CFD Investigations of the HiLiftPW-2 Configuration with MFlow Solver

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outline

- HiLiftPW-2 geometry and test cases
- Numerical methods
- Results and discussions
- Conclusions

HiLiftPW-2 geometry

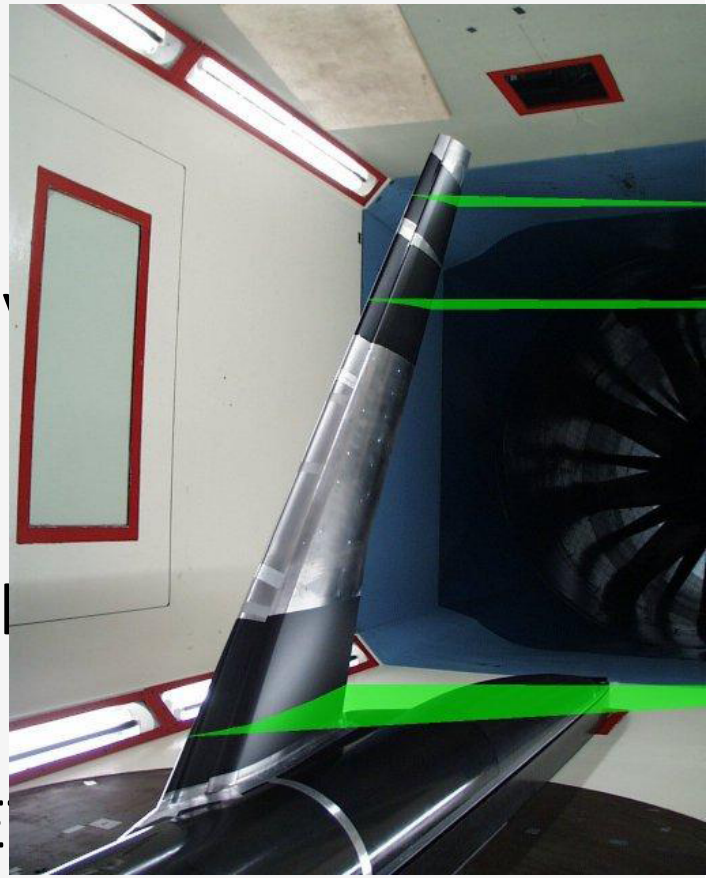
- DLR F11 high lift configuration

✓ representative for commercial

  - typical 3-element high lift s
  - full span slat and flap

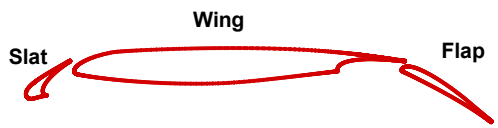
✓ simplified compared to full real

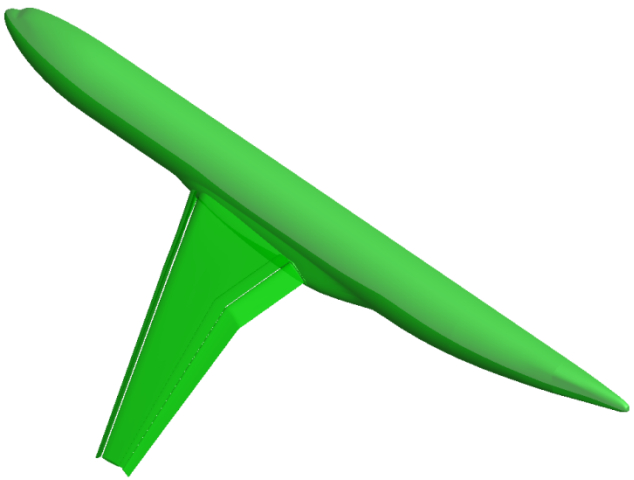
✓ experiments accomplished in E



HiLiftPW-2: Case1Config2

- Config2: Wing/Body/HL system + SOB Flap Seal
- Case1: grid convergence study for Config2 under high Reynolds number condition





HiLiftPW-2: Case1Config2

- ✓ Hex grids generated by Boeing-Huntington Beach
- ✓ Hybrid grids generated by DLR and Pointwise

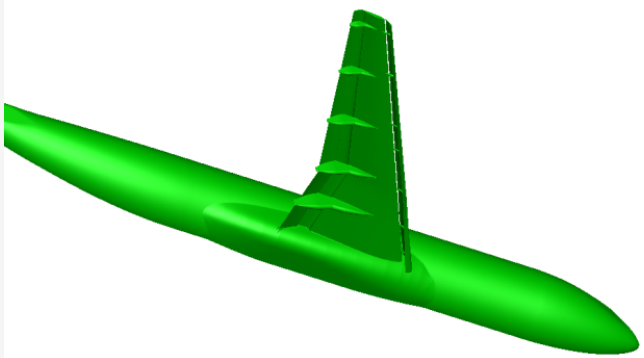
	ExtraCorse	Coarse	Medium	Fine
A (Hex, Boeing)		**9,556,725**	**31,998,440**	**100,561,536**
B (Hybrid, DLR)		21,356,048	59,066,549	
C (Hybrid, Pointwise)	28,695,654	44,394,310		

HiLiftPW-2: Case2Config4

- Config4=Config2+Slat Tracks and Flap Track Fairings
- Case2: Reynolds Number Study for Config4
  - ✓Case2a: Low Reynolds Number Condition
  - ✓Case2b: High Reynolds Num

:

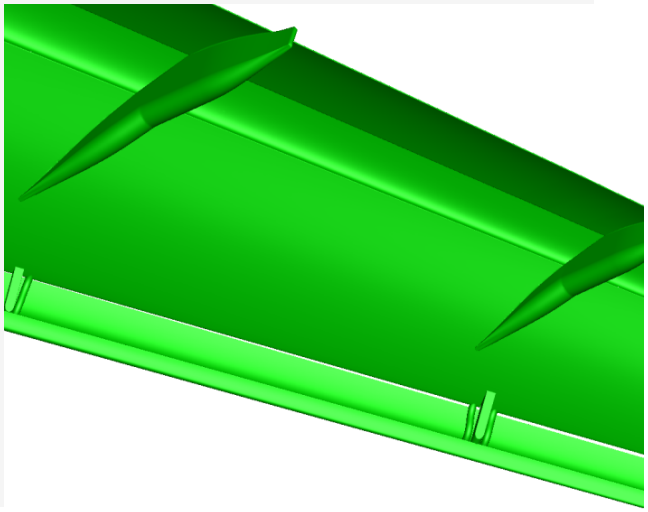
	Case2_HighRe	Case2_LowRe
Total element	73,740,331	76,972,998
Hex	23,727,289	28,970,720
Tetra	48,737,509	46,675,078
Prism	196,800	245,042
Pyramid	1,078,733	1,082,158



HiLiftPW-2: Case3Config5

- Config5=Config4+Slat Pressure Tube Bundles
- Case3: full configuration study
  - ✓Case3a: Low Reynolds Number Condition
  - ✓Case3b: High Reynolds Number Condition
- Hybrid grids generated by DLR:

	Case3_HighRe	Case3_LowRe
Total element	81,603,665	75,547,314
Hex	24,382,376	29,626,850
Tetra	55,905,028	44,558,195
Prism	207,834	256,622
Pyramid	1,108,427	1,105,647



HiLiftPW-2

- High Reynolds number condition

$$Re_c = 15.1\times10^6, Ma = 0.175, T_\infty = 114.0K, P_\infty = 295000Pa$$

$$AoA = 0,\ 7,\ 12,\ 16,\ 18.5,\ 20,\ 21,\ 22.4$$

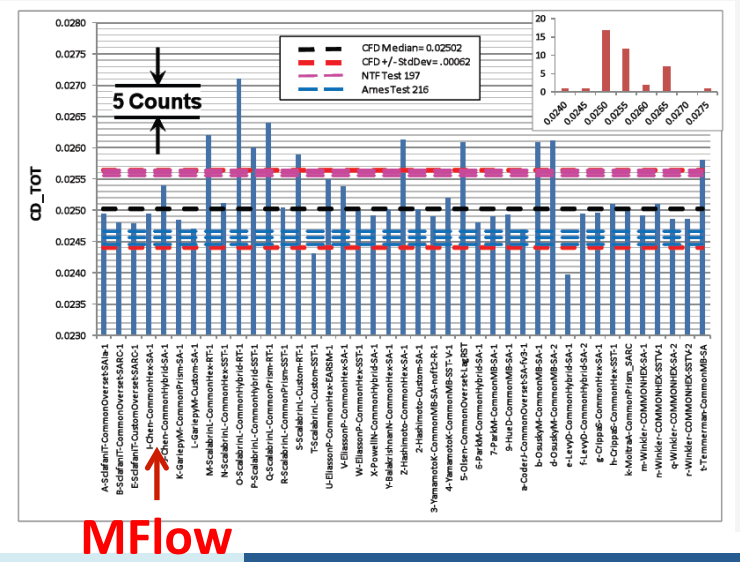
- Low Reynolds number condition

$$Re_c = 1.35\times10^6, Ma = 0.175, T_\infty = 298.6K, P_\infty = 100700Pa$$

$$AoA = 0,\ 7,\ 12,\ 16,\ 18.5,\ 19,\ 20,\ 21$$

CFD Code Descriptions: MFlow

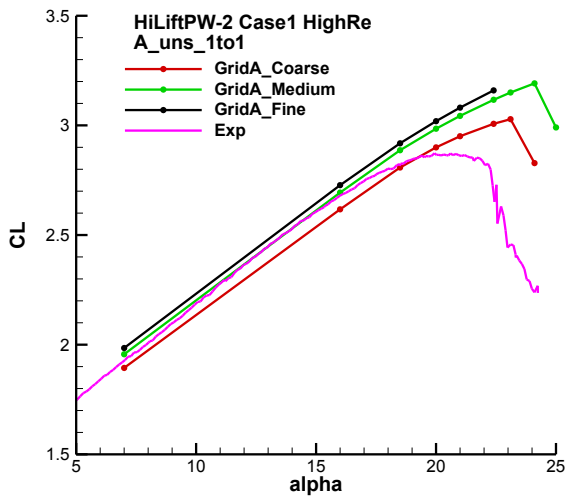
- cell center finite volume method
- capable of handling arbitrary element types
- **M**ulti-: grids, turbulence models, schemes, multi-component flows

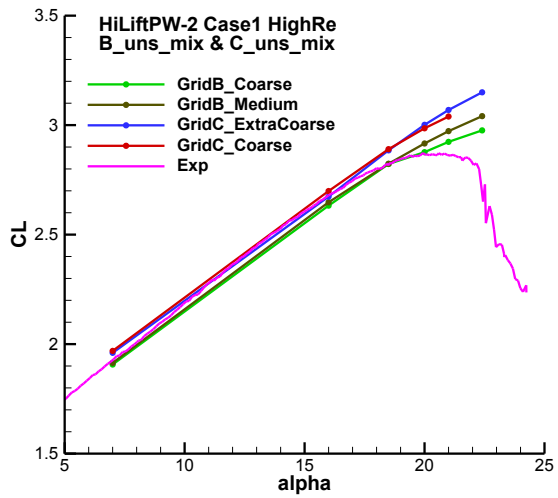


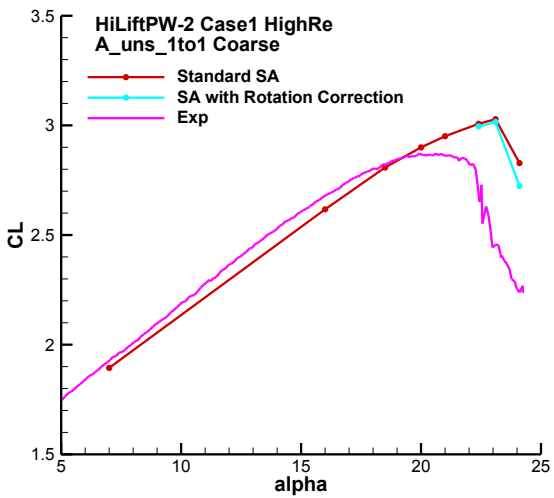
CFD Code Descriptions: MFlow

- **"Standard" SA turbulence model (original formulation, no trip term)**
- Full NS formulation
- Roe
- Gauss-node gradient computation
- Venkatakrishnan's limiter
- Low-Mach-number precondition
- LUSGS for steady-state marching
- **Free stream conditions used as initial conditions**

Case1: CL-alpha







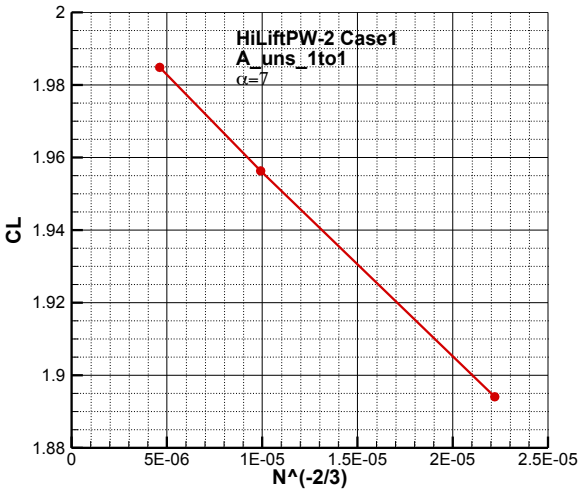
- Same trends are found among different grids:

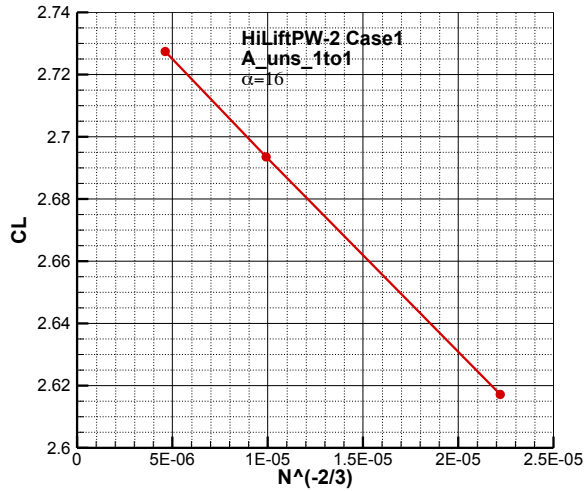
1. delayed stall
2. larger CL_max
3. grid refinement makes 1&2 more evident

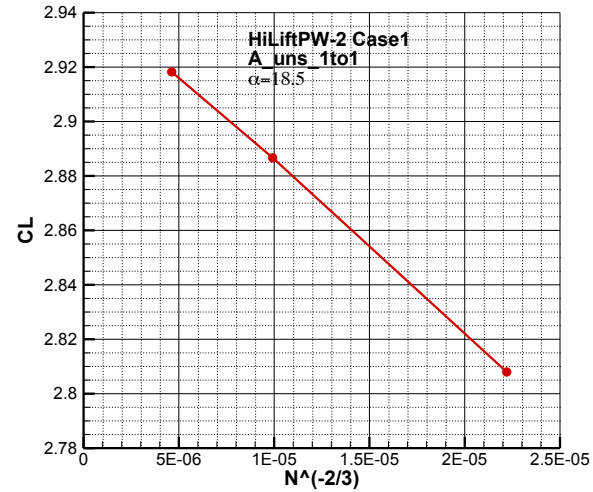
- **Rotation correction of SA model makes little difference to CL curve**

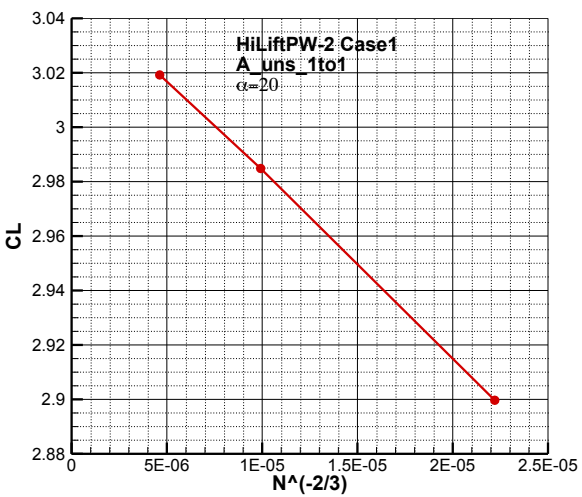
Case1: CL grid convergence

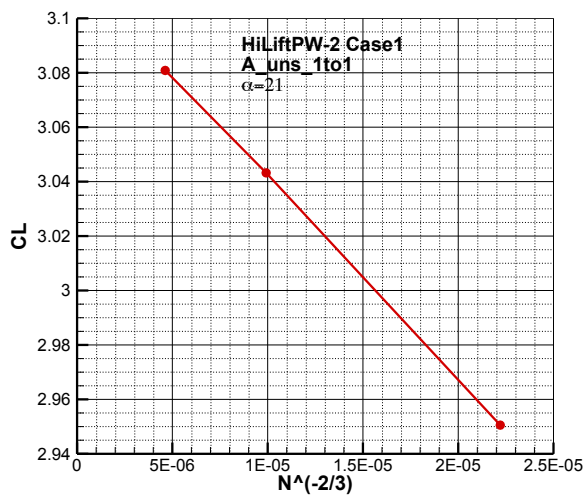
- Nearly linear convergence obtained with grid refinement

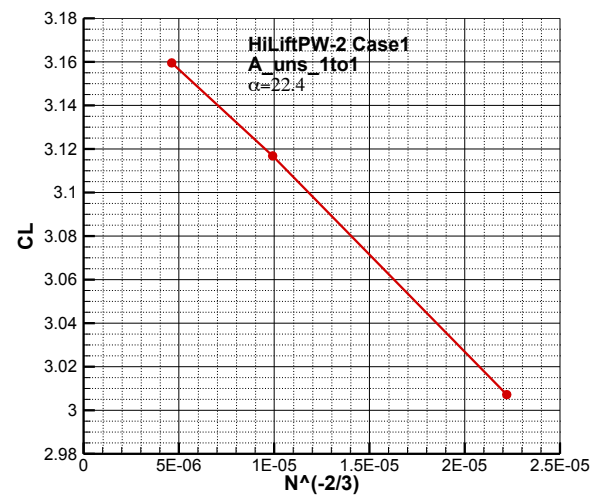




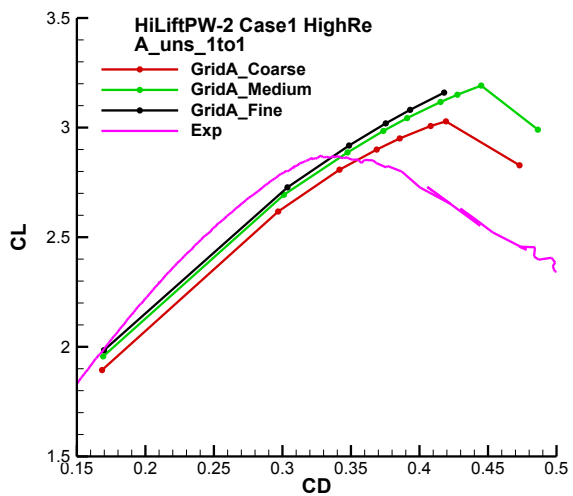


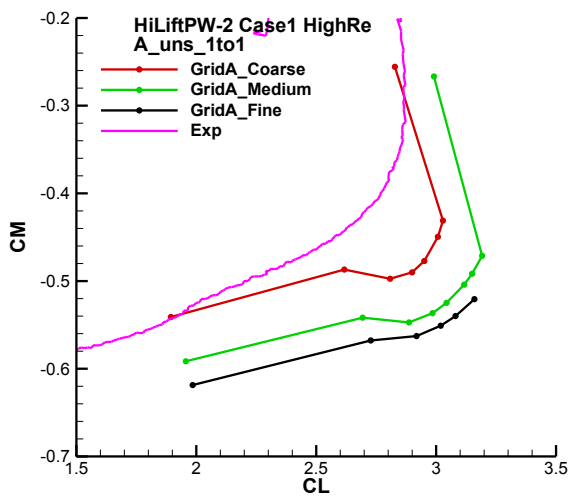






Case1: CD&CM-alpha

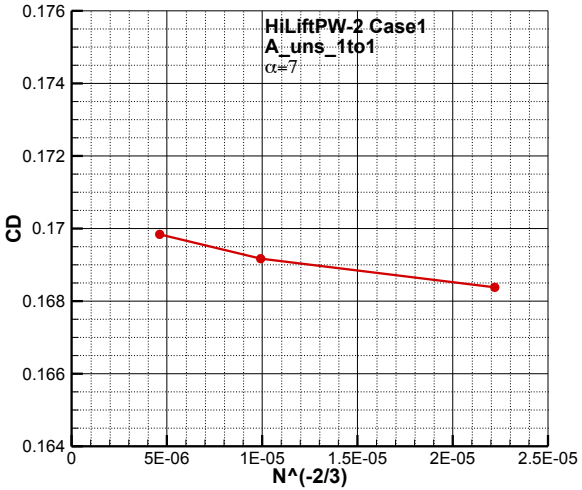


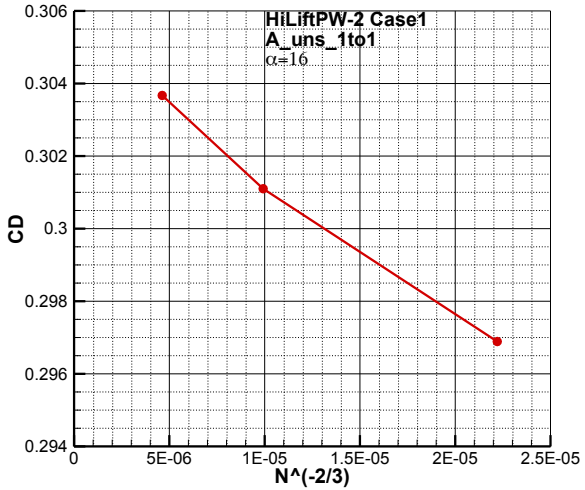


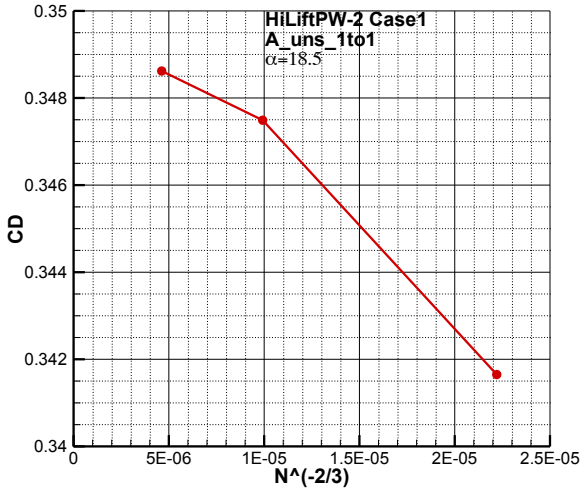
- The CD&CM prediction is unsatisfied and grid refinement doesn't lead to improvement compared to experiment.

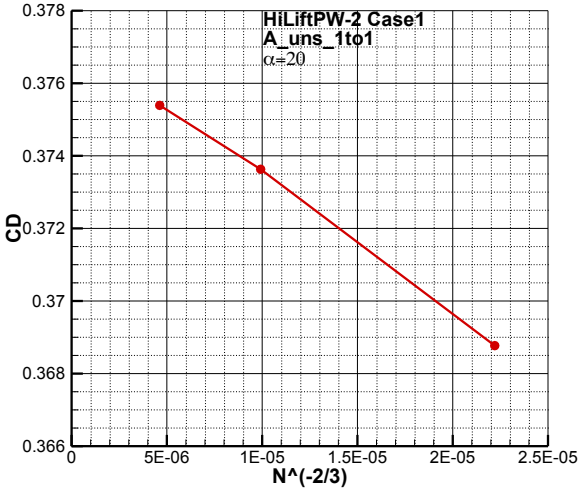
Case1: CD grid convergence

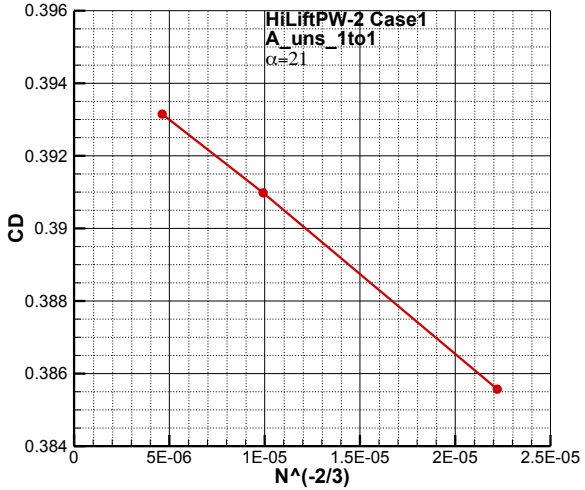
- Nearly linear convergence obtained with grid refinement

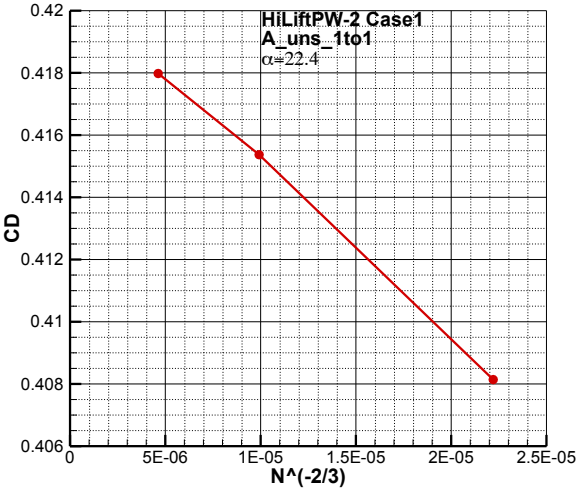






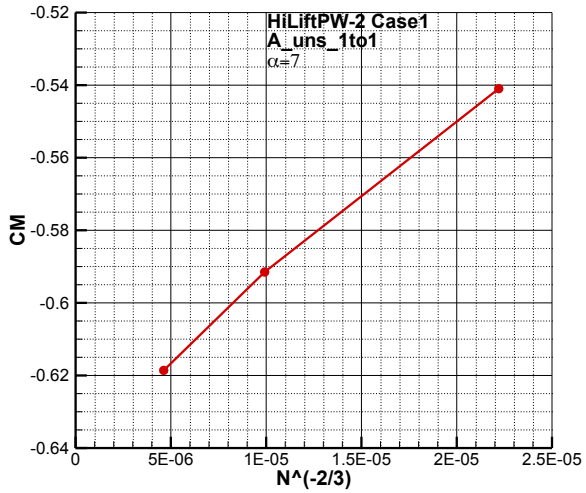


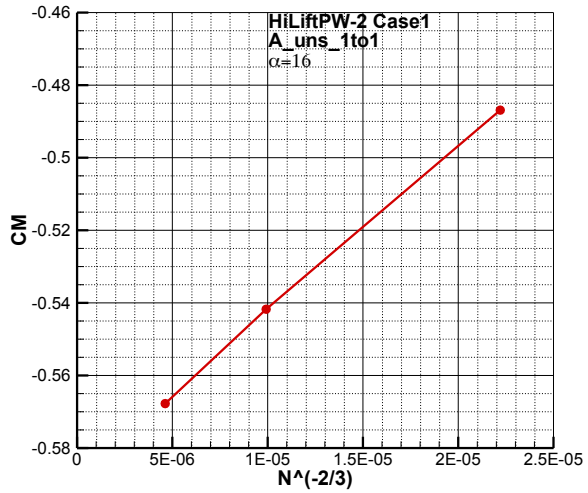


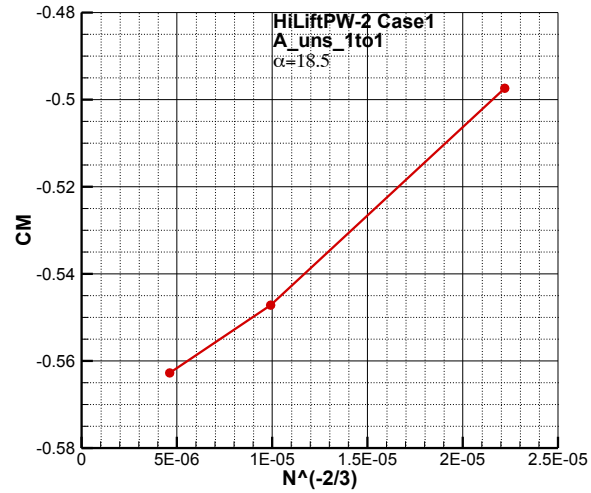


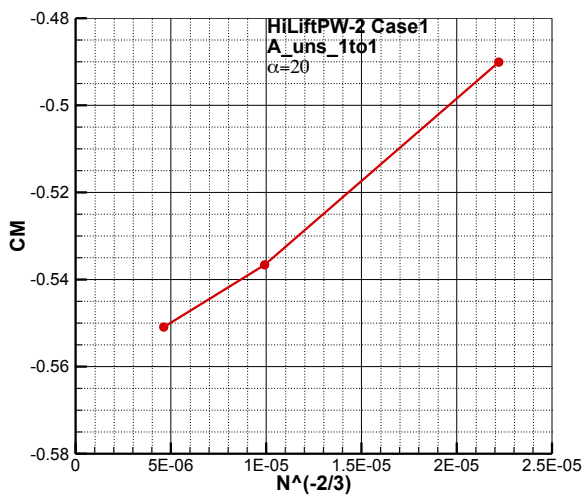
Case1: CM grid convergence

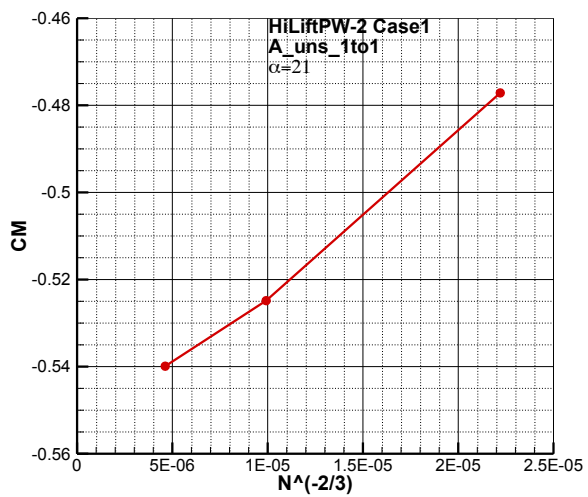
- Nearly linear convergence obtained with grid refinement

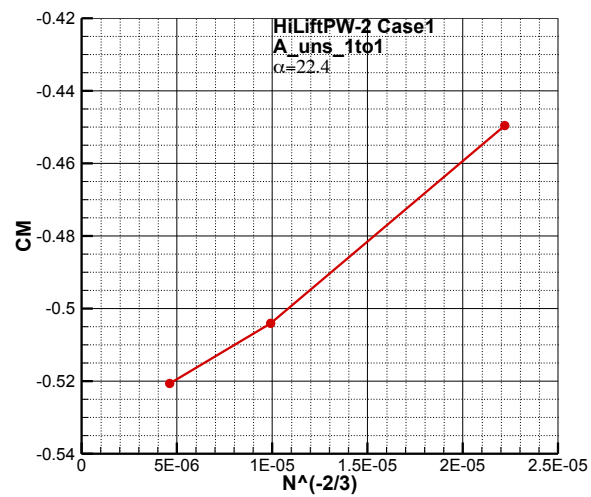






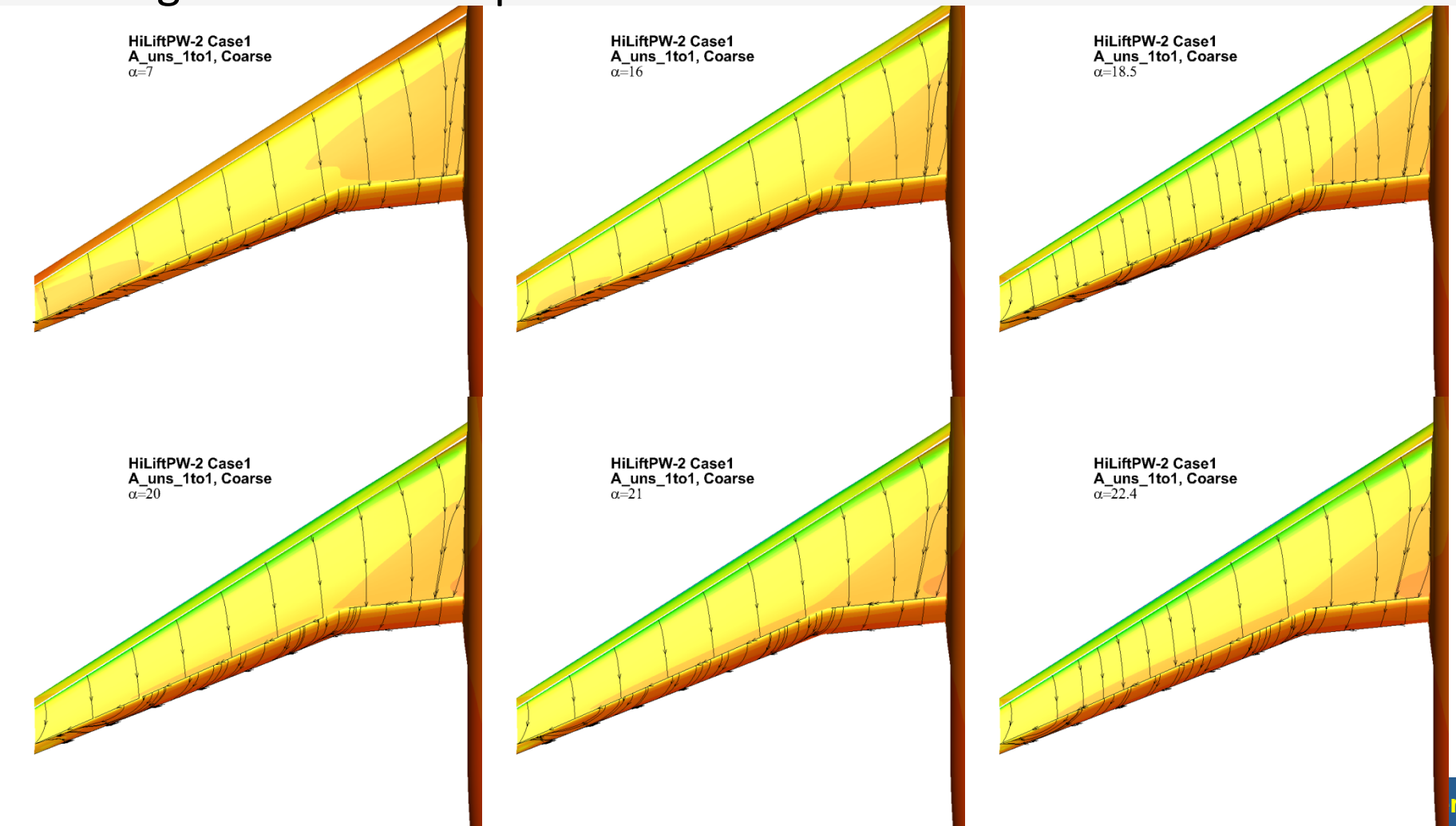




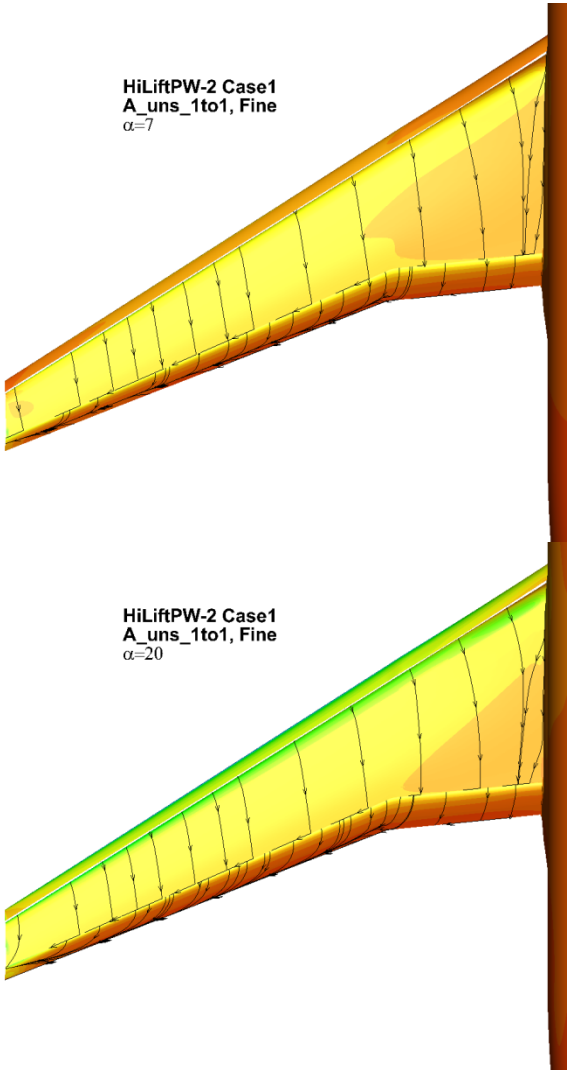


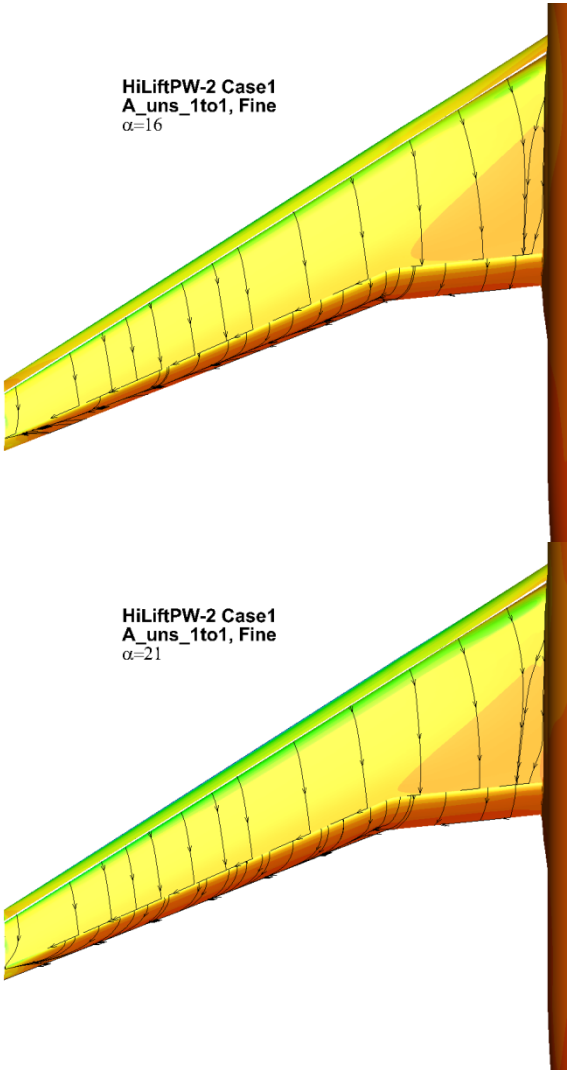
Case1: surface flow/ Coarse Grid

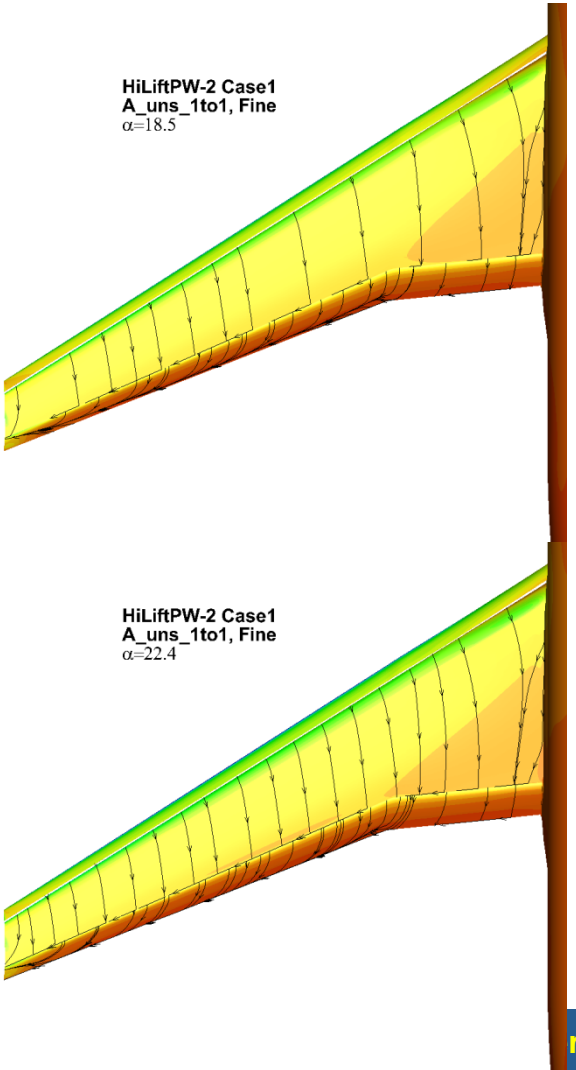
- Flap: TE separation is weakened with the increment of alpha
- Wing: no massive separation exhibits



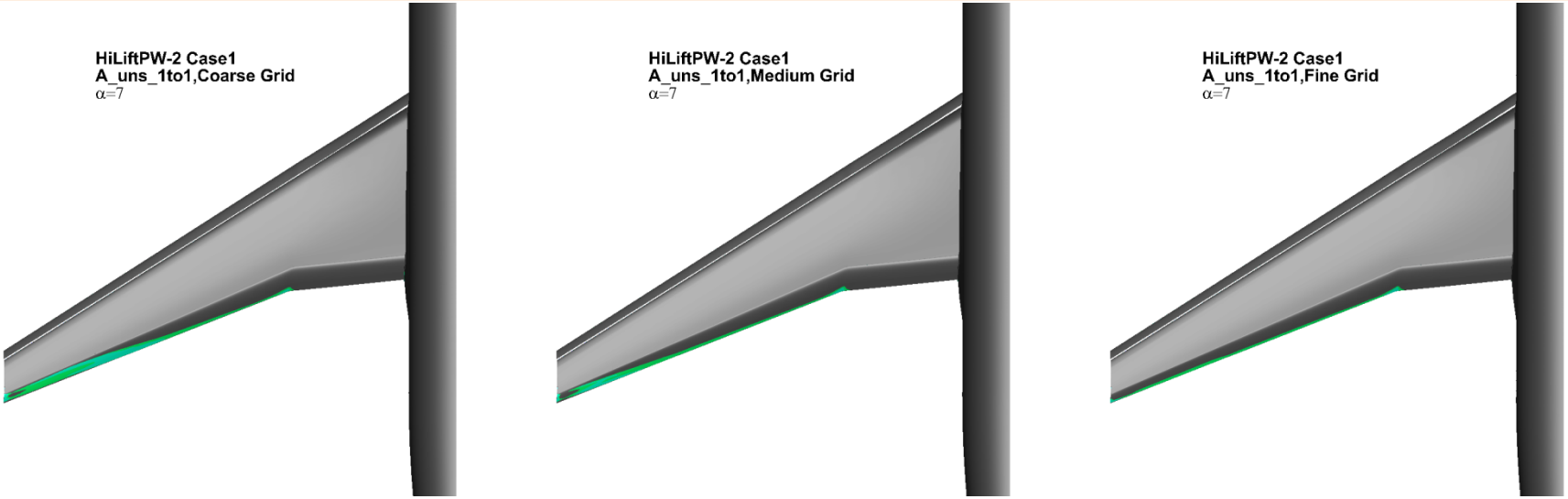
Case1: surface flow/ Fine Grid





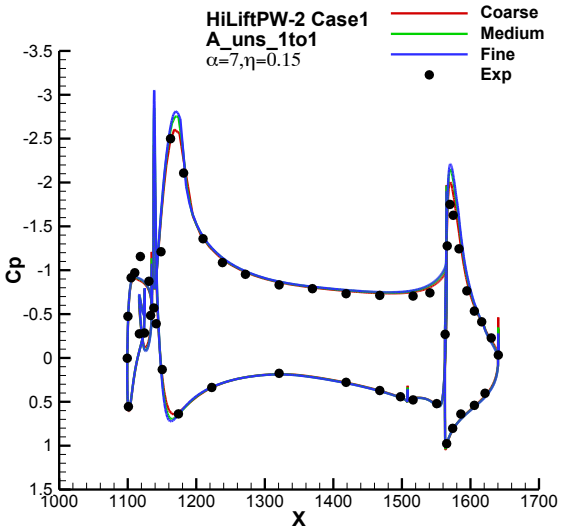


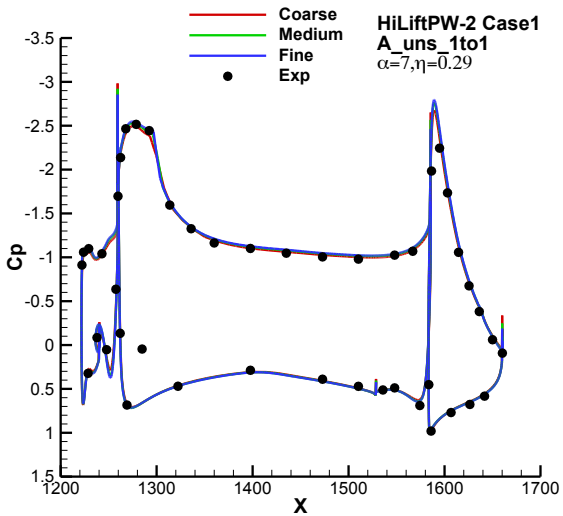
Case1: surface flow/ Grid Effects

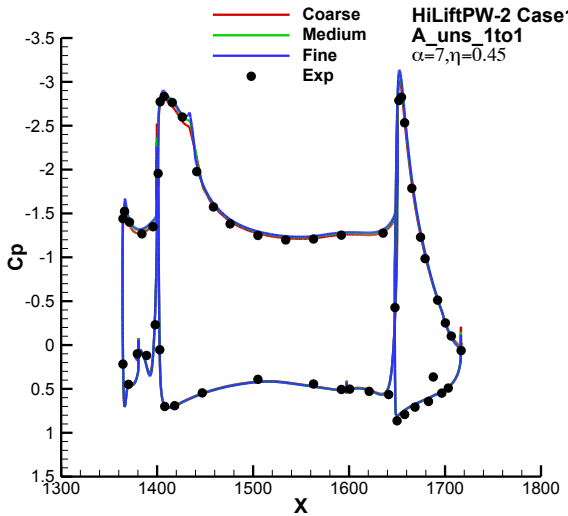


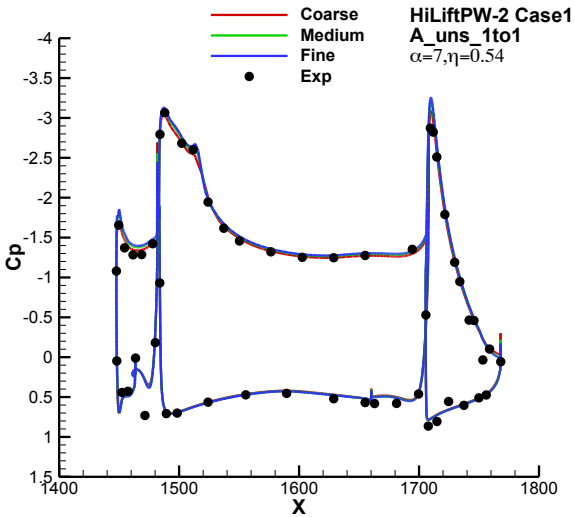
- Green region: cfx<0
- Flap: TE separation is weakened with grid refinement

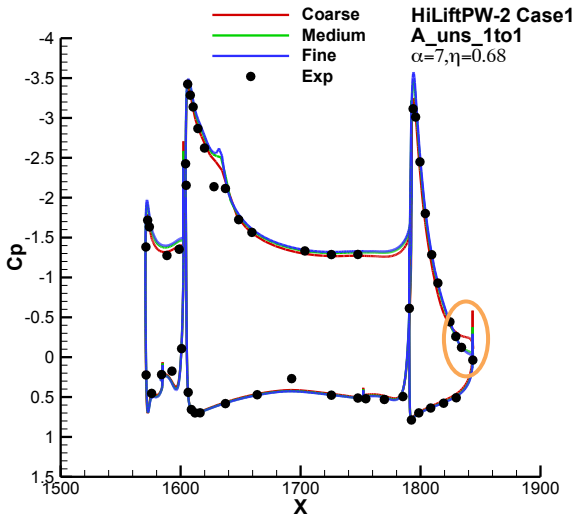
Case1: Cp distribution alpha=7

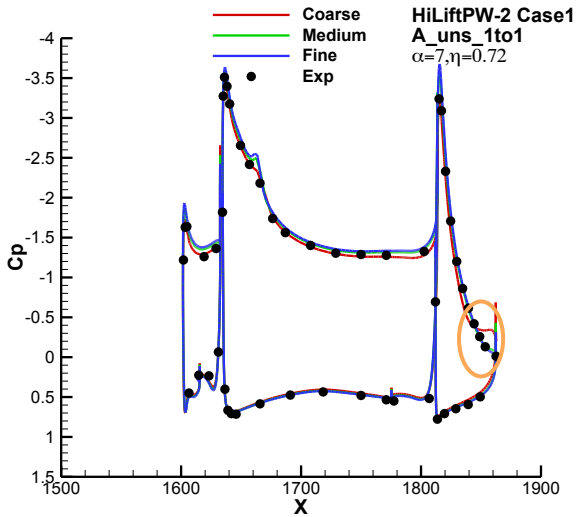




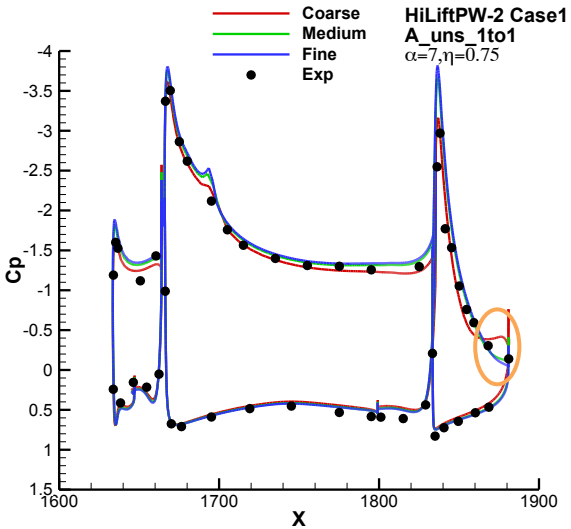


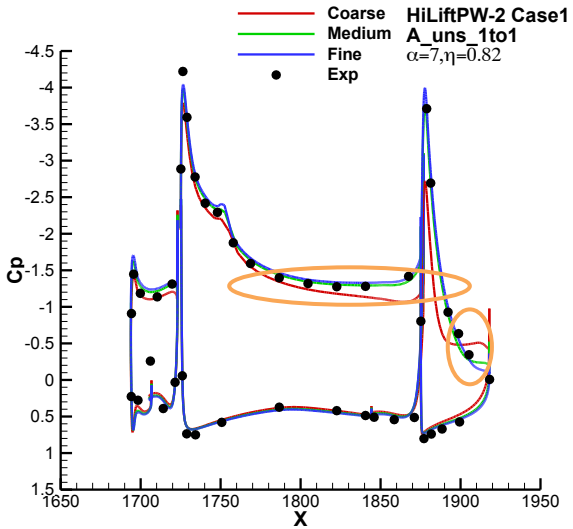


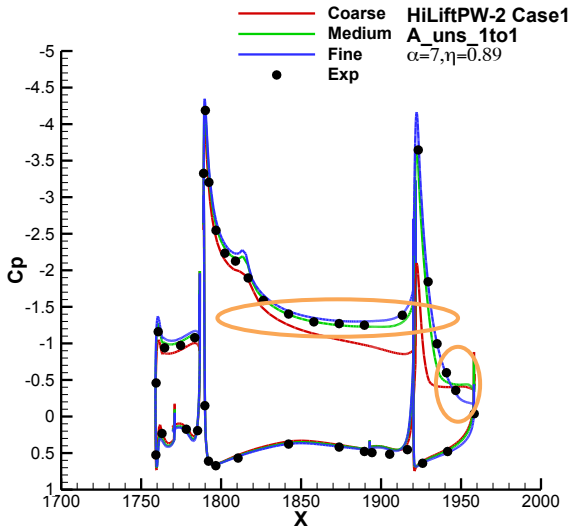


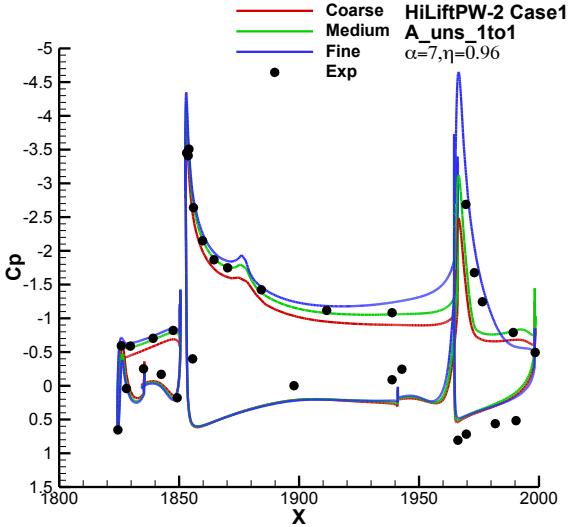


Case1: Cp distribution alpha=7



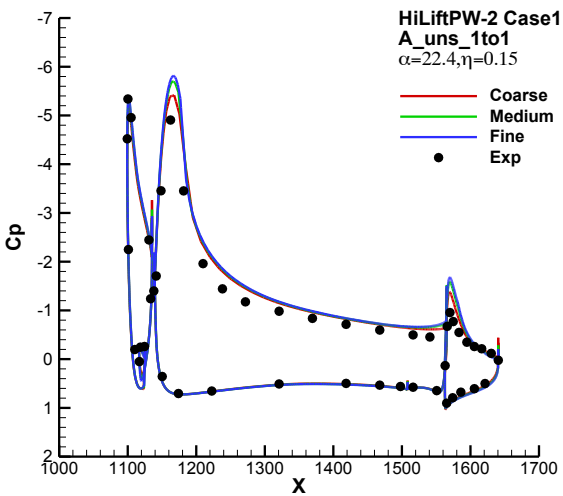


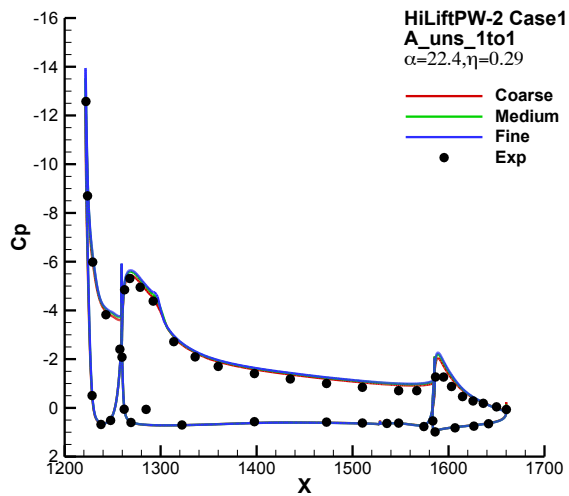


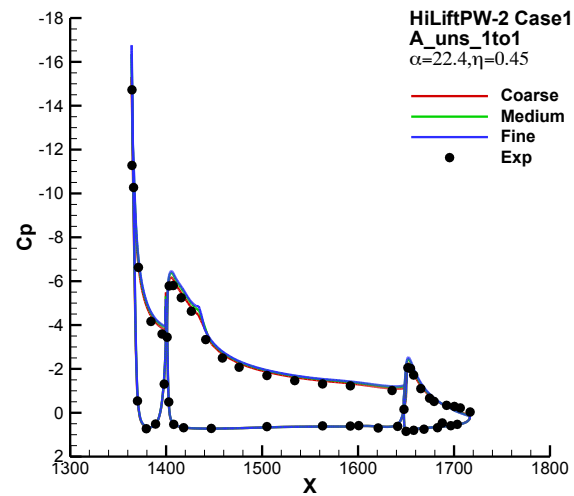


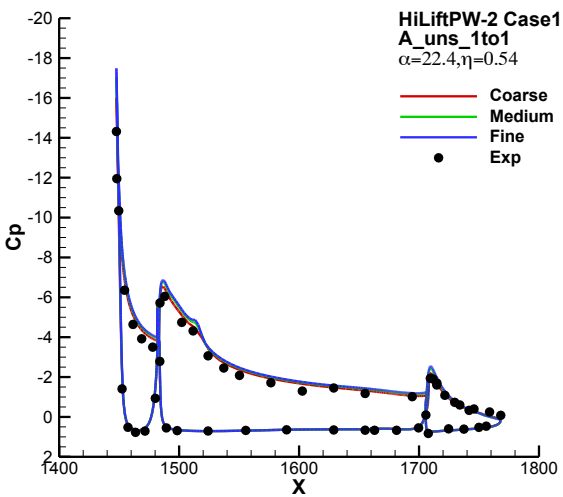
- Grid refinement improves Cp prediction on the wing sections near the tip and on the flap upper surface where actually no separation exhibits

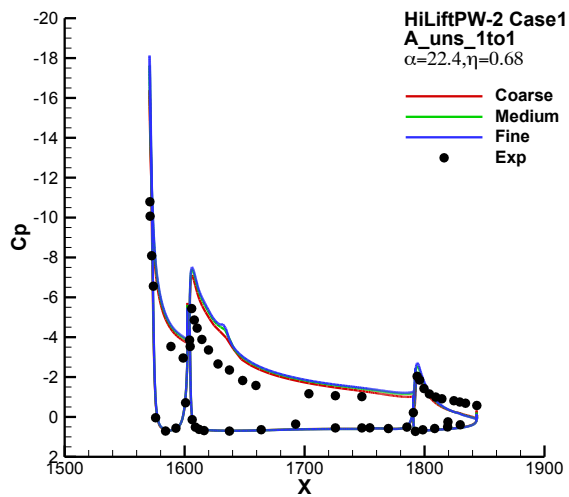
Case1: Cp distribution alpha=22.4

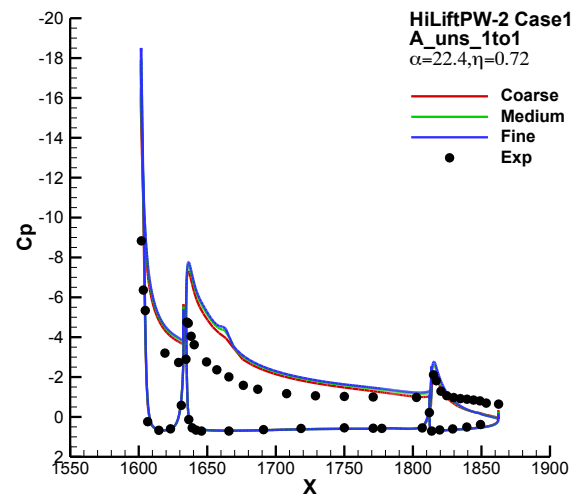




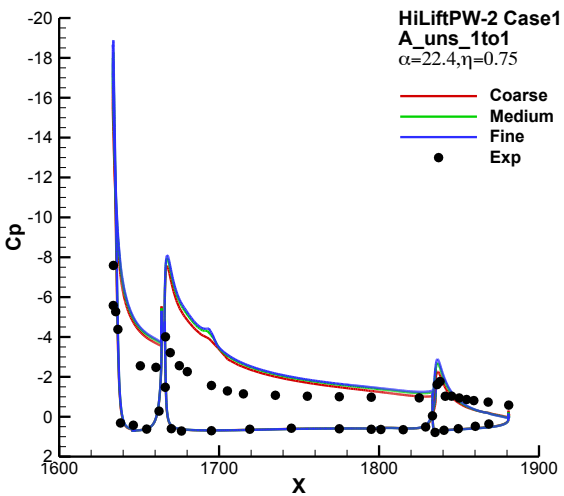


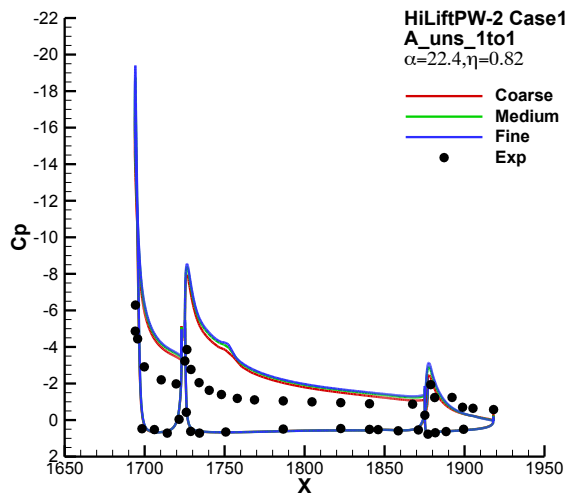


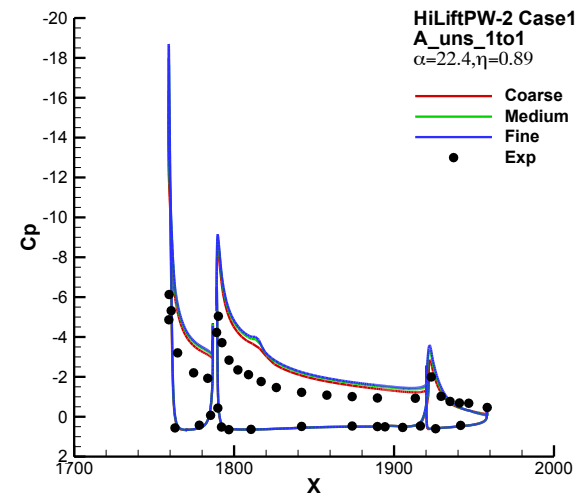


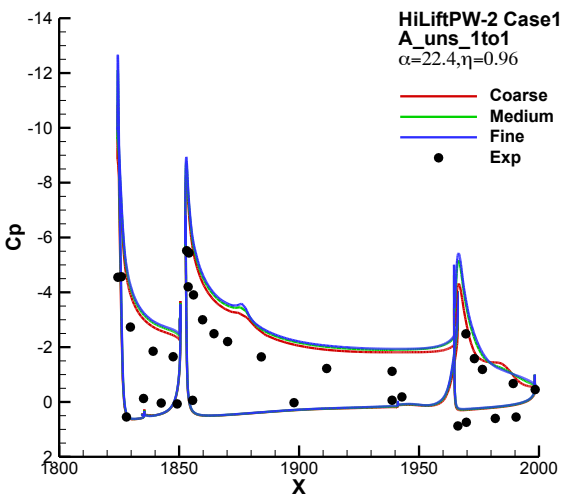


Case1: Cp distribution alpha=22.4





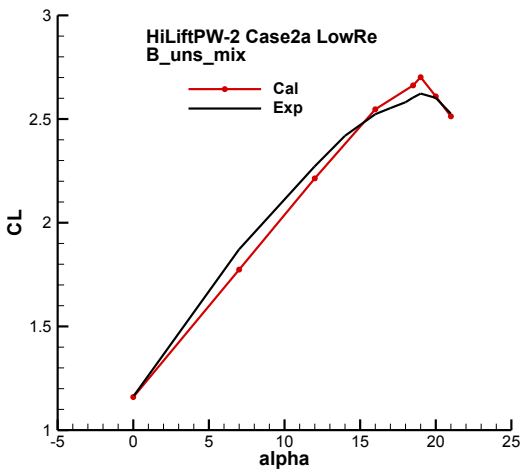


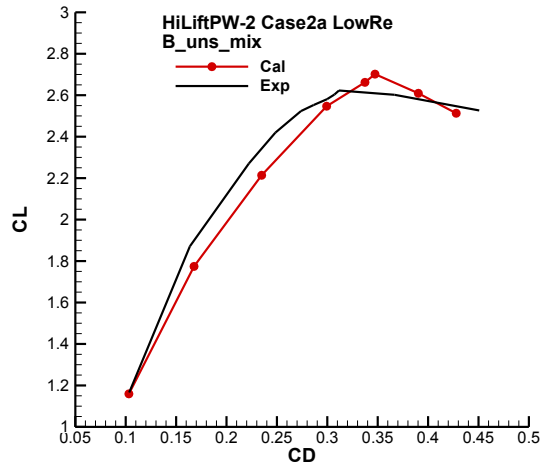


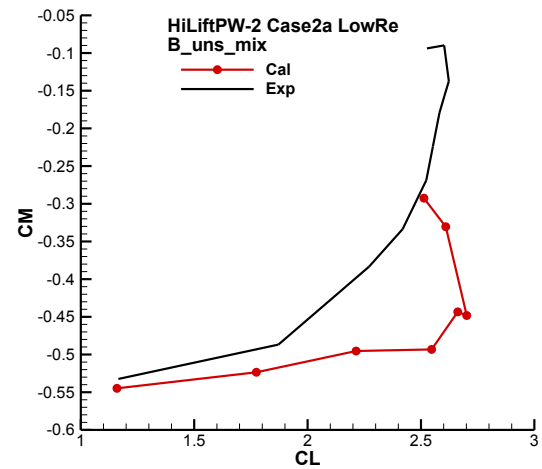
- Cp prediction on suction surface shows much difference with experiment especially on sections near the tip
- Grid refinement does not lead to much improvement.

Results: Case2a LowRe

- Grid used: B_uns_mix



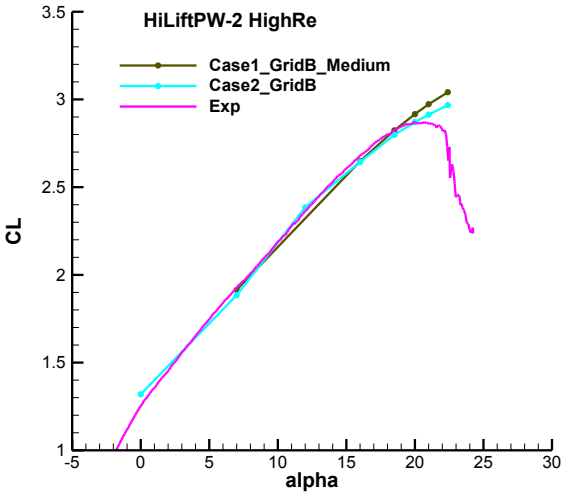


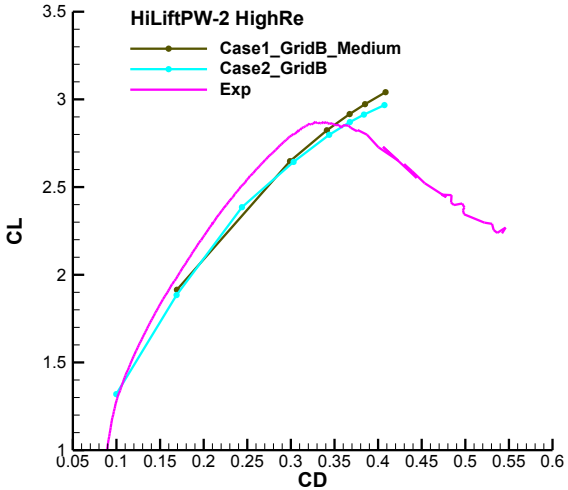


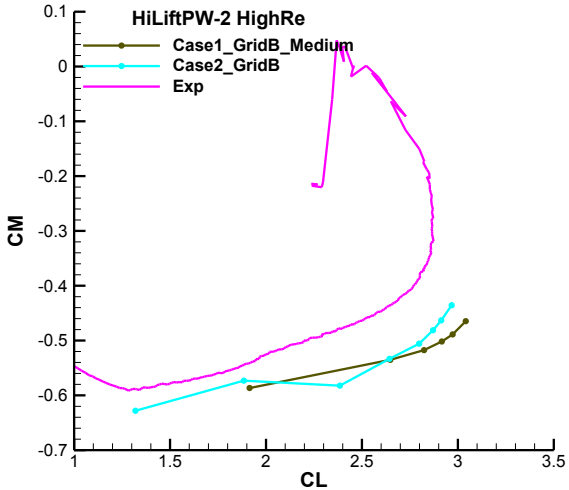
- difference presented in the linear range of the CL curve
- the stall AoA prediction is satisfied compared to experiment: alpha=19 degree
- Predicted CL_max is higher than exp

CL_max_Cal	2.70174
CL_max_Exp	2.62277

Results: Case2b HighRe

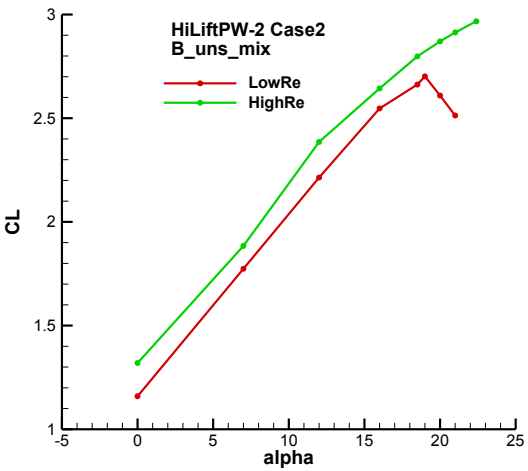


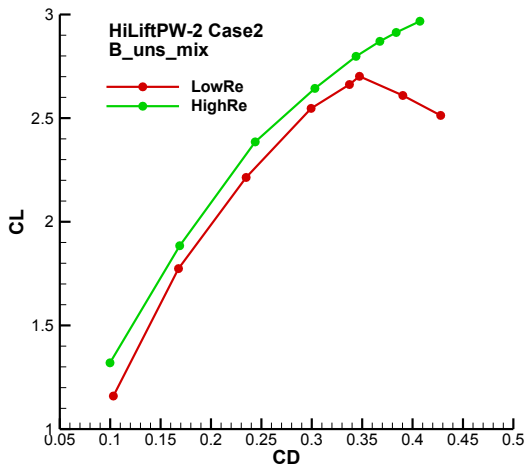


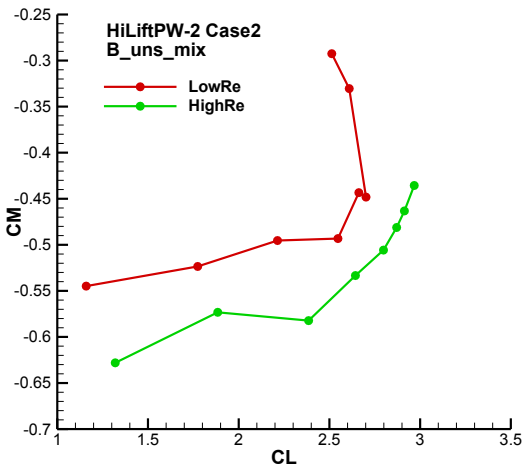


- Almost the same trends are found compared to Case1Config2

Results: Case2 Re Effects

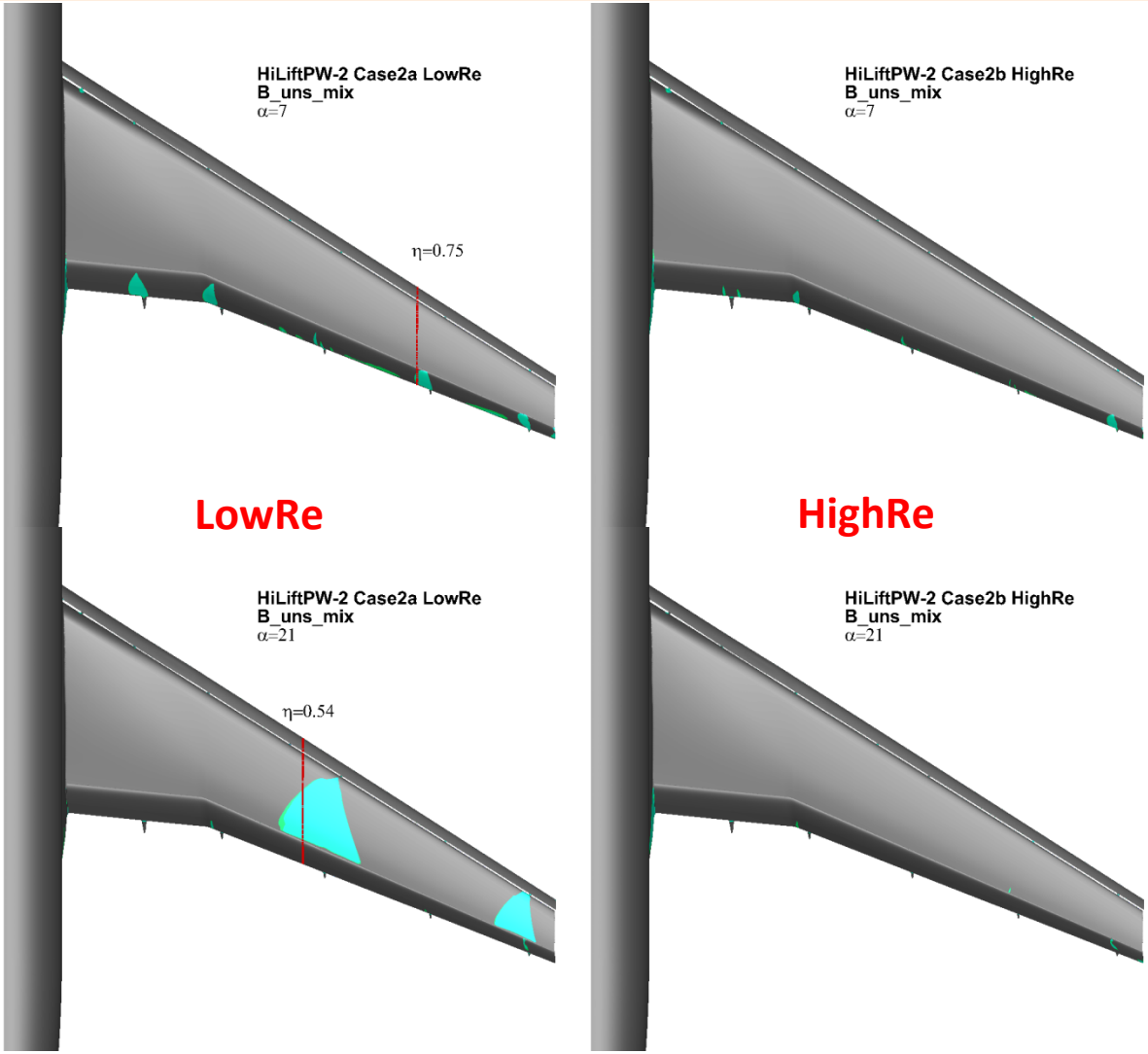


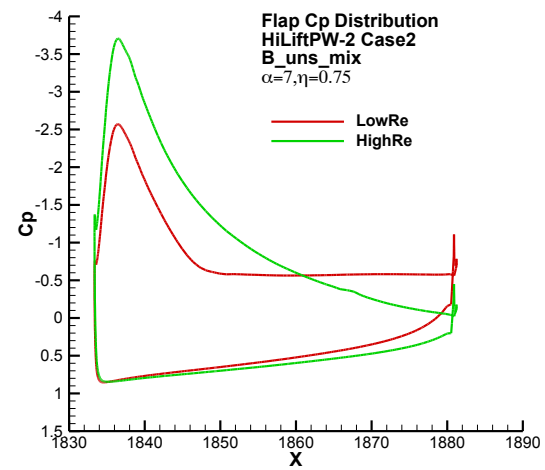


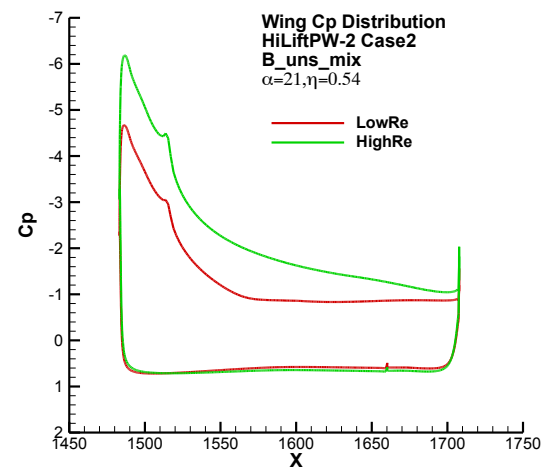


- a shift in CL exists in the linear range of CL curve between Low Re and High Re
- no evident stall exhibits for High Re case up to alpha= 22.4

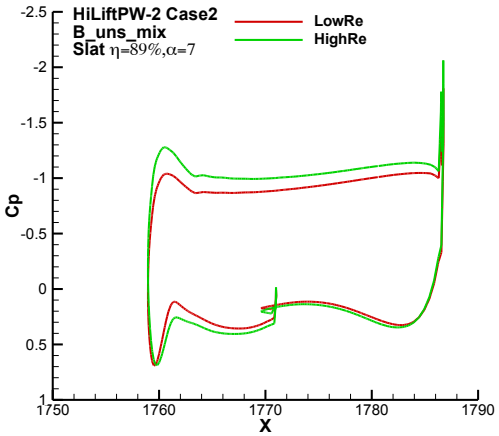
Results: Case2 Re Effects

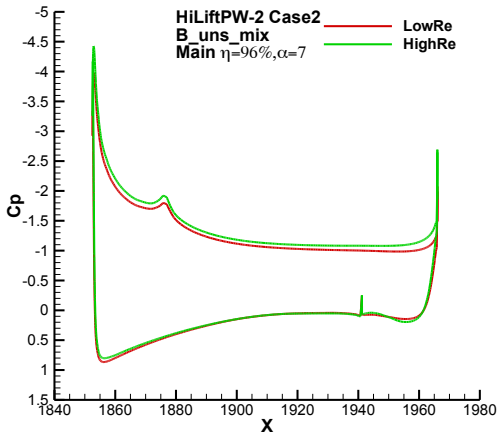


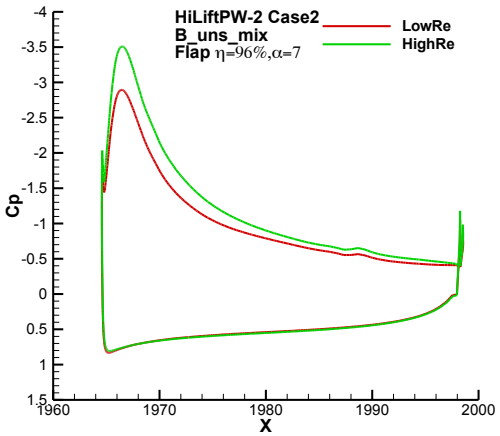


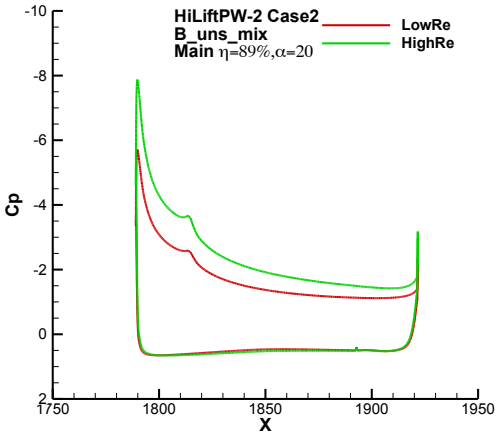


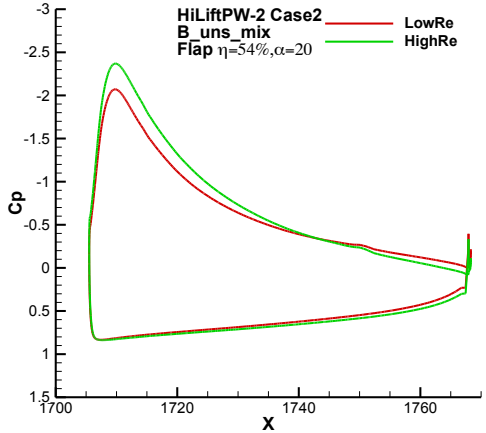
Results: Case2 Re Effects

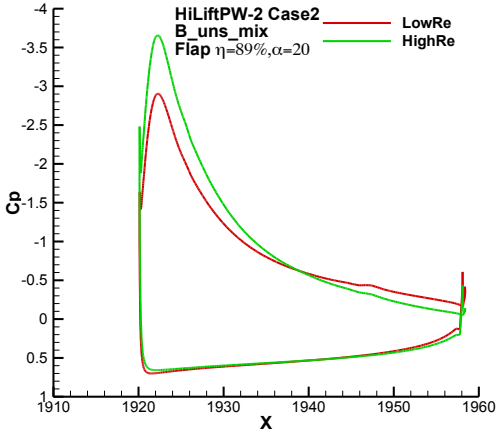






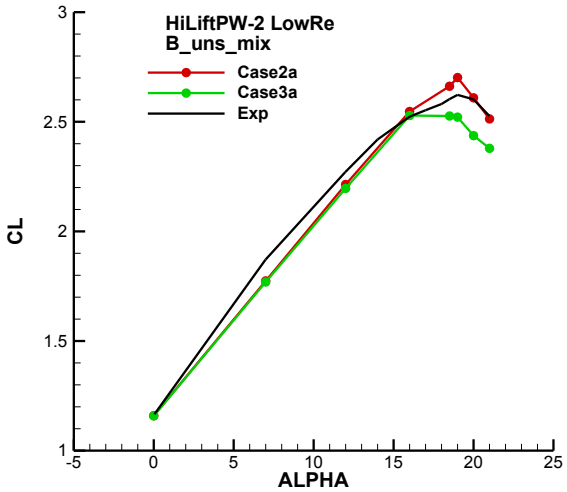


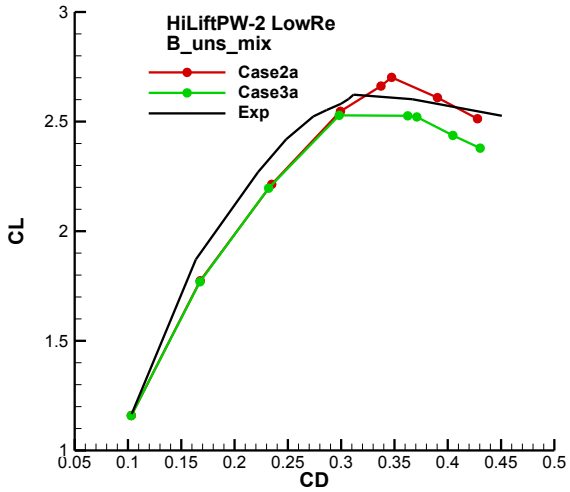


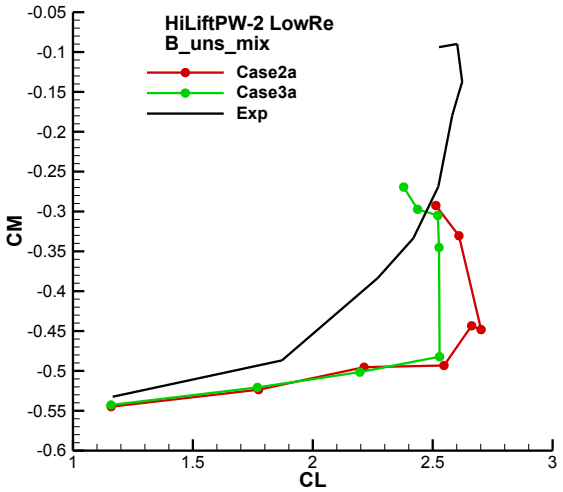


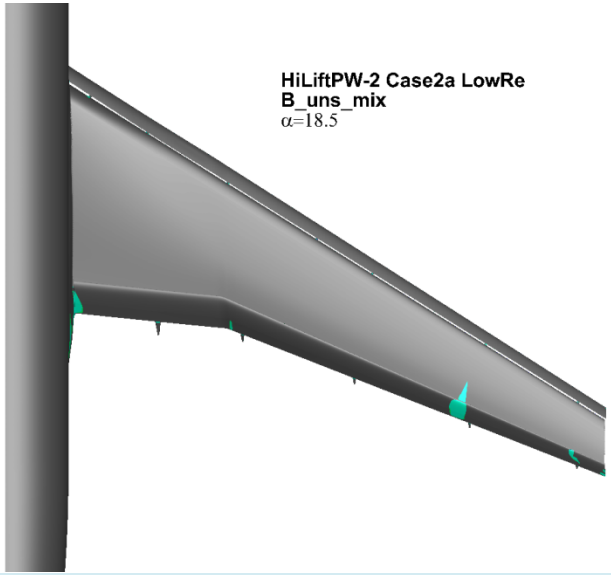
- The effects of Reynolds number are qualitatively captured

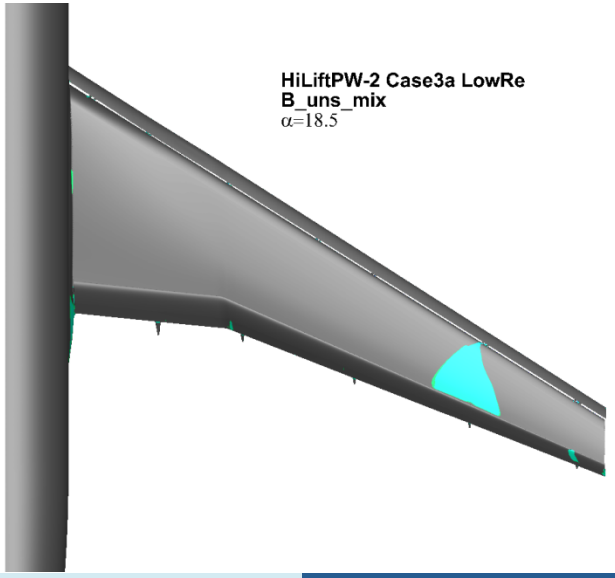
Results: Case3a LowRe FT

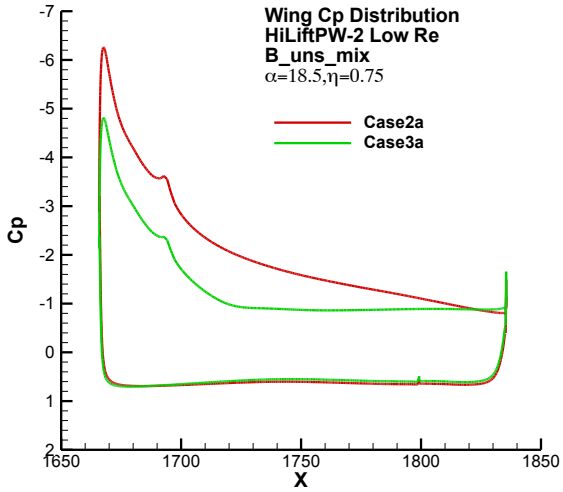




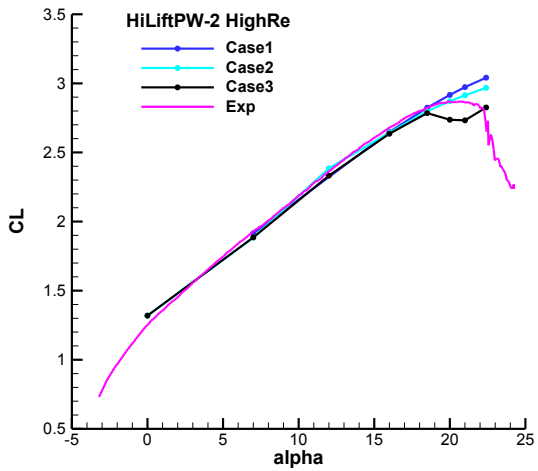


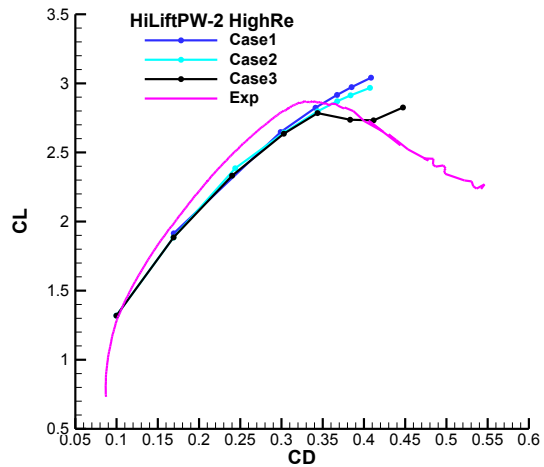


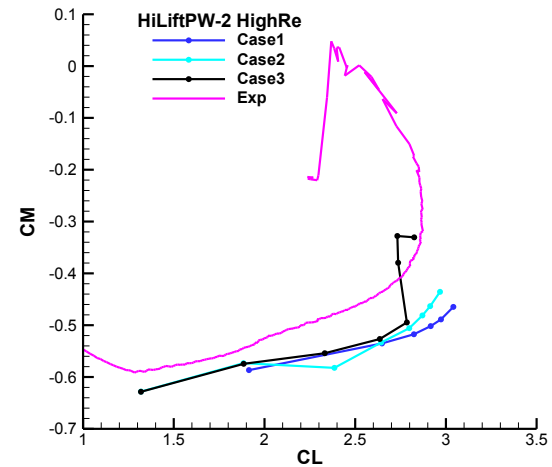




Results: Case3b HighRe FT



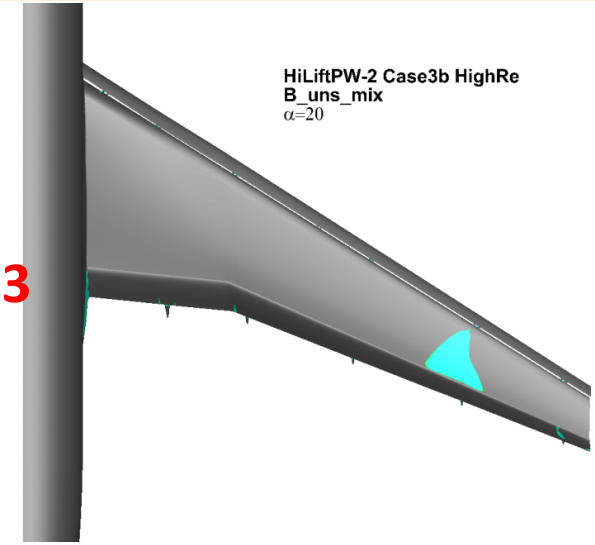


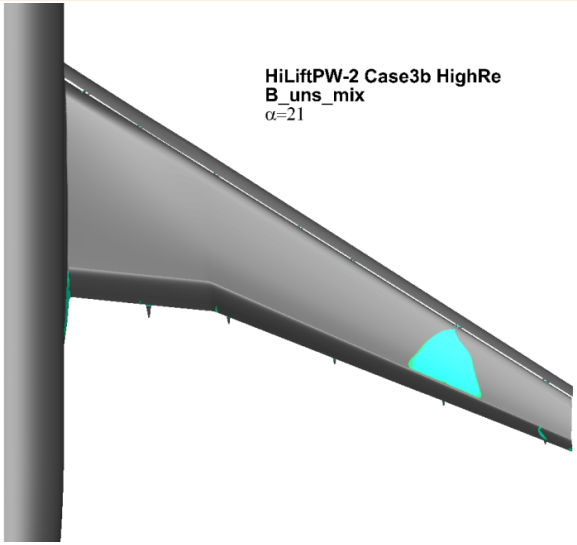


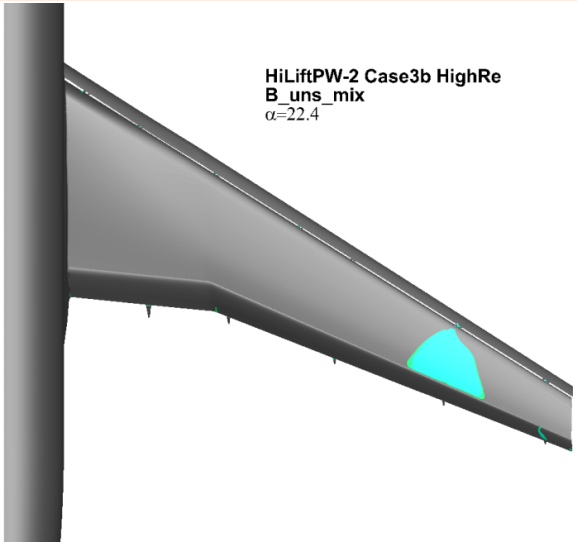
- approximate agreement is reached between the full configuration and two simplified configurations at lower angles
- The angles higher than 20 degree exhibit early stall for the full configuration

Results: Case3b HighRe FT

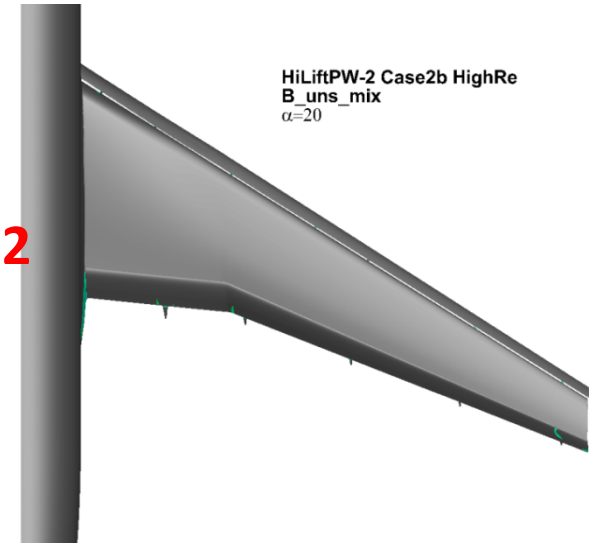
case3

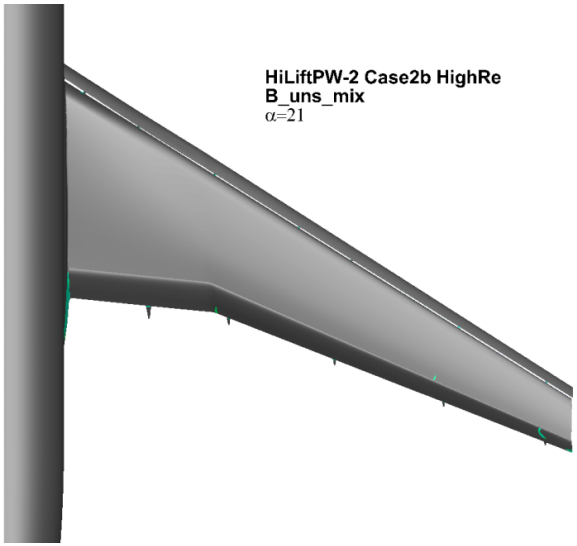


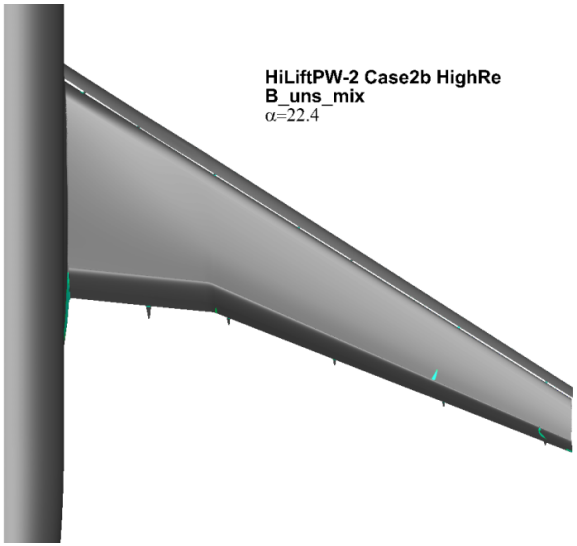




case2

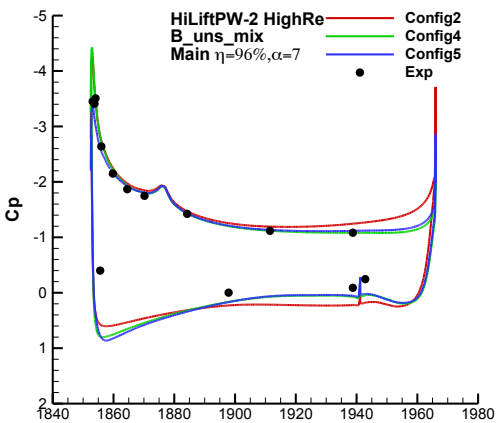


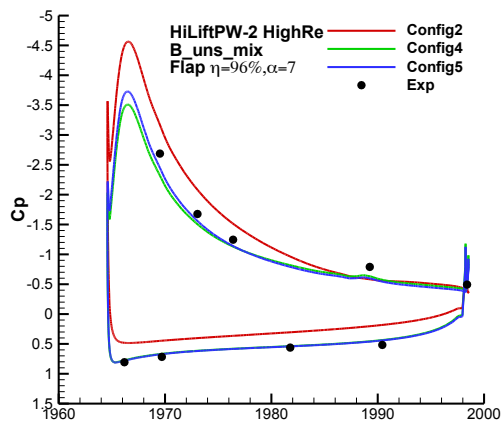




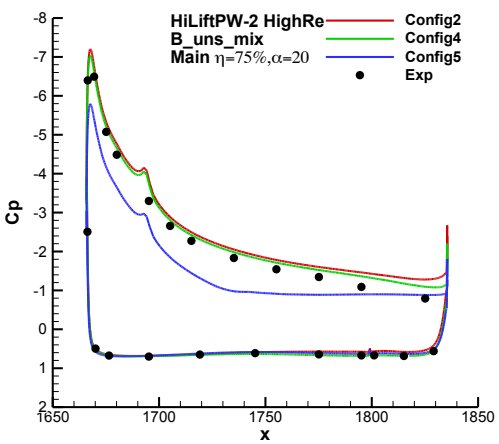
Results: Case3b HighRe FT

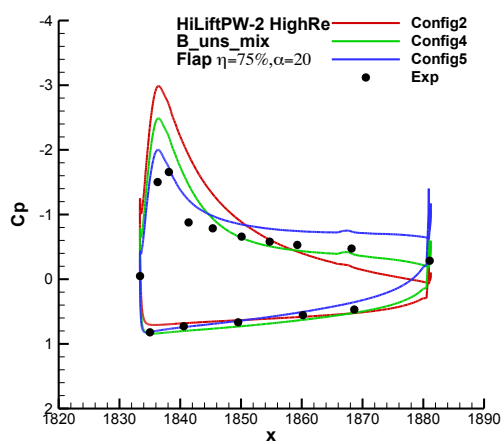
- Full configuration simulation does **not** always present better Cp prediction than simplified configuration simulation





alpha=7°





alpha=20°

Conclusions

- Nearly linear convergence is obtained with grid refinement for Case1Config2
- Delayed stall and larger CL_max compared to experiment are found for HighRe case
- Separation is sensitive to grid refinement, Re and configuration

Thanks for your attention!