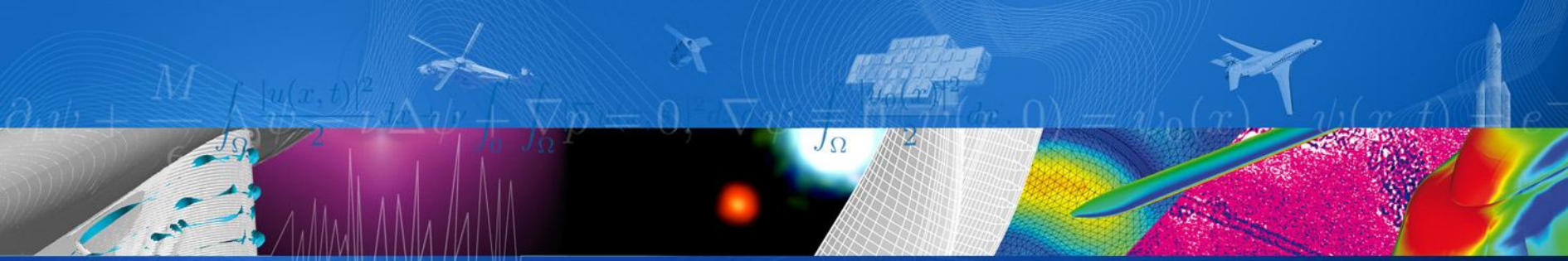

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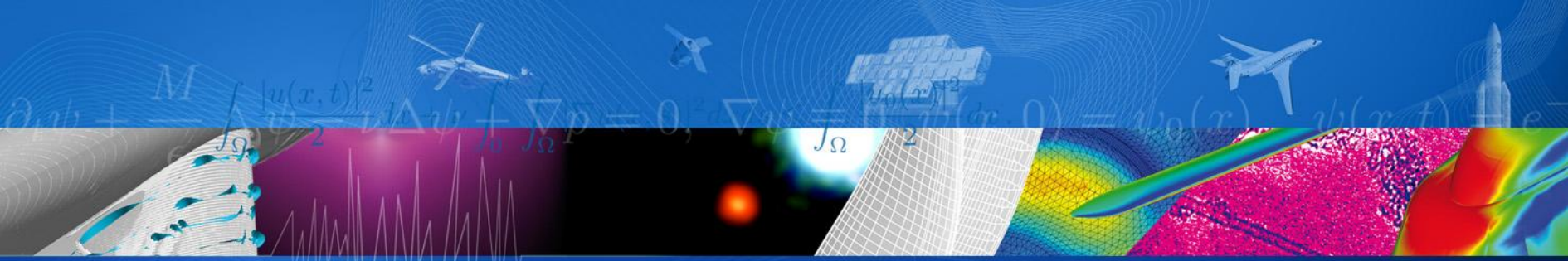

Computational Assessment of the HiLiftPW-1 Trap-Wing Model Using the *elsA* CFD Software

L. Wiart, M. Meunier
Aerospace Engineers, Civil Aircraft Unit, Applied Aerodynamics Department

49th AIAA Aerospace Sciences Meeting
4 January 2011, Orlando, Florida

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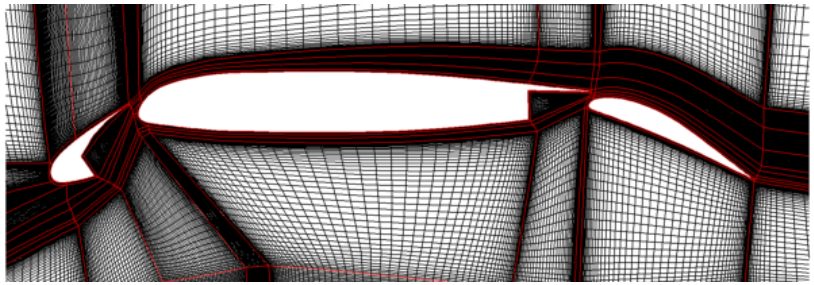
Outline

- Grids overview
- CFD software: *elsA* and ffd72
- Grid convergence and flap deflection studies
  - Computation strategy
  - Turbulence modeling
  - Grid convergence study
  - Flap/SOB separation
  - Far-field analysis
  - Flap deflection study
- Additional studies using the Chimera approach
  - Comparison with coincident grid results
  - Flap support effects

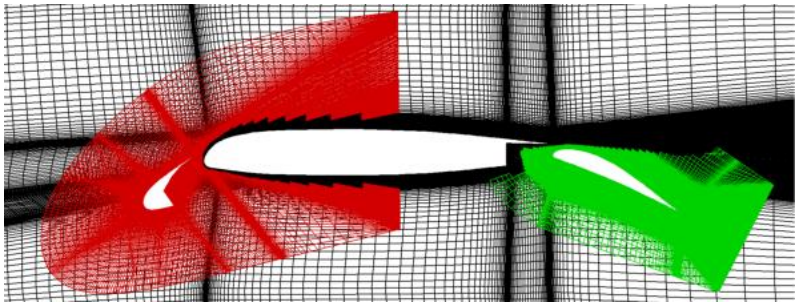
NASA Trap-Wing model

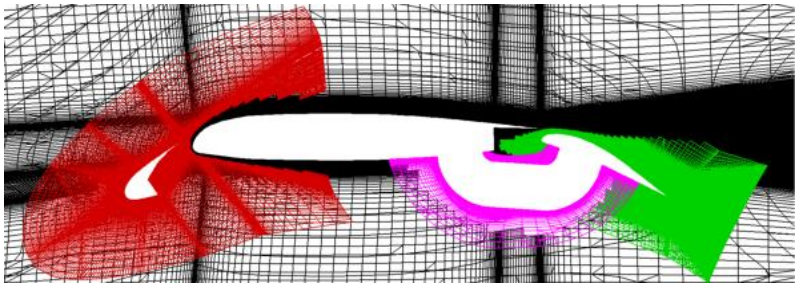
Grids overview

- Str-OnetoOne-A-v1 (supplied by HiLiftPW-1 committee)
  - Coarse: 22.5×10^6 nodes
  - Medium: 52×10^6 nodes
  - Fine: 170.5×10^6 nodes



- Structured overset created in-house using Icem-CFD
  - Bracket-off: 32×10^6 nodes (Equivalent to Config 1 medium grid)
  - With flap brackets: 63×10^6 nodes (bracket grids alone: 3×10^6 nodes)





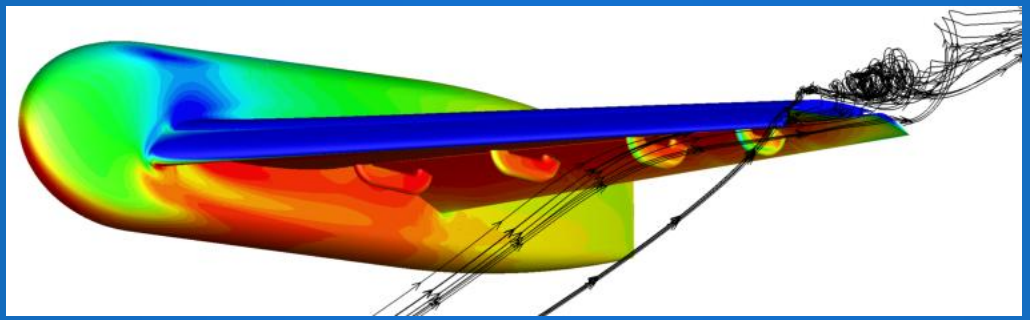
The *elsA* solver

RANS computations

- Cell-centered finite volume on structured multi-block meshes
- Time integration: Backward-Euler scheme with LU-SSOR relaxation
- Spatial discretization: Jameson's second-order centered scheme
- V-cycle multigrid technique
- Low-speed preconditioning

CGNS input and output format

Parallel mode (SGI Altix ICE 8200 EX)



ffd72 far-field drag extraction tool

$$CD_{nearfield} = CD_f + CD_p$$

$$CD_v = CD_f + CD_{vp}$$

$$CD_{farfield} = CD_v + CD_w + CD_i$$

$$CD_{sp} = CD_{nearfield} - CD_{farfield}$$

CD_p: pressure drag coefficient

CD_f: friction drag coefficient

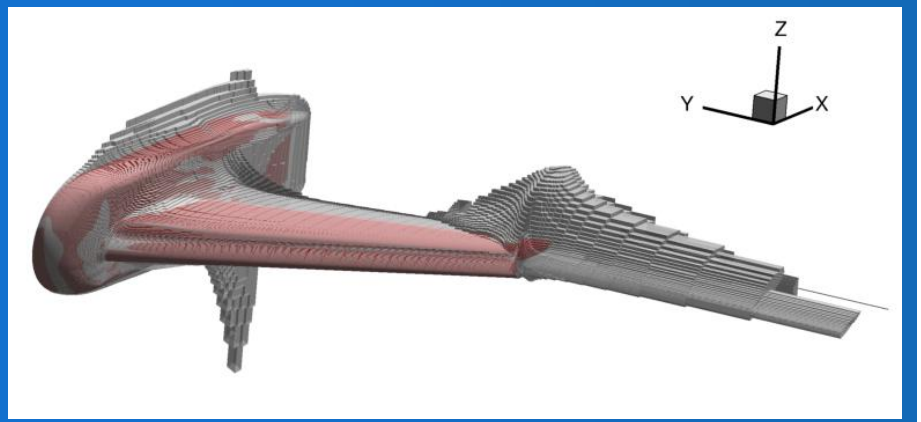
CD_v: viscous drag coefficient

CD_{vp}: viscous pressure drag coefficient

CD_w: wave drag coefficient

CD_i: induced drag coefficient

CD_{sp}: spurious drag coefficient



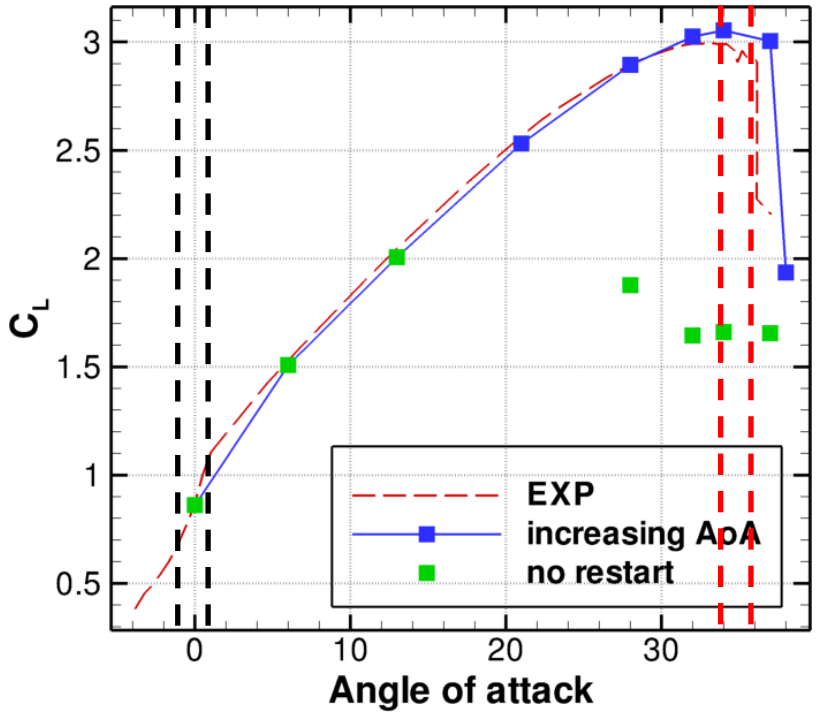
Viscous drag integration volumes (Config 1, α=13 deg.)

Computation strategy

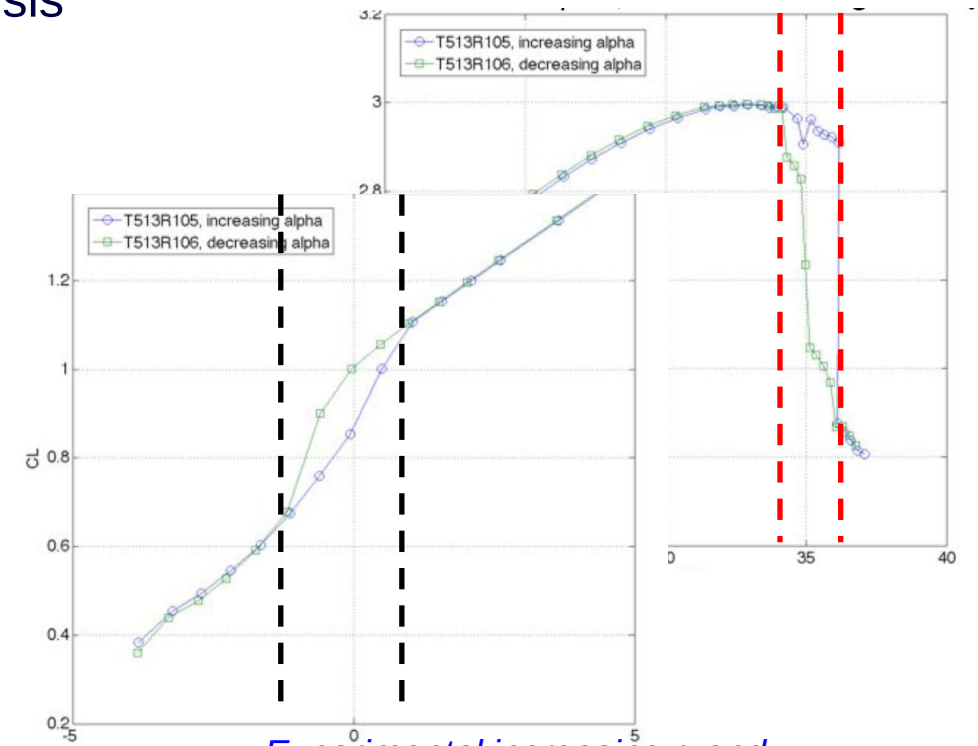
- Polars obtained with increasing AoA
- Non-unique solutions
  - if no initialization from previous AoA
  - not directly related to hysteresis

M = 0.2

Re = 4.3 M



Config 1, SA



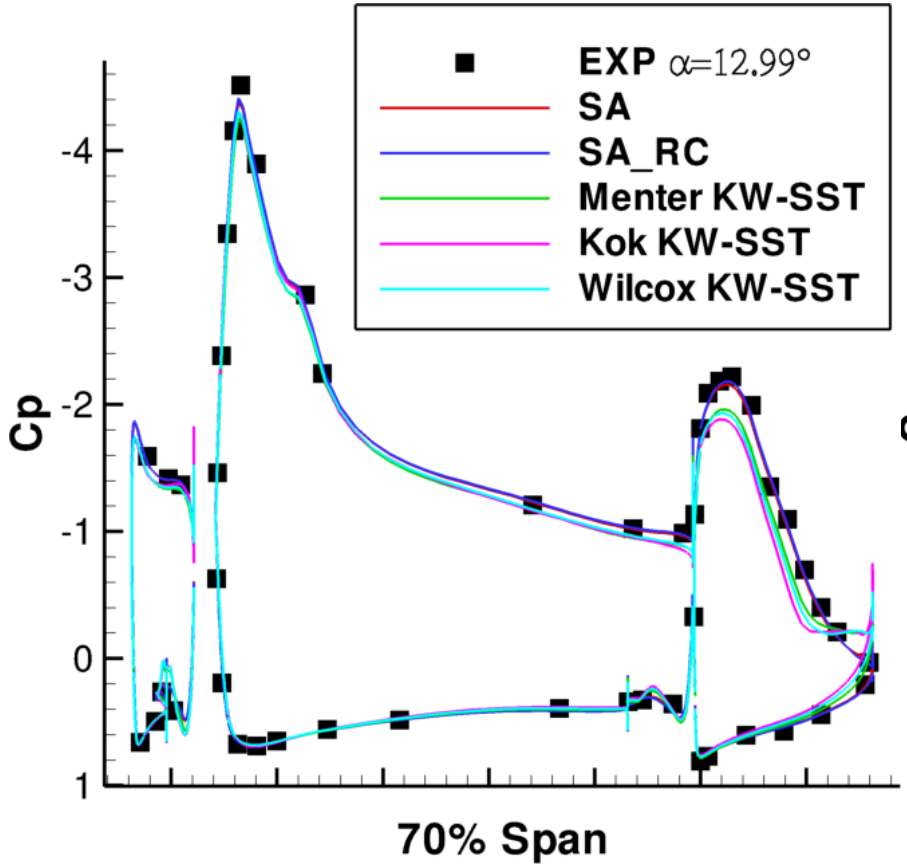
Experimental increasing α and decreasing α lift polars

Turbulence modeling (1/2)

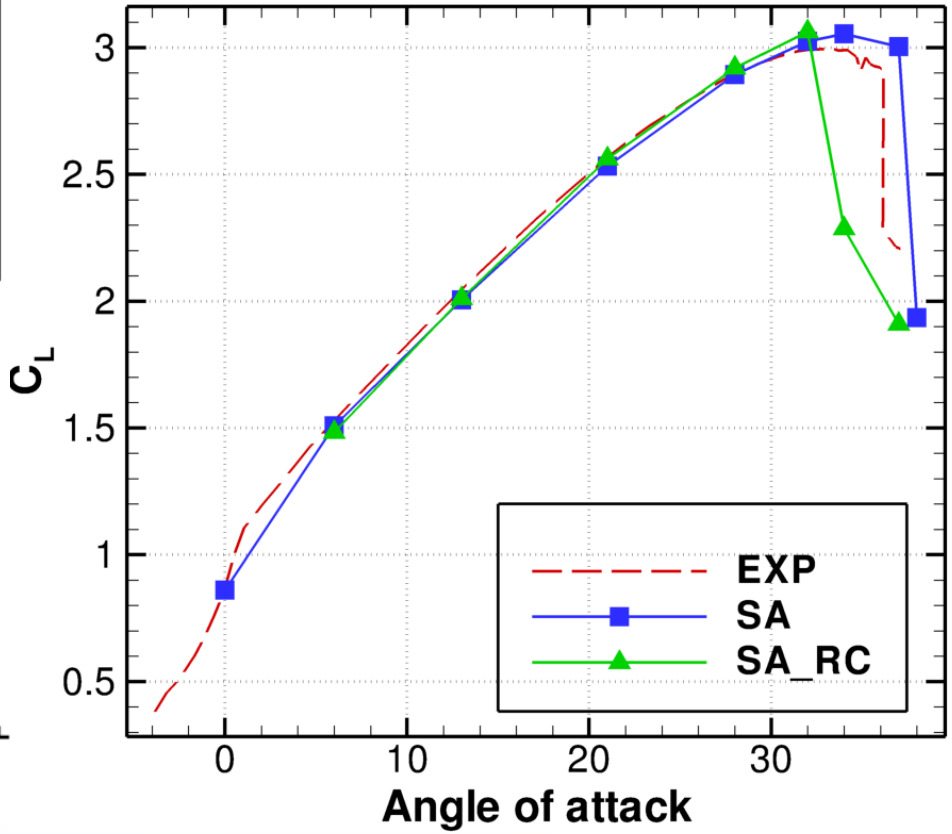
- All kw-SST models over-predict flap TE separation

→ not suited for this configuration

- Rotation correction in SA changes the stall behavior

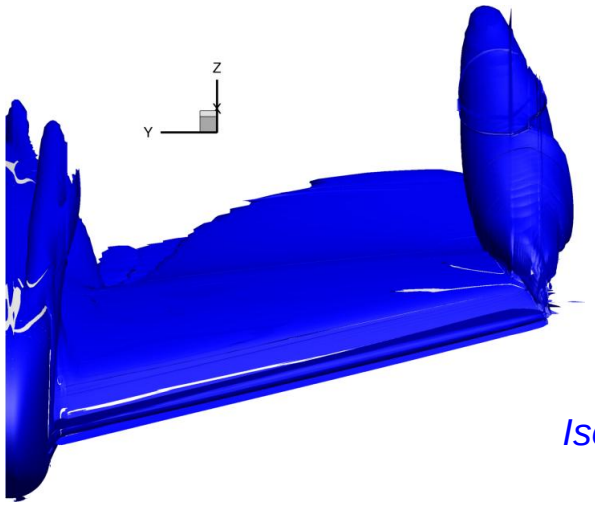


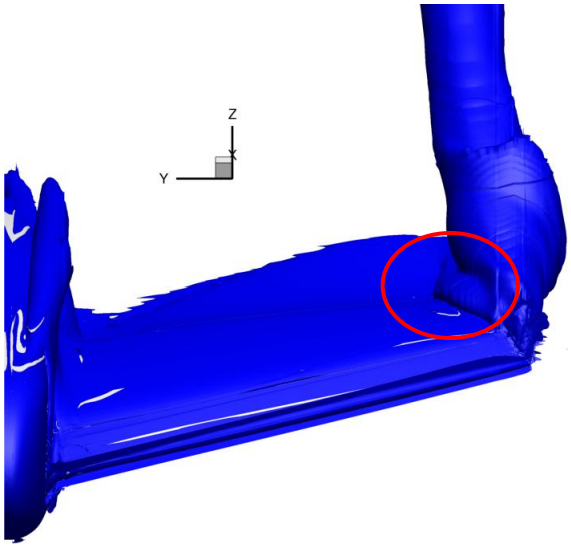
Config 1,α=13 deg.



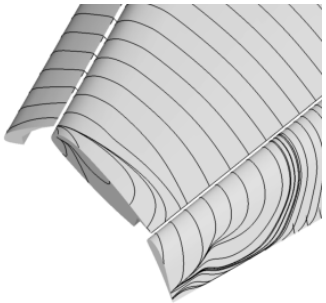
Turbulence modeling (2/2)

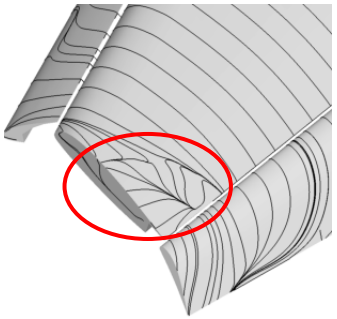
- Major impact of slat-tip vortex resolution on stall





Isosurfaces of vorticity





Friction lines

Config 1, SA, α=32 deg.

Config 1, SA_RC, α=32 deg.

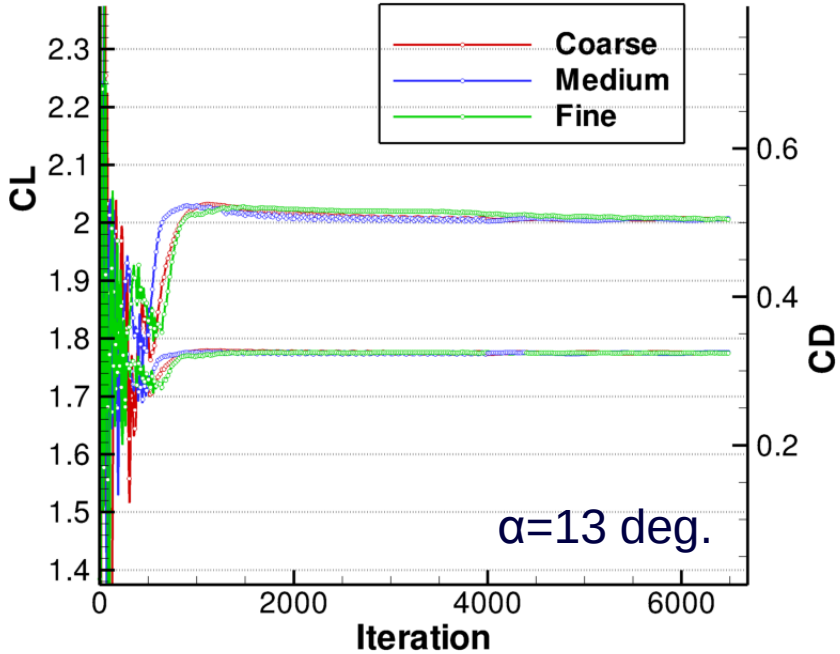
Test Case 1
Grid Convergence Study

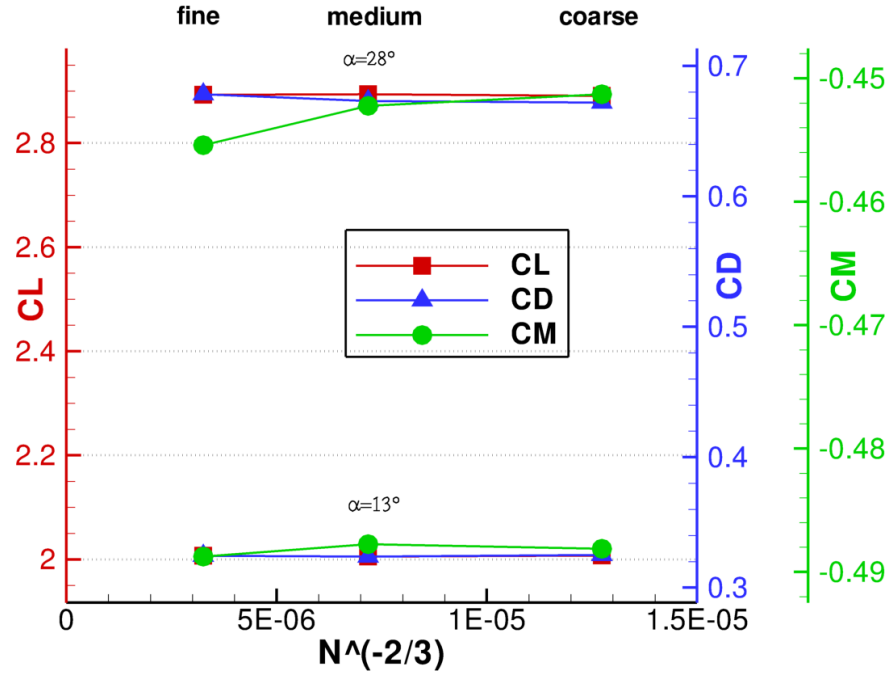
Grid convergence study (1/2)

CFD High Lift Prediction Workshop

- Fairly small variations between the different grid levels

	ΔCL	ΔCD	ΔCm	$\Delta CL/CL_{exp}$	$\Delta CD/CD_{exp}$	$\Delta Cm/Cm_{exp}$
α=13 deg.	2x10-3	10 dc.	1x10-3	0.1%	0.3%	0.2%
α=28 deg.	3x10-3	60 dc.	4x10-3	0.1%	0.8%	0.9%



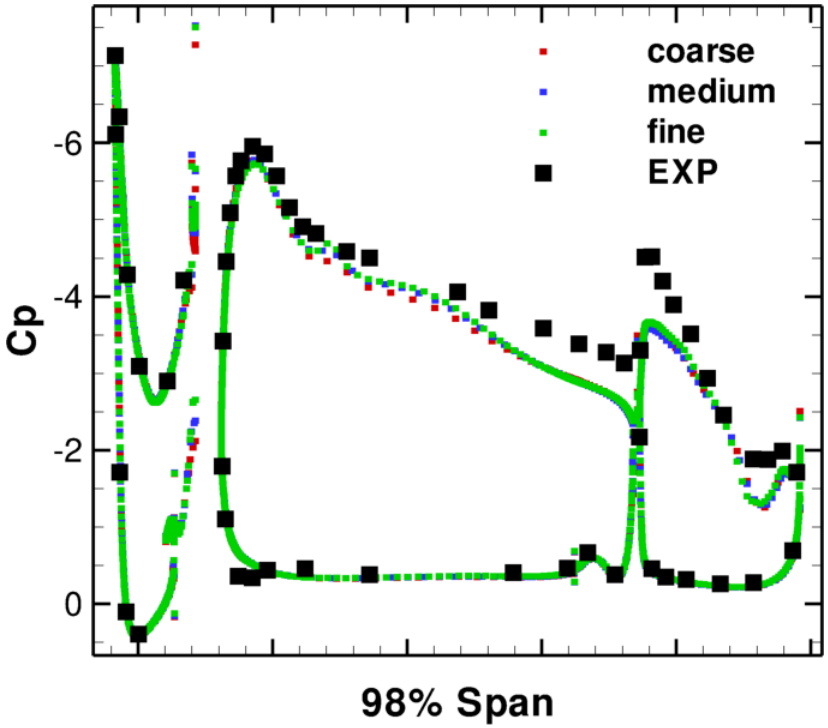


Influence of grid refinement on aerodynamic coefficients (Config 1, SA)

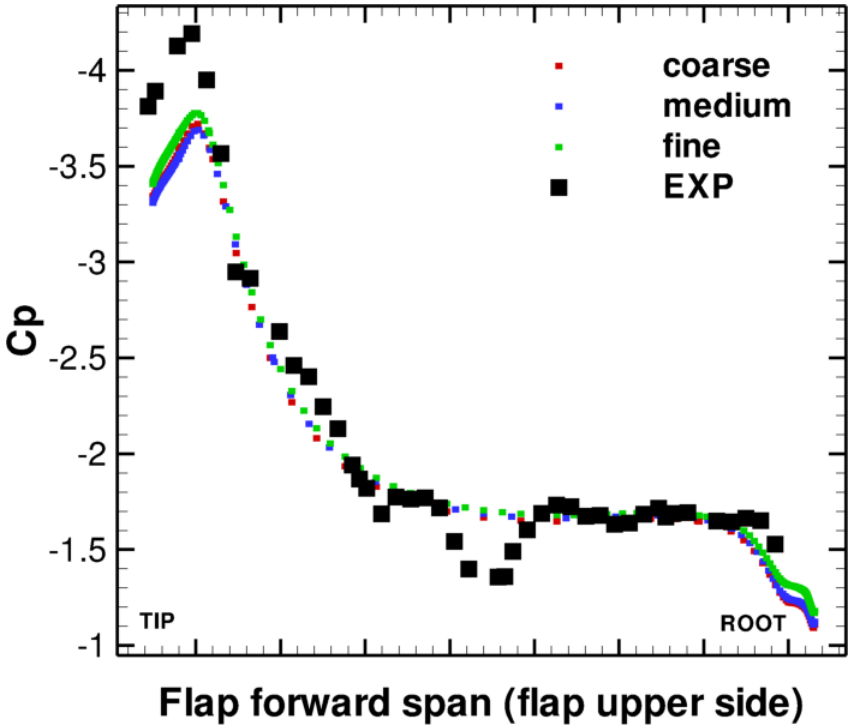
Grid convergence study (2/2)

CFD High Lift Prediction Workshop

- Small variations on Cp distributions too, even in areas supposed to be sensitive to mesh refinement



wing tip

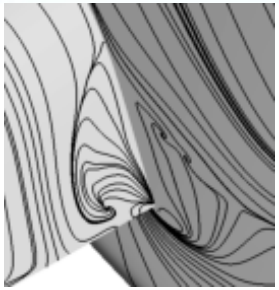


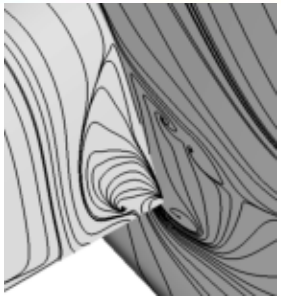
flap leading edge

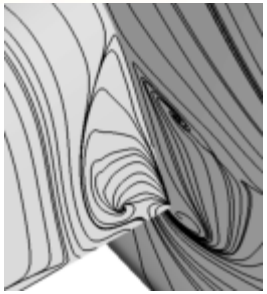
Config 1, SA, α=28 deg.

Flap/SOB separation

- Grid refinement impact (α=13 deg.)
  - little influence on separation bubble topology
  - → indication of achieved grid convergence



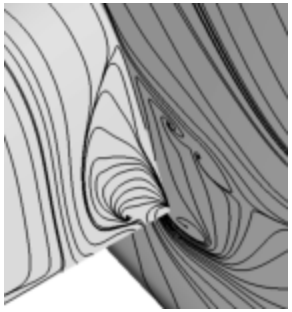


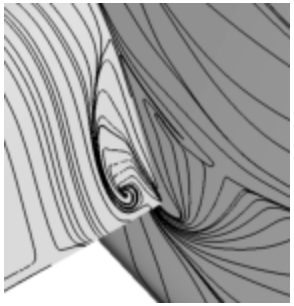


Coarse *Medium* *Fine*

Config 1

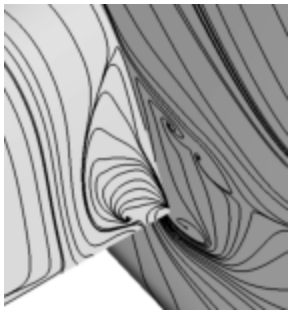
- Influence of AoA
  - ↗ AoA → ↘ bubble size

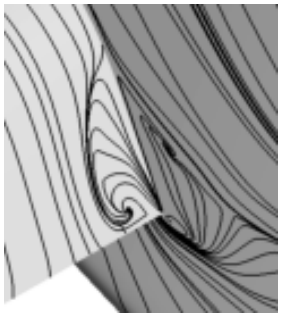




α=13 deg. *α=28 deg.*

- Flap deflection effect (α=13 deg.)
  - ↗ flap deflection → ↗ bubble size
  - similar to an increase of AoA

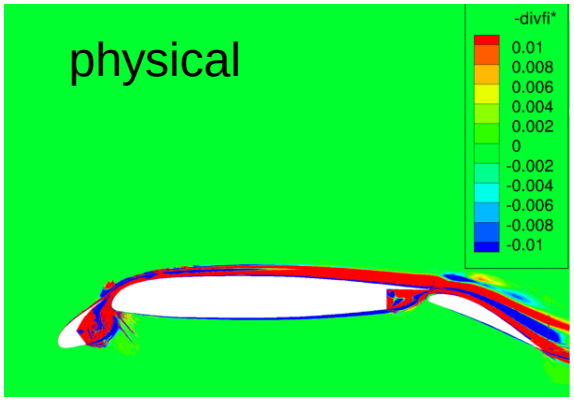




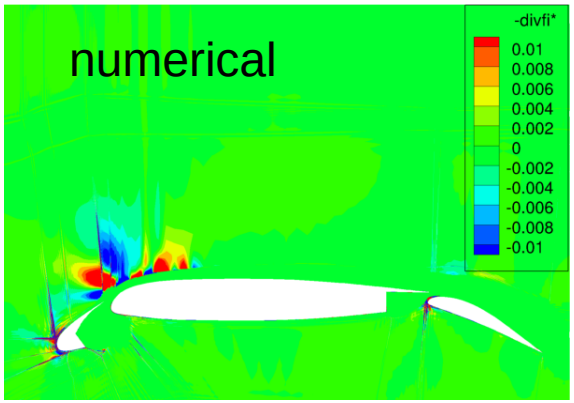
Flap 25 deg. *Flap 20 deg.*

Far-field drag analysis

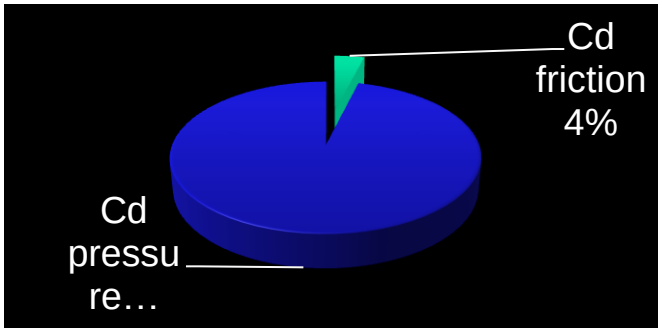
- Viscous drag created in boundary layers, wakes and coves
- Spurious drag mainly created in high curvature areas
  - drops from 4.66 to 0.35 drag counts from coarse to medium grid



Irreversible drag creation areas (η=50%)



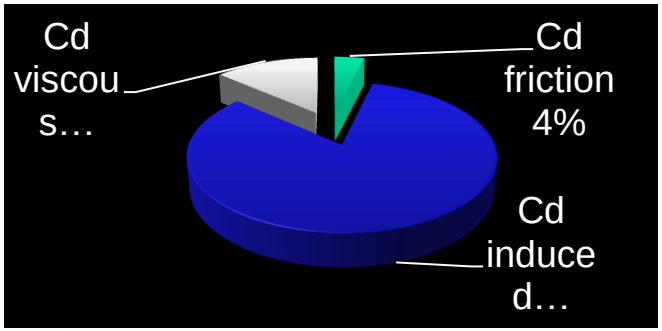
- Drag mostly dominated by induced component



Near-field drag breakdown

Config 1, SA

α=13 deg.



Far-field drag breakdown

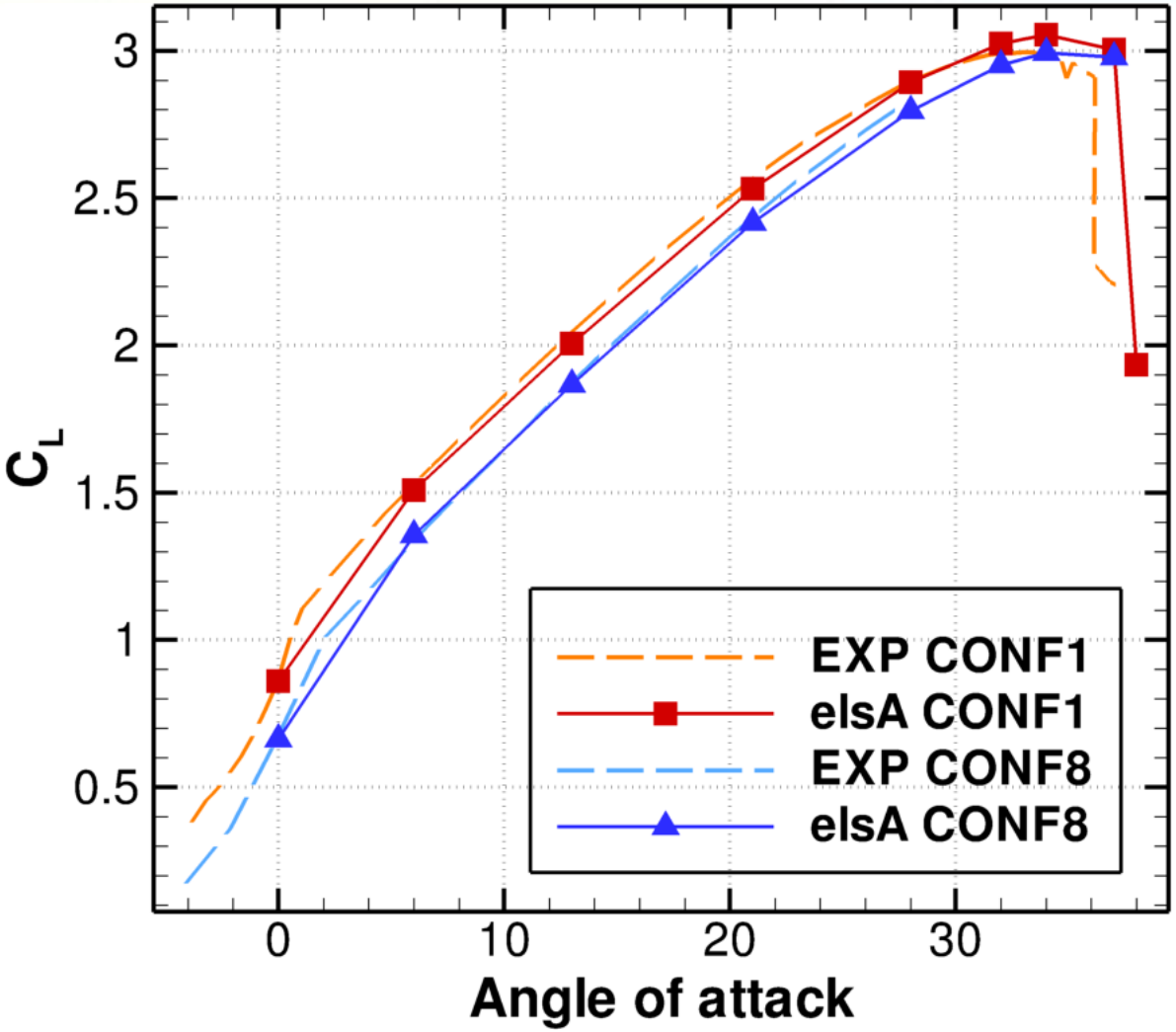
Test Case 2
Flap Deflection Prediction Study

Flap deflection prediction study (1/3)

CFD High Lift Prediction Workshop

Config 1: flap 25 deg.

Config 8: flap 20 deg.



Config 1:

- *Exp*

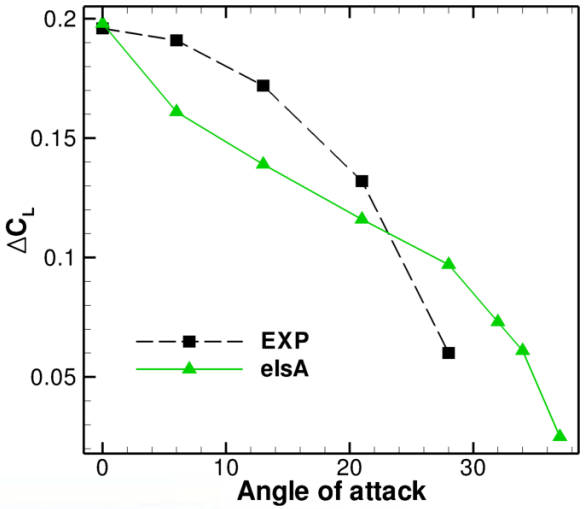
α_{max}=33 deg.

CL_{max}=2.995

- *elsA (SA)*

α_{max}=~34 deg.

CL_{max}=3.054

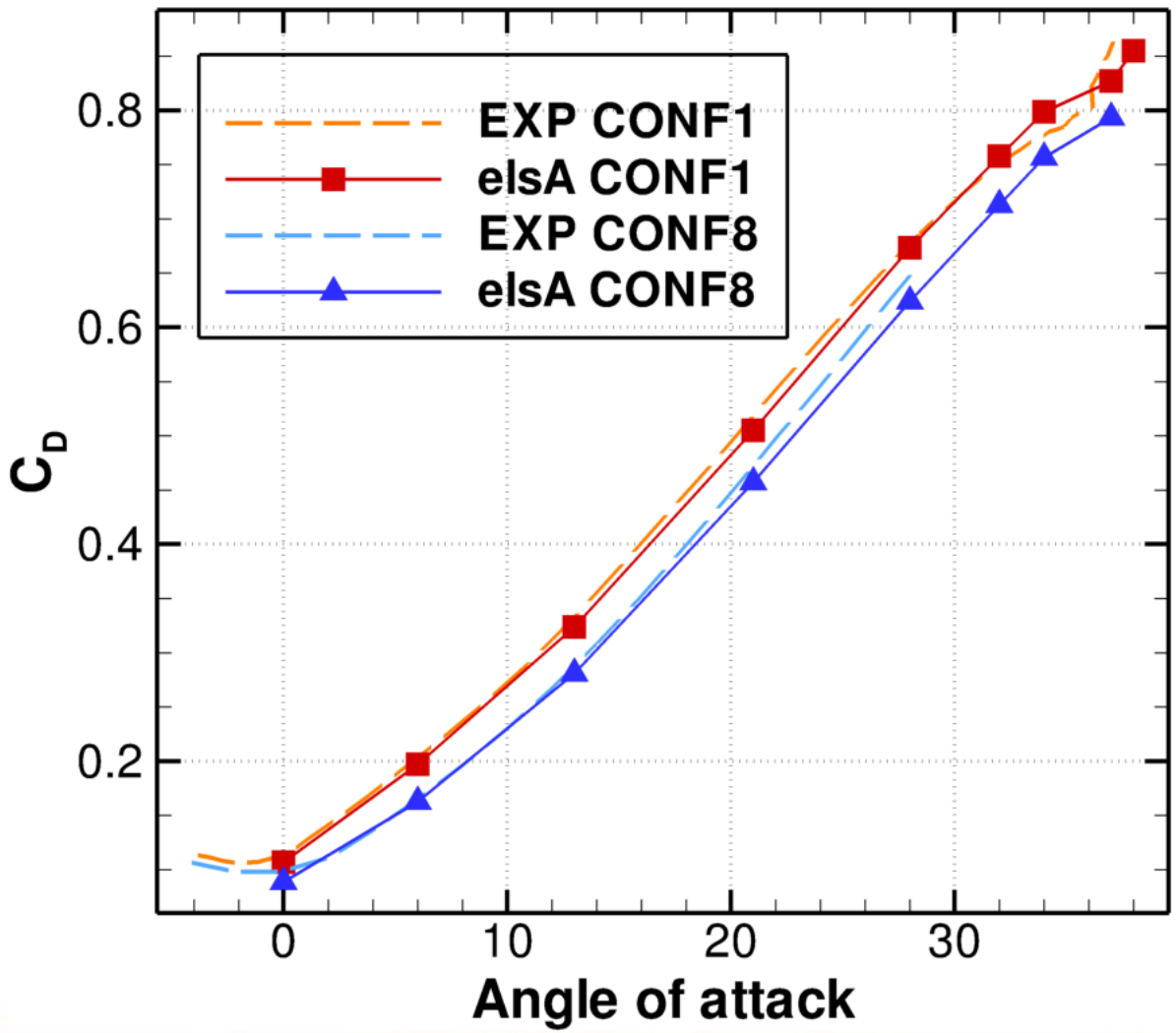


Flap deflection prediction study (2/3)

CFD High Lift Prediction Workshop

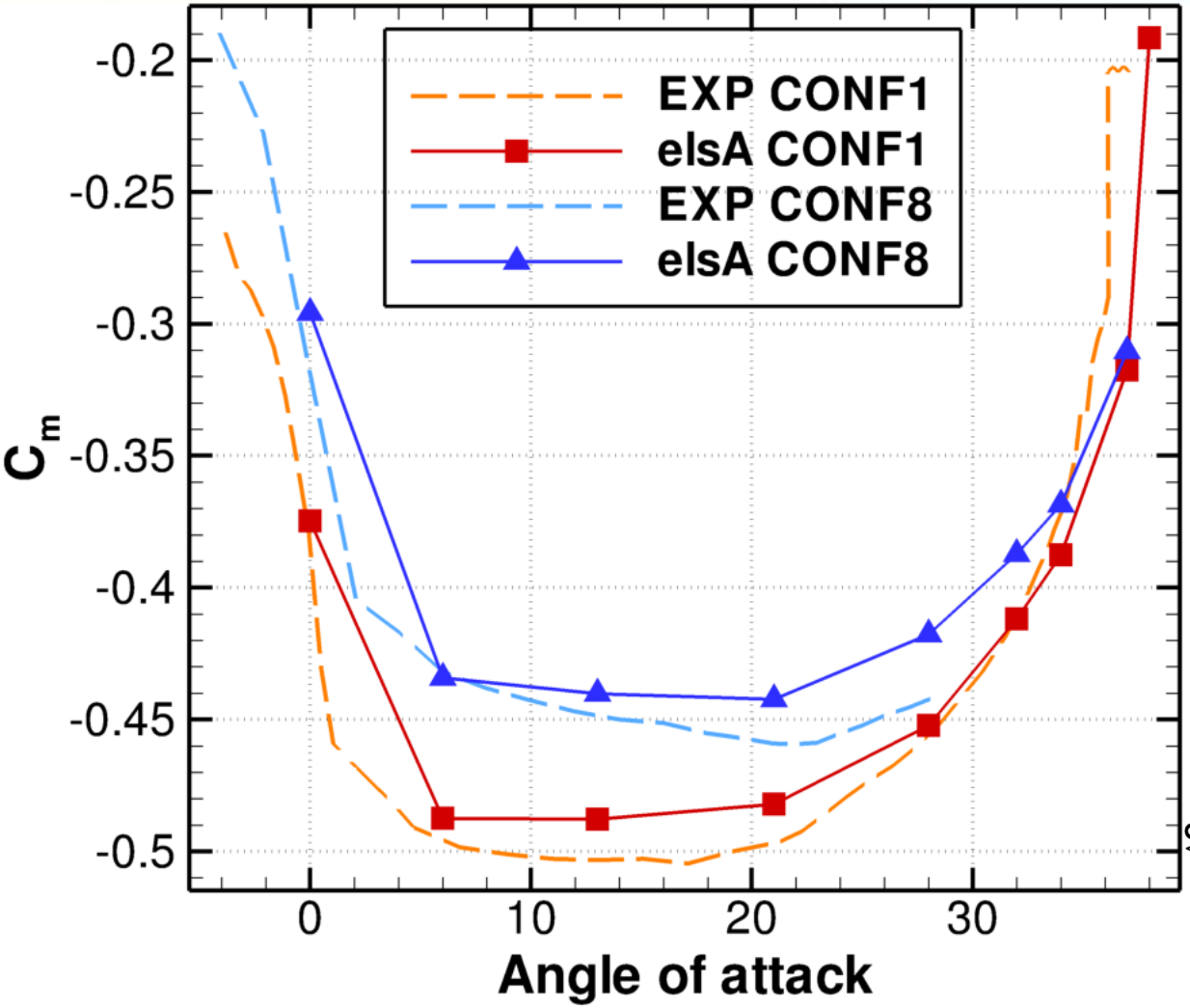
Config 1: flap 25 deg.

Config 8: flap 20 deg.



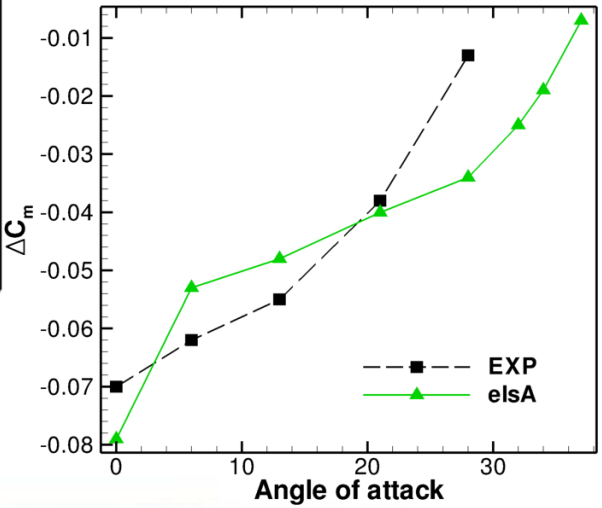
Flap deflection prediction study (3/3)

CFD High Lift Prediction Workshop



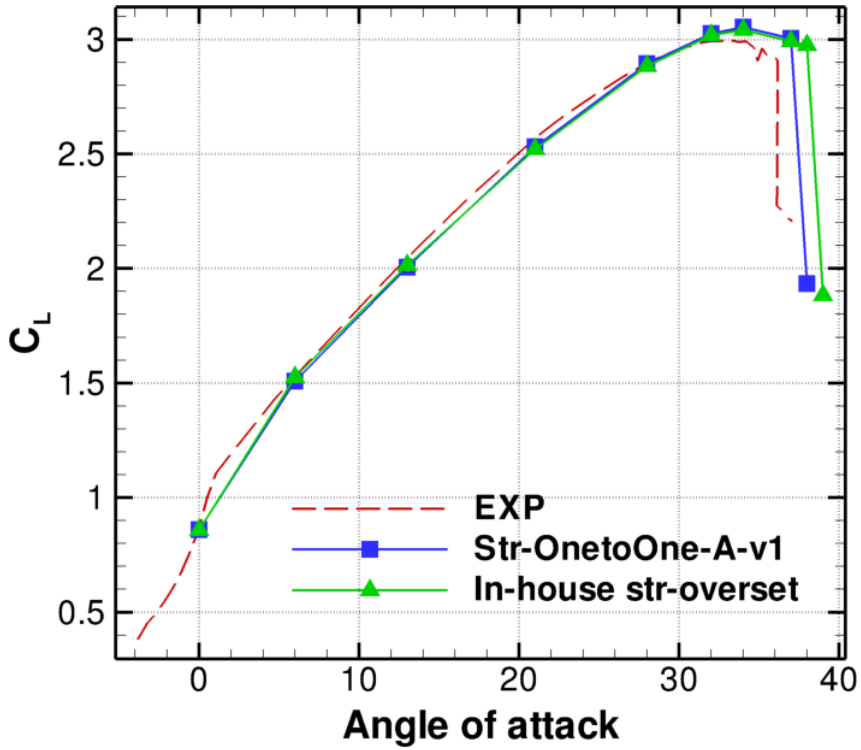
Config 1: flap 25 deg.

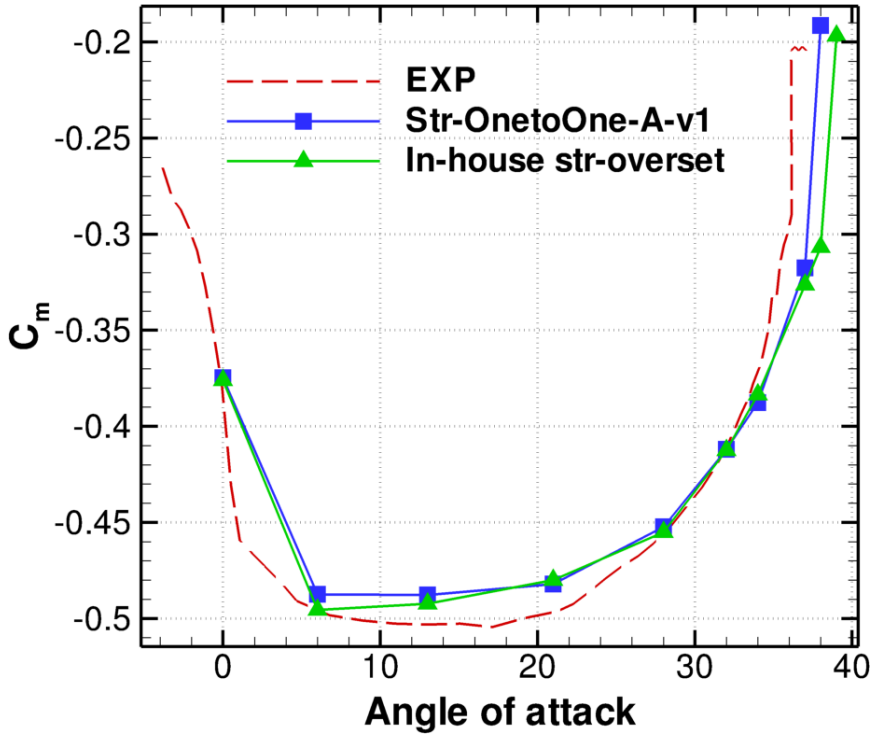
Config 8: flap 20 deg.



Additional Studies Using the Chimera Approach

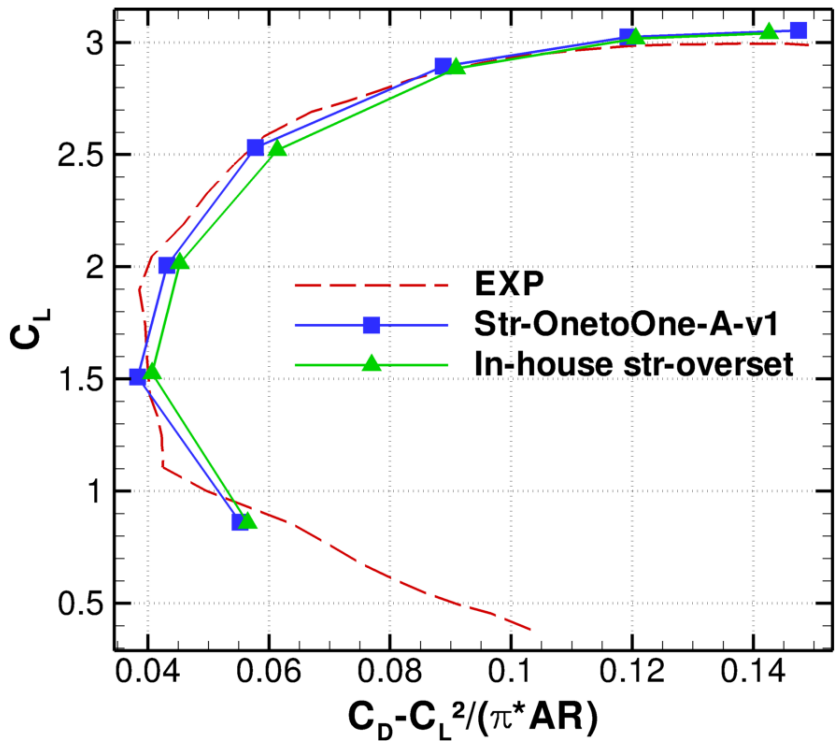
Overset grid results (1/4)

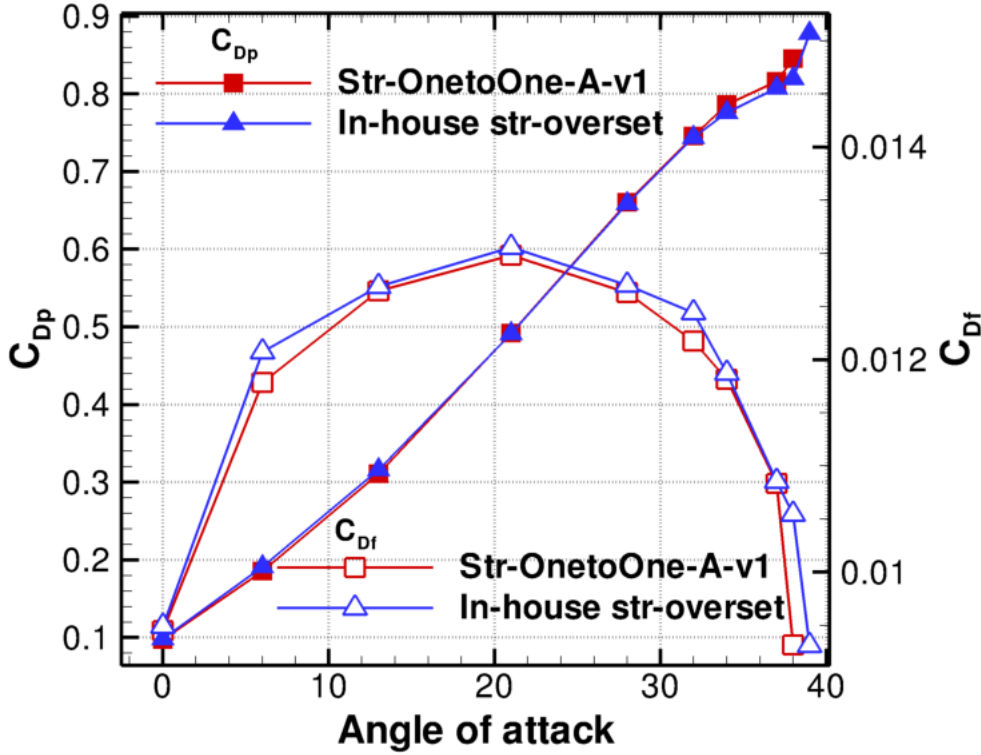




Config 1, SA

Overset grid results (2/4)

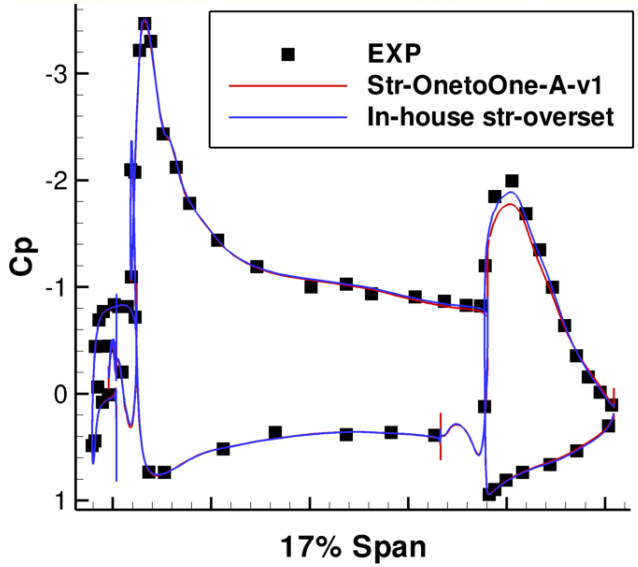




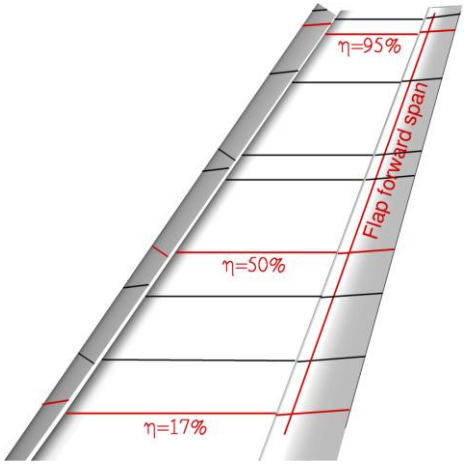
Config 1, SA

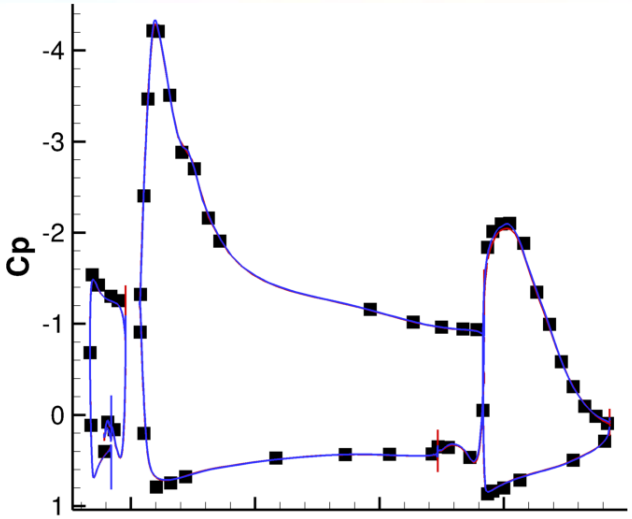
- Excellent agreement with coincident grid results
- Lesser meshing effort !!

Overset grid results (3/4)

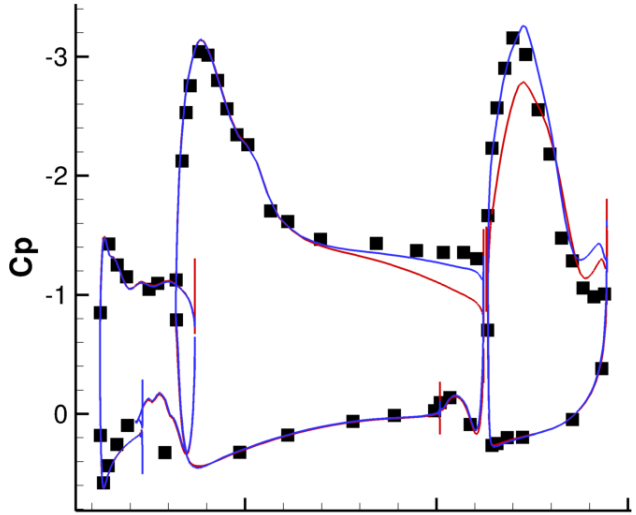


17% Span





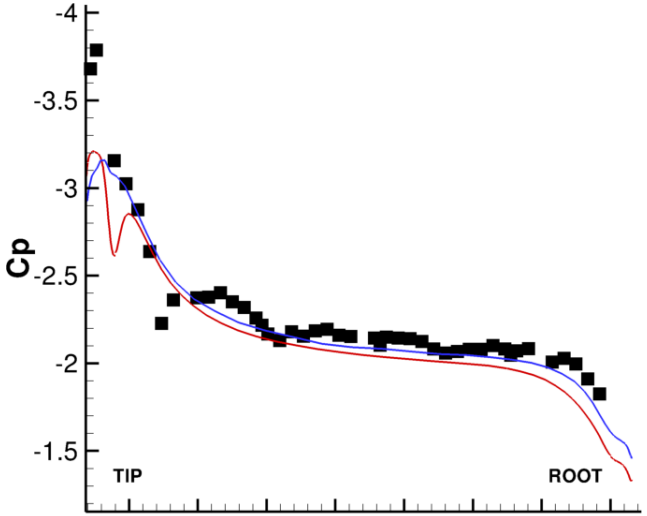
50% Span



95% Span

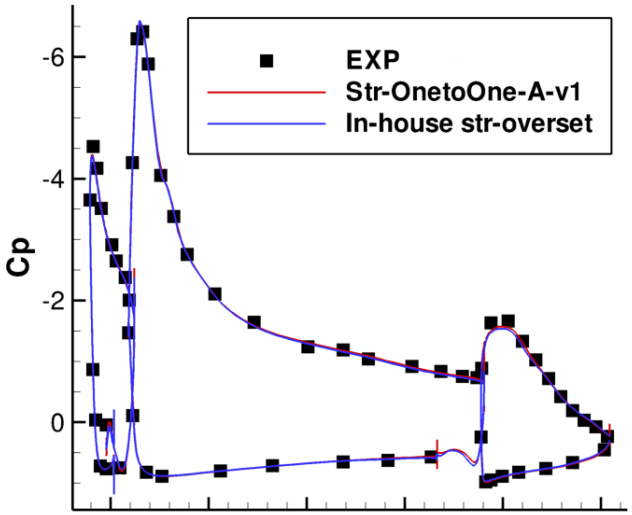
Config 1, SA

α=13 deg.

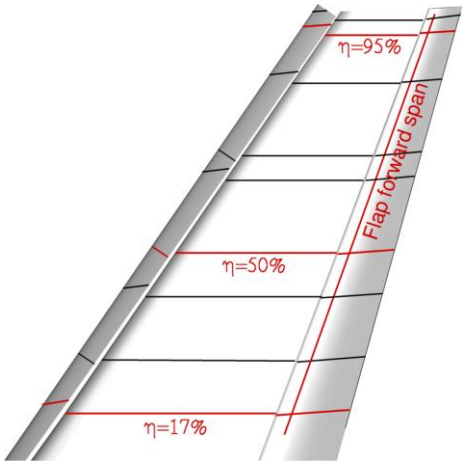


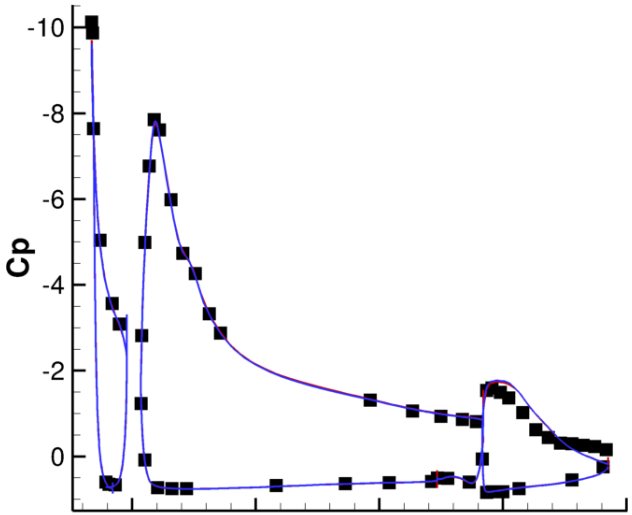
Flap forward span (upper side)

Overset grid results (4/4)

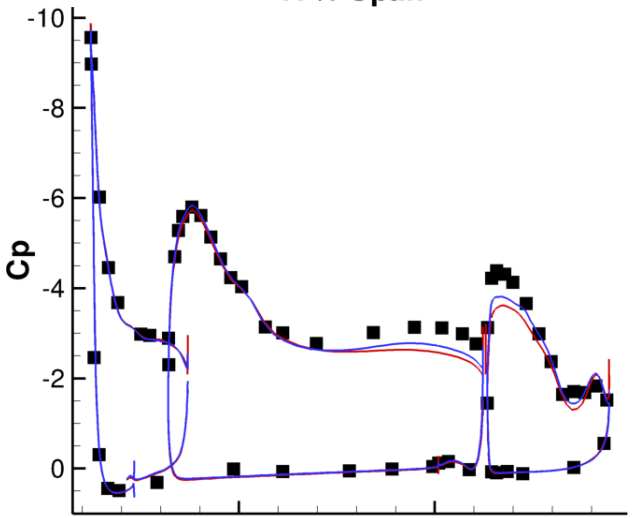


17% Span





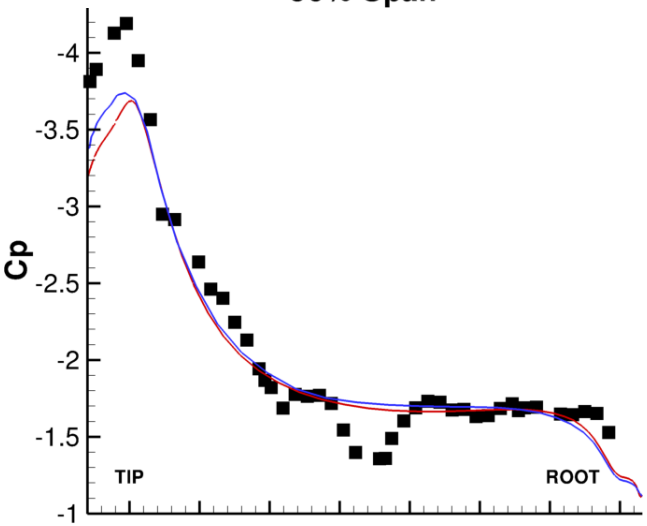
50% Span



95% Span

Config 1, SA

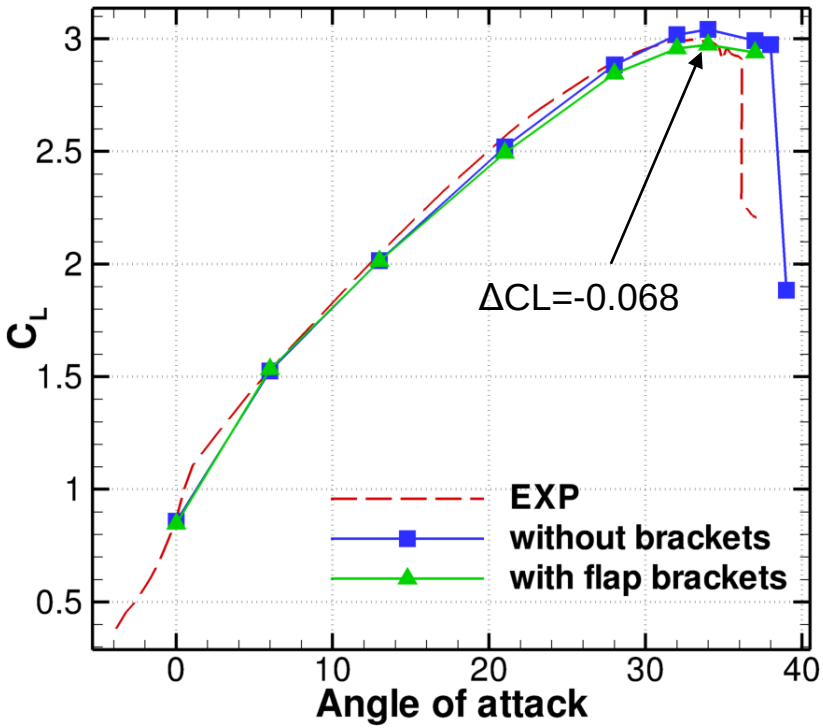
α=28 deg.

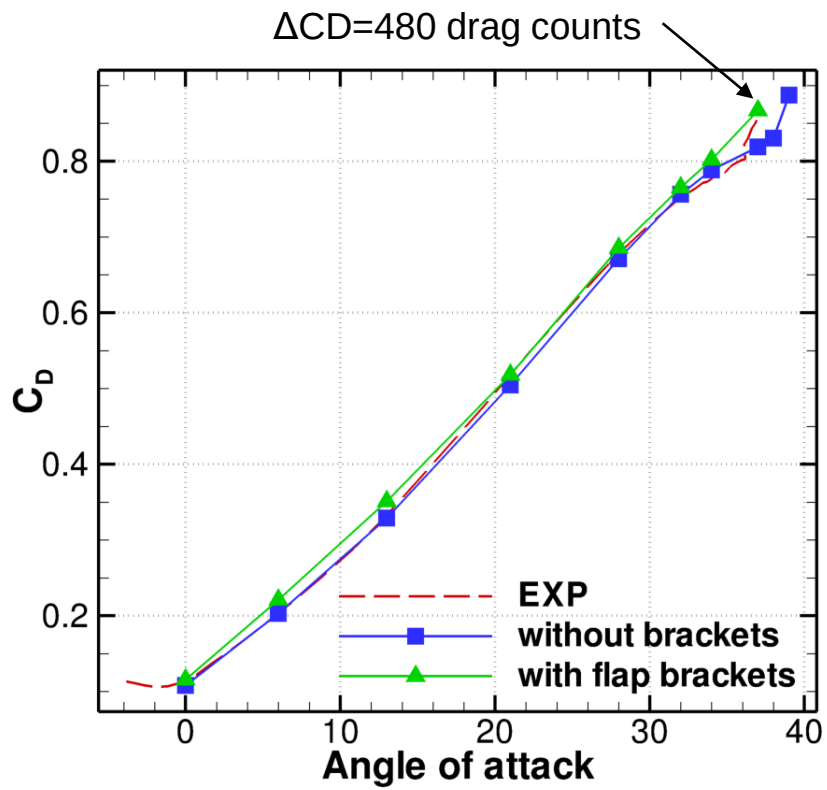


Flap forward span (upper side)

Flap support effects (1/5)

- As expected: less lift (ΔCL ↗ with AoA) and more drag

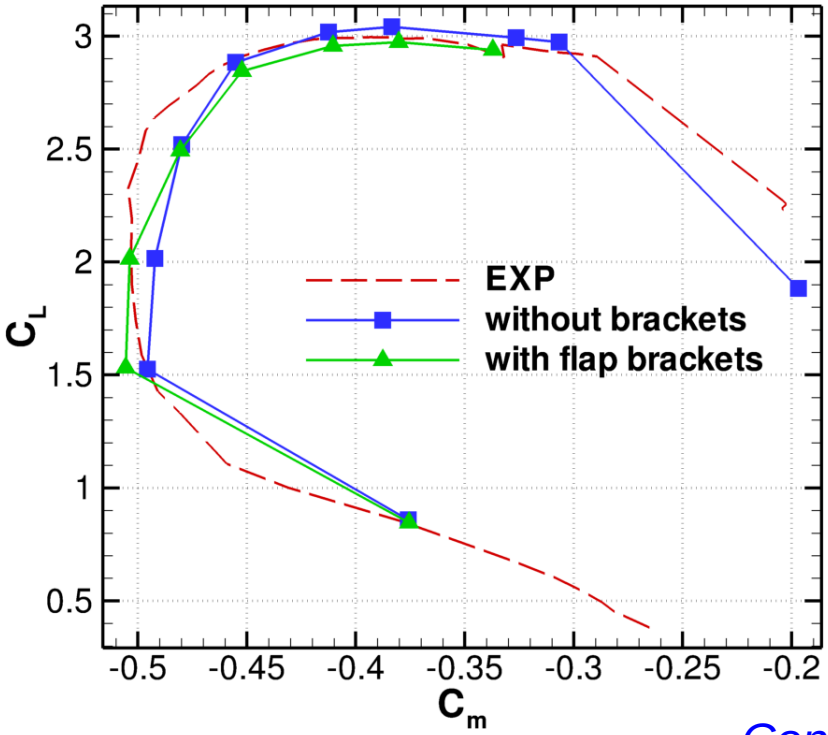


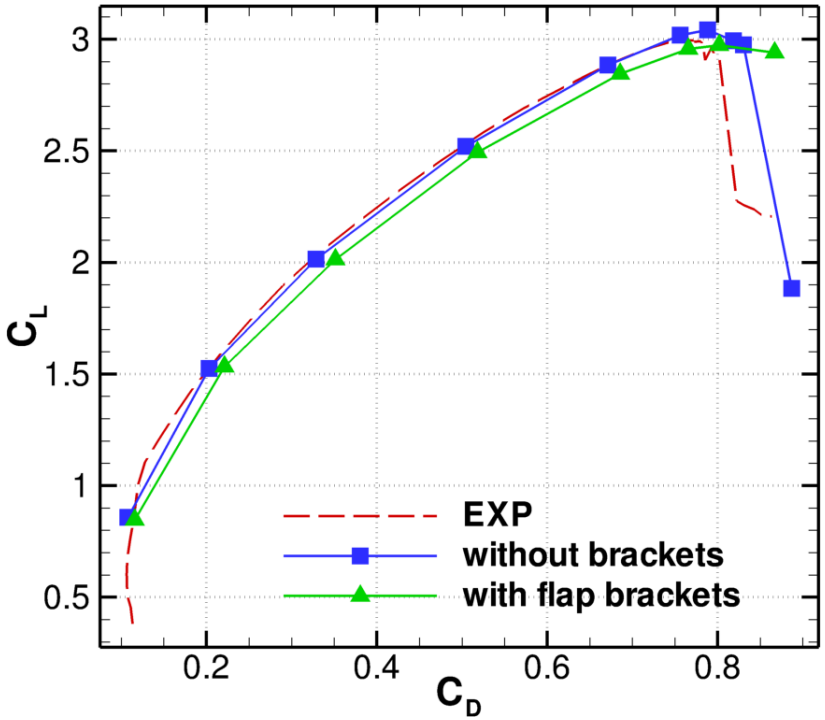


Config 1, SA

Flap support effects (2/5)

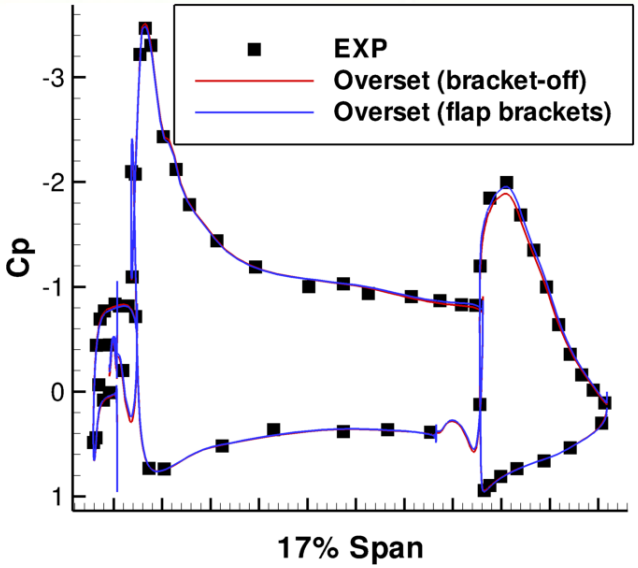
- The gradients are still well predicted, but in terms of absolute values, the bracket-on trend is away from the experiment (except on Cm prediction)



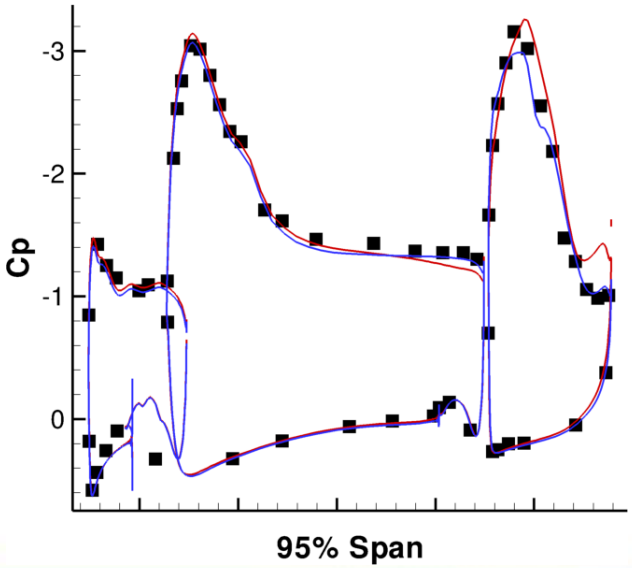


Config 1, SA

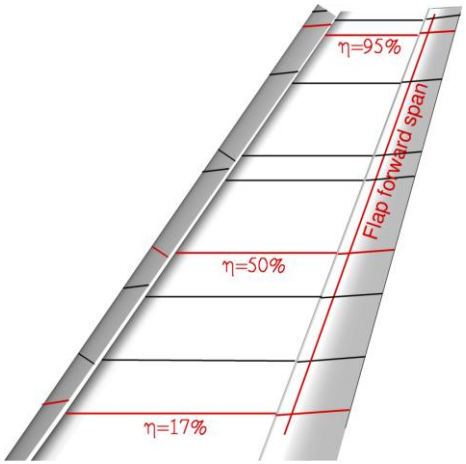
Flap support effects (3/5)



17% Span

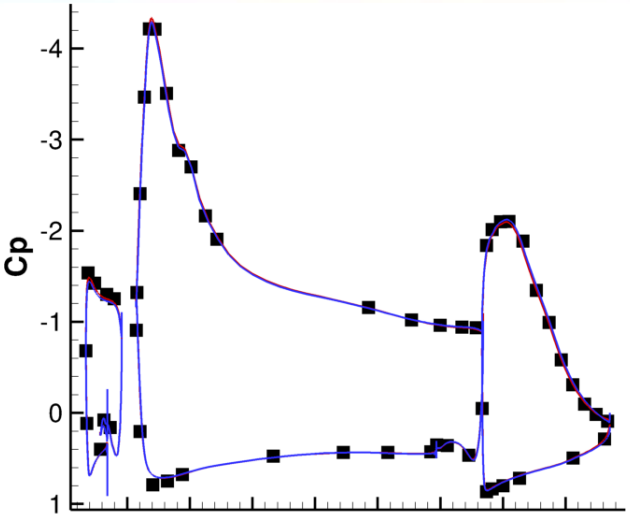


95% Span

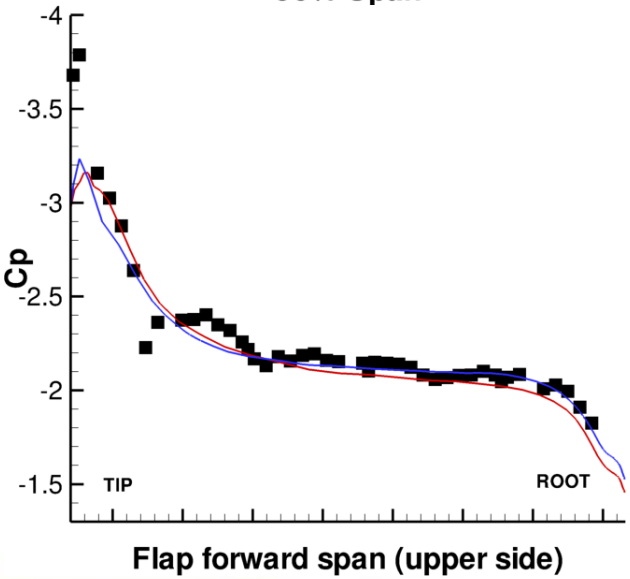


Config 1, SA

α=13 deg.

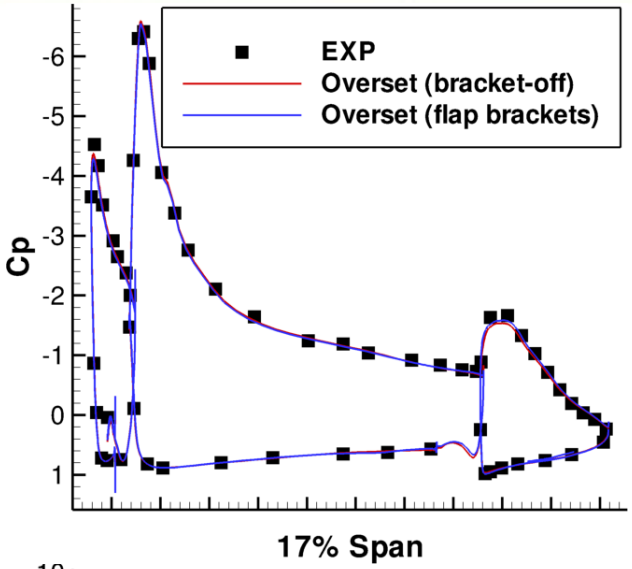


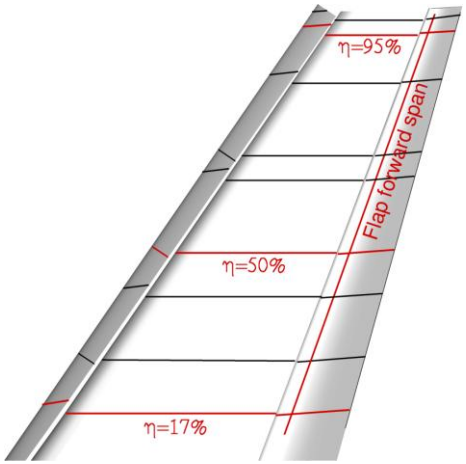
50% Span

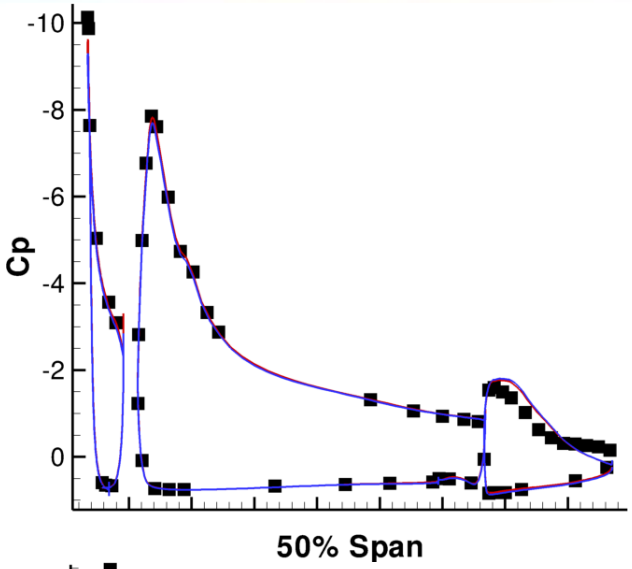


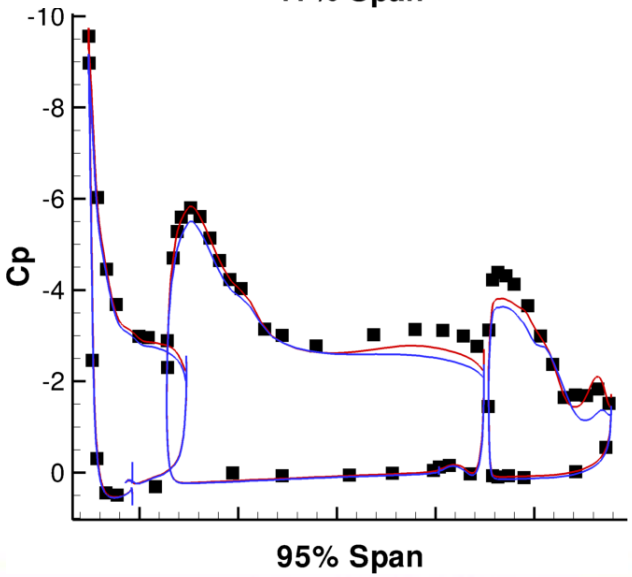
Flap forward span (upper side)

Flap support effects (4/5)



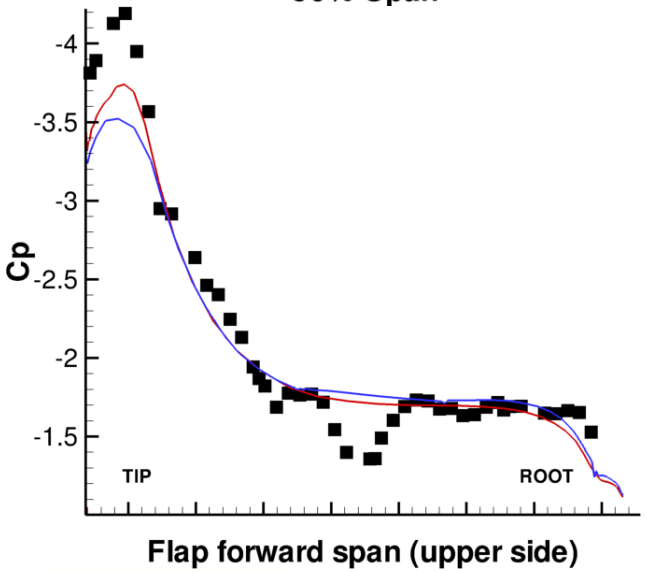




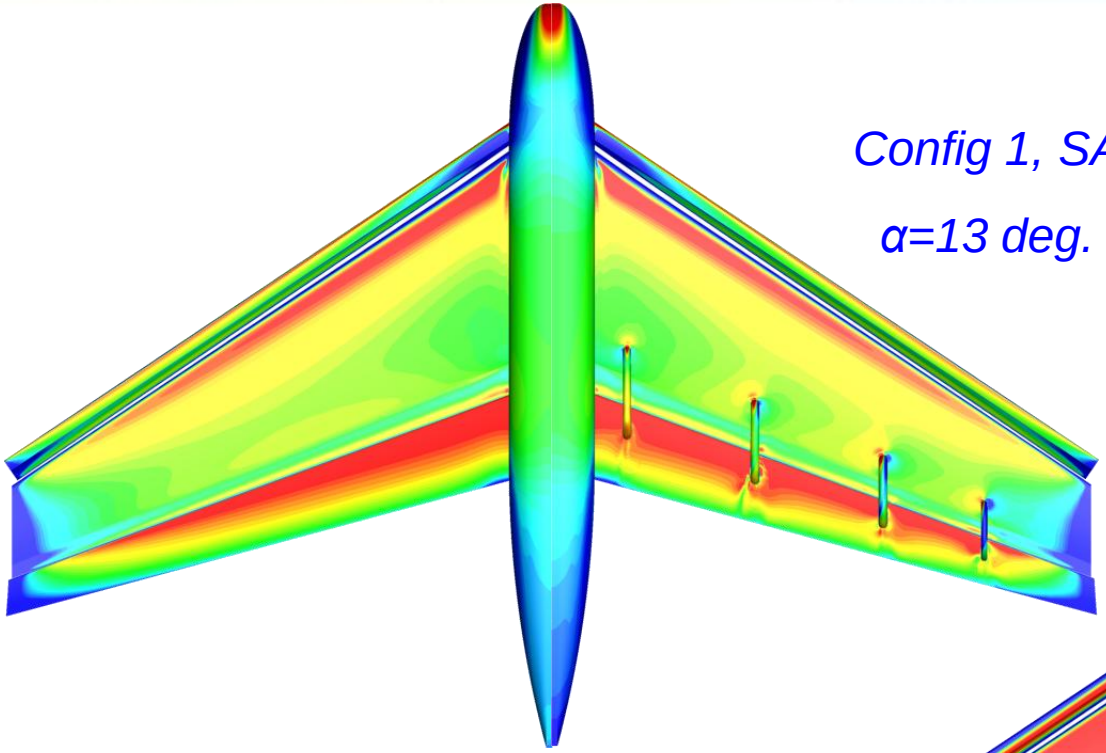


Config 1, SA

α=28 deg.

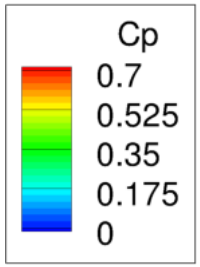


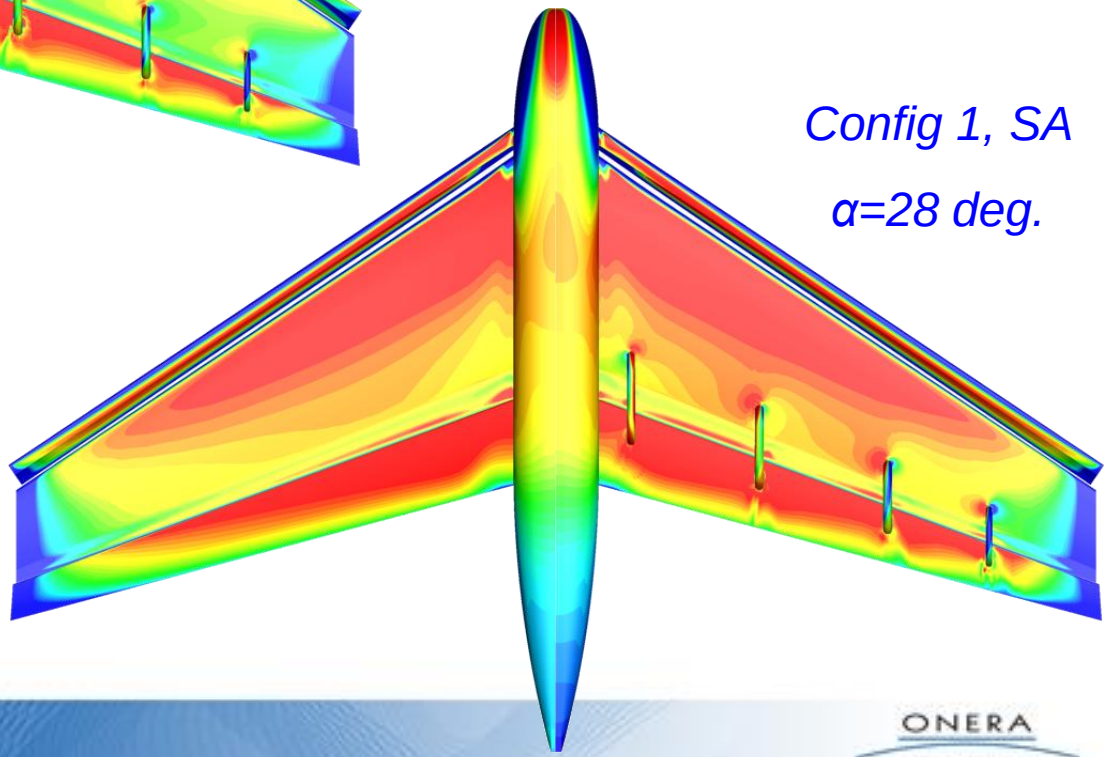
Flap support effects (5/5)



Config 1, SA

α=13 deg.





Config 1, SA

α=28 deg.

Conclusion

- Grid convergence study
  - major impact of turbulence models, especially on flap TE separation and stall behavior
  - fairly small differences between the different grid levels with SA (almost linear in $N^{-2/3}$ plot)
- Flap deflection prediction study
  - good overall agreement with experimental data (better for Config 1 than for Config 2)
  - remaining discrepancies with test data mainly due to geometric effects (brackets)
  - difficult to accurately predict the forces and moments increments
- Flap support effects
  - mitigated effects on aerodynamic coefficients prediction (deteriorated on CD and CL, except in near-CL_{max} region, improved on Cm)
  - the focus should be on relative comparisons with test data rather than on absolute values due to the type of model mounting used

Possible additional studies

- Hysteresis investigation
- Slat support effects
- Transition calculation
- Unsteady calculations around CL_{max}

Thank you for your attention