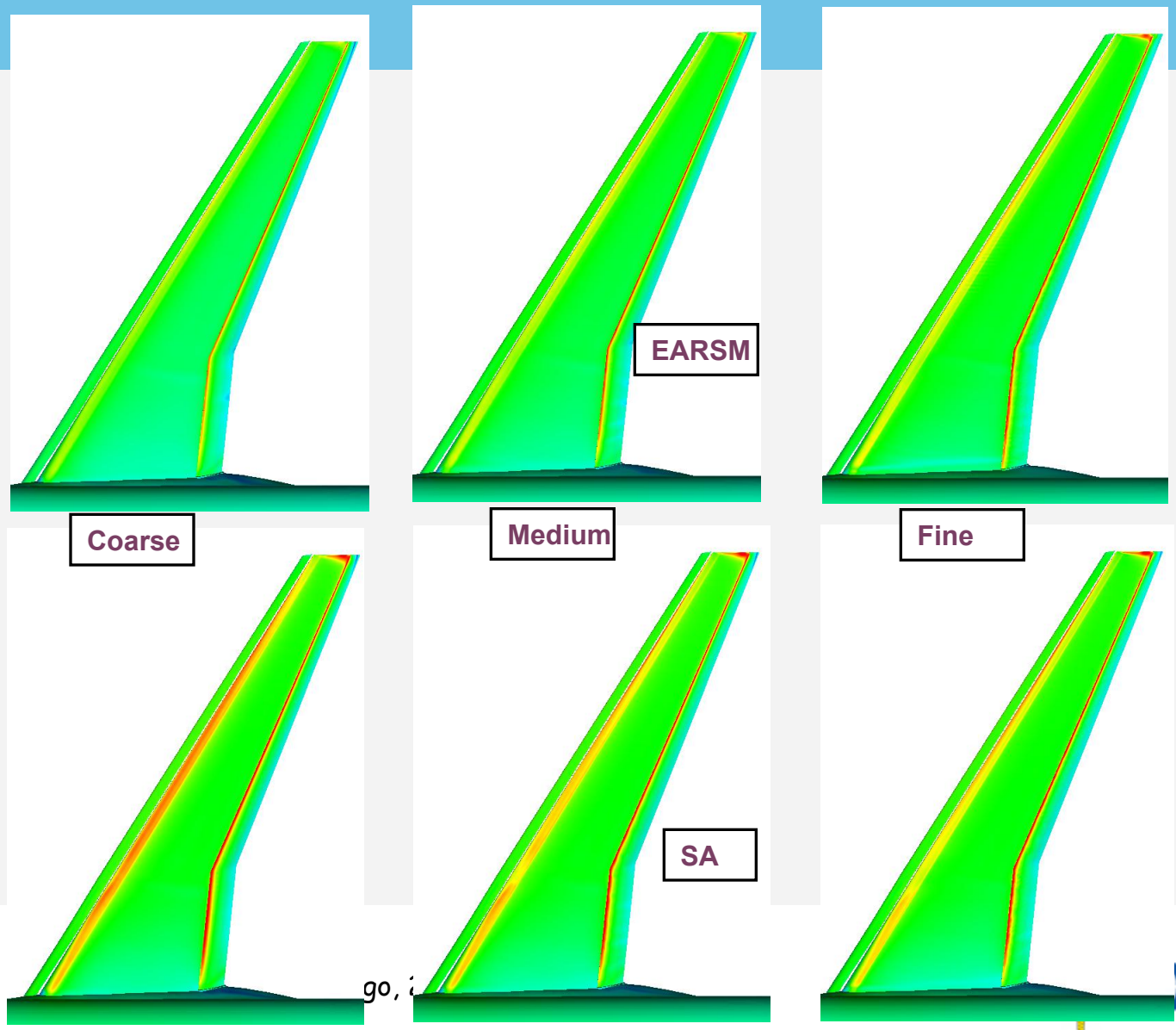




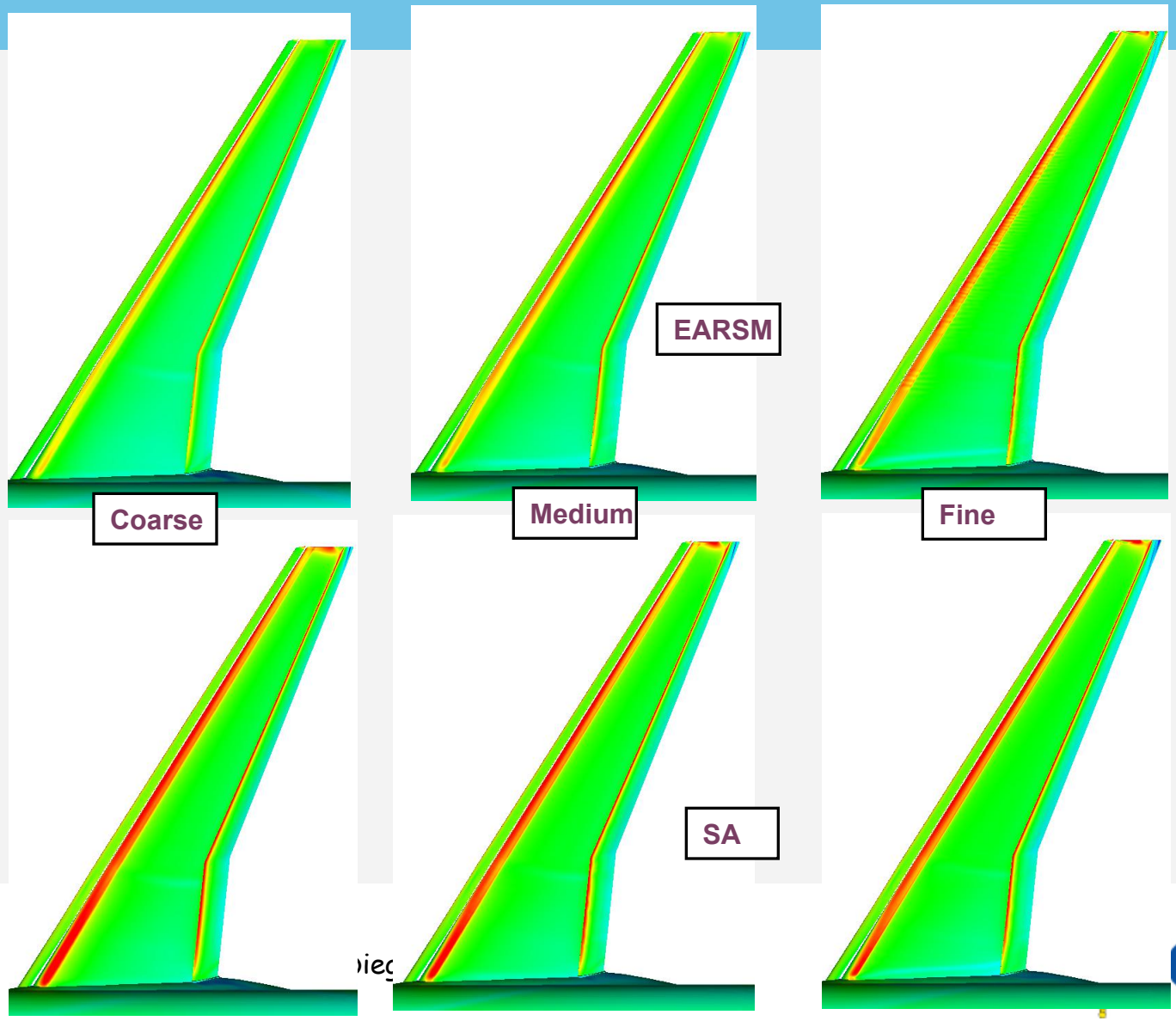




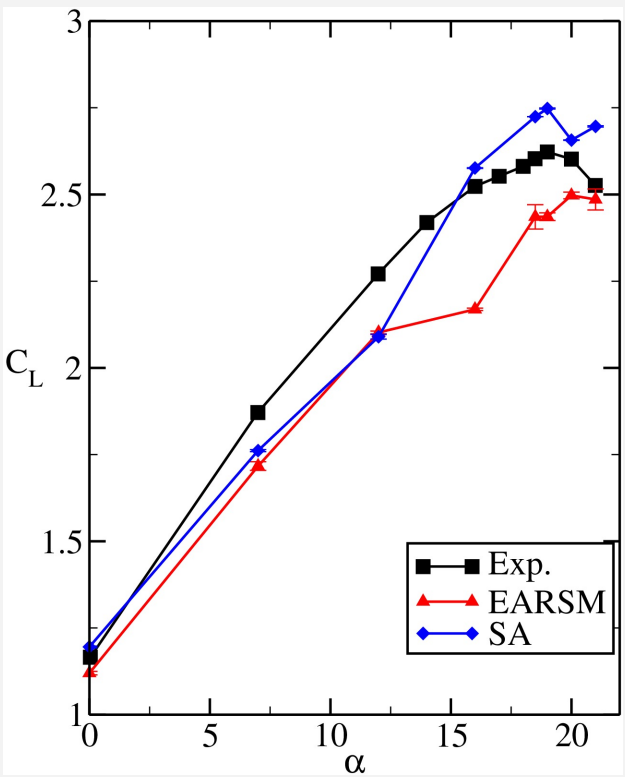
Case1, Skin friction, alfa 7

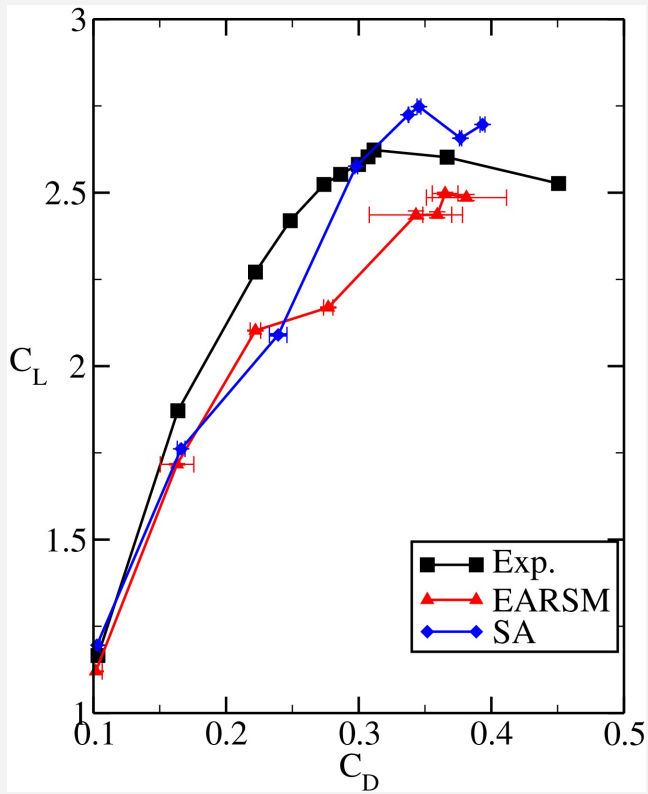


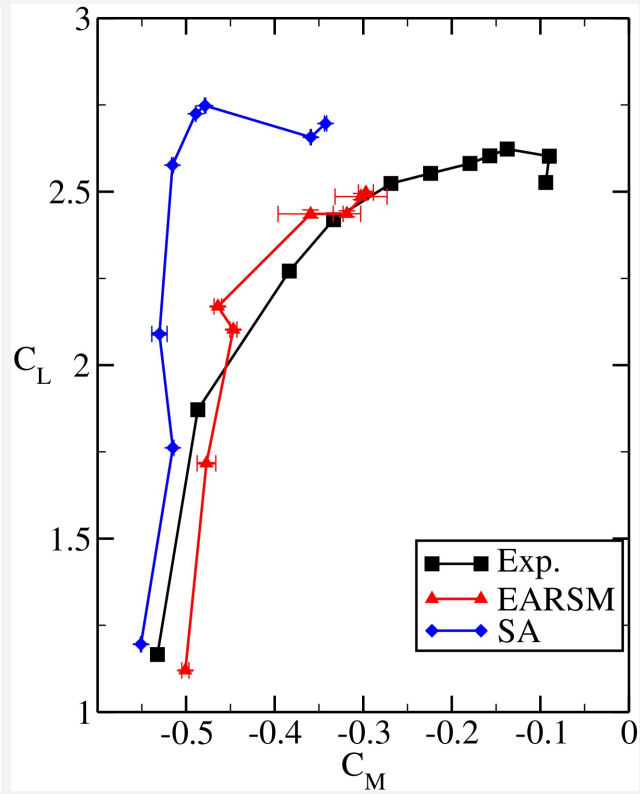
Case1, Skin friction, alfa 16



Case2a (low Re), Forces and moments

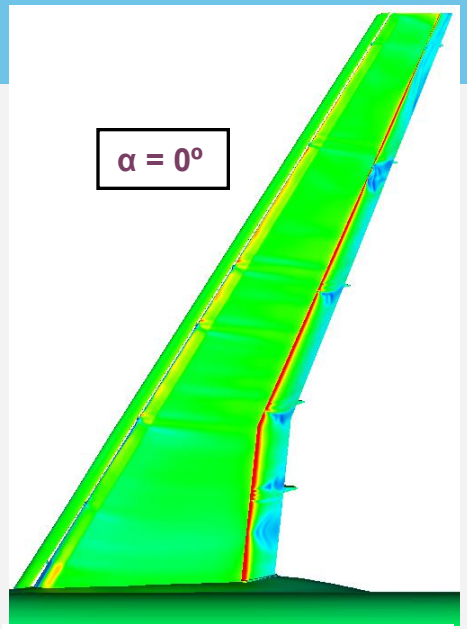


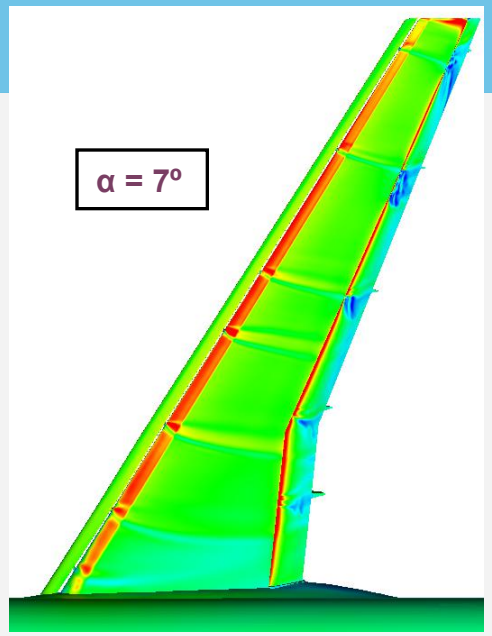


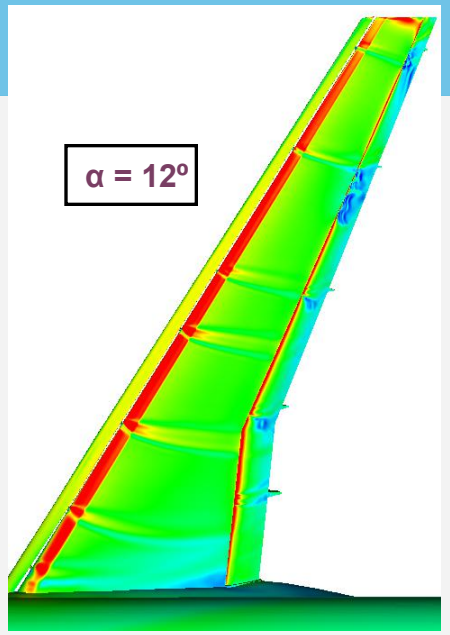


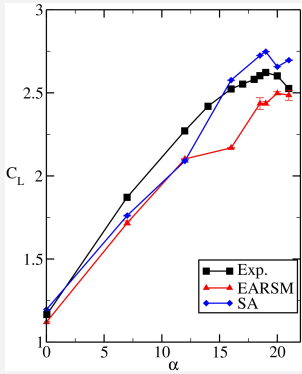
- SA over predicts max C_L
- EARSM under predicts max C_L

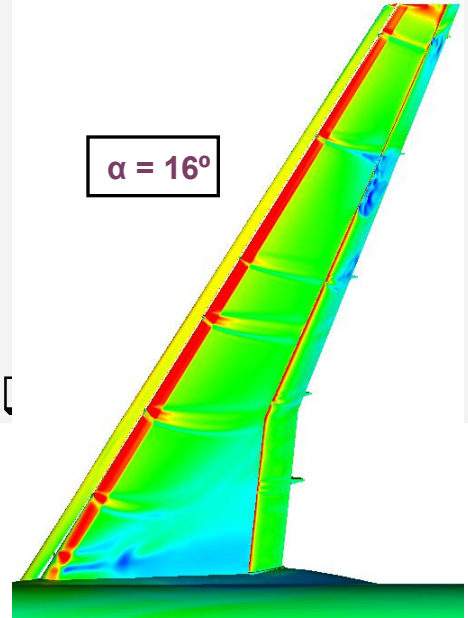
Case2a, Cf, EARSM

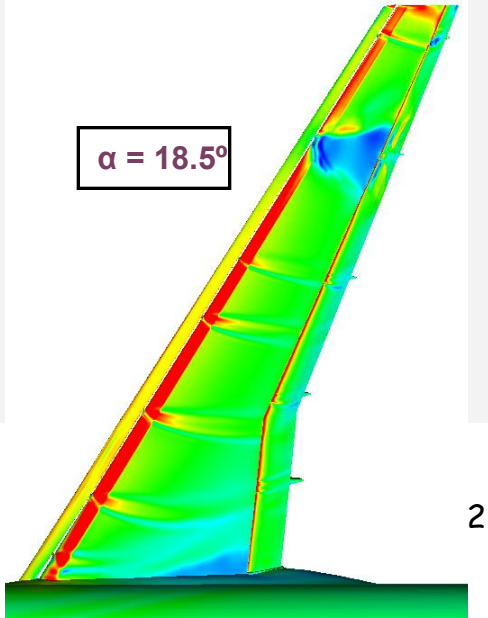


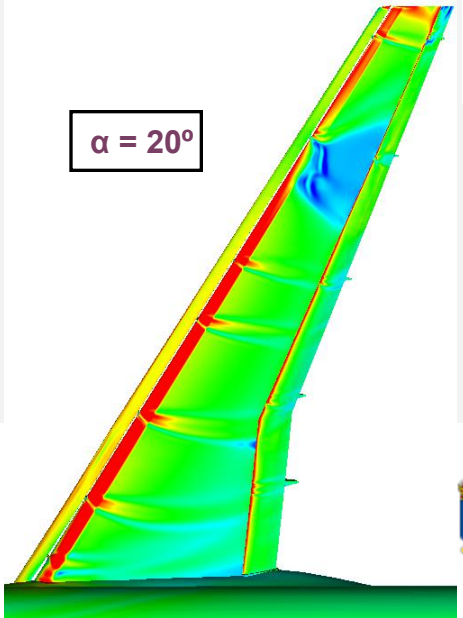




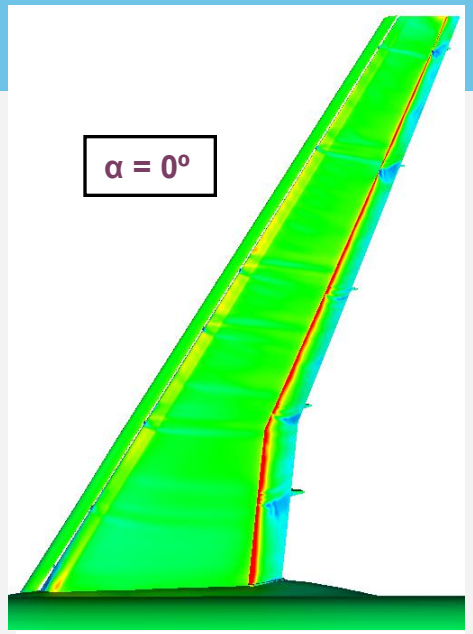


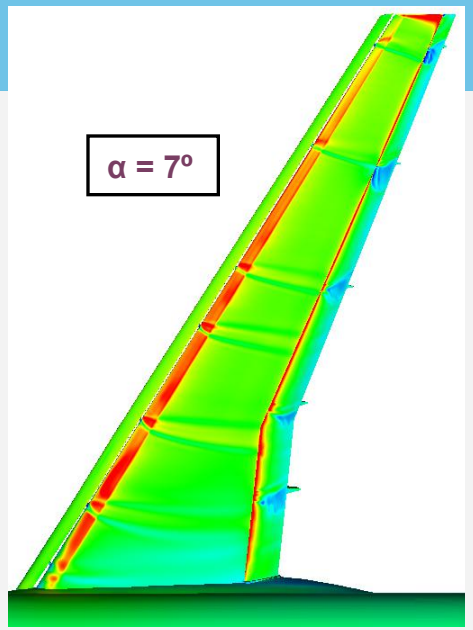


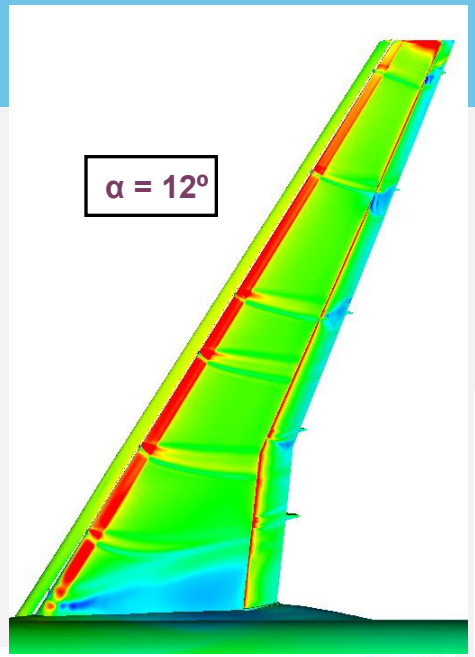


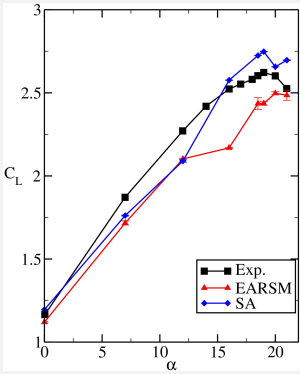


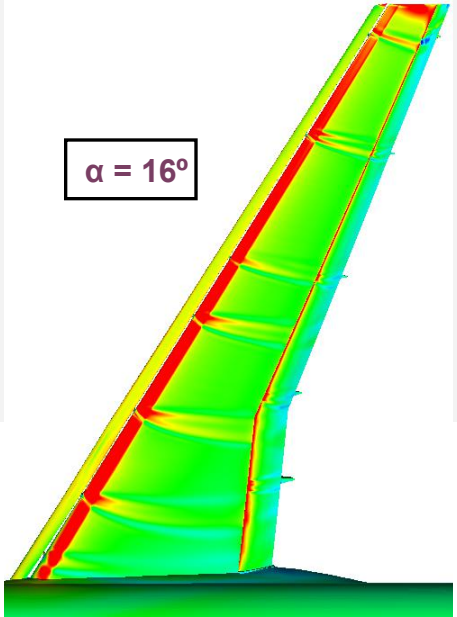
Case2a, Cf, SA

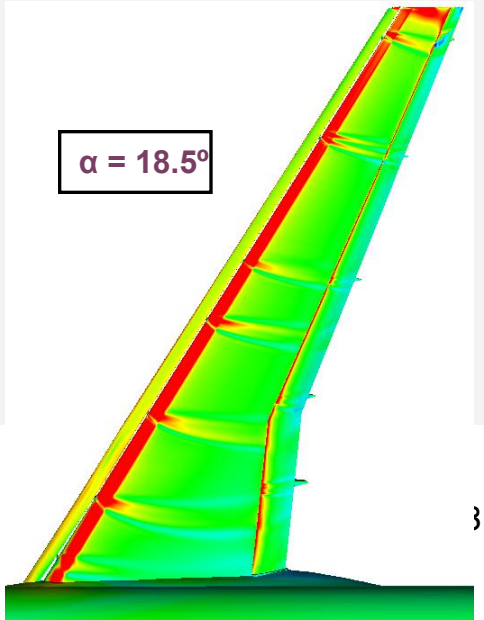


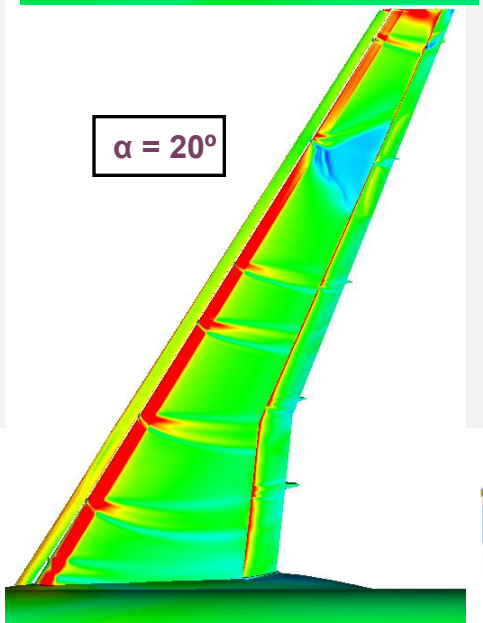






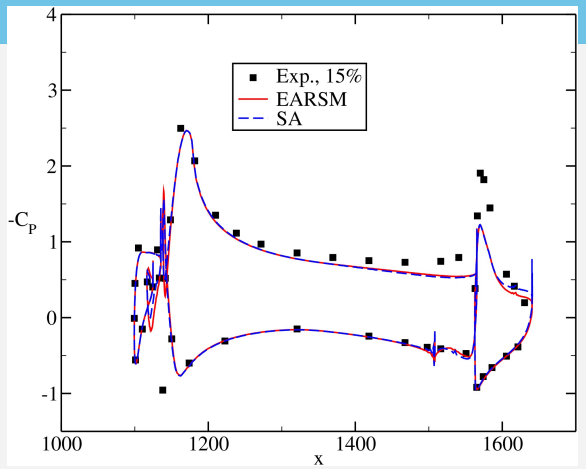


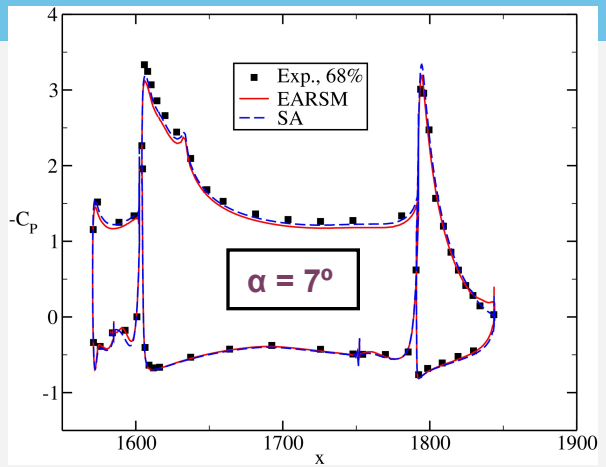


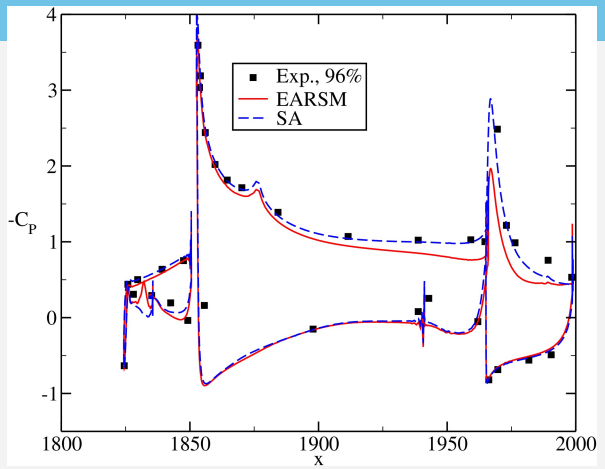


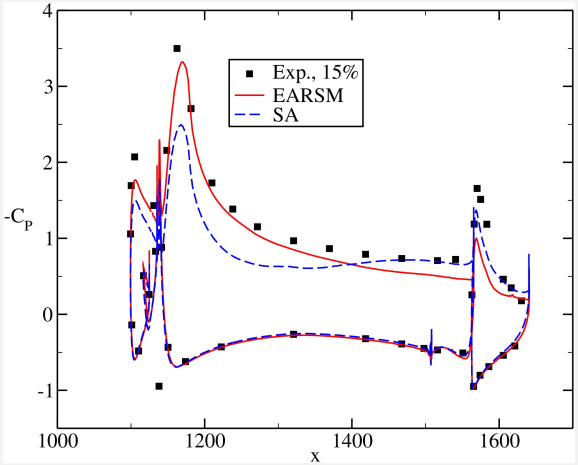
FOI

Case2a, Cp, alfa 7, 12

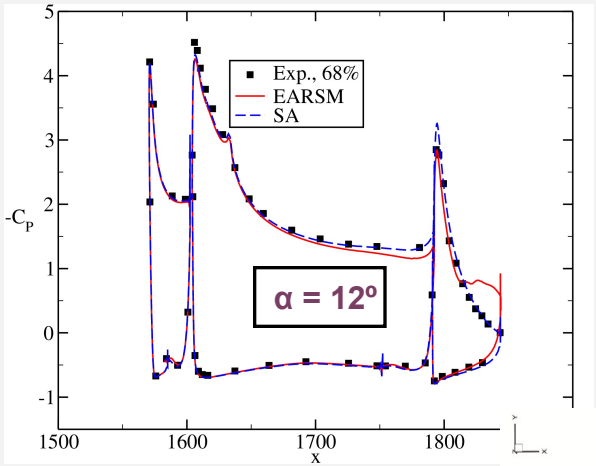




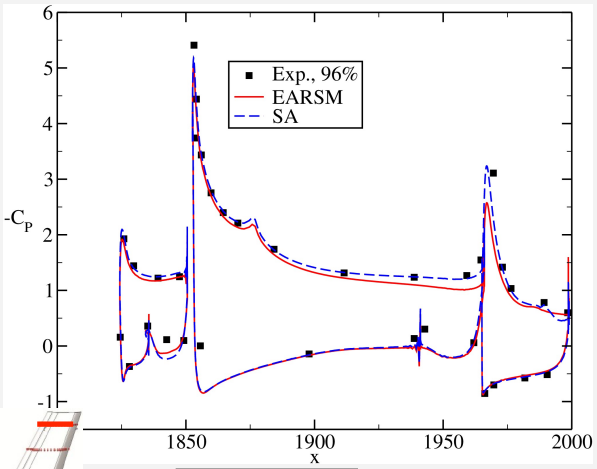




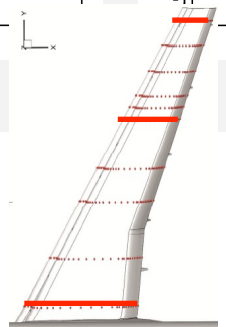
15% span



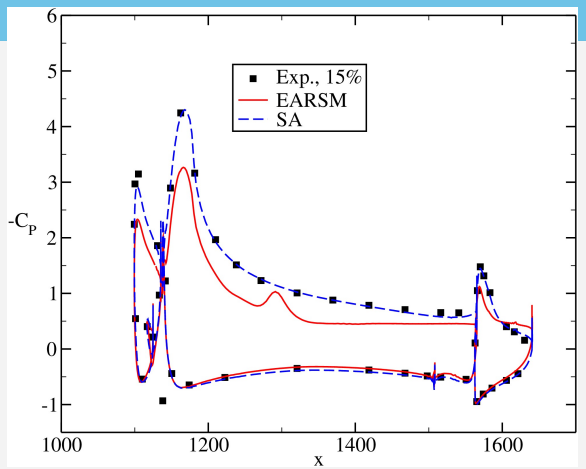
68% span

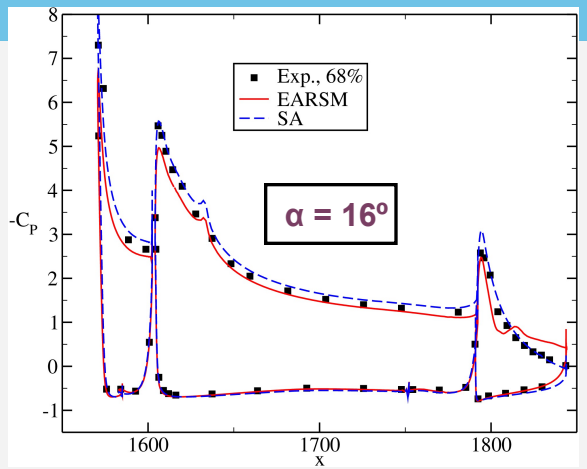


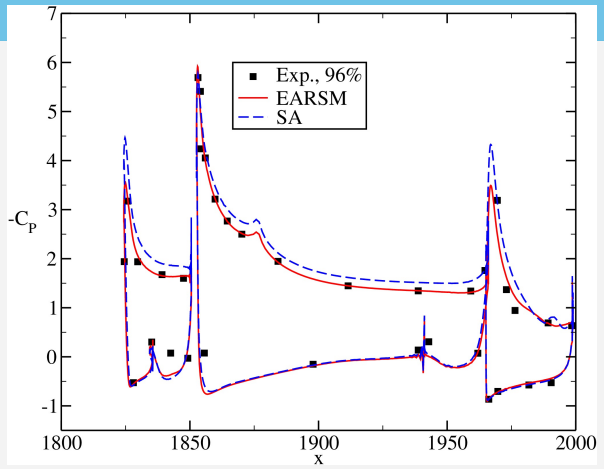
96% span

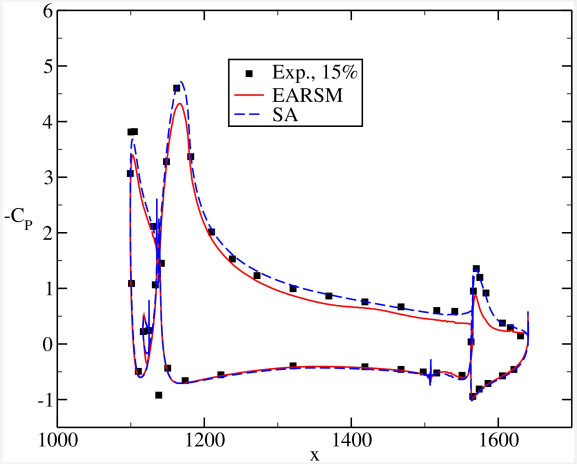


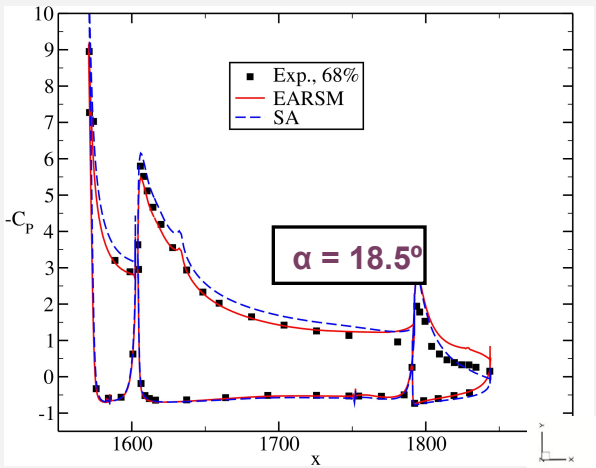
Case2a, Cp, alfa 16, 18.5

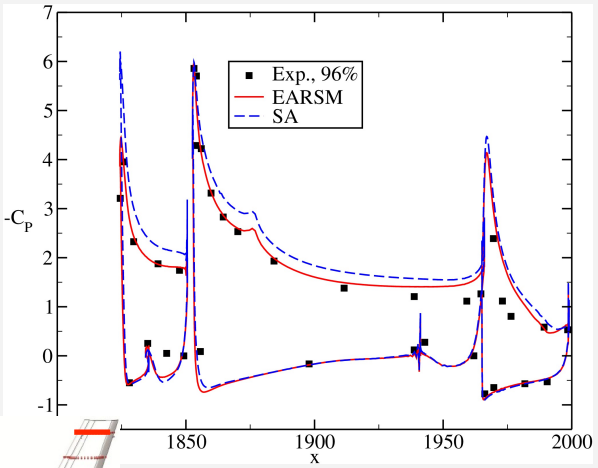








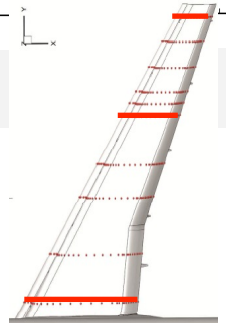




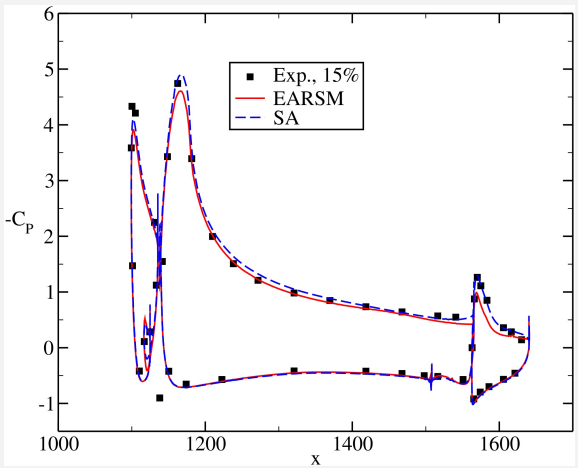
15% span

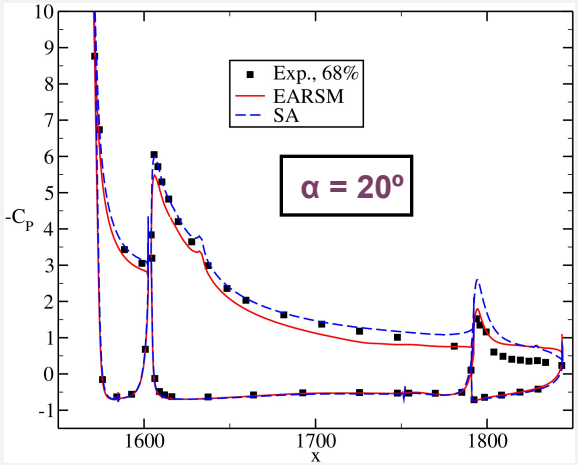
68% span

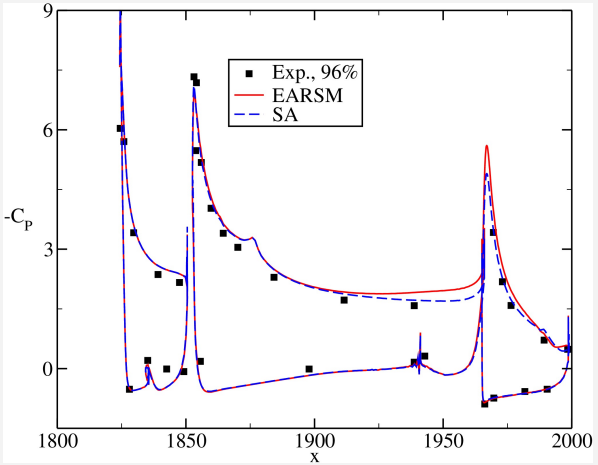
96% span



Case2a, Cp, alfa 20

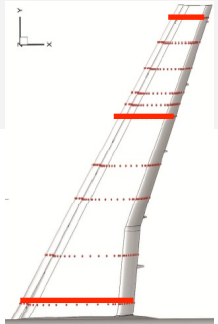






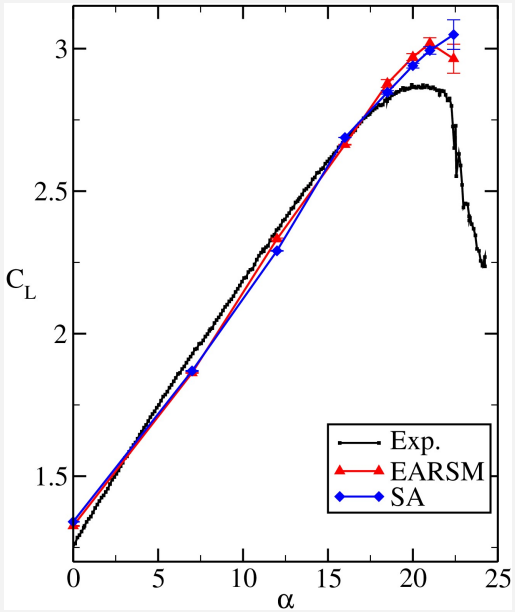
15% span

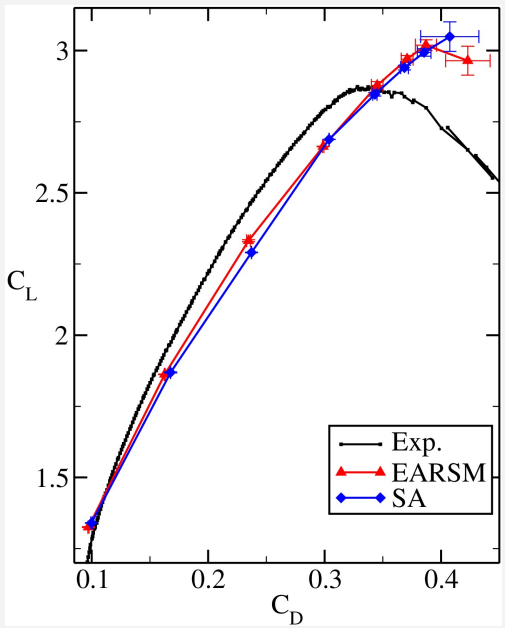
68% span

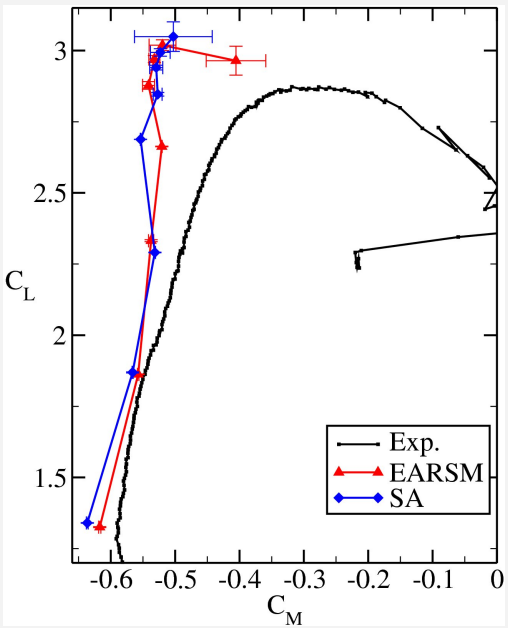


96% span

Case2b (high Re), Forces and moments

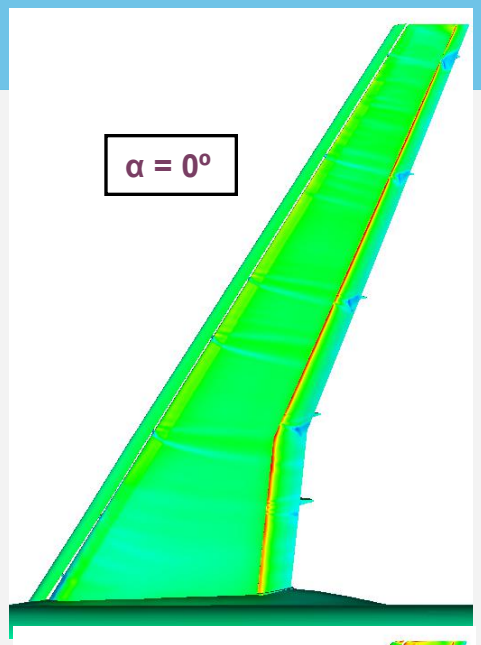


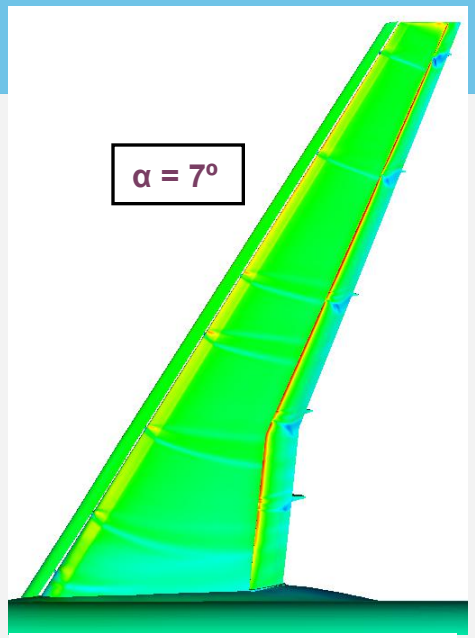


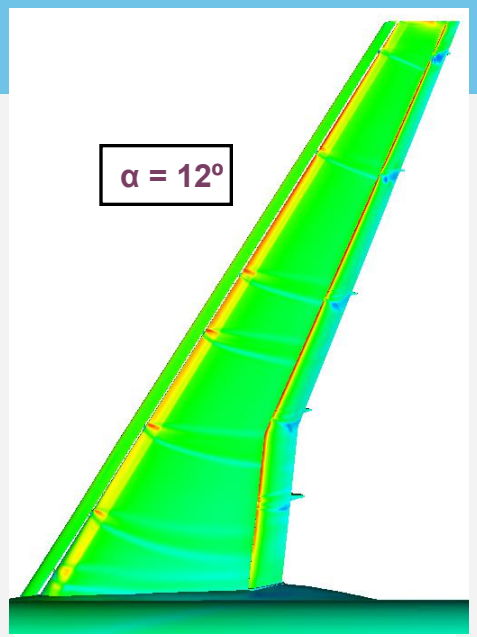


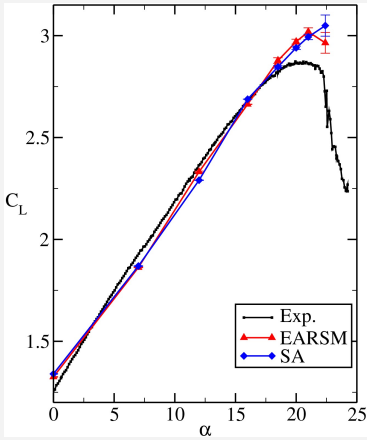
- Max C_L over predicted
- C_D over predicted
- C_M ?

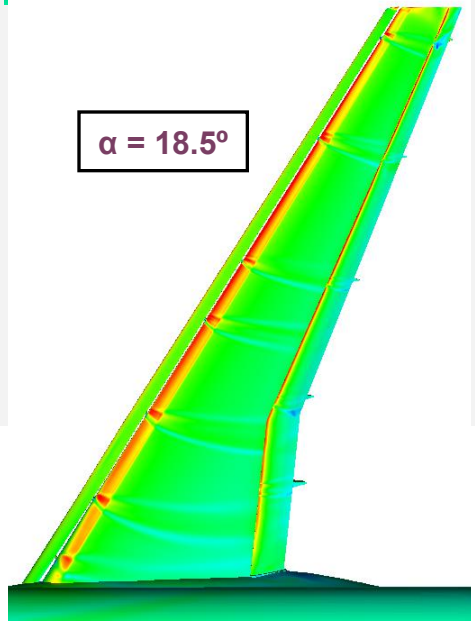
Case2b, Cf, EARSM

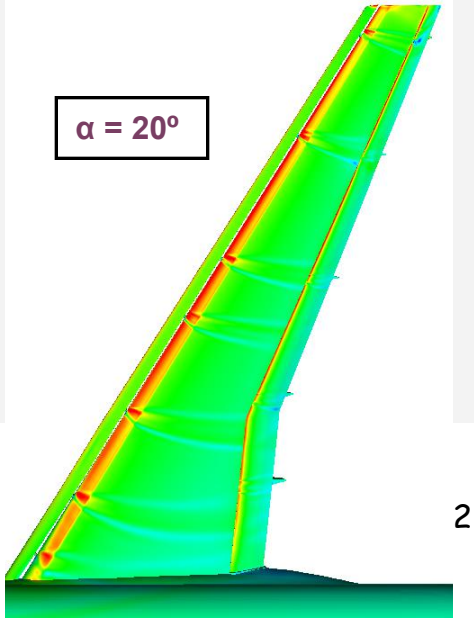


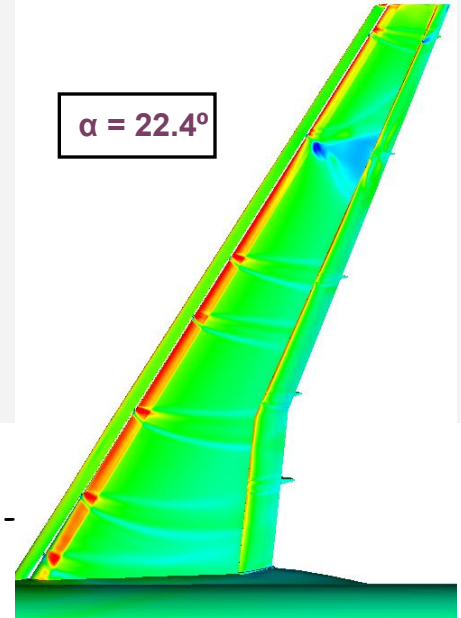




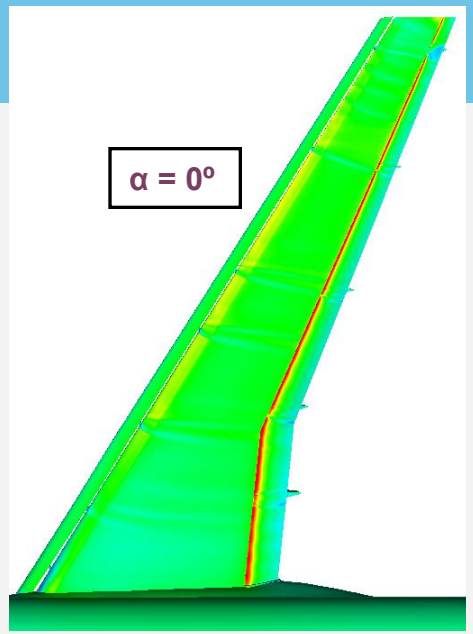


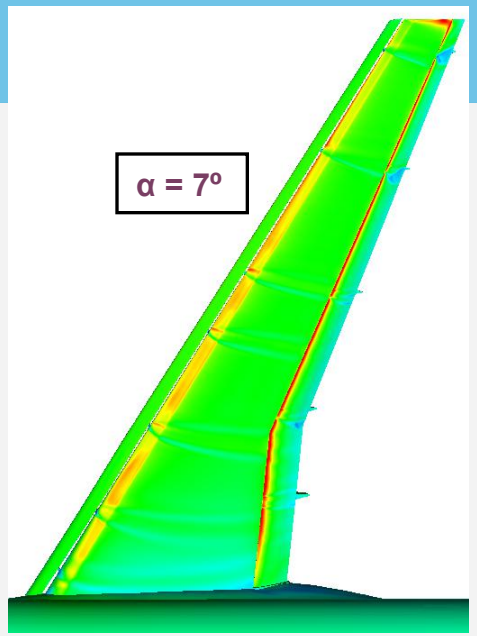


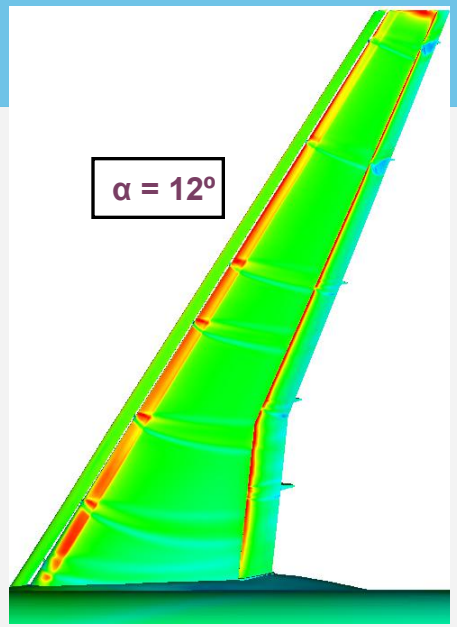


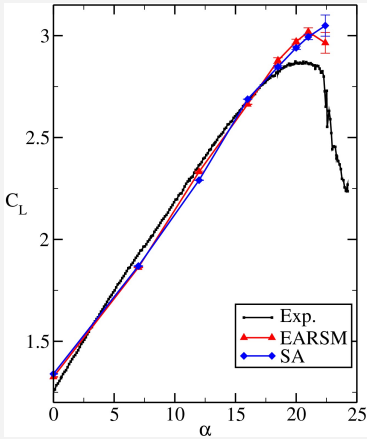


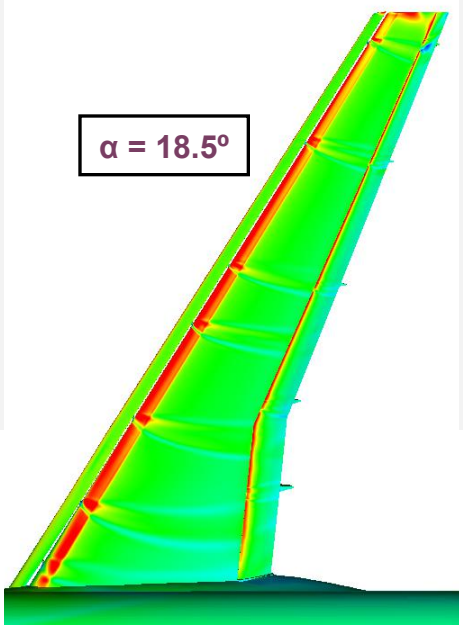
Case2b, Cf, SA

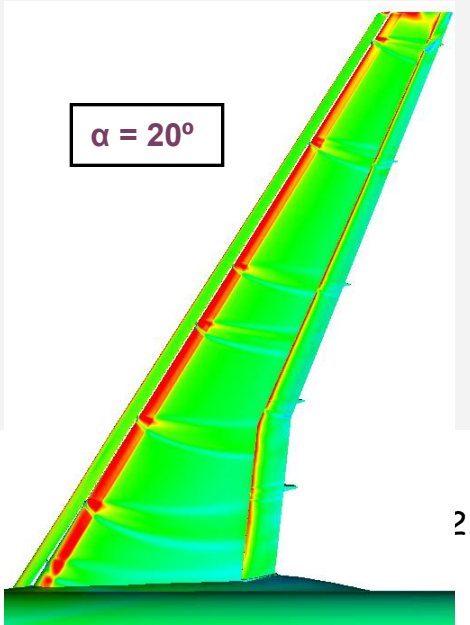

α = 0º

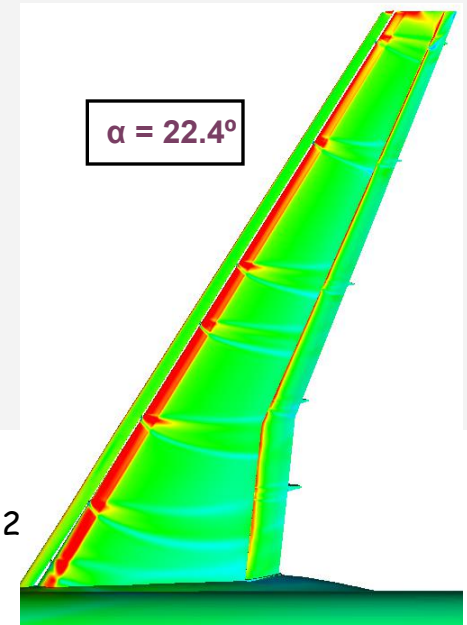

α = 7º


α = 12º

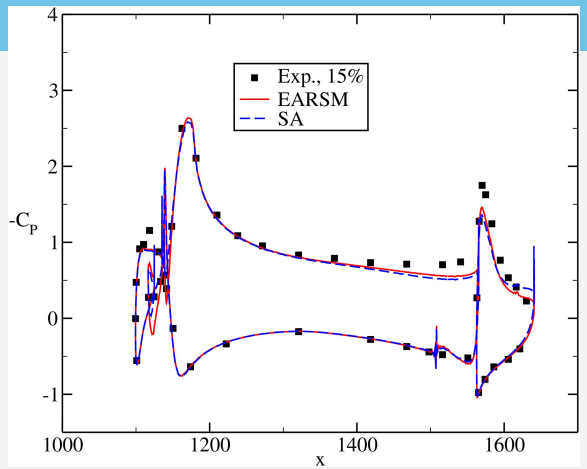

3
2.5
2
1.5
C_L
0
5
10
15
20
25
α
Exp.
EARSM
SA

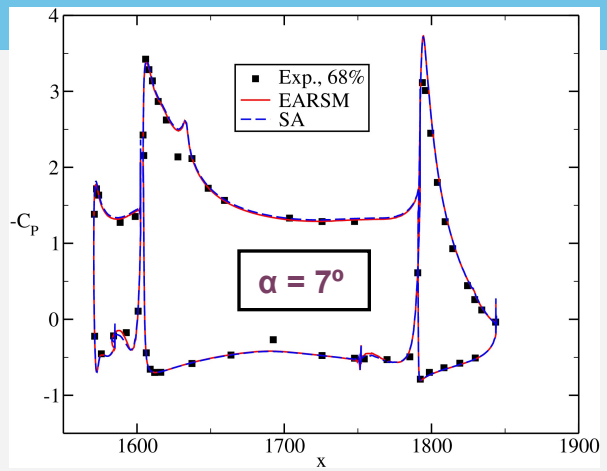

α = 18.5º

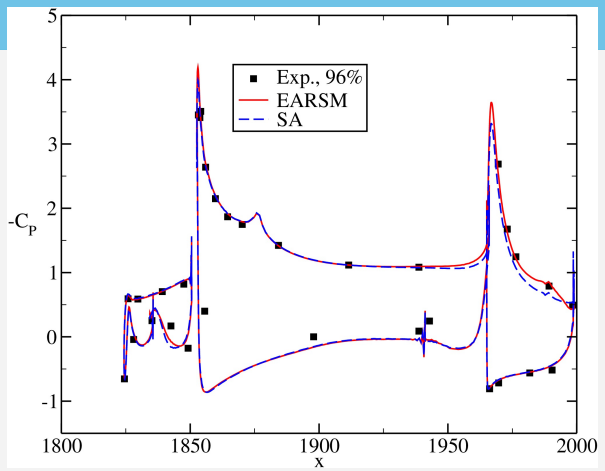

α = 20º

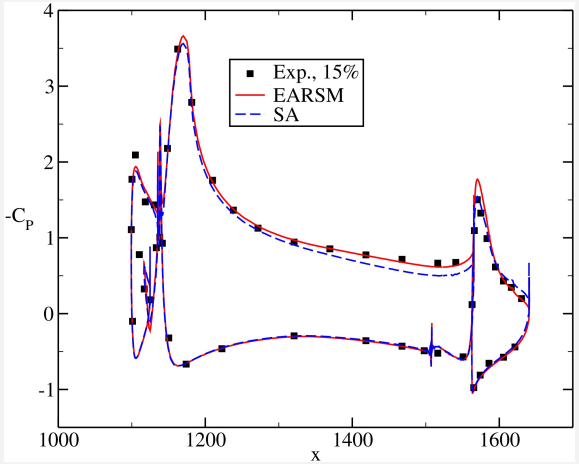

α = 22.4º

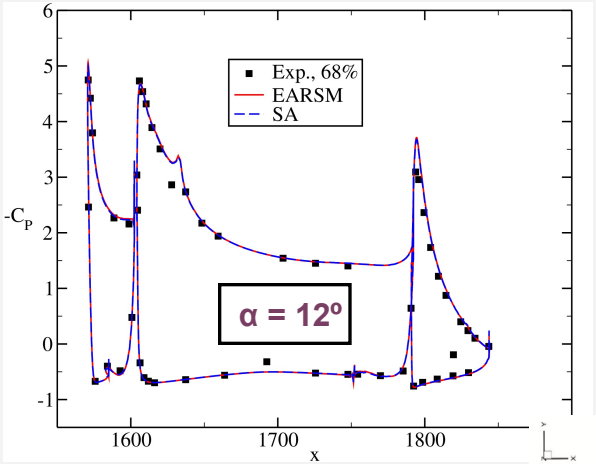
Case2b, Cp, alfa 7, 12

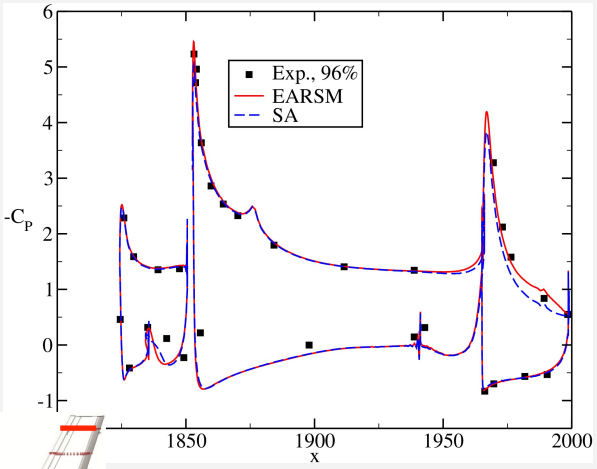








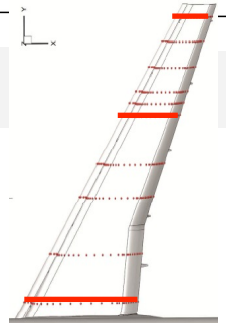




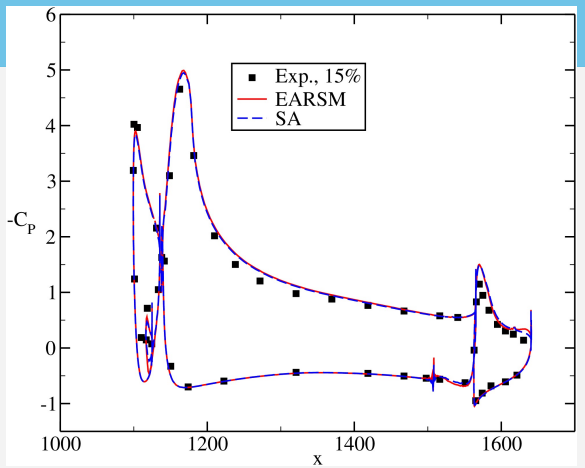
15% span

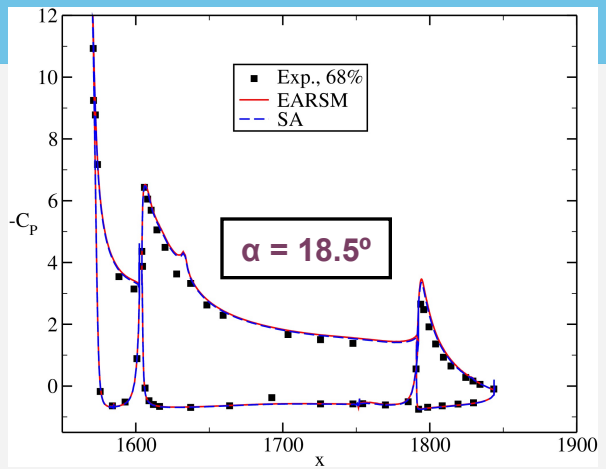
68% span

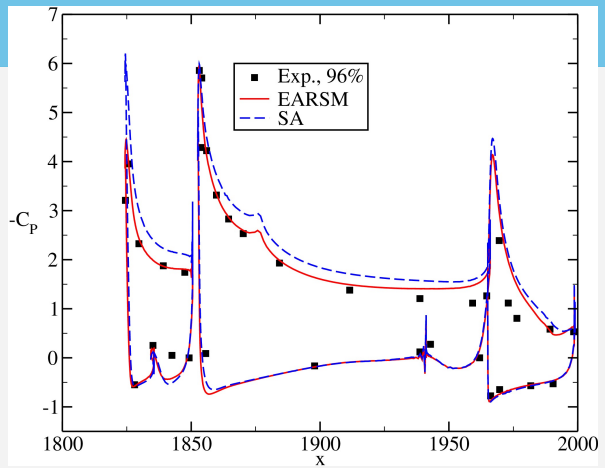
96% span

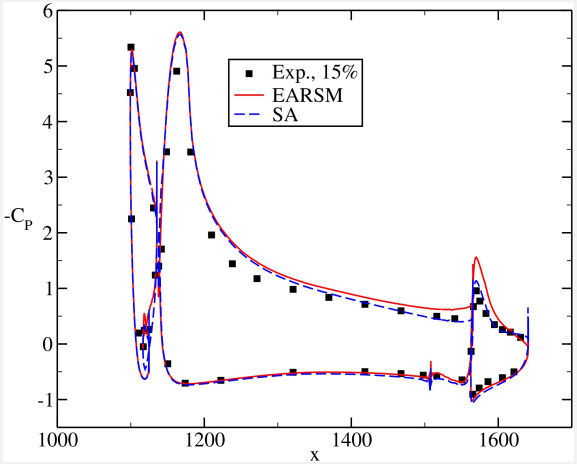


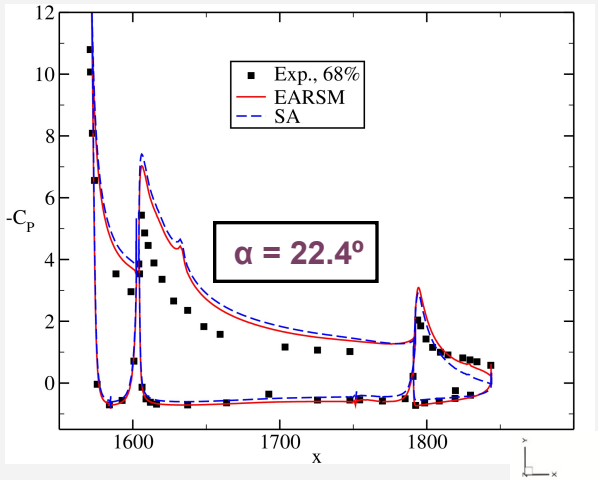
Case2b, Cp, alfa 18.5, 22.4

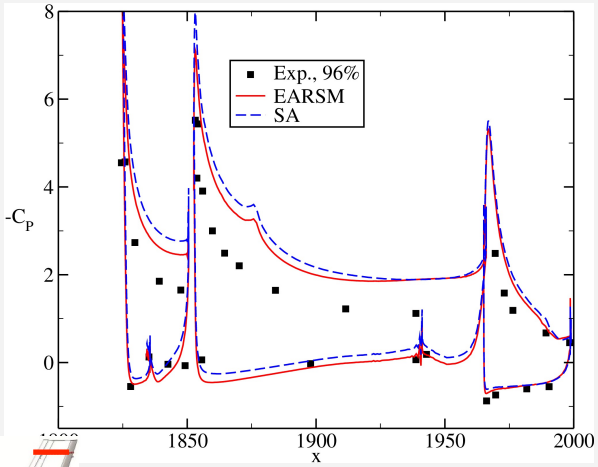








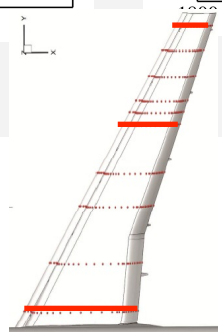




15% span

68% span

96% span



Summary

- High quality SOLAR grids
  - Reasonable steady-state convergence
- Case1 – grid convergence
  - Higher C_L with EARSM, ≤ 7 lift cts on fine grid
  - Some oscillations on fine grid, < 1 lift cts
  - C_D over predicted
- Case2a – low Re fully turbulent
  - SA over predicts max lift, EARSM under predicts
  - Separated areas on flap
  - Lift break down on outer part of wing
  - C_M off at higher incidences
- Case2b – high Re fully turbulent
  - Similar C_L with EARSM and SA
  - Over prediction of max lift
  - Similar lift break down as for low Re

FOI