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THE FRENCH AEROSPACE LAB

Review of 2D buffet simulations on OAT15A profile

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ONERA - DAAA/ACI
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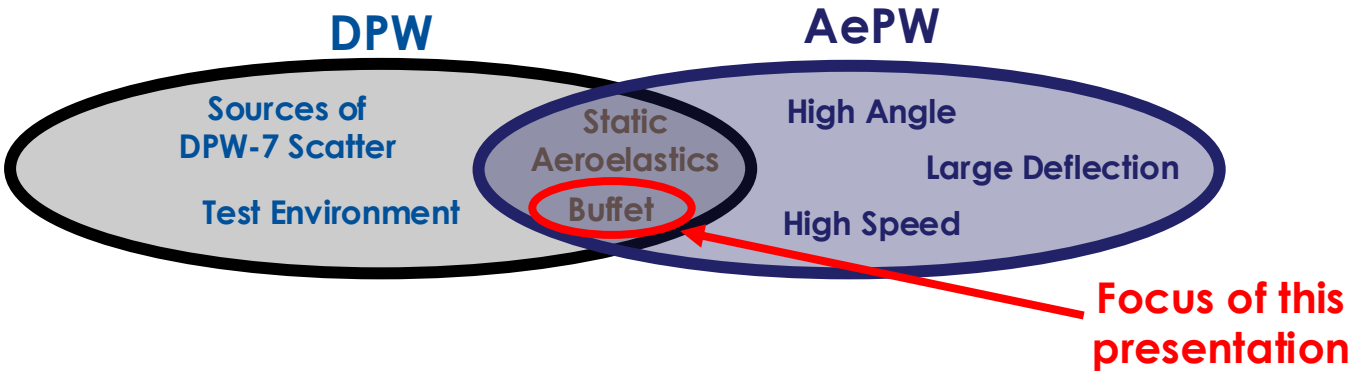
Outline

- Introduction
  - Overview work performed on OAT15A within DPW-8
  - Grids and approach
- Simulations using *elsA*
  - Steady-state simulations
  - Time-accurate simulations
- Comparison with experimental data
- Conclusions

Introduction: DPW-8



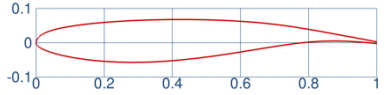
DPW and AePW

- ONERA involved in many activities, mainly in DPW
- DAAA/ACI contributed to Buffet and Scatter Working Group (elsA and CODA)

WG#3 Buffet

- Test case 1: OAT15A simulations (steady/unsteady)
- Test case 2 and 3: CRM, not discussed here

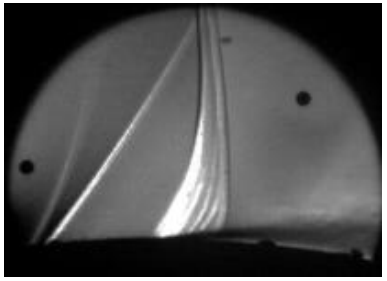
Introduction: Test case 1



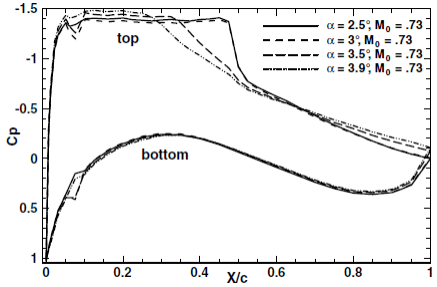
OAT15A

→ Reference for 2D buffet since Jacquin et al. (2009)

- ONERA shared CAD files with geometry details
- Experimental data: Cp, Cp_{rms}, time-history signals, PSD
- Some 2D grids also provided by the workshop (Cadence, HeldenMesh, ONERA)



Experiments from Jacquin et al



Experiments indicated buffet onset around 3.5°

- What solver can reproduce it? On which grid?
- What can be delivered using different approaches?
- Best practices for turbulent models, numerical schemes, limiters?

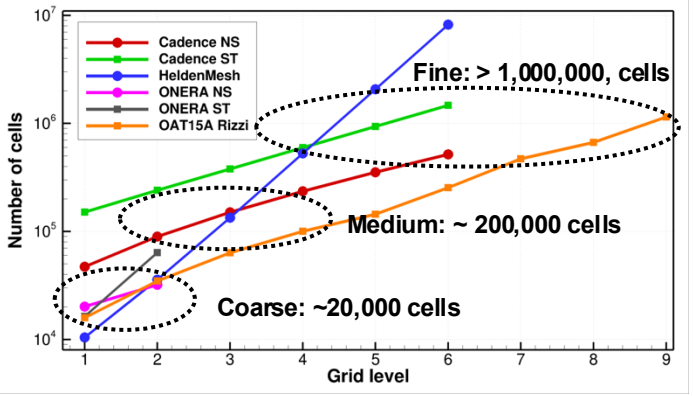
In this presentation:

Solver	Grids	Approach	Turb. Model	Scheme	AoA
• elsA	• Supplied • Custom	• RANS • URANS	• Mainly SA • Other tested	• Any	• 1.36° - 3.90° *10 in total*

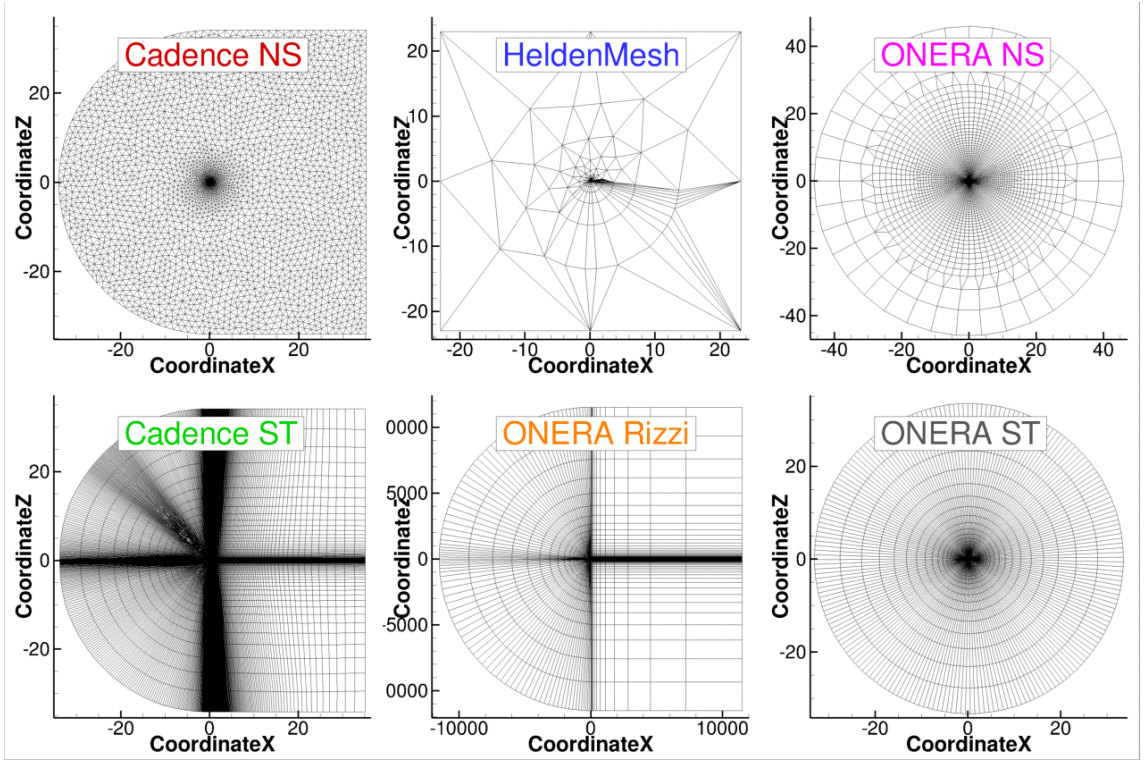
Introduction: available grids

6 families, 30 grids in total:

- Cadence (unst.): 6 levels
- Helden Mesh (unst.): 6 levels
- ONERA O-grid (unst.) : 2 levels
- Cadence (st): 6 levels
- ONERA O-grid (st): 2 levels
- ONERA Rizzi (st): 9 levels



Number of cells vs grid level



Visualisation of grid level 1 for all 6 tested grids

Introduction: simulations completed

***elsA* code:**

- Co-developed by ONERA and Safran
- Finite volume, centered cells, RANS/URANS approach
- Structured or unstructured, depending on the grid
- Intensively used for buffet simulations since many years, both in 2D and 3D

First approach:

→ test ALL the grids in RANS/URANS using the same “standard” parameters, for all AoA

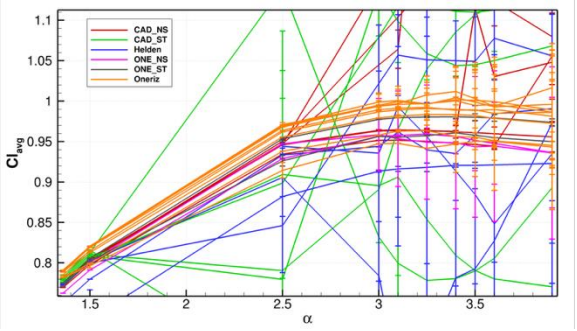
- ONERA best practices have second order in both conservative and turbulent fluxes
- This does not yield buffet! Not even one grid, one AoA, for all the turbulence models tested
- Decided to use first order turbulence
- This behavior have already been observed with elsA in the past for 2D and 3D buffet simulations

Final approach:

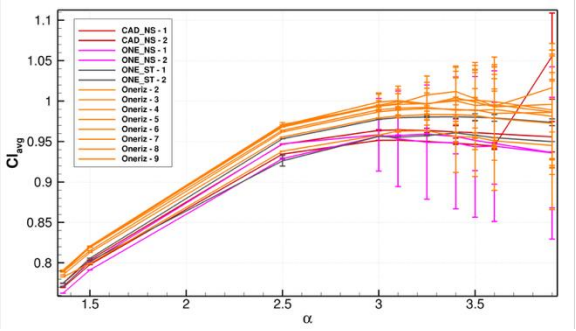
- elsA solver, RANS on most grids, SA, Roe scheme, all AoA
- First order on turbulent fluxes
- Run of roughly 300 steady and 300 unsteady cases
- Additional 100 parametric simulations changing some parameters, only on AoA=3.5°
- Conclusions analyzing and comparing the “only” 15 cases that show buffet at 3.5°

RANS results using elsA

Result example of **steady-state** simulation, using **all grids**, elsA solver using standard best practices

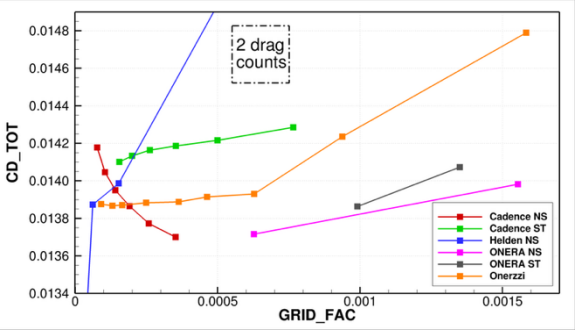


Some cases still not converging at all

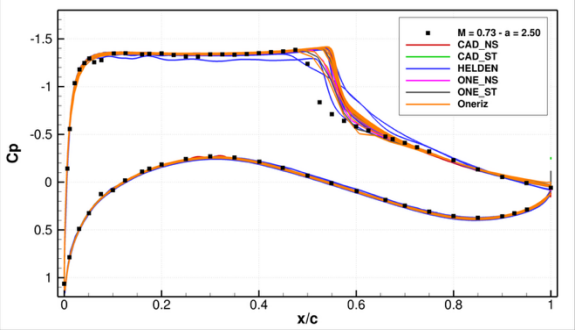


Polars for cases that converge at low AoA

- Cl vs alpha. Error bars showing Cl_{std}
- Low-dissipation setup not converging
- Down-selection of converging grids
- Still a lot of grid dependency
- Some grids are unsteady already at 3.0°



Grid convergence at 1.36 deg only for “Onerizzi”

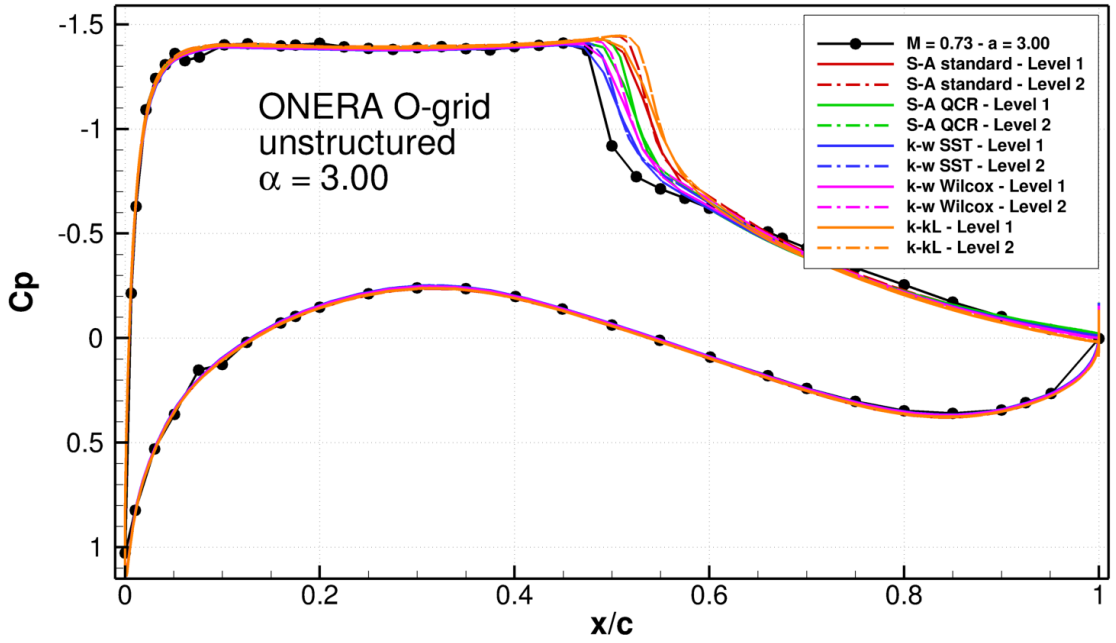


Cp at AoA = 2.50° for all grids

- Grid convergence: only ONERA-Rizzi grid shows some sort of grid convergence
- Reasonable comparison with exp. data
- No grid has correct shock location with this combination of model/limiter

RANS results using elsA

Focus on ONERA O-grids (2 levels): effect of turbulence model for AoA = 3.00°



Turbulence model and grid dependency for ONERA O-grid (unstructured)

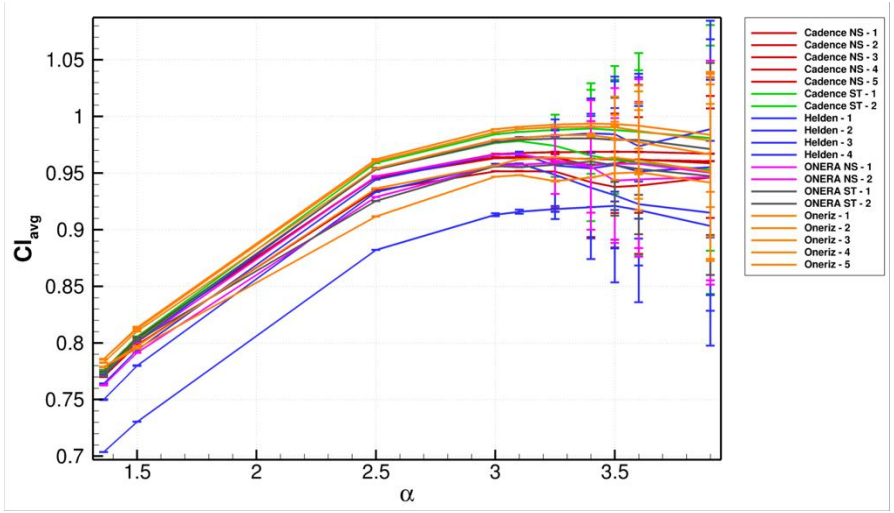
Conclusions:

- As expected, turbulence-model dependency
- k-w SST closer to experiments than SA, but shock still too downstream
- Different results when changing grid
- Model dependency more important than grid dependency

RANS reliable only for small angles of attack:
need for time-accurate simulations

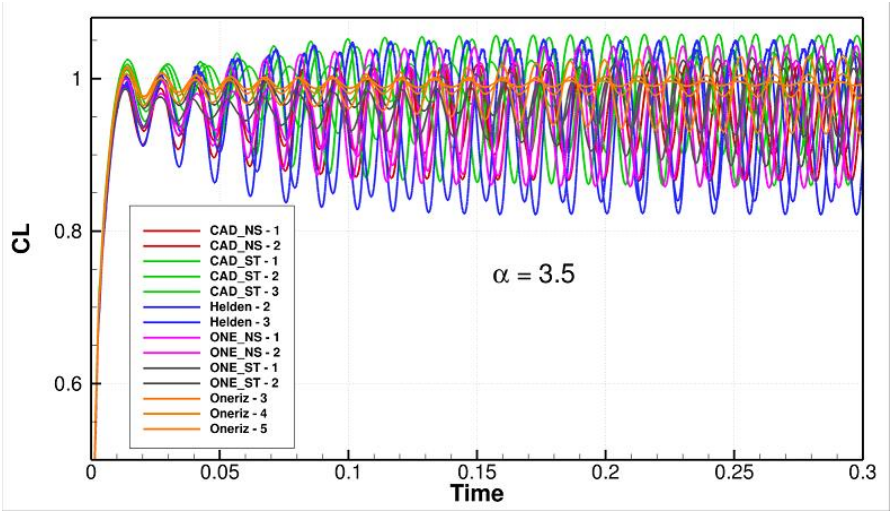
URANS results using elsA: time-accurate simulations

Lift polars still not showing grid convergence
Some agreement about buffet onset



Polars of average Cl, error bars with std of lift (unsteady cases)

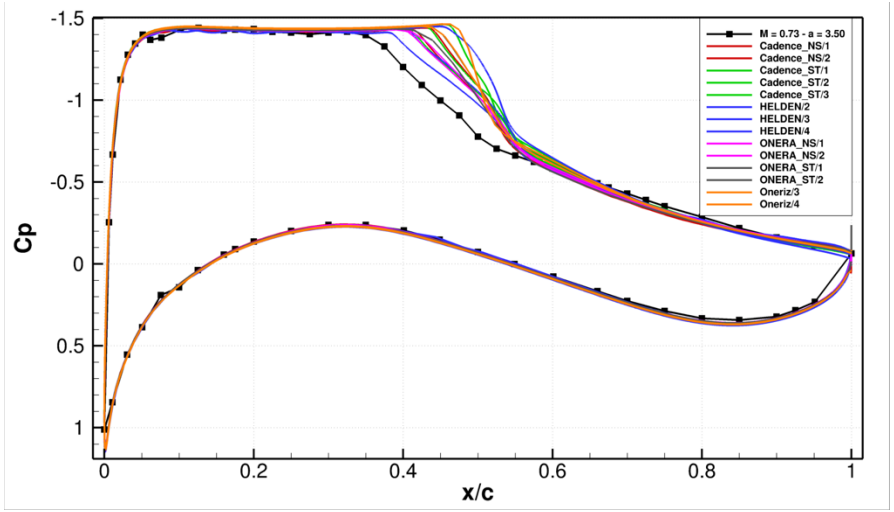
Time-history of lift coefficient quite similar in transient, average Lift and buffet frequency, different amplitudes



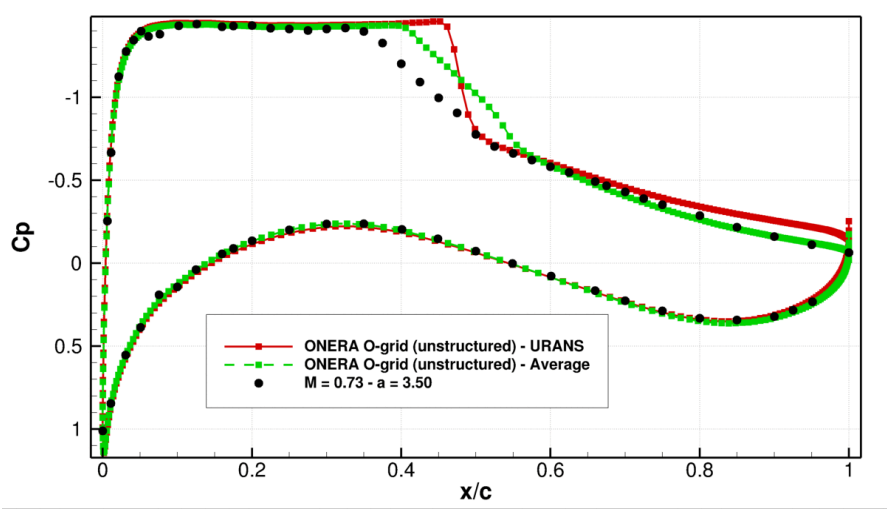
Typical CL-iterations for all unsteady cases when AoA = 3. 50

URANS results using elsA: average Cp

Focus on all grids, using best practices for time-accurate simulations. AoA = 3.50°



Average Cp distribution for all unsteady cases

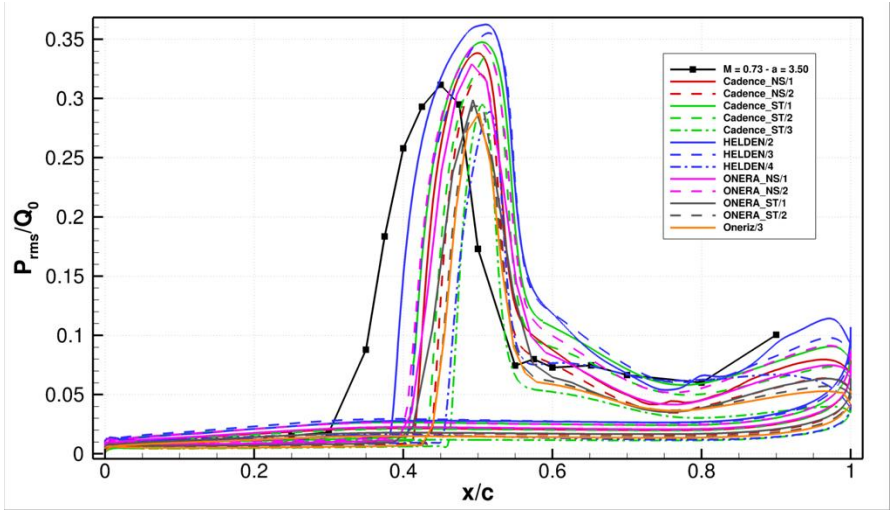


Animation of Cp distribution vs average on ONERA O-grid, AoA = 3.50°

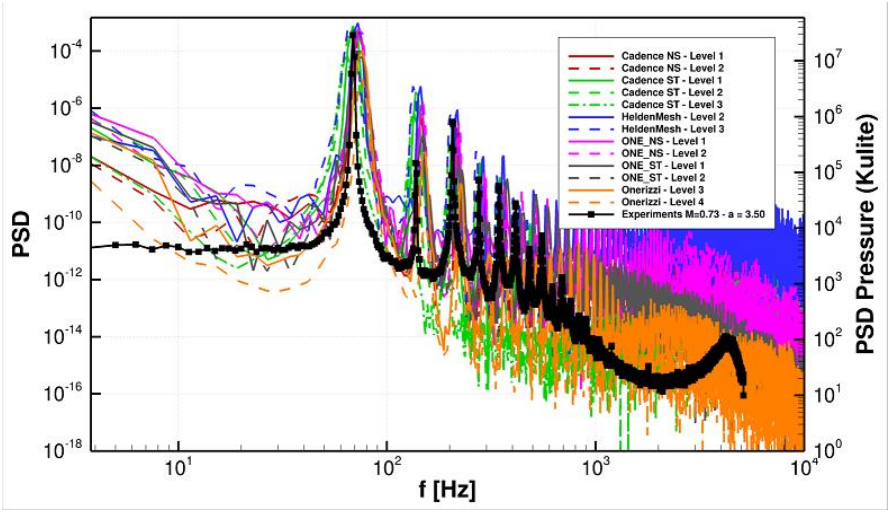
- Shock location always downstream w.r.t. experiments among the 14 grids showing buffet at 3.50°
- All other grids yields steady solutions (no shock movements)
- Favorable comparison elsewhere: upstream shock, downstream separation, pressure side, LE, TE

URANS results using elsA: fluctuations

Focus on all grids, using best practices for time-accurate simulations. AoA = 3.50°



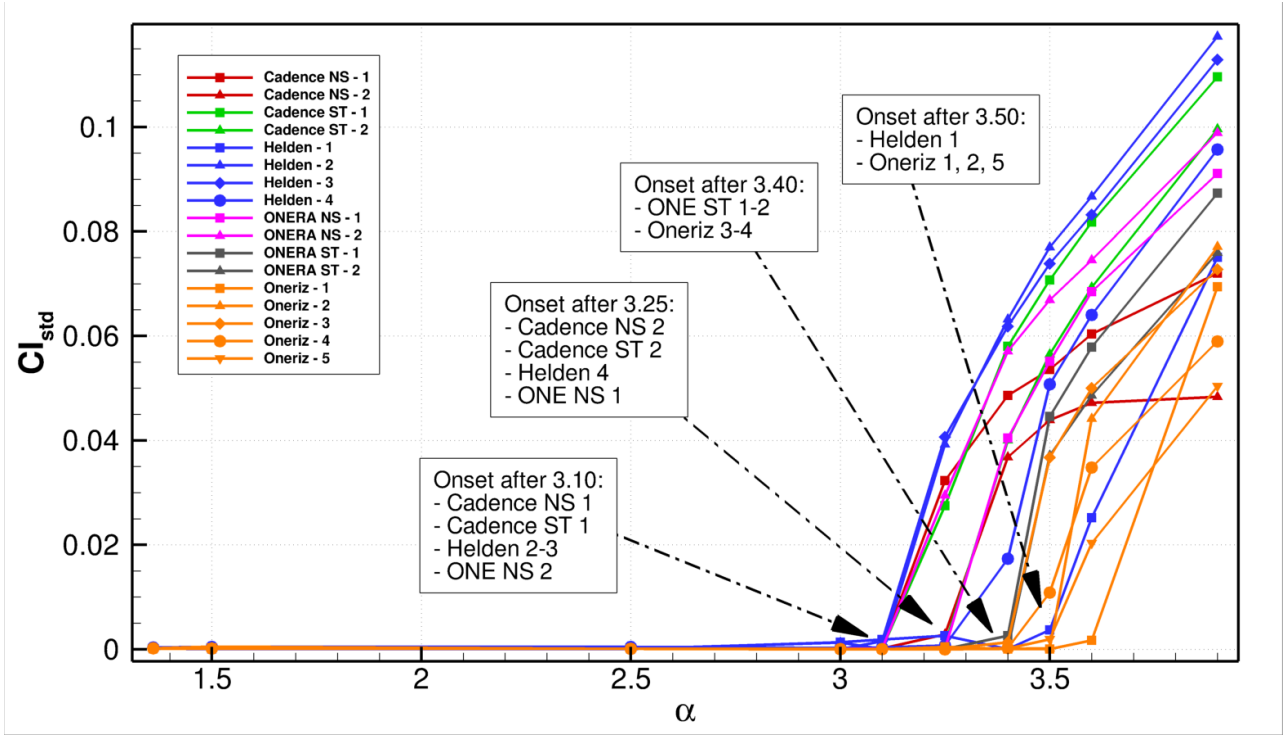
RMS on suction side for all unsteady cases at 3.50°



Power Spectral density of all unsteady cases at 3.50°

- RMS show shock downstream, but similar amplitudes
- Good agreement in separated region
- Power Spectral Density: very good agreement for the main buffet frequency

URANS results using elsA: buffet onset



Buffet onset criterion: increase of STD of lift coefficient

- Buffet criterion: CL oscillations
- No grid convergence
- Coarse grids: onset sooner
- Unst. grids: ~ onset sooner
- Some grids never show buffet!

Conclusion: very hard to select the best grid or refinement level

Conclusions

Recap of work performed:

- Started elsA “best practices”, no buffet at all
- Moved to second order for conservatives, first for turbulent equation(s):
  - RANS: poor residual convergence for high AoA, need for time-accurate simulations
  - URANS: tested all grids with “standard best practices” (only few of them are unsteady)
  - URANS: some extra simulations for tStep, inner-iterations, model, scheme

Conclusions

- Very strong grid dependency, even at low AoA:
  - When changing the grid, the behavior changes
  - No grid convergence: if we refine we get different results
- Time-step and inner iteration:
  - Fairly stable. Minimum number of iteration per period required
- Buffet simulations:
  - Shock always slightly downstream w.r.t. experiments
  - Buffet frequency and shock amplitudes fairly well captured and consistent
  - Onset depends both on grid family and grid level
- “Best grid”: hard to tell, but O-grids (20-40k cells/vertex) can give satisfying results