Flexcompute Contribution to the VIIth AIAA Drag Prediction Workshop

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Flexcompute

Presented at the AIAA 2022 Aviation Forum & Exposition

Outline

1. Flow360 Solver
2. Grids
3. Cases
4. Case 1 – Grid Convergence Study
5. Case 2 – Alpha Sweep Study
6. Case 3 – Reynolds Number and Q Effect Study
7. Conclusions

Flow360 Solver

- Hardware/Software co-design with emerging hardware computing

- Node-centered
- Unstructured solver
- 2nd order finite volume method
- Roe inviscid fluxes
- Central difference viscous fluxes
- MUSCL Extrapolation
- SA, SA-RC, SA-QCR, kw-SST turbulence models (DDES, transition also available)

Grids

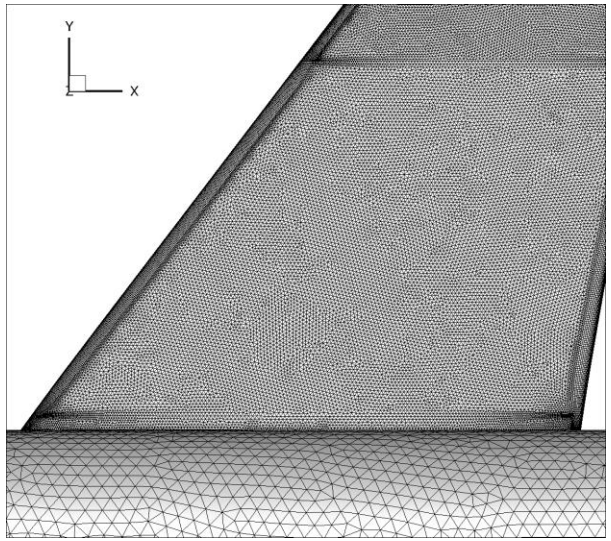
JAXA grids were used for Flow360 simulations

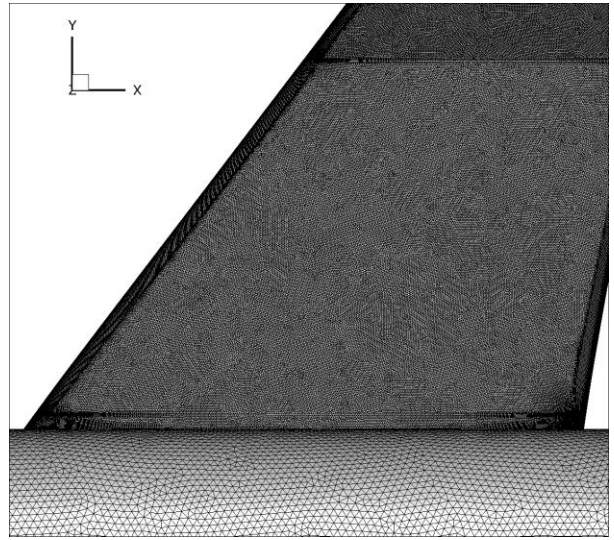
Mesh Statistics	Number of Nodes	BL 1st cell size (non. dim by c_ref)	BL growth rate
Tiny	8,687,830	8.455E-07	1.323
Coarse	26,891,512	5.638E-07	1.205
Medium	60,184,023	4.228E-07	1.150
Fine	111,843,367	3.383E-07	1.118

Grids

JAXA grids – Root region

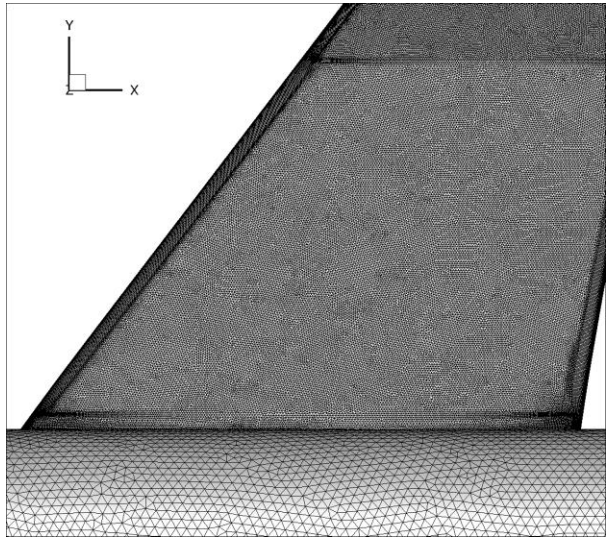
Tiny

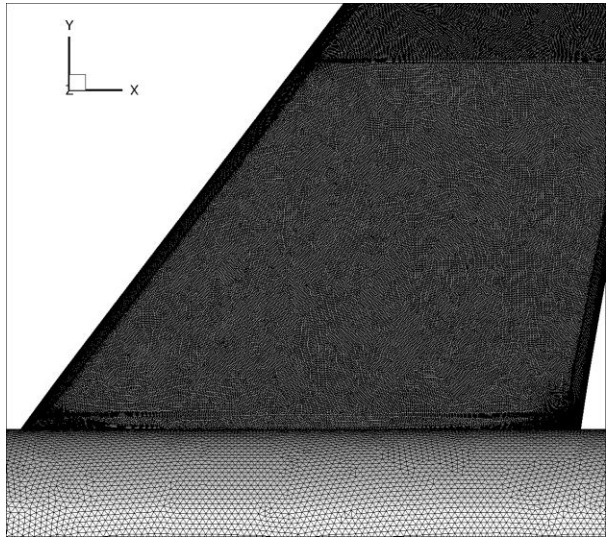




Medium

Coarse



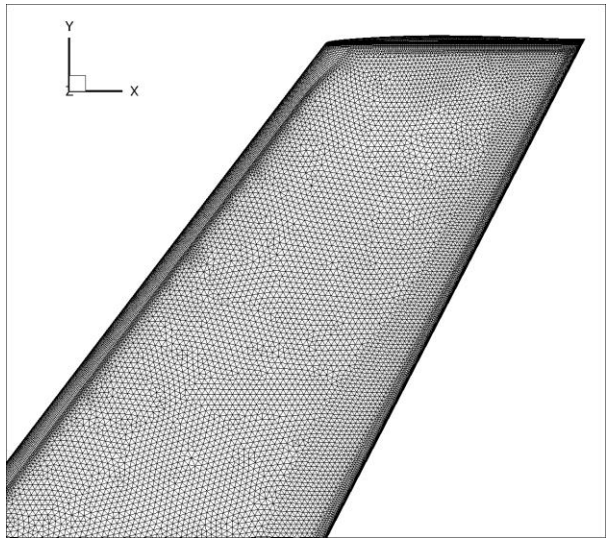


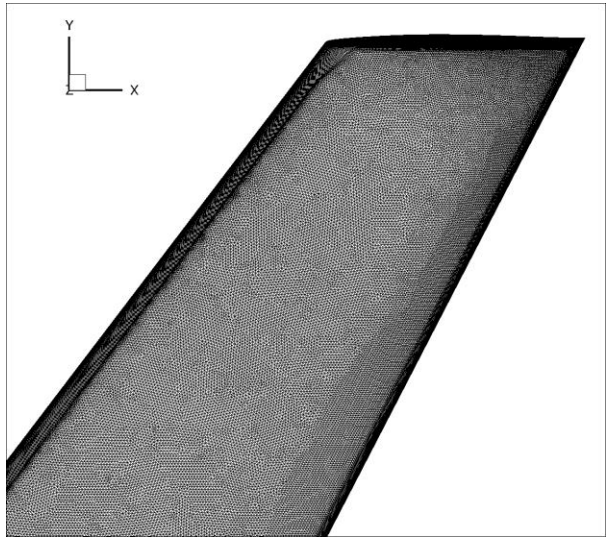
Fine

Grids

JAXA grids – Tip region

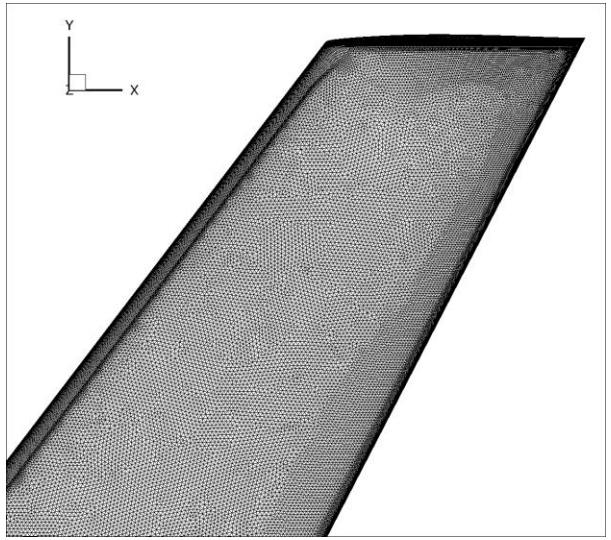
Tiny

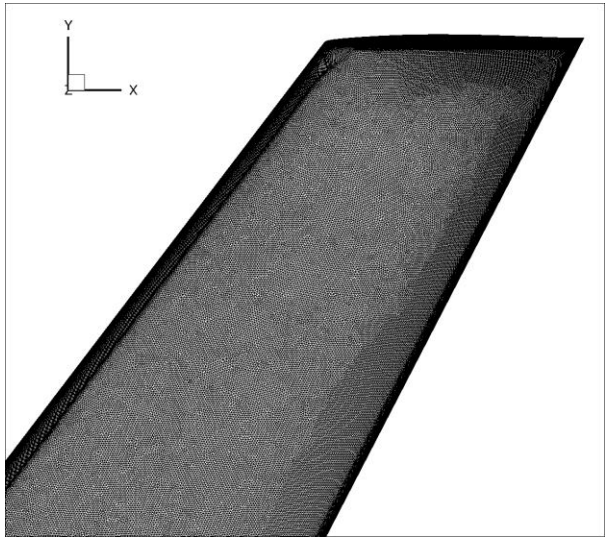




Medium

Coarse





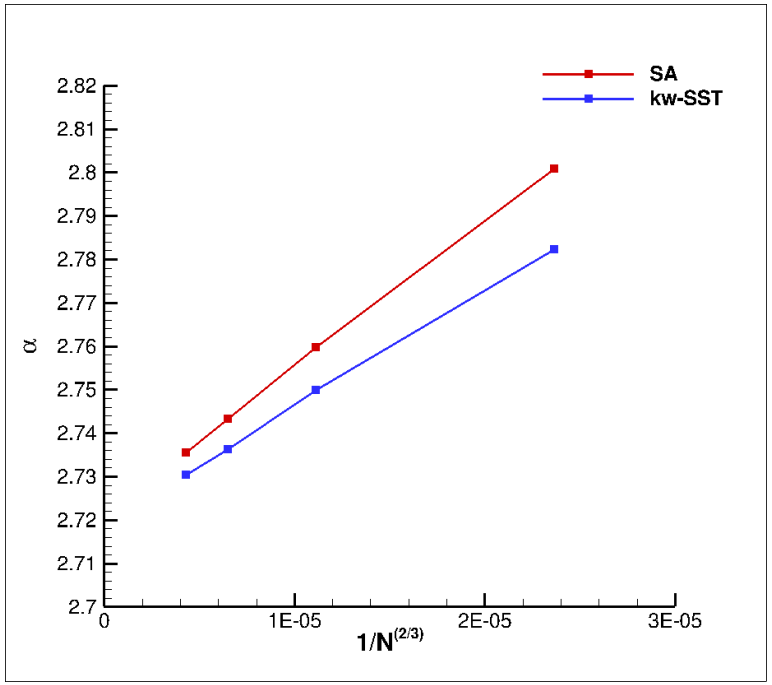
Fine

Test Cases

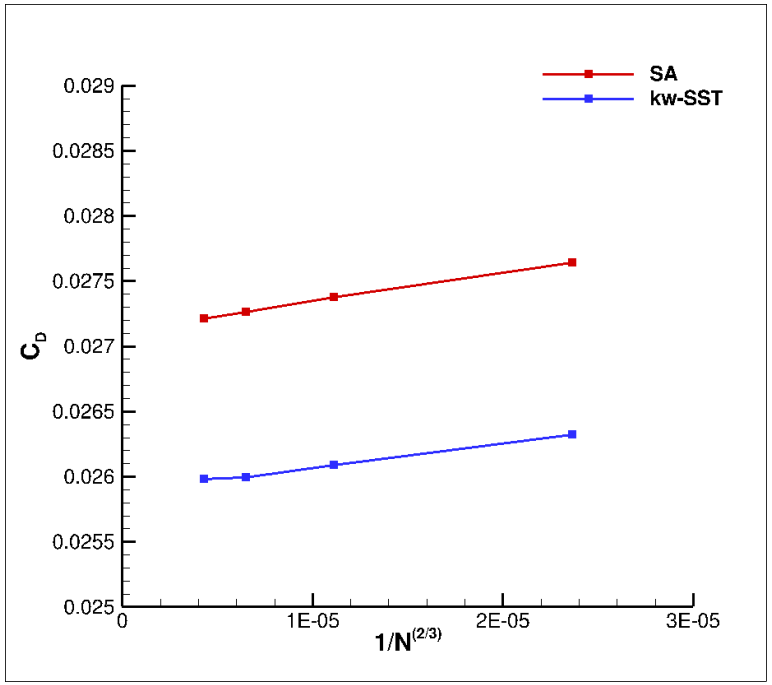
4 different turbulence models used: SA, SA-QCR, SA-RC-QCR and kω-SST

Case 1	Case 2	Case 3
Grids: Tiny – Fine Turbulence models: SA, kω-SST	Grids: Medium Turbulence models: SA, SA-QCR, SA-RC-QCR and kω-SST	Grids: Medium Turbulence models: SA, kω-SST

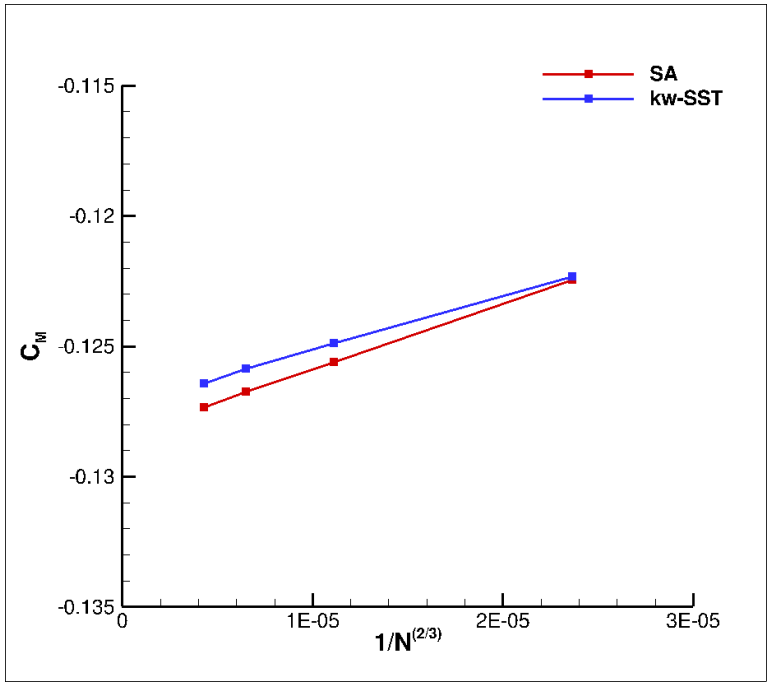
Case 1 - Grid Convergence Study



Alpha

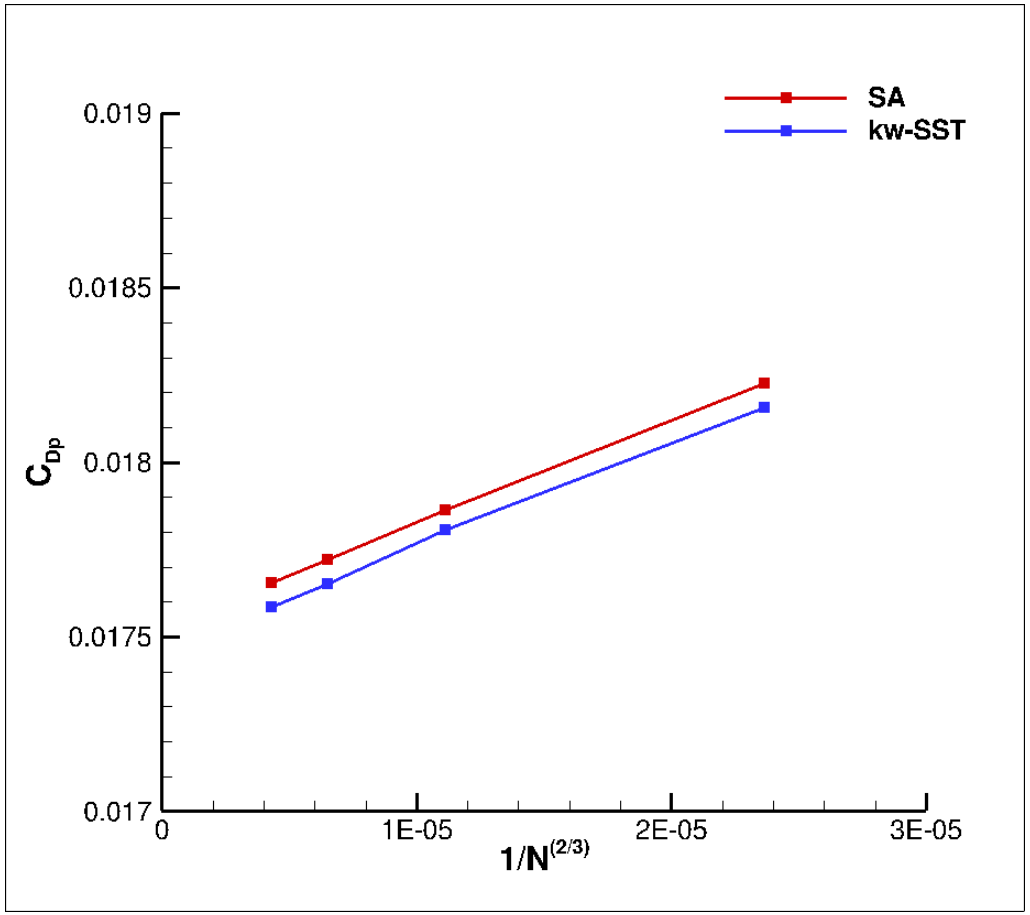


CD

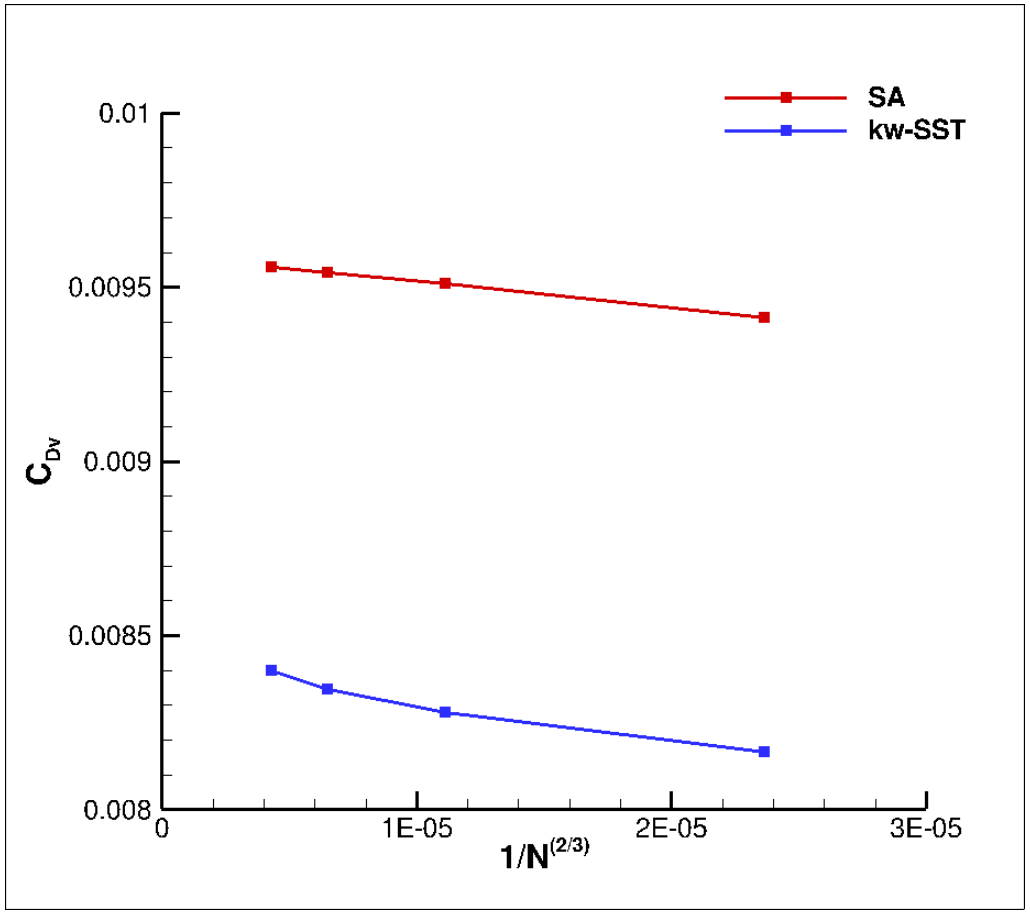


CM

Case 1 - Grid Convergence Study



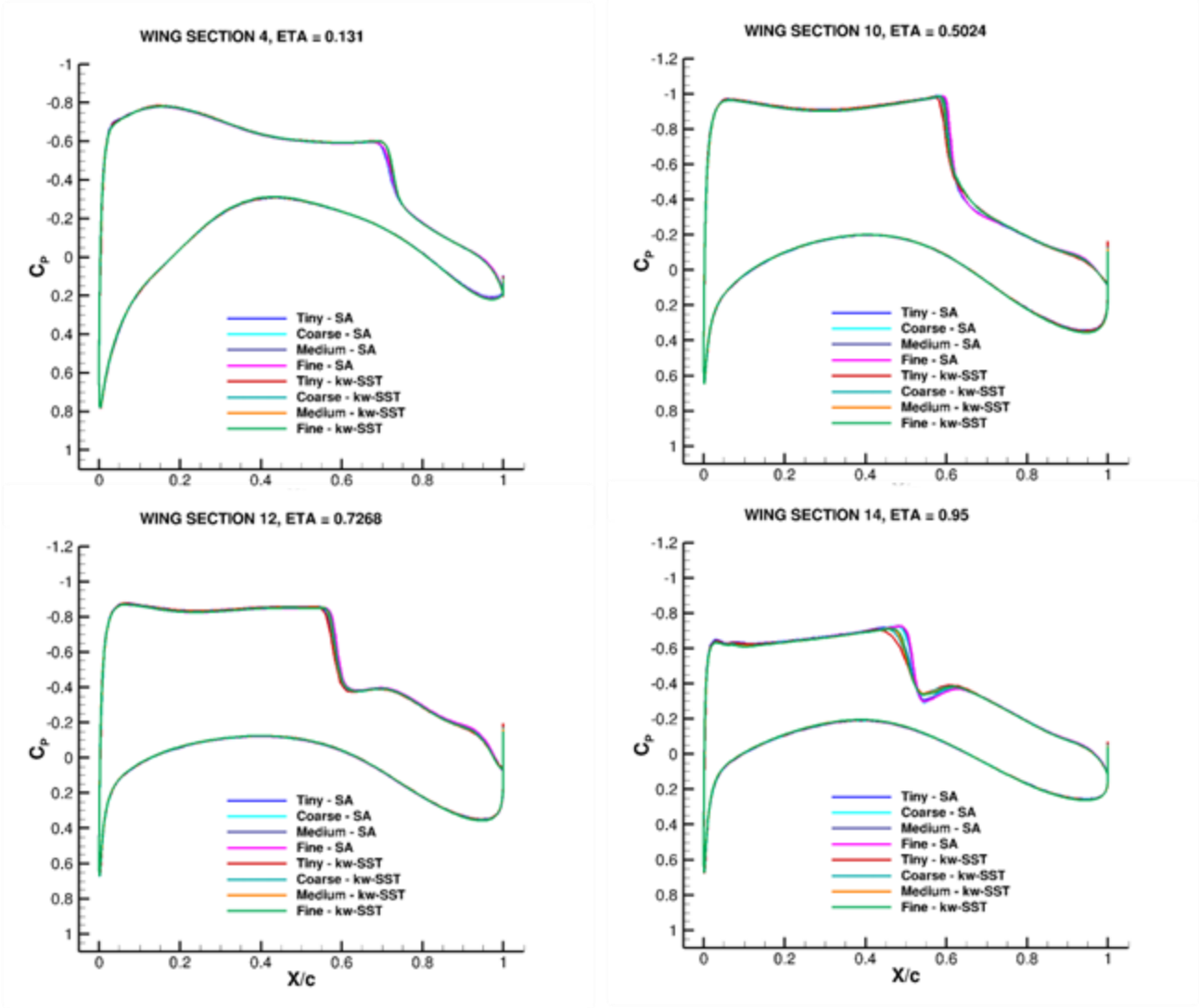
CDp



CDv

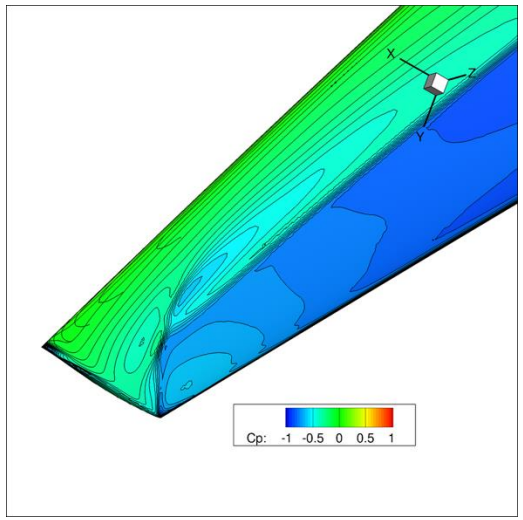
Case 1 - Grid Convergence Study

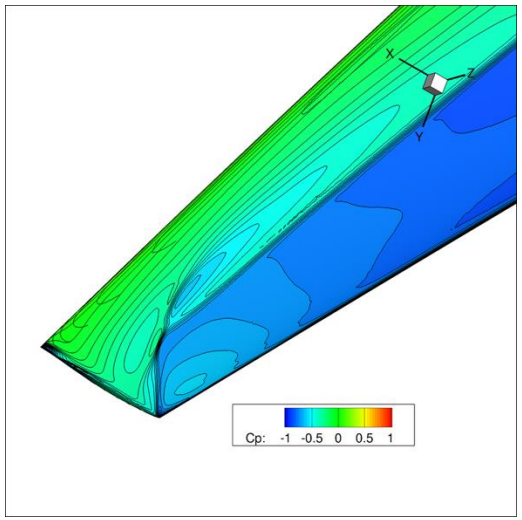
Surface pressure curves at 4 locations along the wing

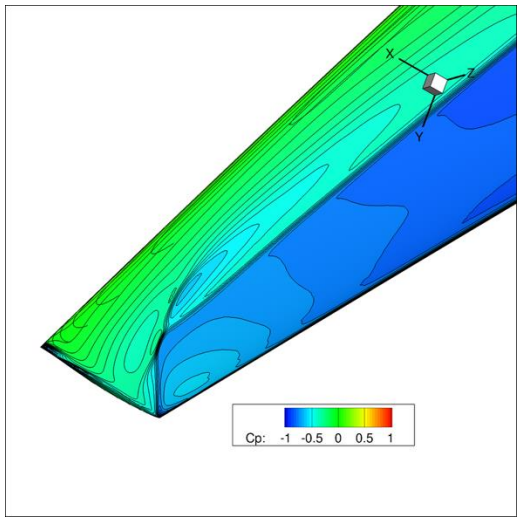


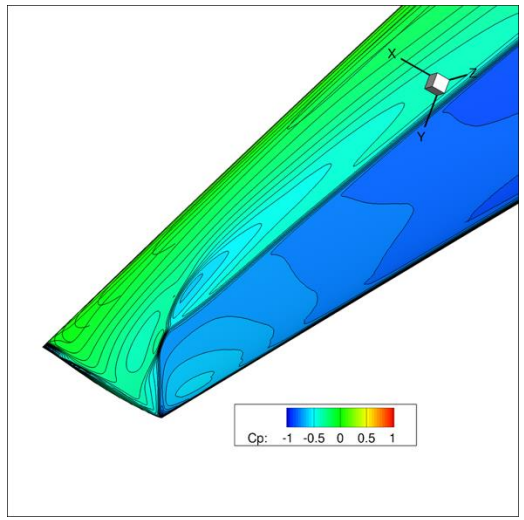
Case 1 - Grid Convergence Study

Tip surface pressure contours

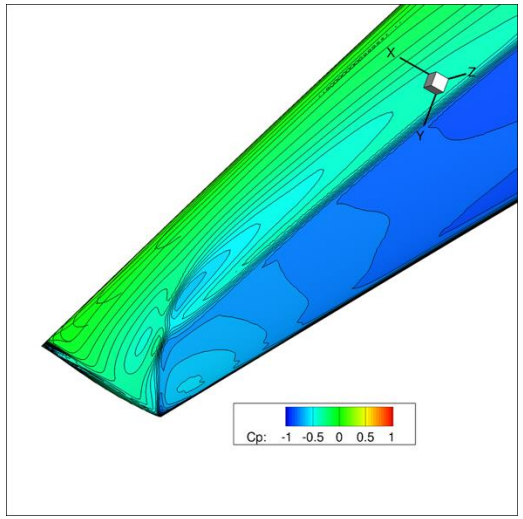


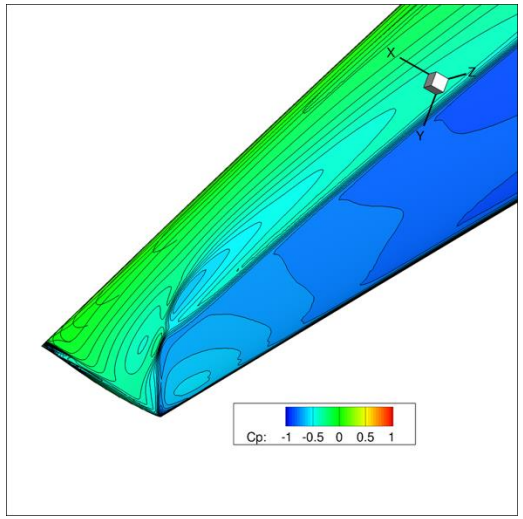


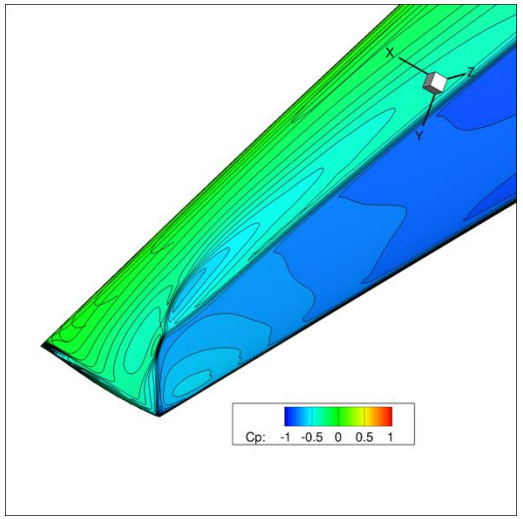


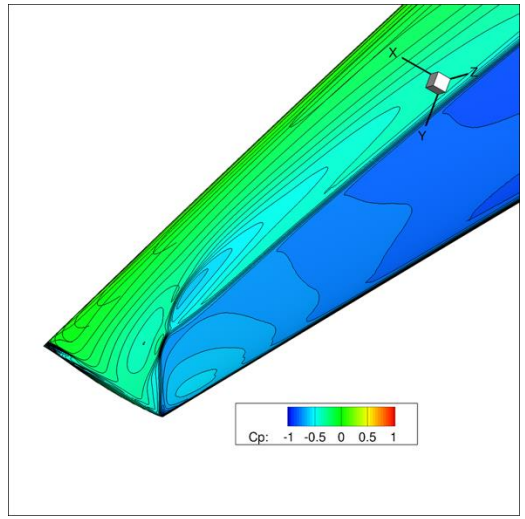


SA







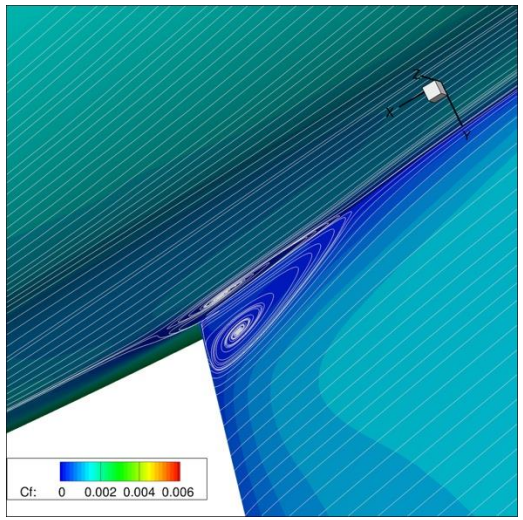


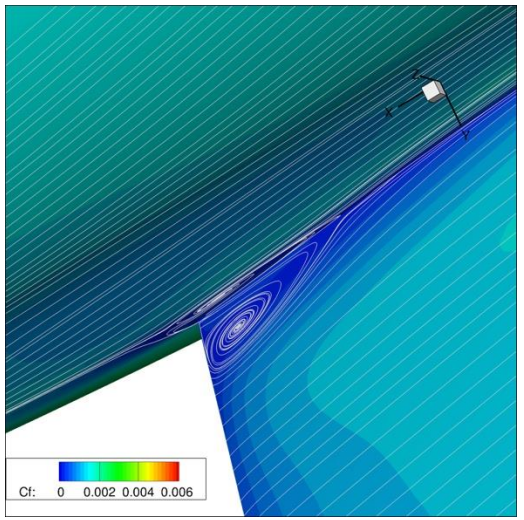
Kw-SST

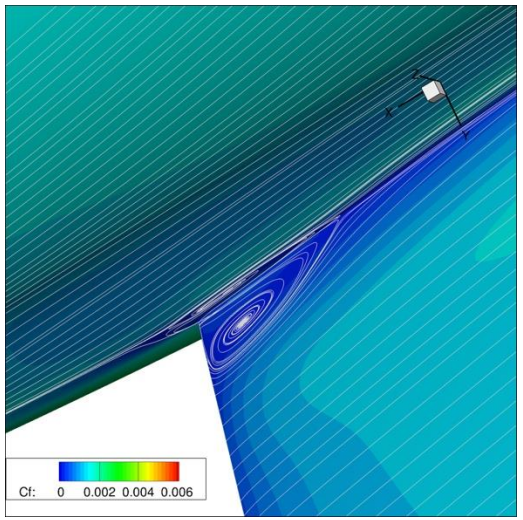
Tiny **Coarse** **Medium** **Fine**

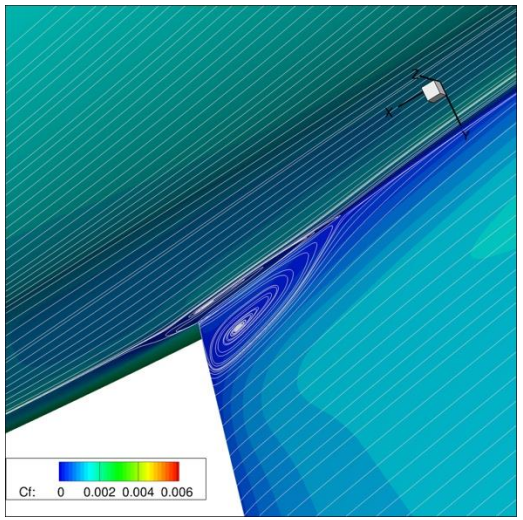
Case 1 - Grid Convergence Study

Corner separation at root

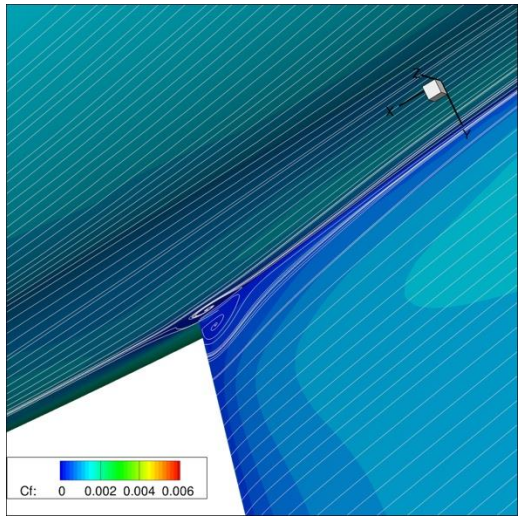


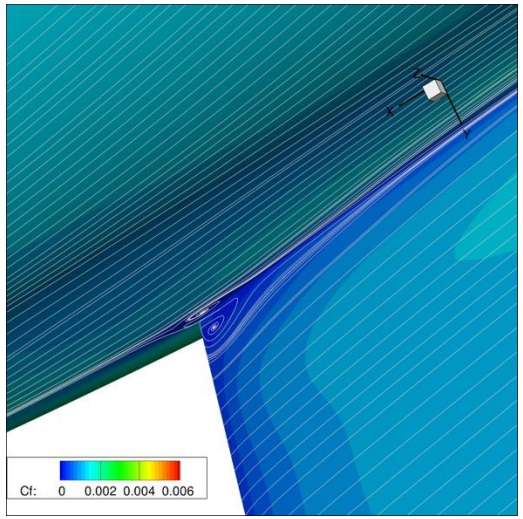


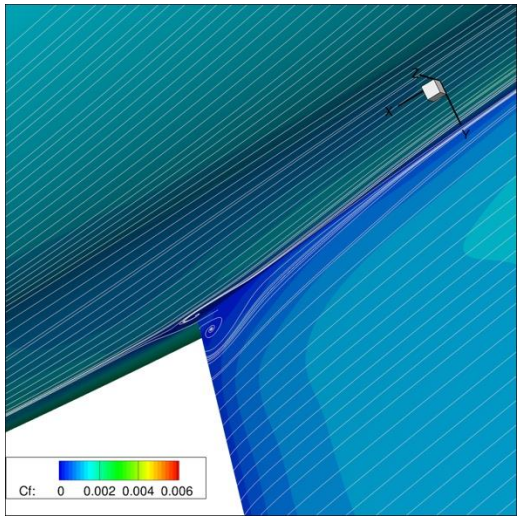


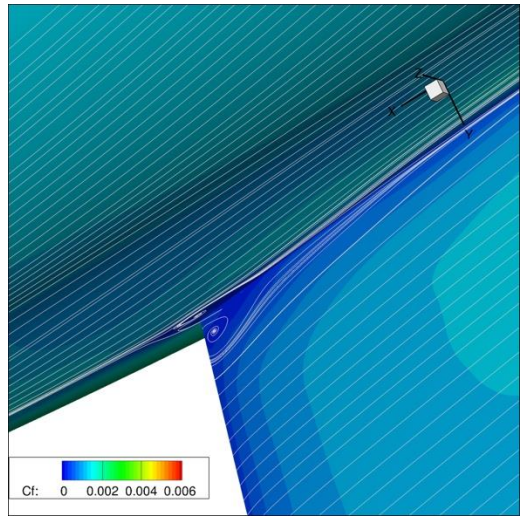


SA





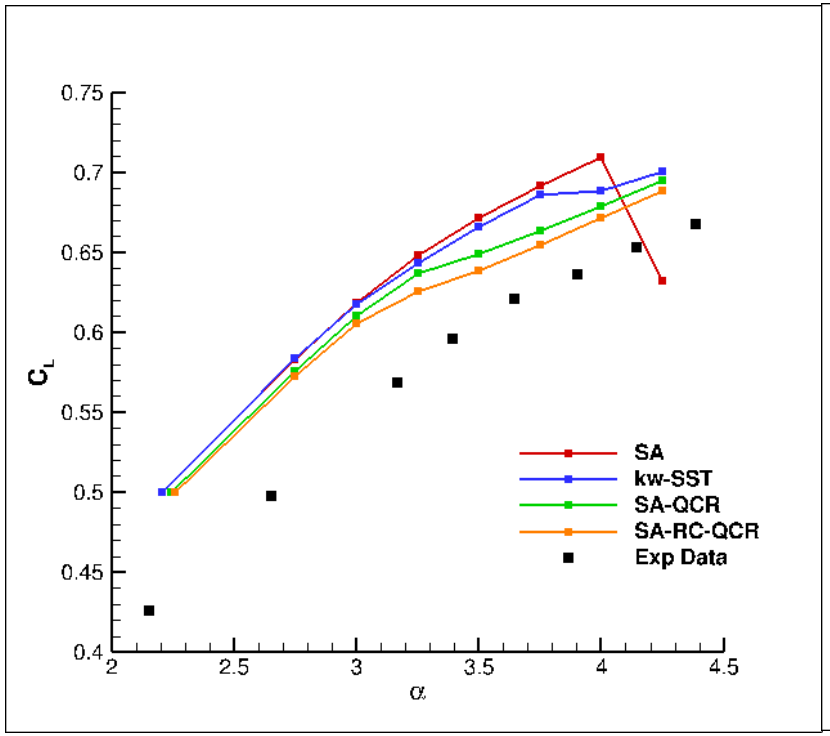




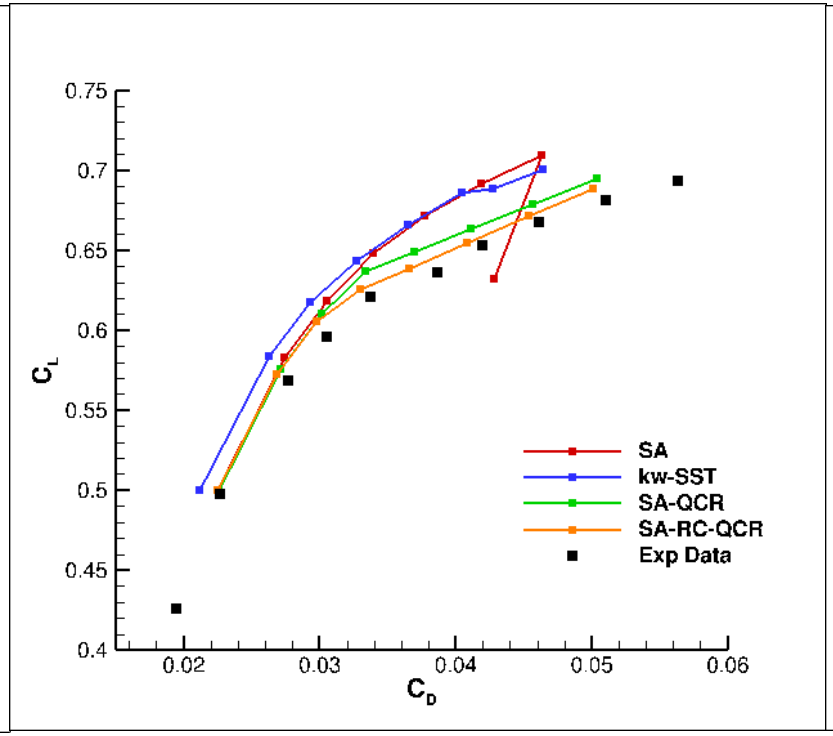
Kw-SST

Tiny **Coarse** **Medium** **Fine**

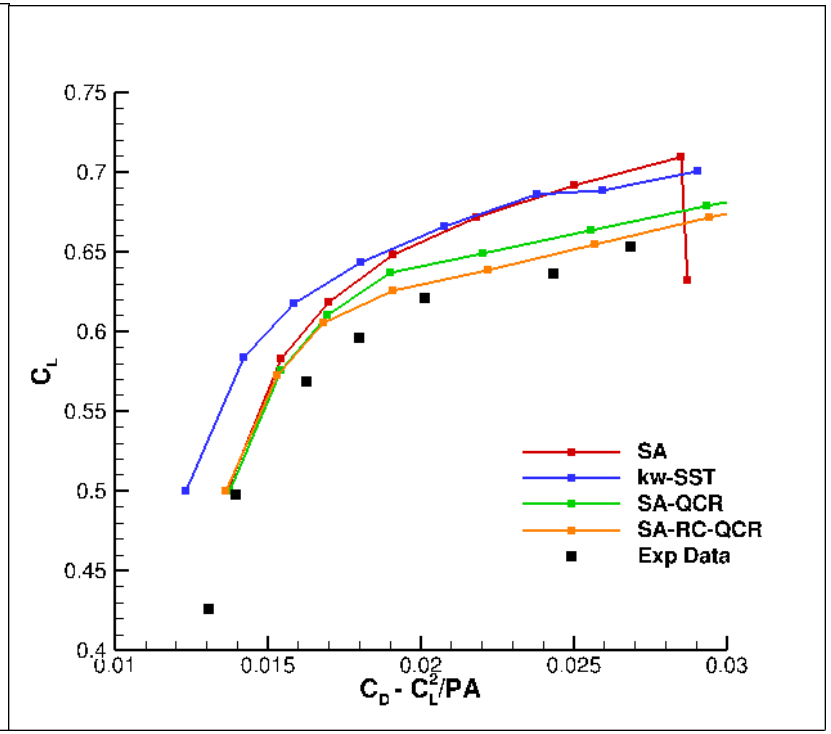
Case 2 – Alpha Sweep Study



CL



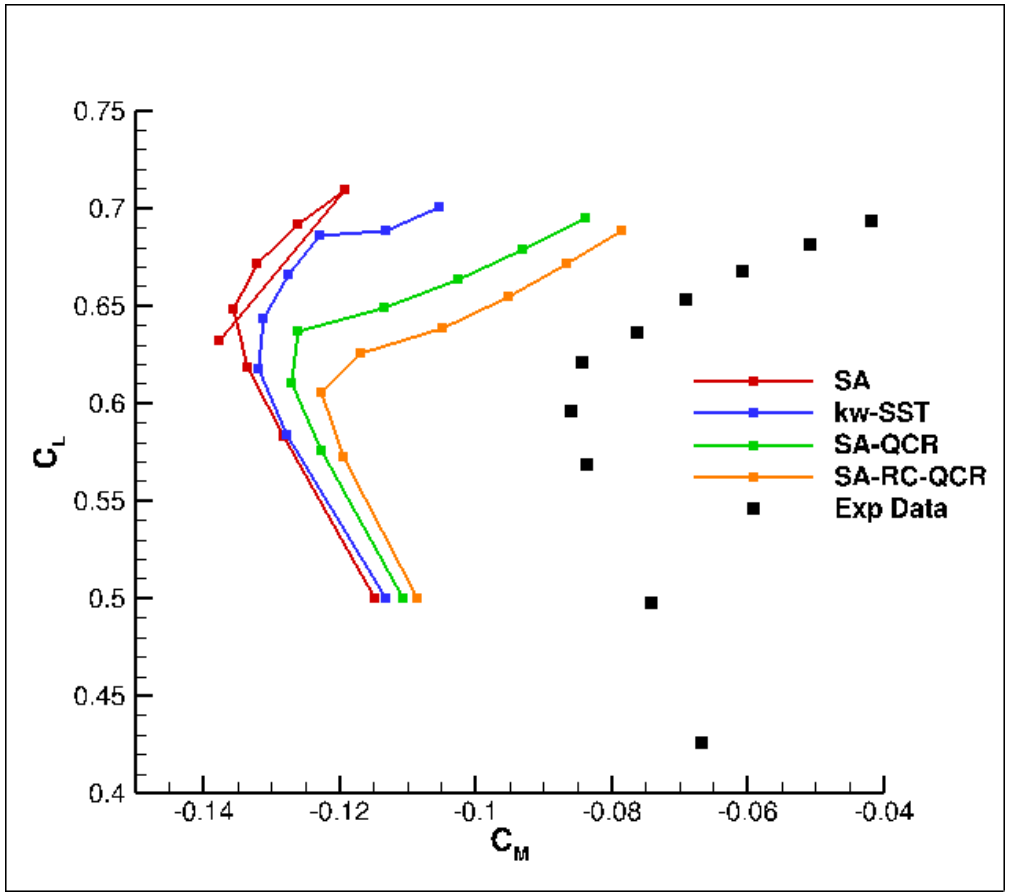
CD



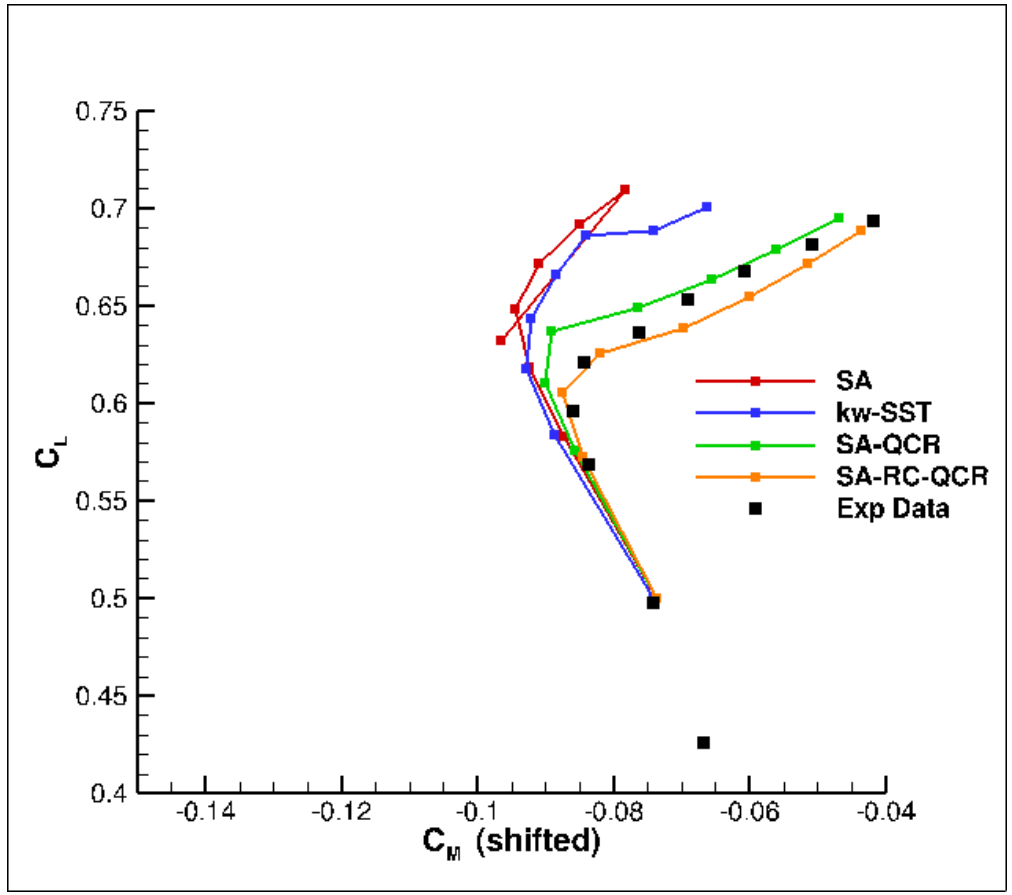
CD Trim

t197R165 experimental data

Case 2 – Alpha Sweep Study



CM



CM + shift

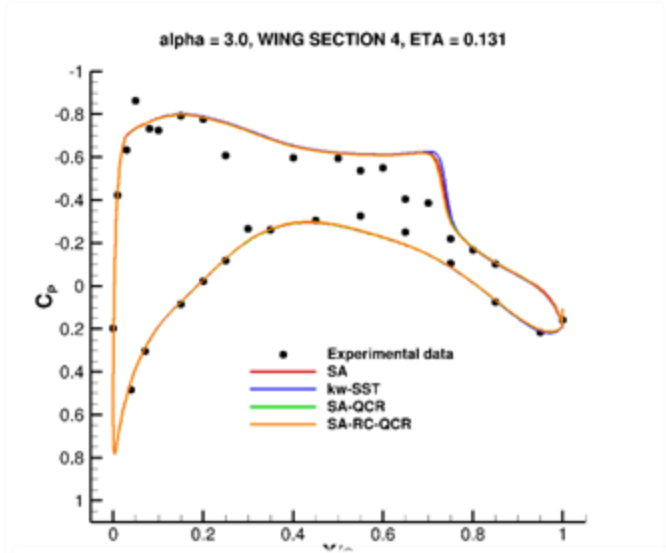
t197R165 experimental data

Case 2 – Alpha Sweep Study

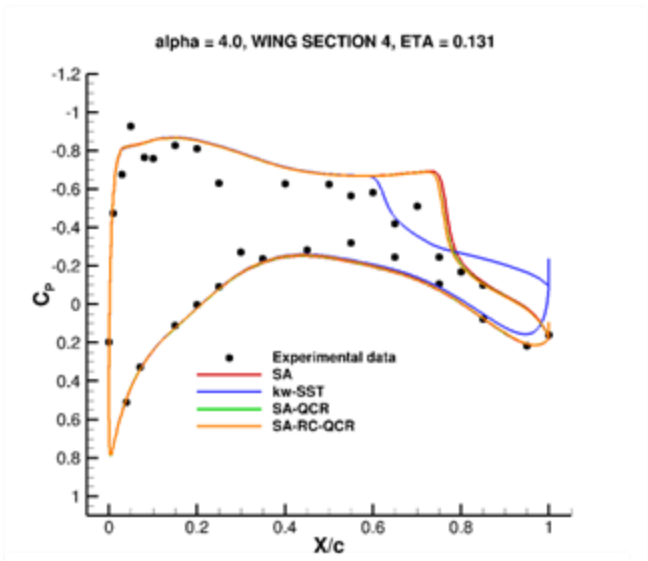
Surface CP – eta = 0.131

t197R242 experimental data

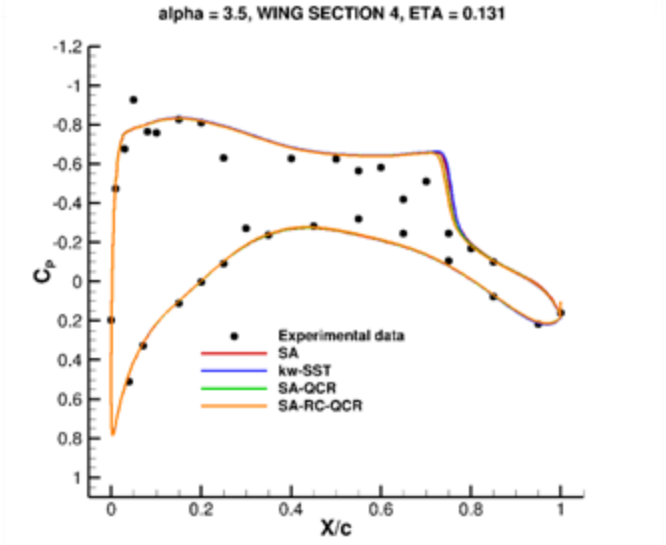
α= 3.0



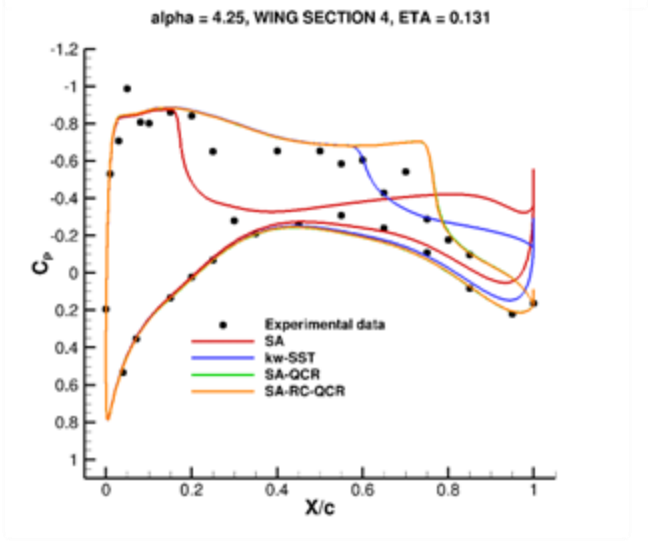
α= 4.0



α= 3.5



α= 4.25

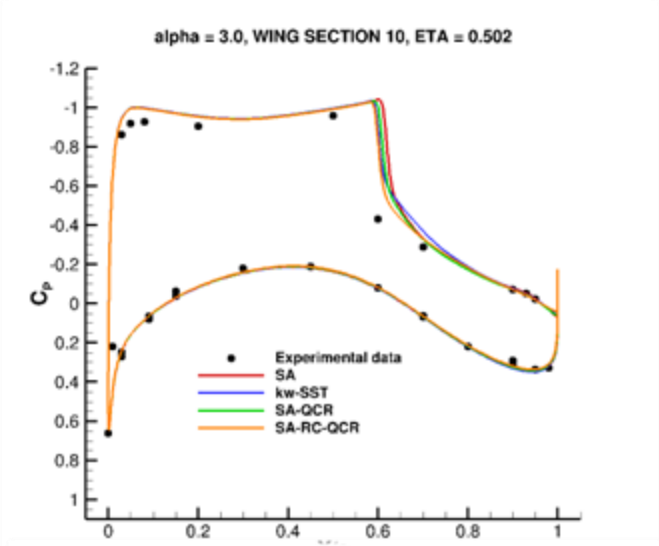


Case 2 – Alpha Sweep Study

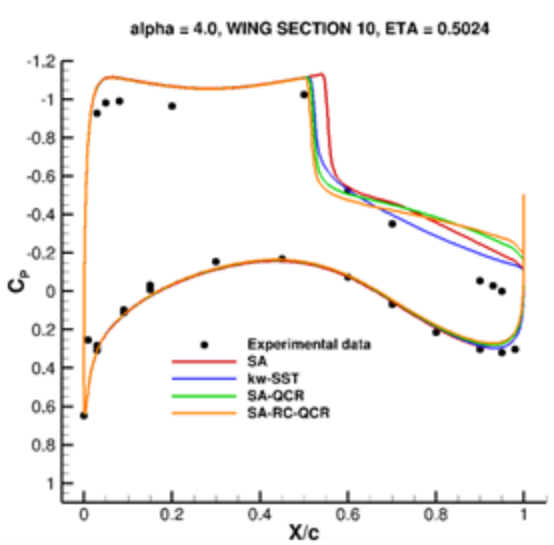
Surface CP – eta = 0.5024

t197R242 experimental data

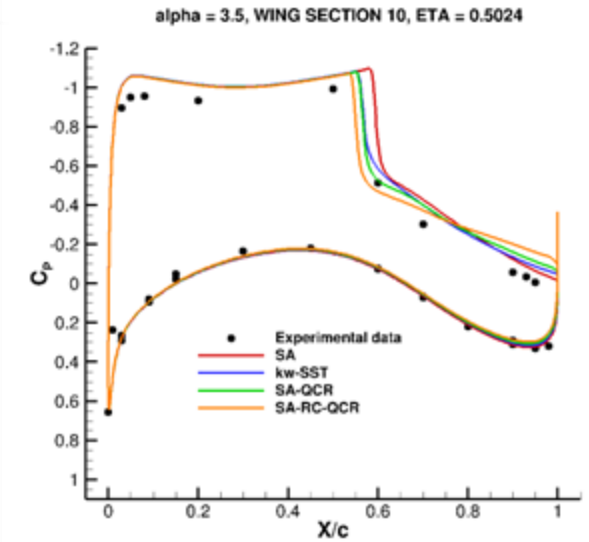
α= 3.0



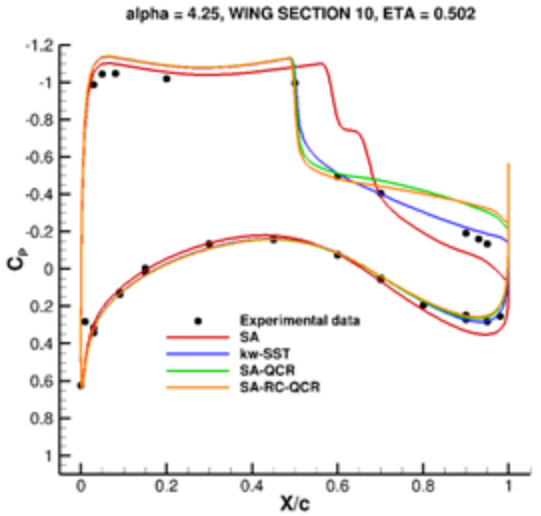
α= 4.0



α= 3.5



α= 4.25

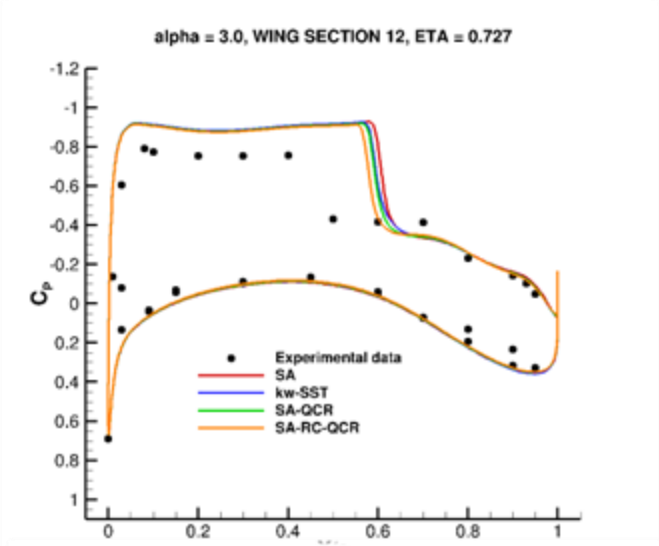


Case 2 – Alpha Sweep Study

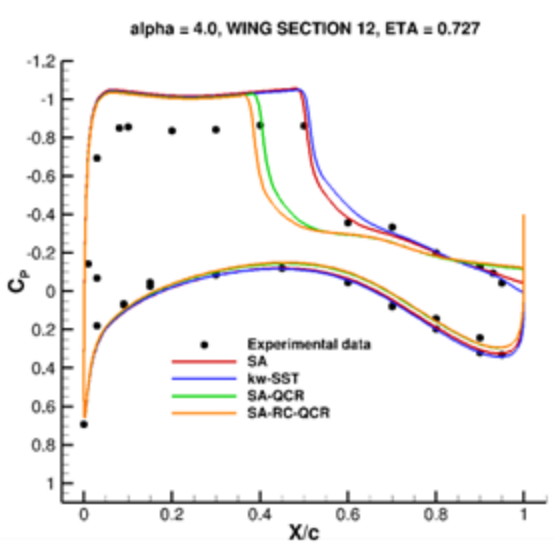
Surface CP – eta = 0.727

t197R242 experimental data

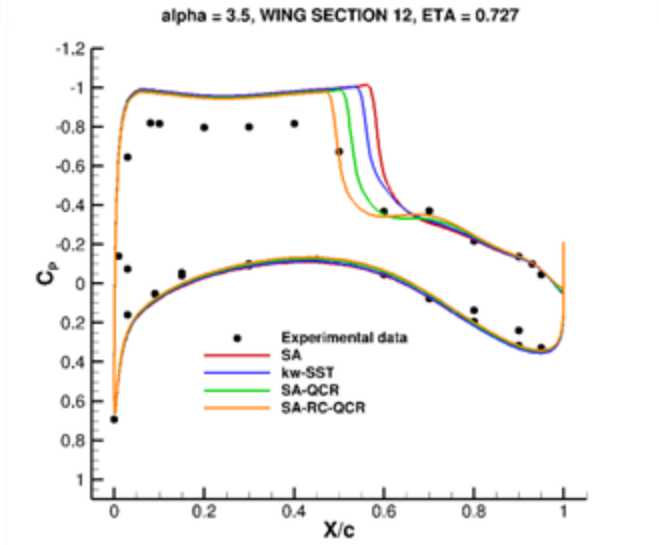
α= 3.0



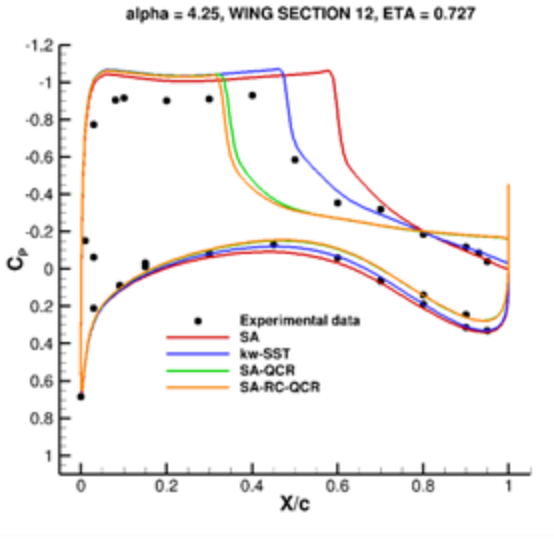
α= 4.0



α= 3.5



α= 4.25

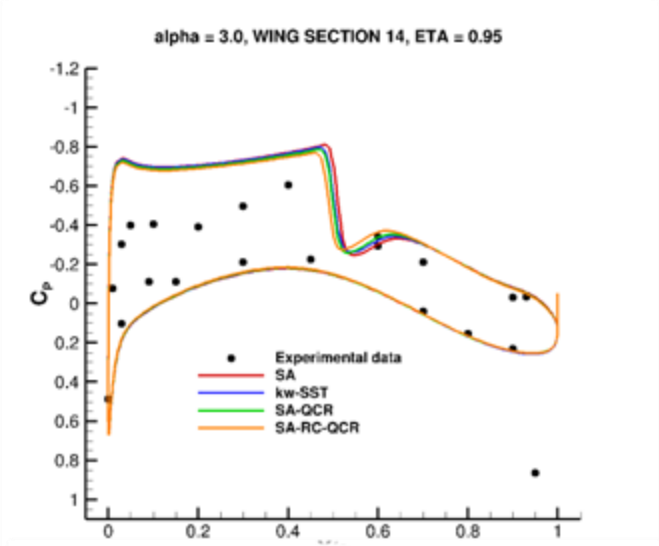


Case 2 – Alpha Sweep Study

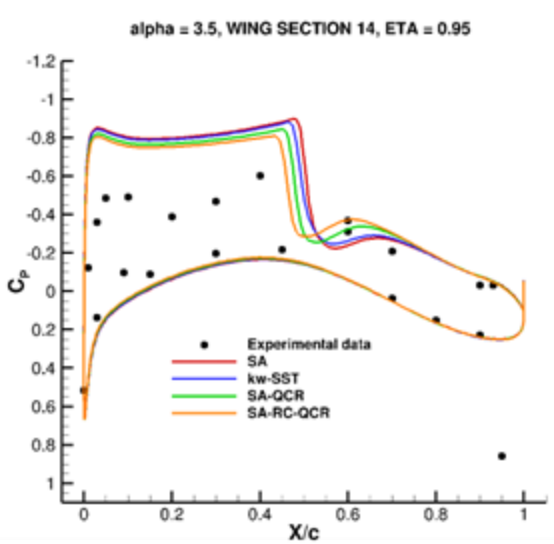
Surface CP – eta = 0.950

t197R242 experimental data

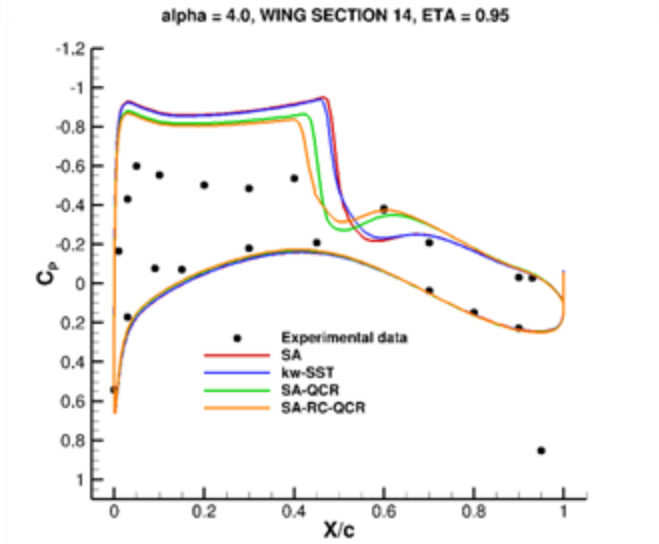
α= 3.0



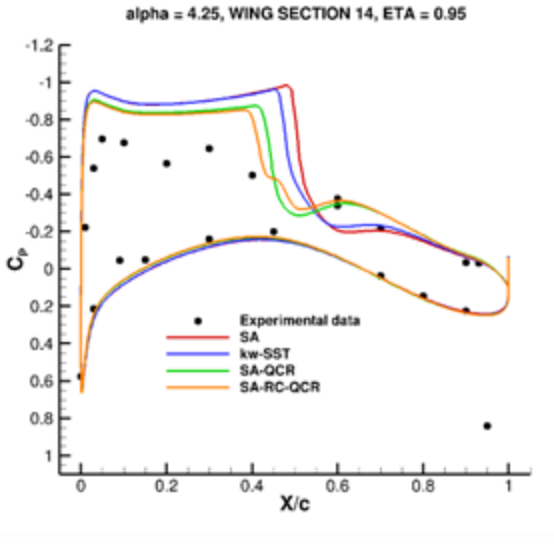
α= 4.0



α= 3.5



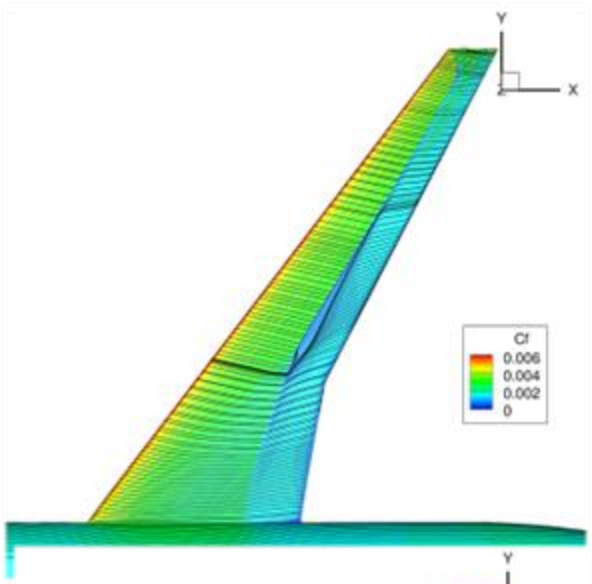
α= 4.25



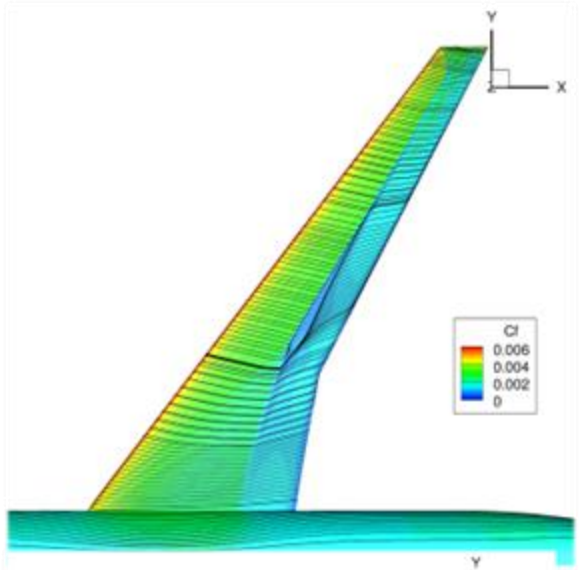
Case 2 – Alpha Sweep Study

Alpha = 3.0

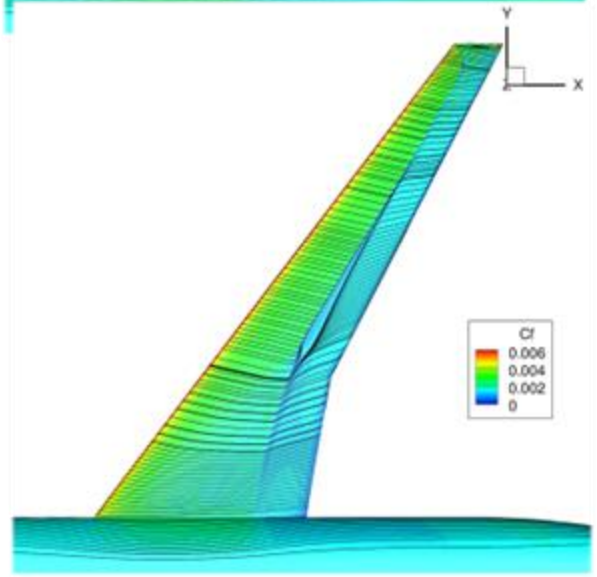
SA



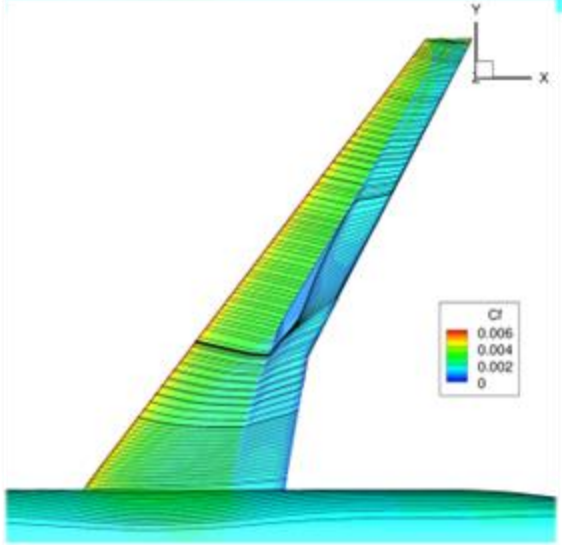
SA-QCR



kw-SST



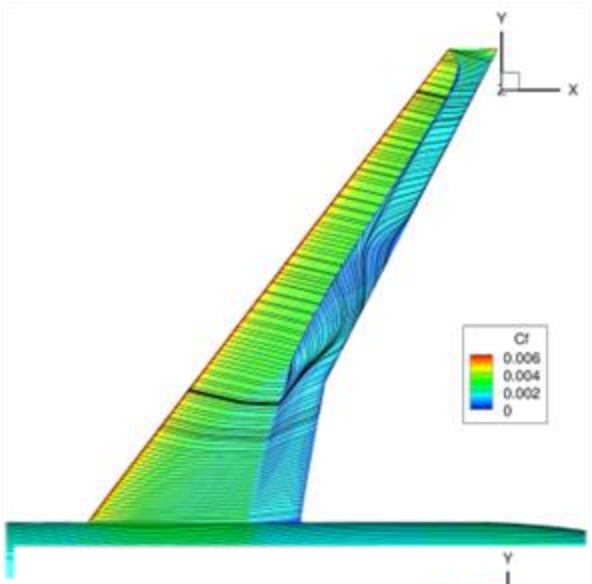
SA-RC-QCR



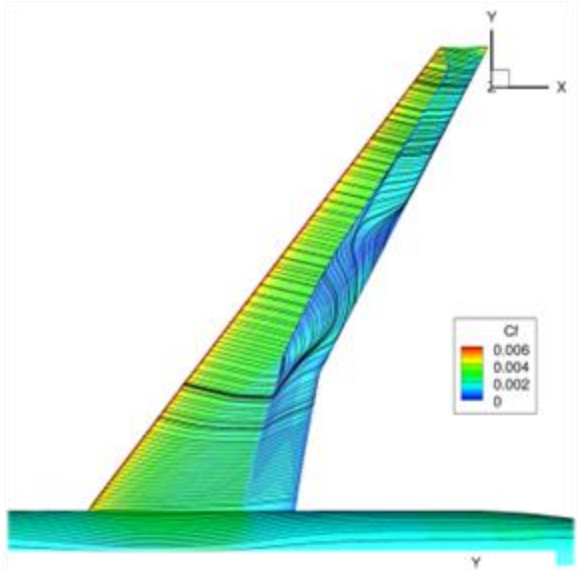
Case 2 – Alpha Sweep Study

Alpha = 3.5

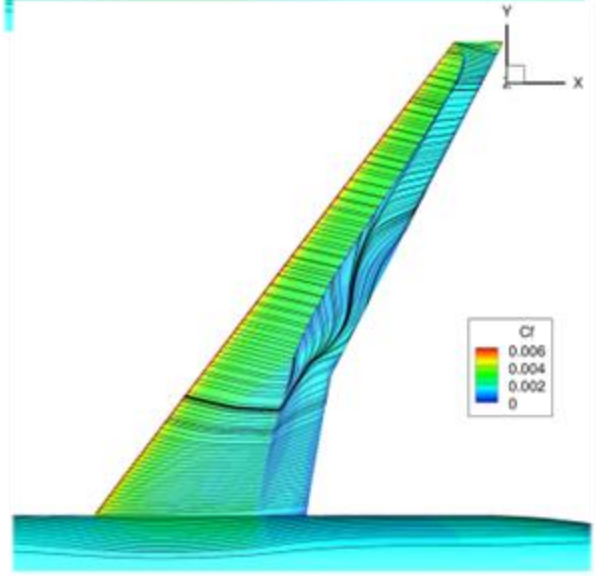
SA



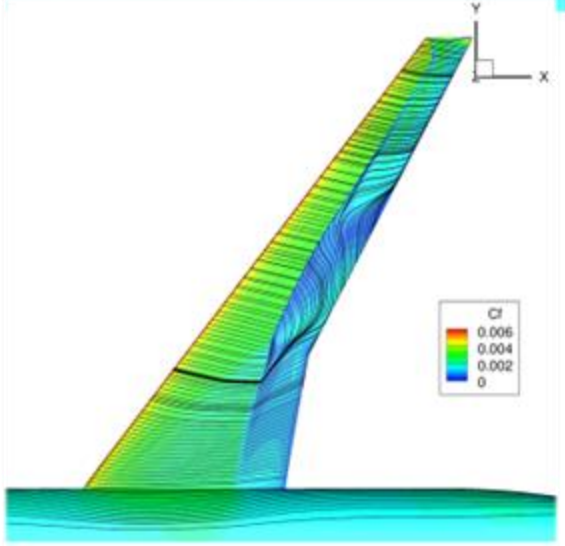
SA-QCR



kw-SST



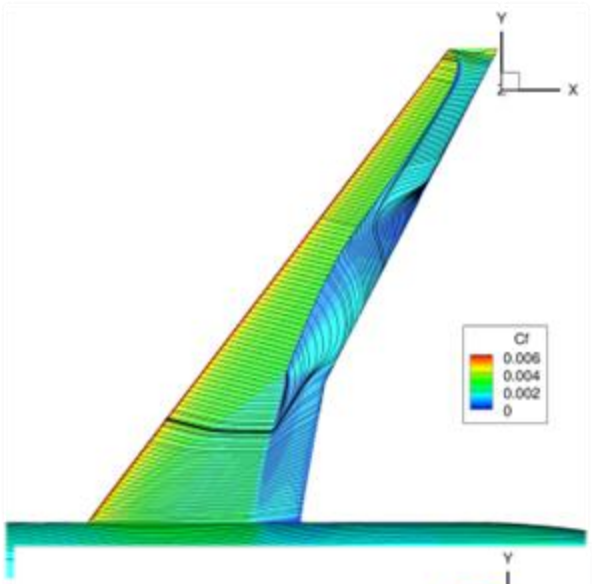
SA-RC-QCR



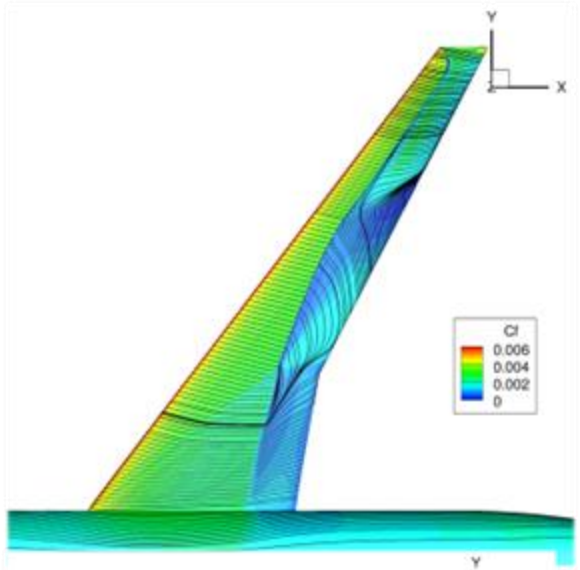
Case 2 – Alpha Sweep Study

Alpha = 4.0

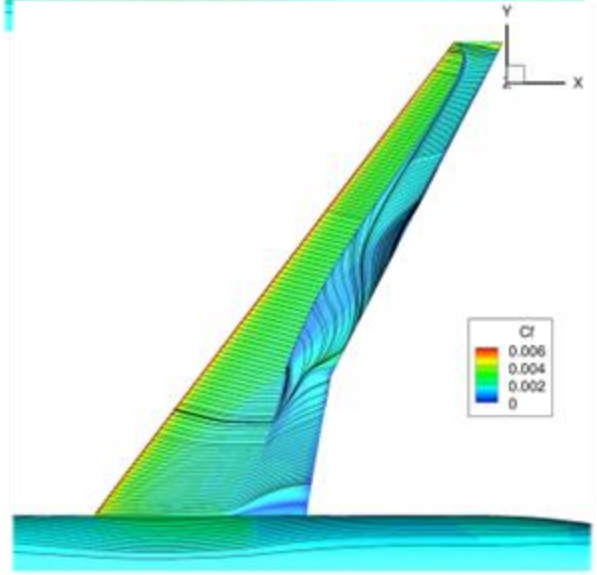
SA



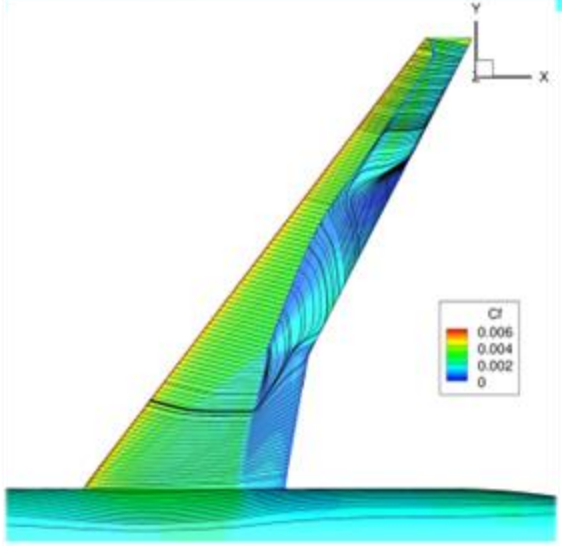
SA-QCR



kw-SST



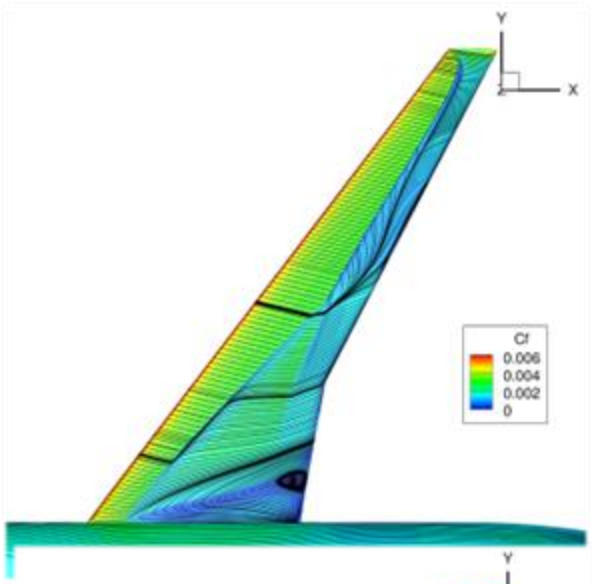
SA-RC-QCR



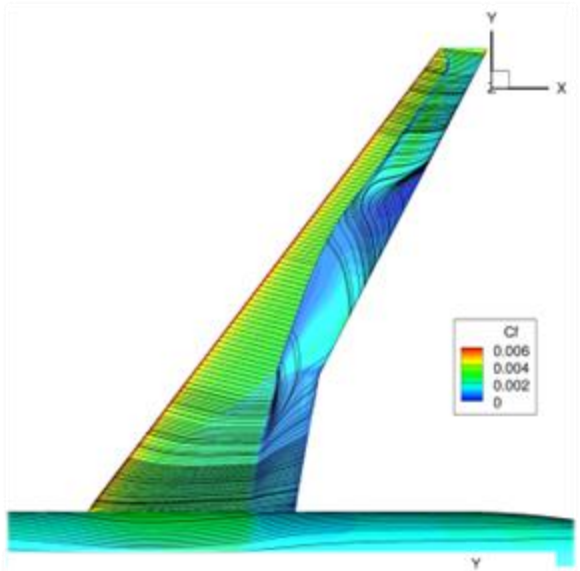
Case 2 – Alpha Sweep Study

Alpha = 4.25

SA



SA-QCR



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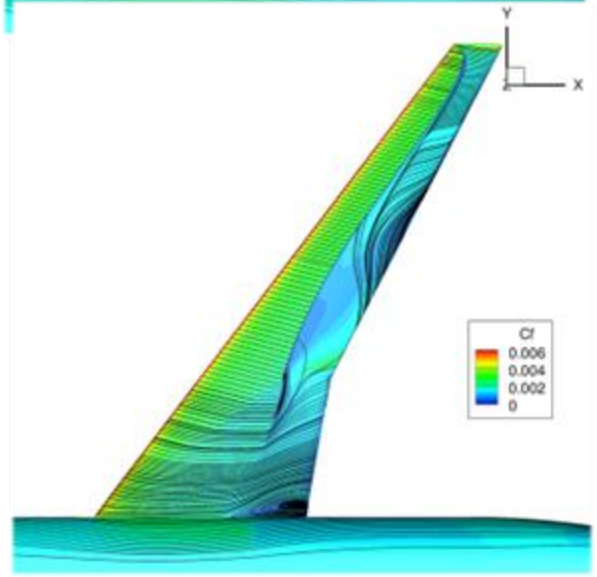

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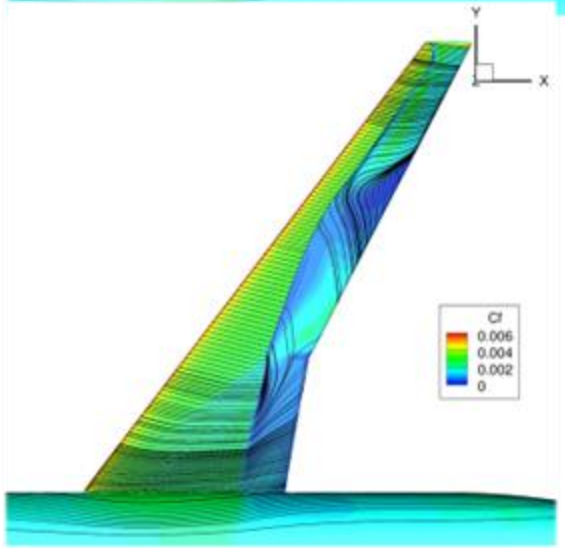
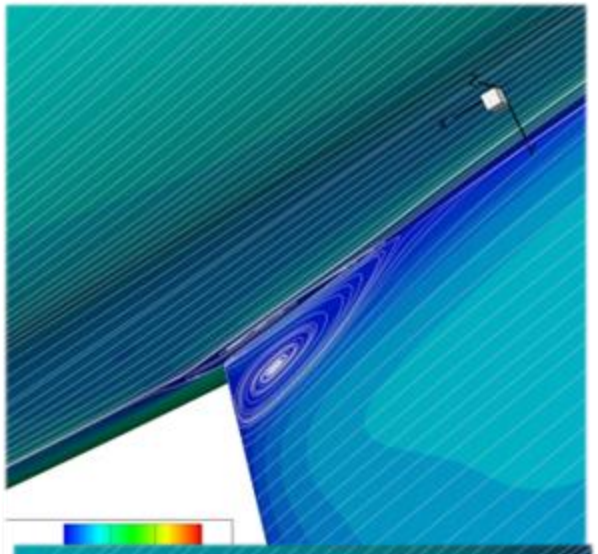


Case 2 – Alpha Sweep Study

Alpha = 3.0

SA



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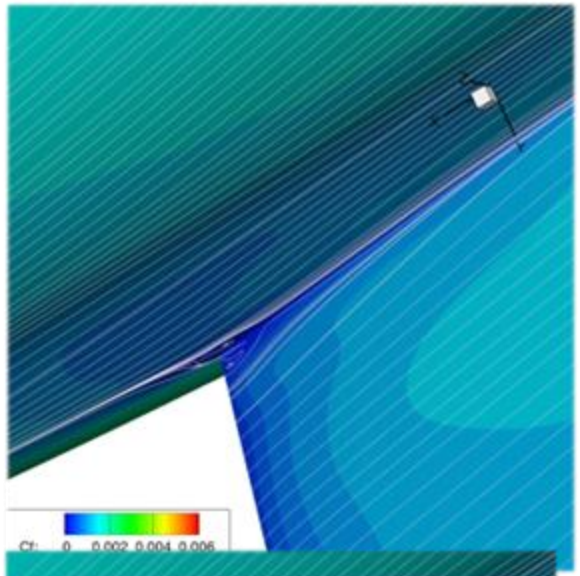
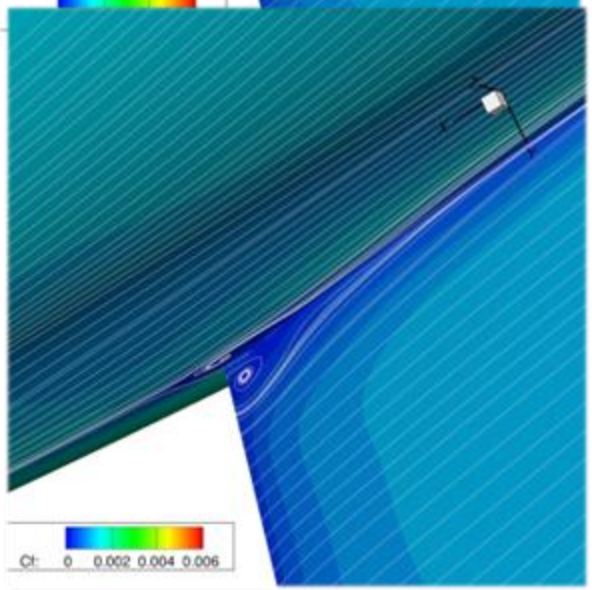
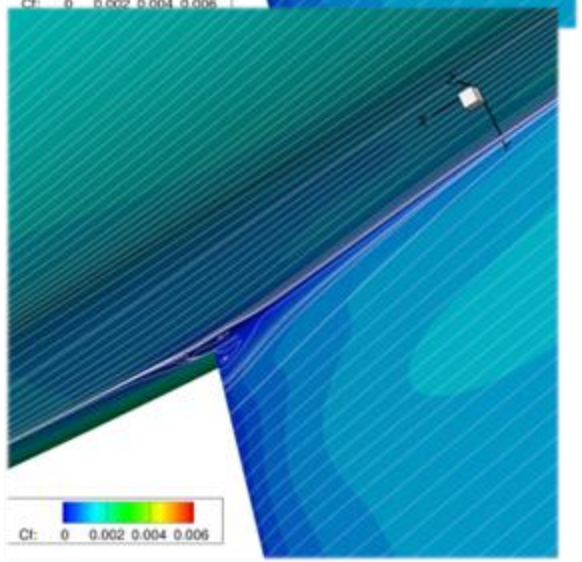


kw-SST



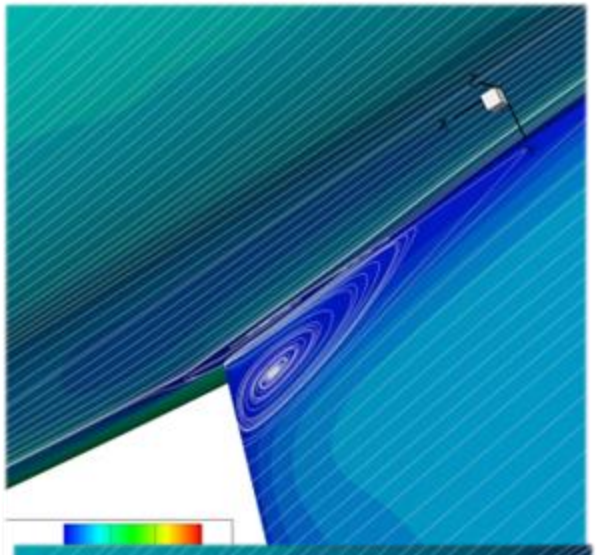
SA-RC-QCR



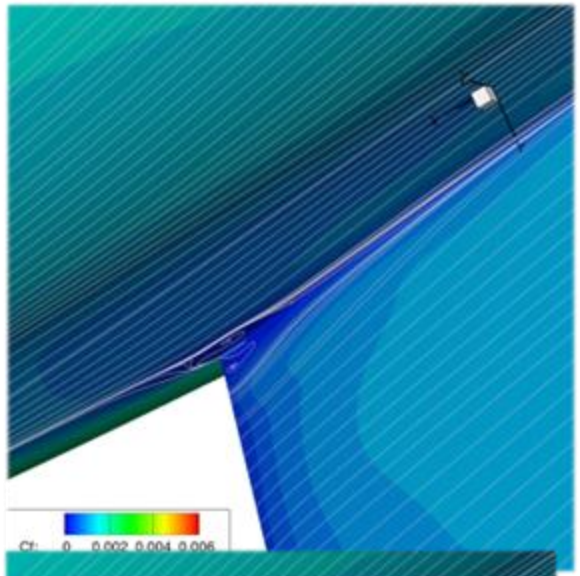
Case 2 – Alpha Sweep Study

Alpha = 3.5

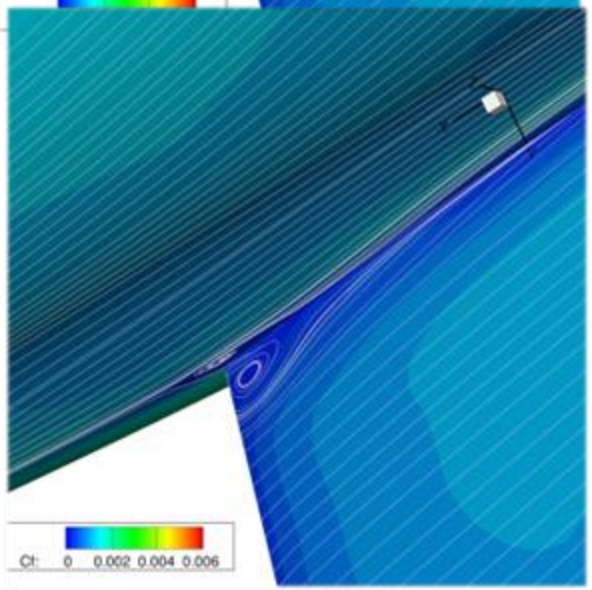
SA



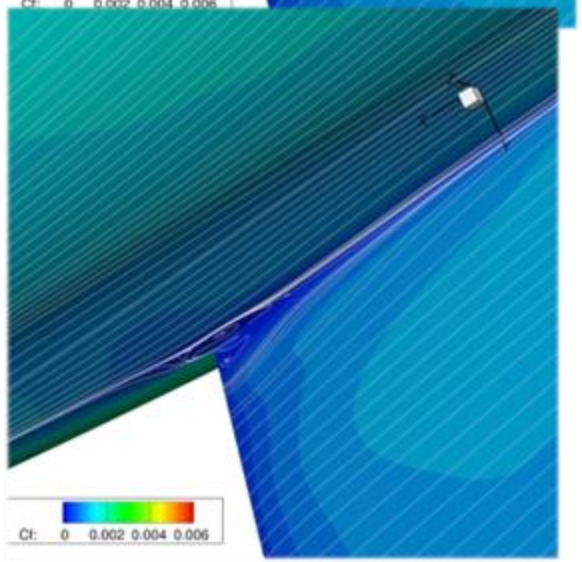
SA-QCR



kw-SST



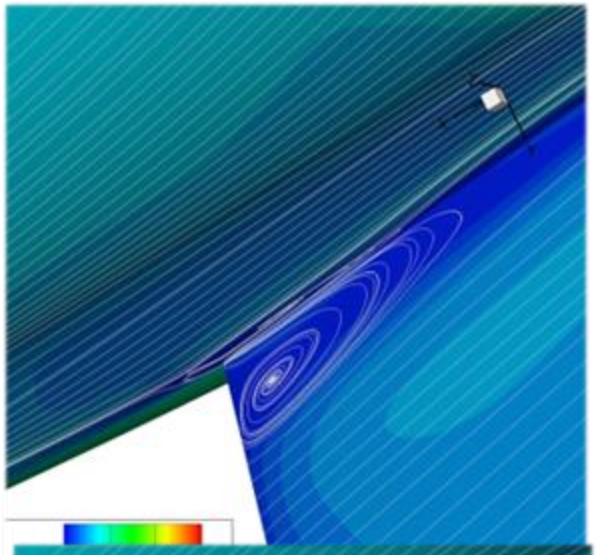
SA-RC-QCR



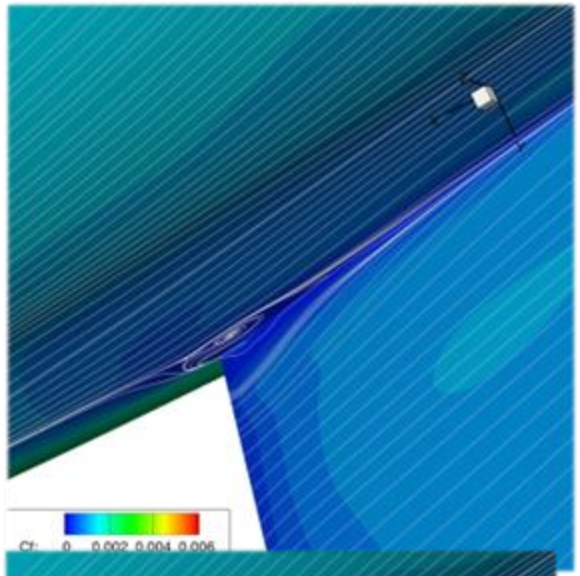
Case 2 – Alpha Sweep Study

Alpha = 4.0

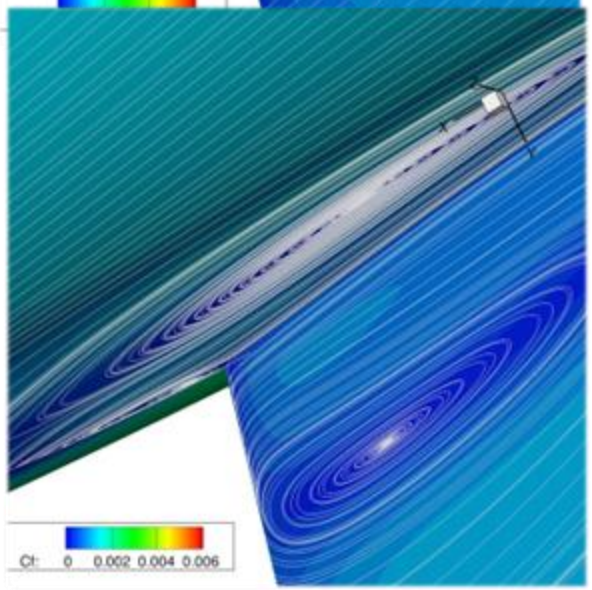
SA



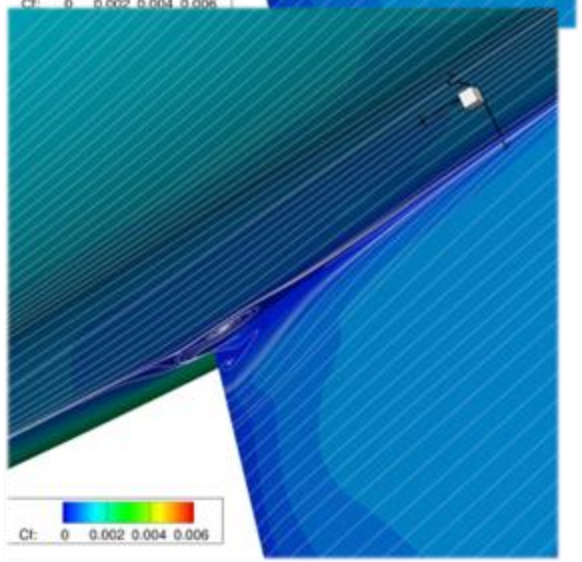
SA-QCR



kw-SST



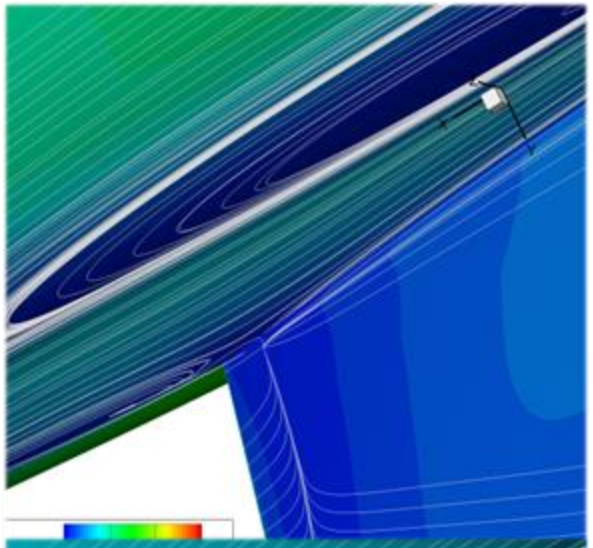
SA-RC-QCR



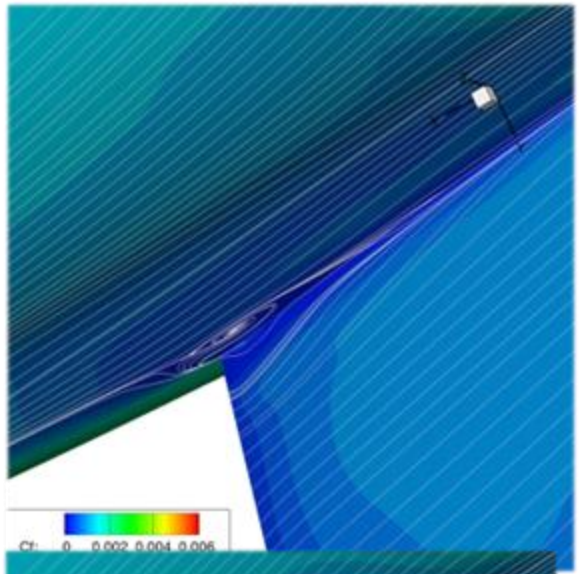
Case 2 – Alpha Sweep Study

Alpha = 4.25

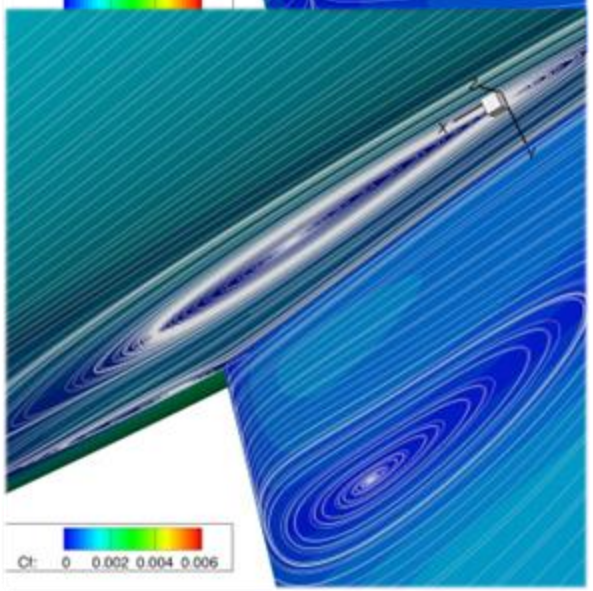
SA



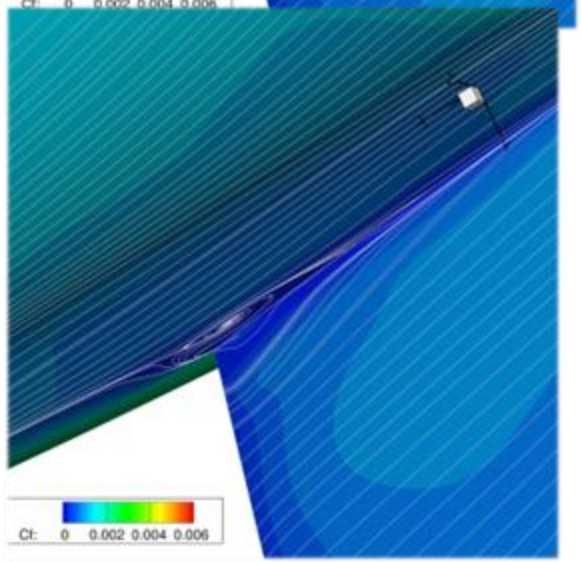
SA-QCR



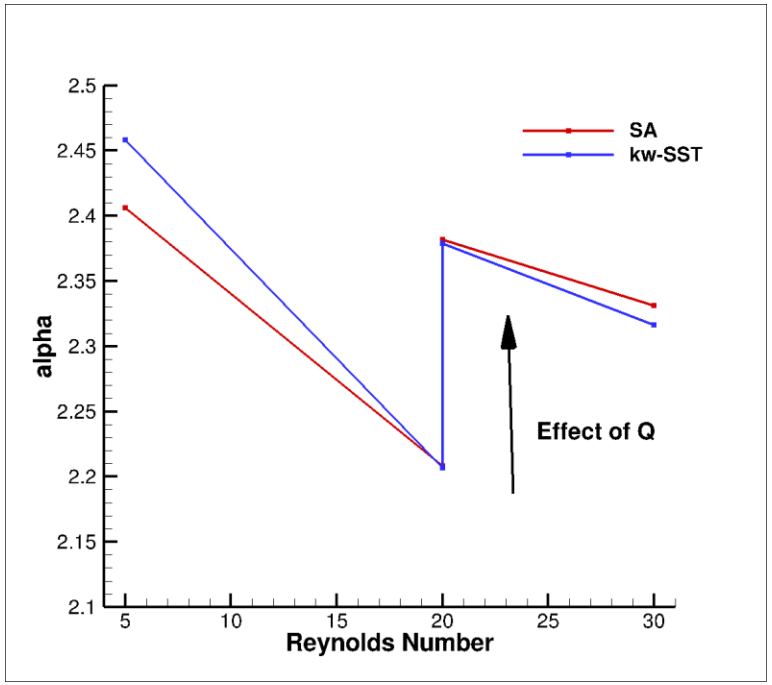
kw-SST

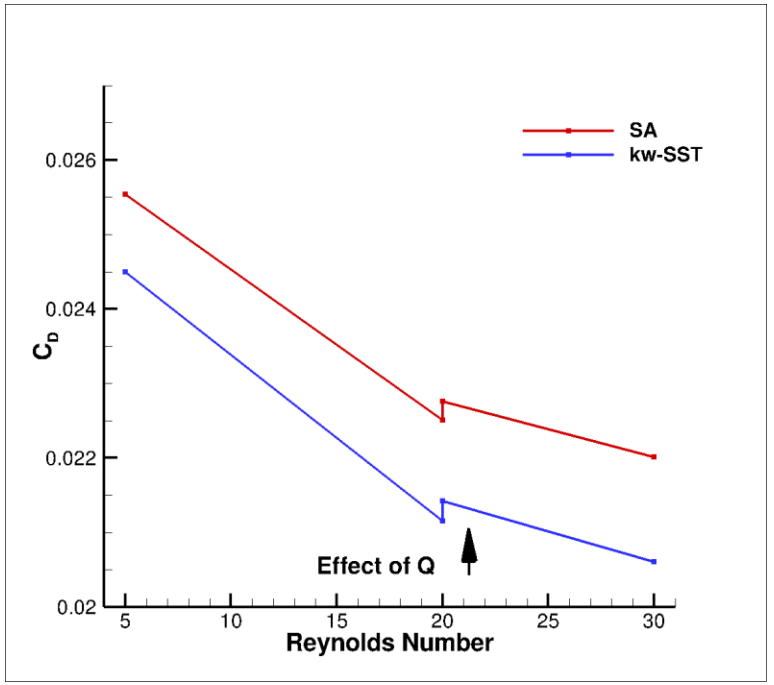


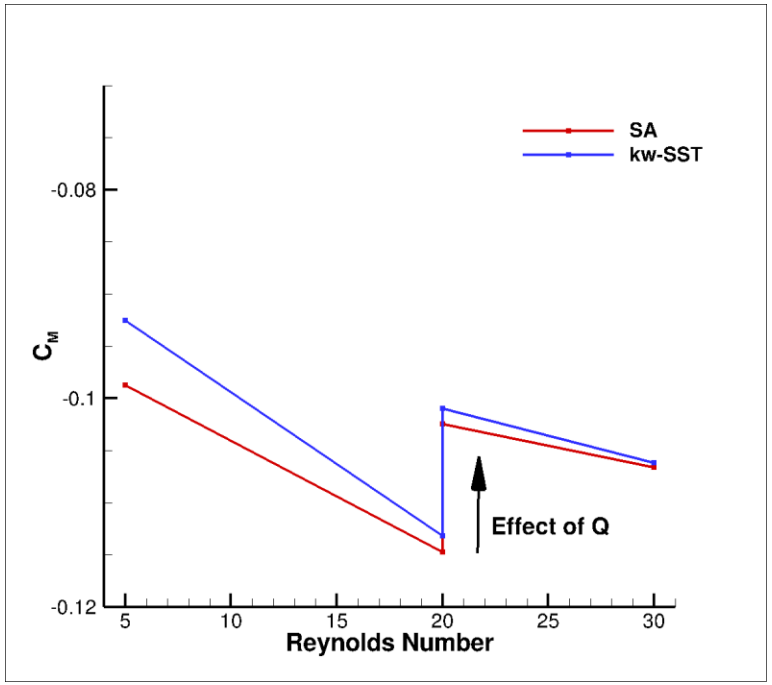
SA-RC-QCR



Case 3 – Reynolds number and Q effect study

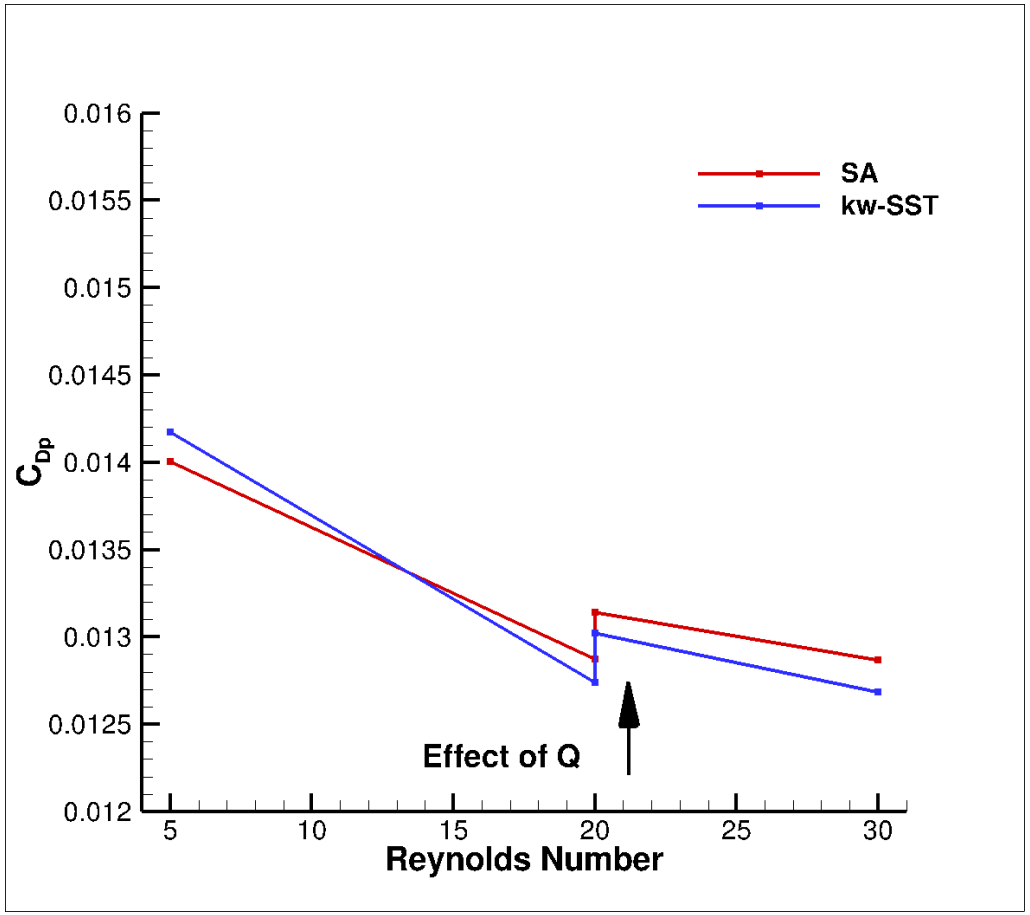




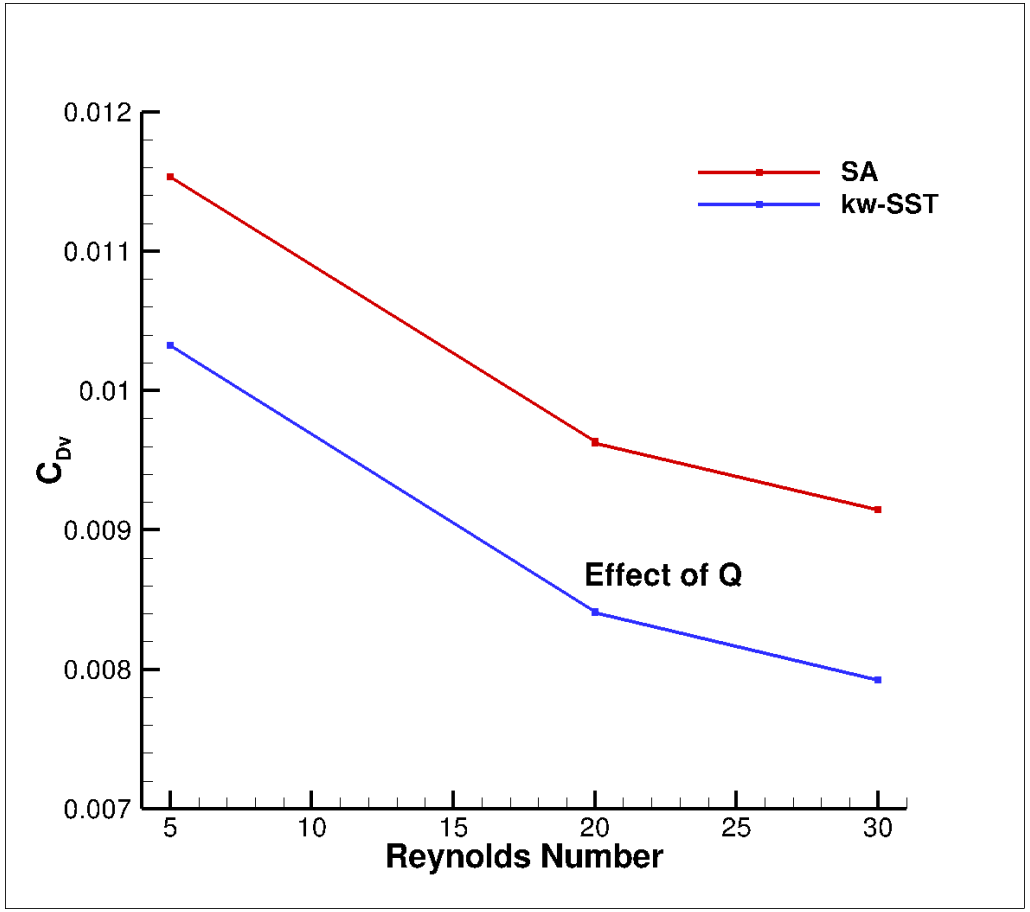


Alpha **CD** **CM**

Case 3 – Reynolds number and Q effect study



CDp



CDv

Conclusions

- The grid convergence study shows good convergence properties, with grid refinement primarily affecting the shock position and resolution.

- The alpha sweep study showed a strong sensitivity of turbulence modelling on the result. The QCR-correction was found to significantly improve the unphysical strong separation at the root, whereas the RC-correction, shifts the shock aft.

- The Reynolds number study showed reduced drag and alpha with increasing Re. whereas the Q primarily increased the alpha and reduced the negative pitching moment.

Potential further investigations:

- Mesh sensitivity study -> repeat study on ultra-fine grids/ grids of a different family
- Warm-started alpha sweep (each grid needs exactly the same number of nodes)
- Scale-resolving simulations