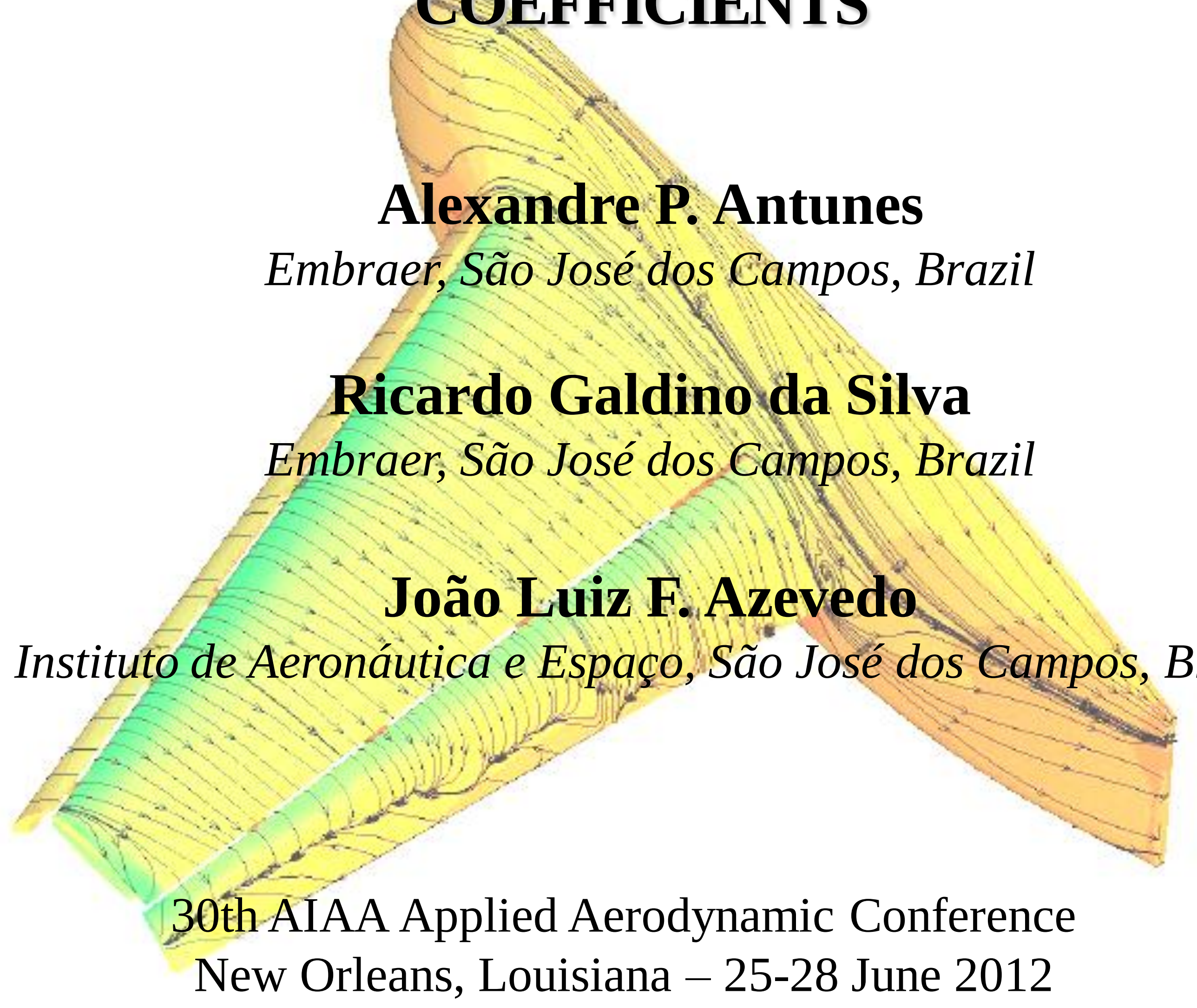
INFLUENCE OF HIGH-LIFT SUPPORTING SYSTEMS ON THE TRAPEZOIDAL WING AERODYNAMIC COEFFICIENTS



Alexandre P. Antunes
Embraer, São José dos Campos, Brazil

Ricardo Galdino da Silva
Embraer, São José dos Campos, Brazil

João Luiz F. Azevedo
Instituto de Aeronáutica e Espaço, São José dos Campos, Brazil

30th AIAA Applied Aerodynamic Conference
New Orleans, Louisiana – 25-28 June 2012

Outline

- Objectives
- Theoretical and Numerical Formulations
- High-Lift Configuration
- Mesh Generation
- Results
- Conclusions

Outline

- **Objectives**
- Theoretical and Numerical Formulations
- High-Lift Configuration
- Mesh Generation
- Results
- Conclusions

Objectives

The main objectives of the present work are:

- Build upon previous work but now considering the effects of the supporting brackets over the aerodynamic coefficients for the trapezoidal wing.

- Evaluate the effects of a surface and a volumetric mesh refinement over the aerodynamic coefficients.

Outline

- Objectives
- Theoretical and Numerical Formulations
- High-Lift Configuration
- Mesh Generation
- Results
- Conclusions

Outline

- Objectives
- **Theoretical and Numerical Formulations**
- High-Lift Configuration
- Mesh Generation
- Results
- Conclusions

Theoretical and Numerical Formulation

The numerical simulations are performed using the CFD++ software considering the RANS formulation (Reynolds-averaged Navier-Stokes Equations) and the SA and SST turbulence models.

Numerical aspects of the CFD++ software:

- Finite volume cell-based mixed element unstructured
- Inviscid fluxes: multi-dimensional TVD, minmod limiter
- Viscous fluxes: non-decoupling non-limited face polynomials
- Point implicit with multi-grid relaxation for steady state.

Outline

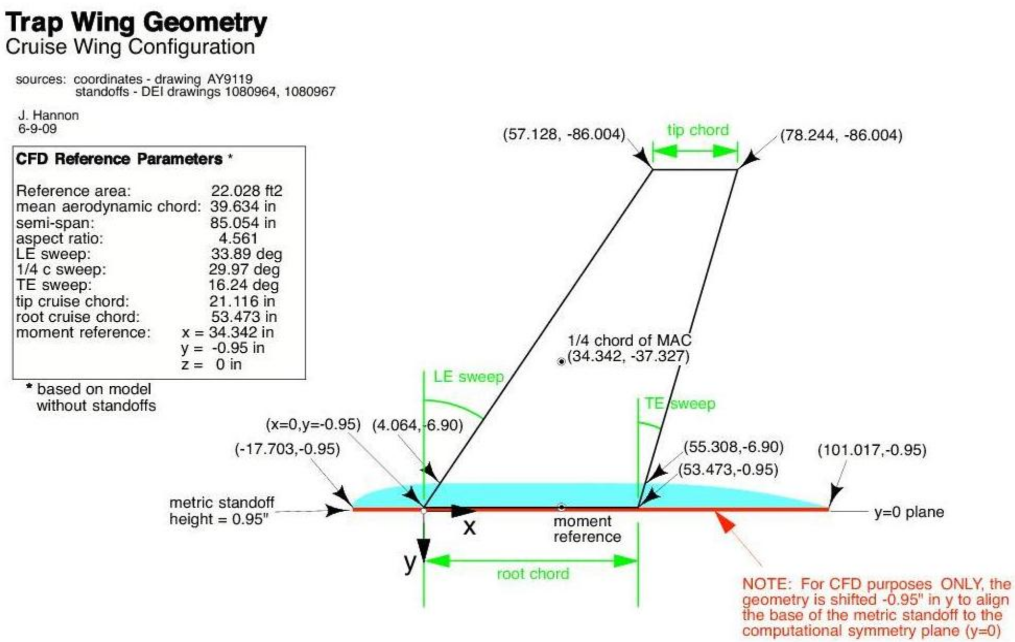
- Objectives
- Theoretical and Numerical Formulations
- High-Lift Configuration
- Mesh Generation
- Results
- Conclusions

Outline

- Objectives
- Theoretical and Numerical Formulations
- **High-Lift Configuration**
- Mesh Generation
- Results
- Conclusions

High-Lift Configuration

The Trap-Wing configuration, tested at NASA Ames PWT and NASA Langley SWT wind tunnels, is the object of study in the present work.

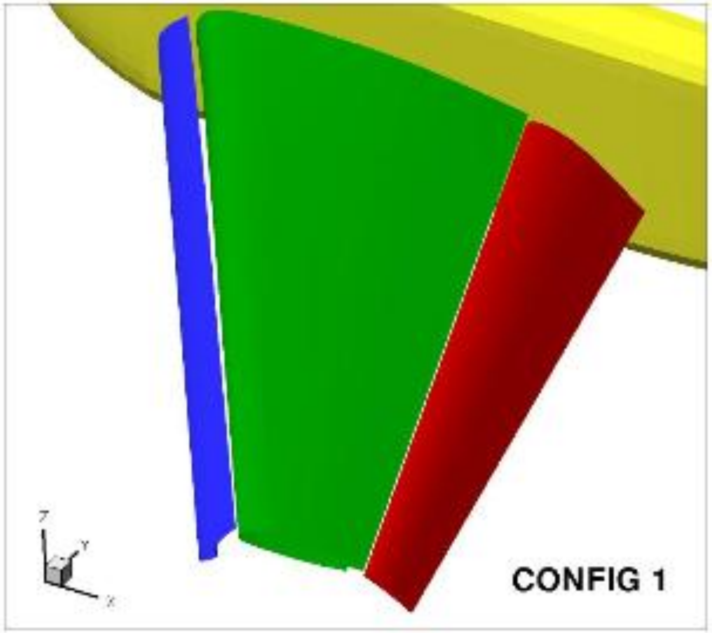


Wind Tunnel Model

High-Lift Configuration

The simulations are performed for the flight condition given by Mach number of 0.20 and Reynolds number of 4.3 million (NASA SWT – experimental test) for configuration one.

Configuration	Flap Spanwise	Slat Deflec.	Flap Deflec.
01	full	30	25



Outline

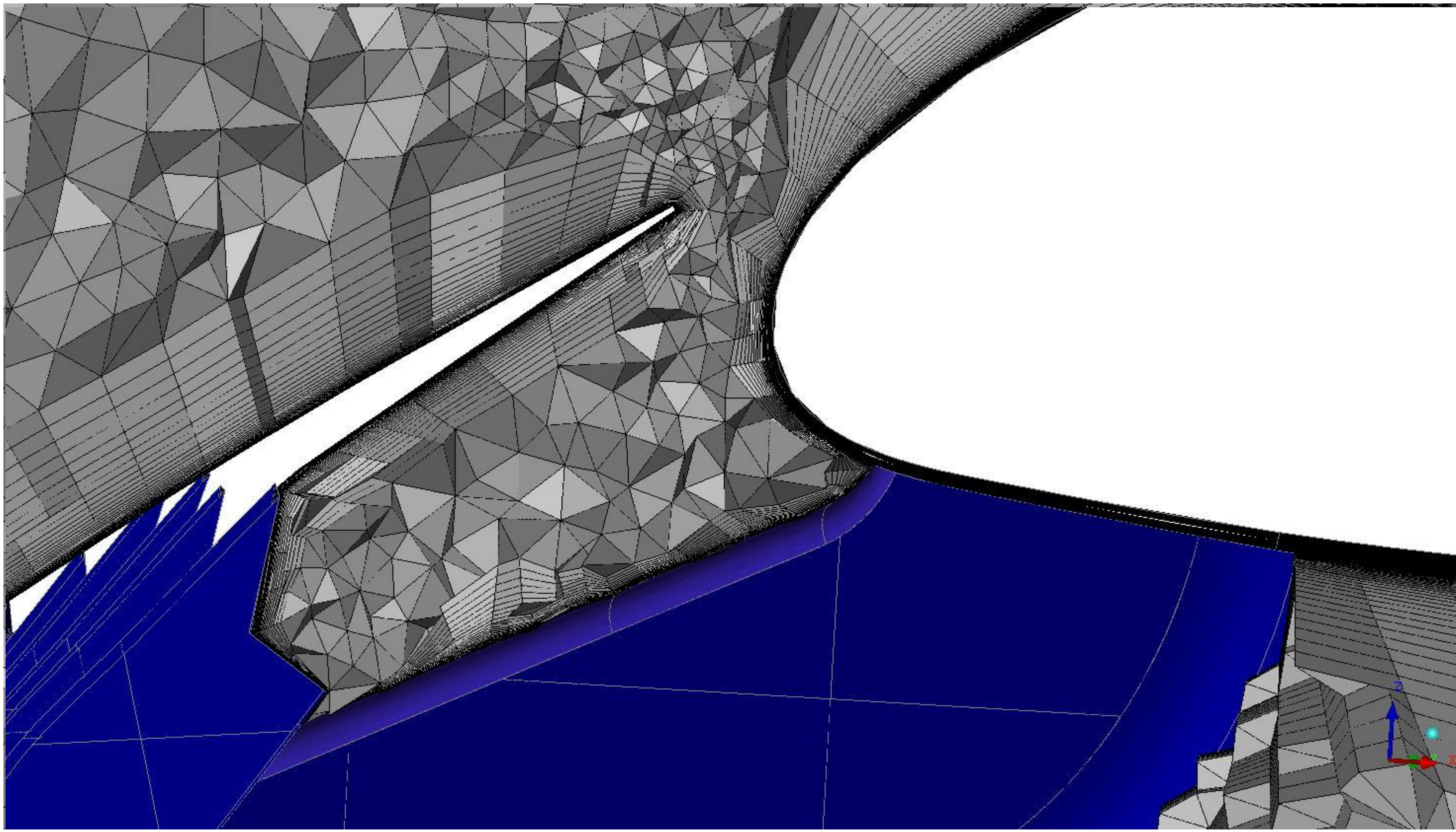
- Objectives
- Theoretical and Numerical Formulations
- High-Lift Configuration
- Mesh Generation
- Results
- Conclusions

Outline

- Objectives
- Theoretical and Numerical Formulations
- High-Lift Configuration
- **Mesh Generation**
- Results
- Conclusions

Mesh Generation Aspects

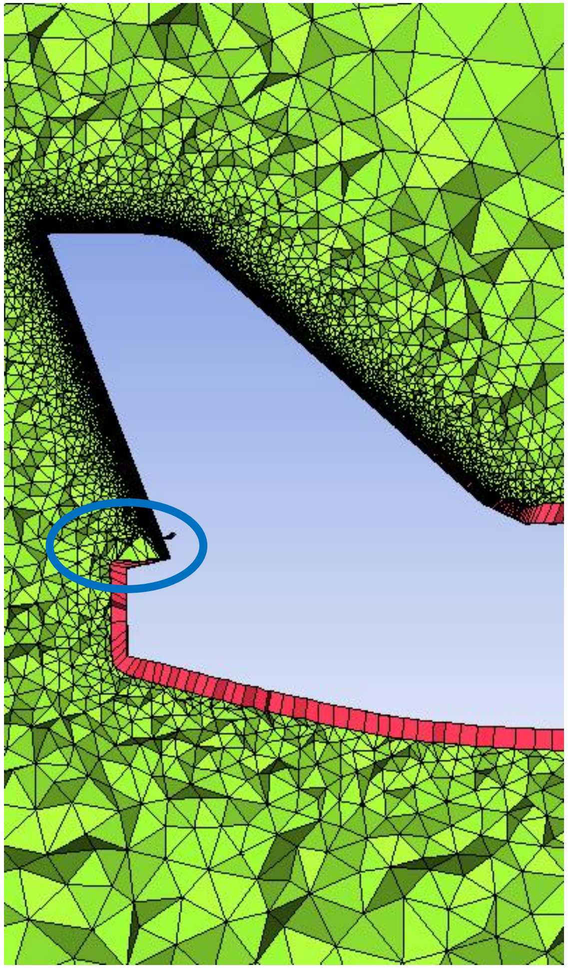
Complicated mesh generation process due to the proximity between the geometrical components of the configuration.



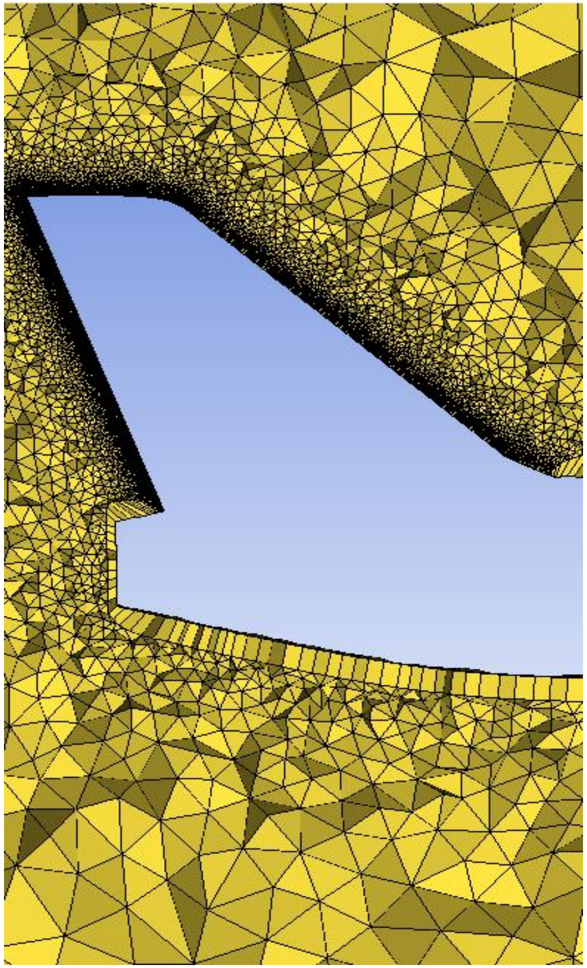
Mesh Generation Aspects

A simple example exposing the need to be careful and patient during the mesh generation process in concave regions.

Case (A)

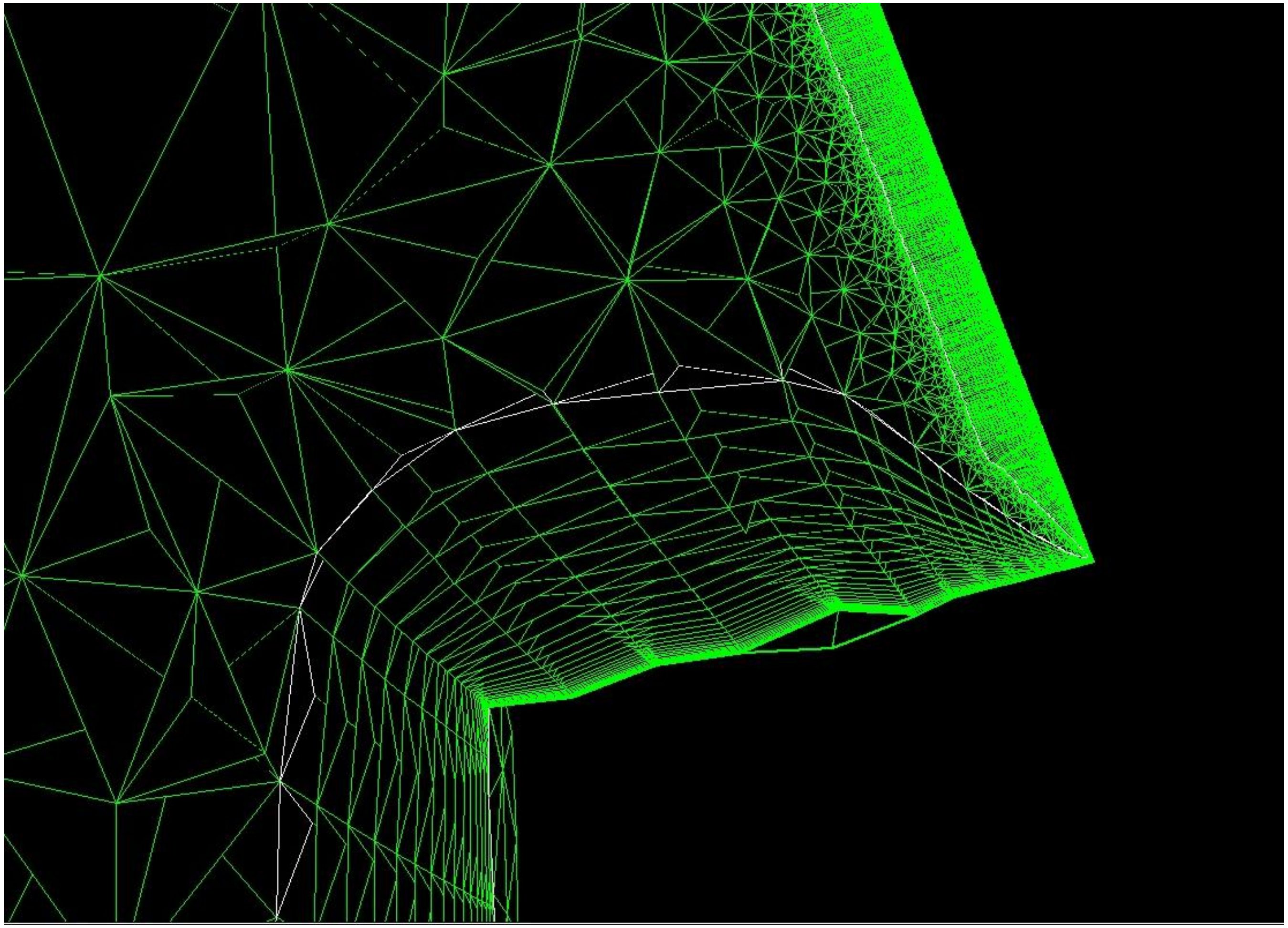


Case (B)



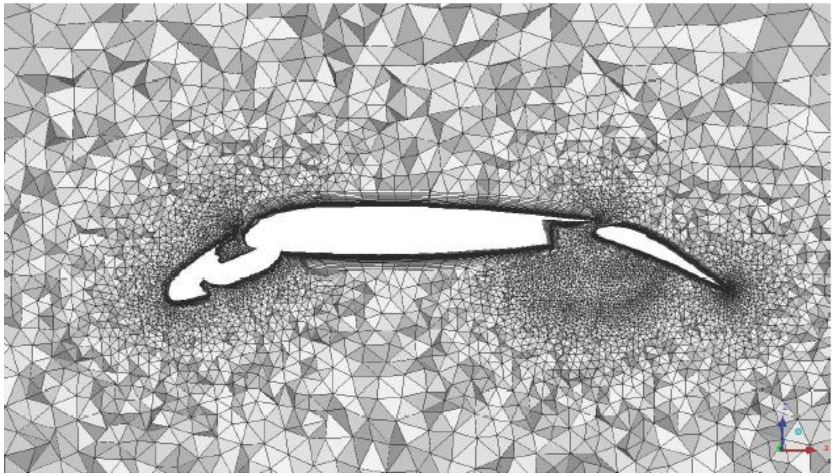
Mesh Generation Aspects

Case (B)



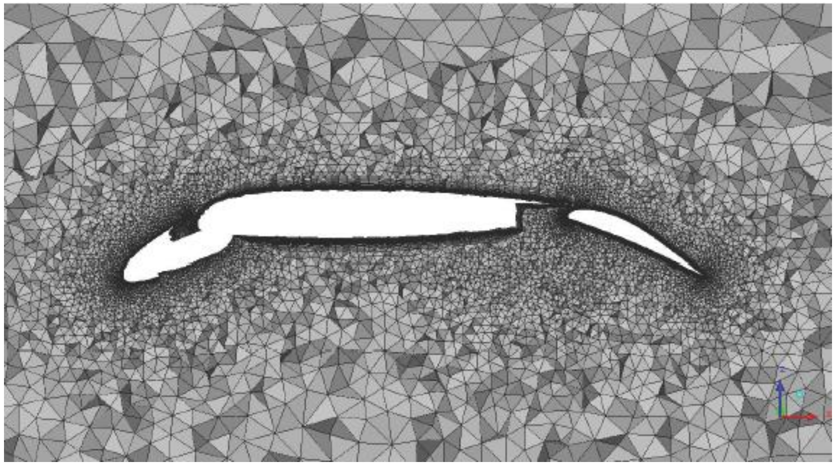
Mesh Generation –Hybrid Meshes

Meshes considering one surface and one spatial refinements.



Coarse Mesh - Baseline

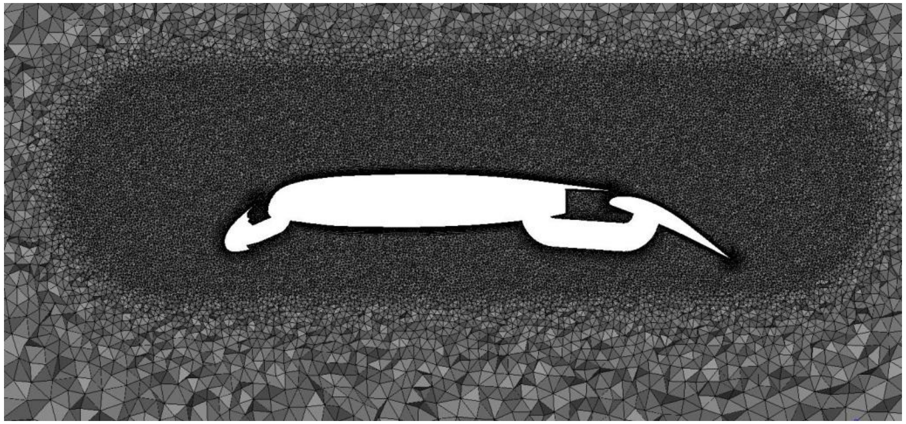
- Mesh size 24.8 million cells
- Y+ around one
- Stretching factor 1.15
- Total number of prismatic layers 46



Medium Mesh – Surface Refinement

- Mesh size 49.3 million cells
- Y+ around one
- Stretching factor 1.15
- Total number of prismatic layers 46

Mesh Generation –Hybrid Meshes

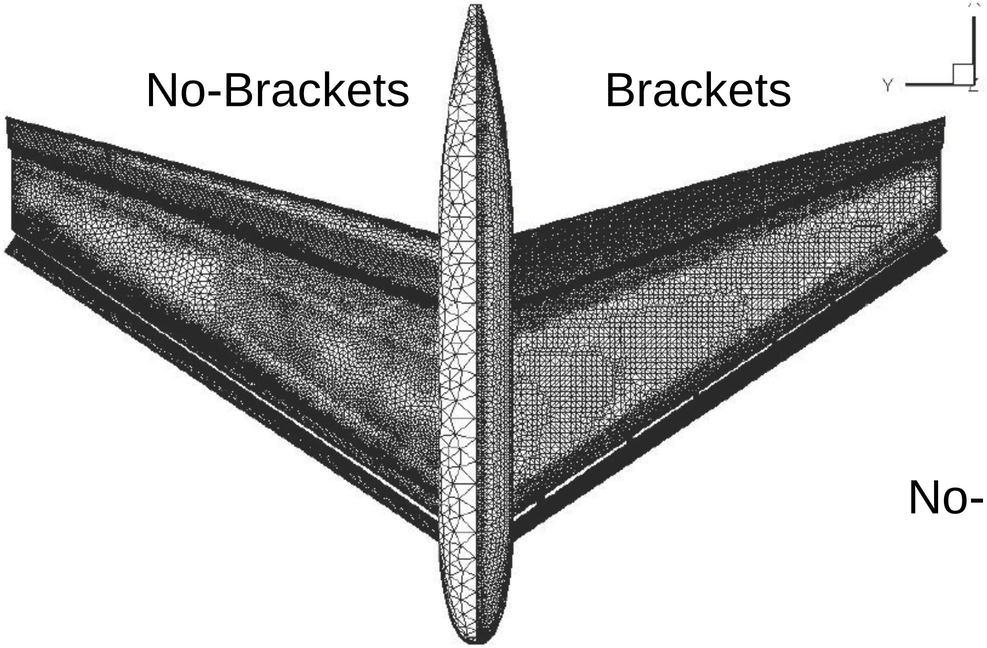


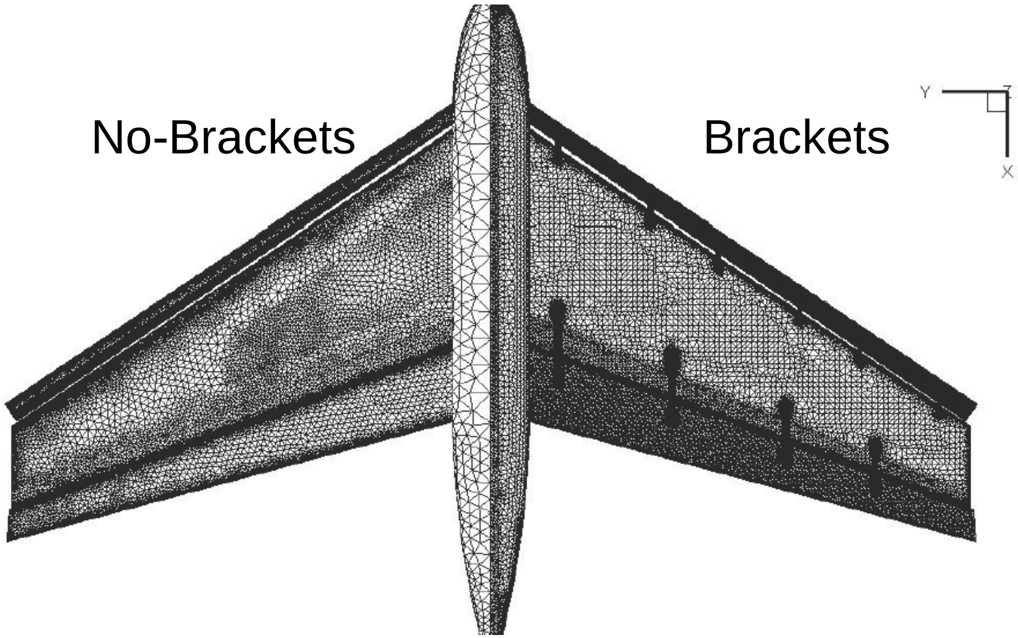
Fine Mesh – Volumetric Refinement

- Mesh size 69.5 million cells
- Y+ around one
- Stretching factor 1.15
- Total number of prismatic layers 46

Mesh Generation – w and wt Brackets

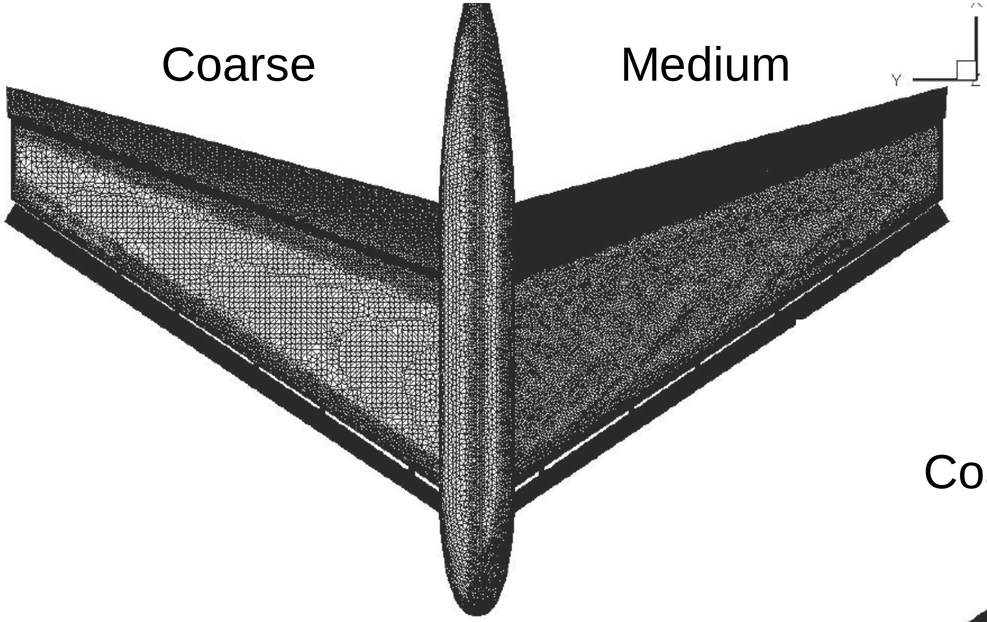
Coarse Mesh

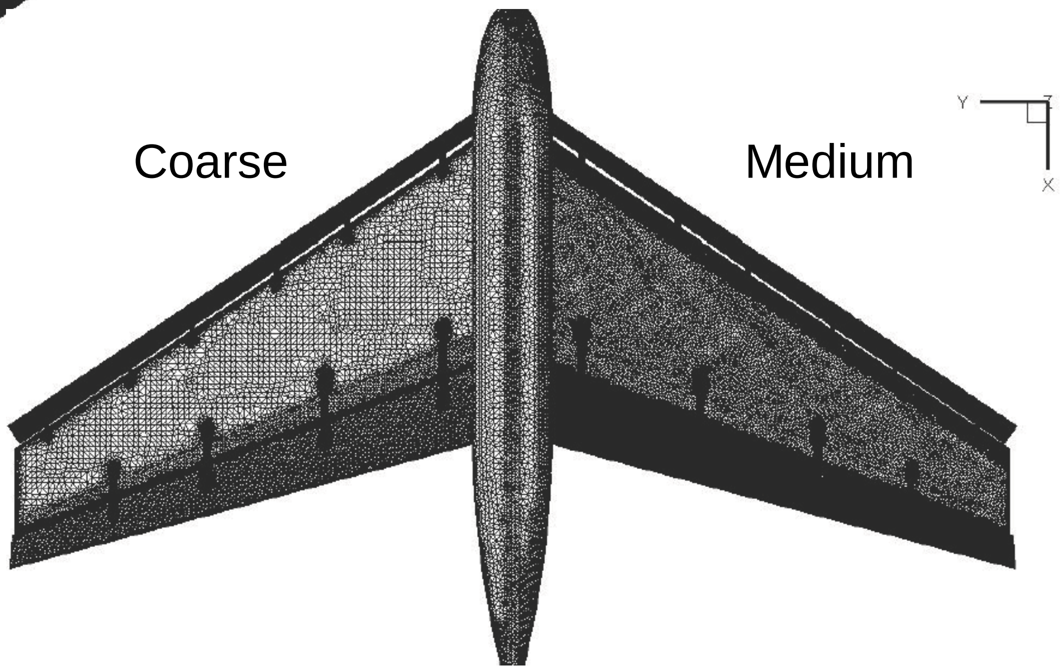




Mesh Generation – w Brackets

Coarse Mesh X Medium Mesh

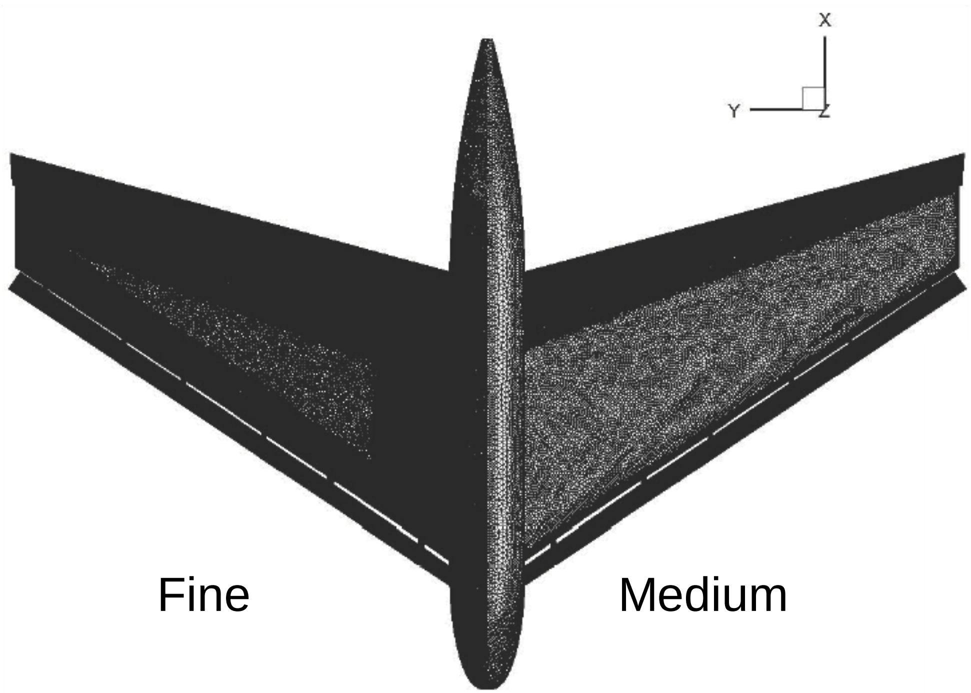


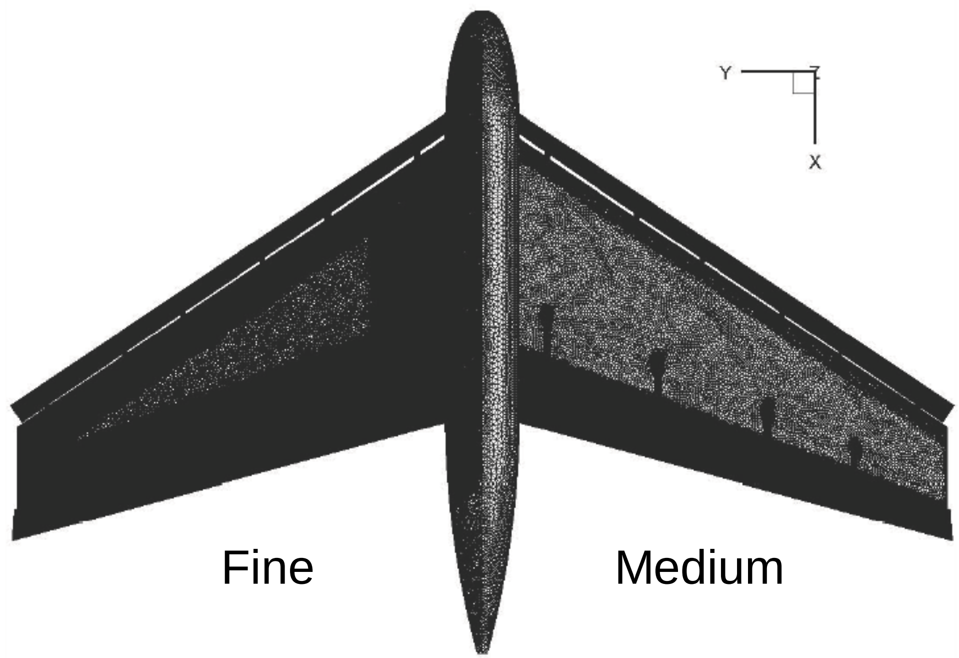


Surface refinement without doubling the number of surface elements.

Mesh Generation – w Brackets

Fine Mesh X Medium Mesh



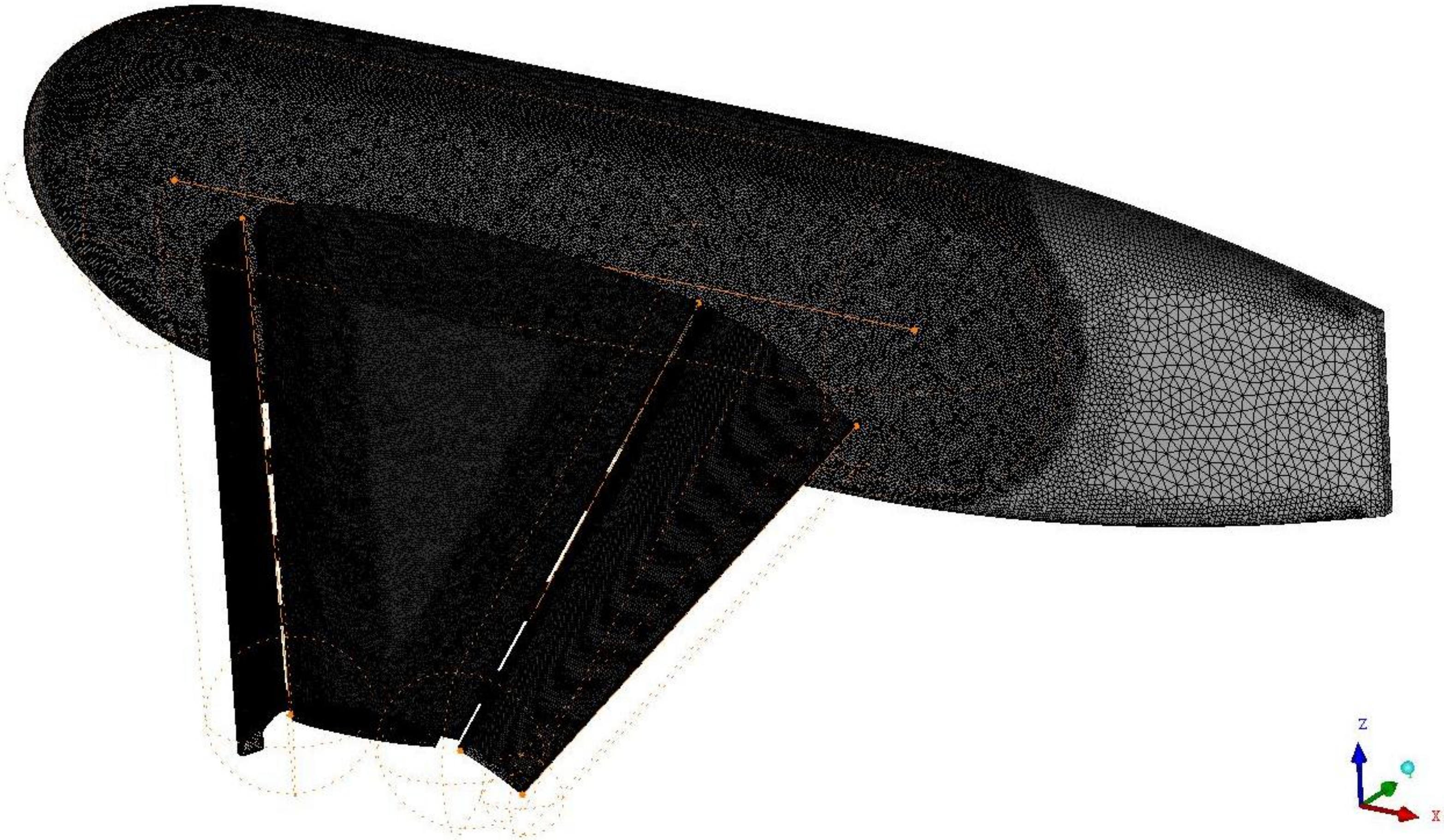


Mesh Generation – Volumetric Refinement

Regions where volumetric refinement is performed.

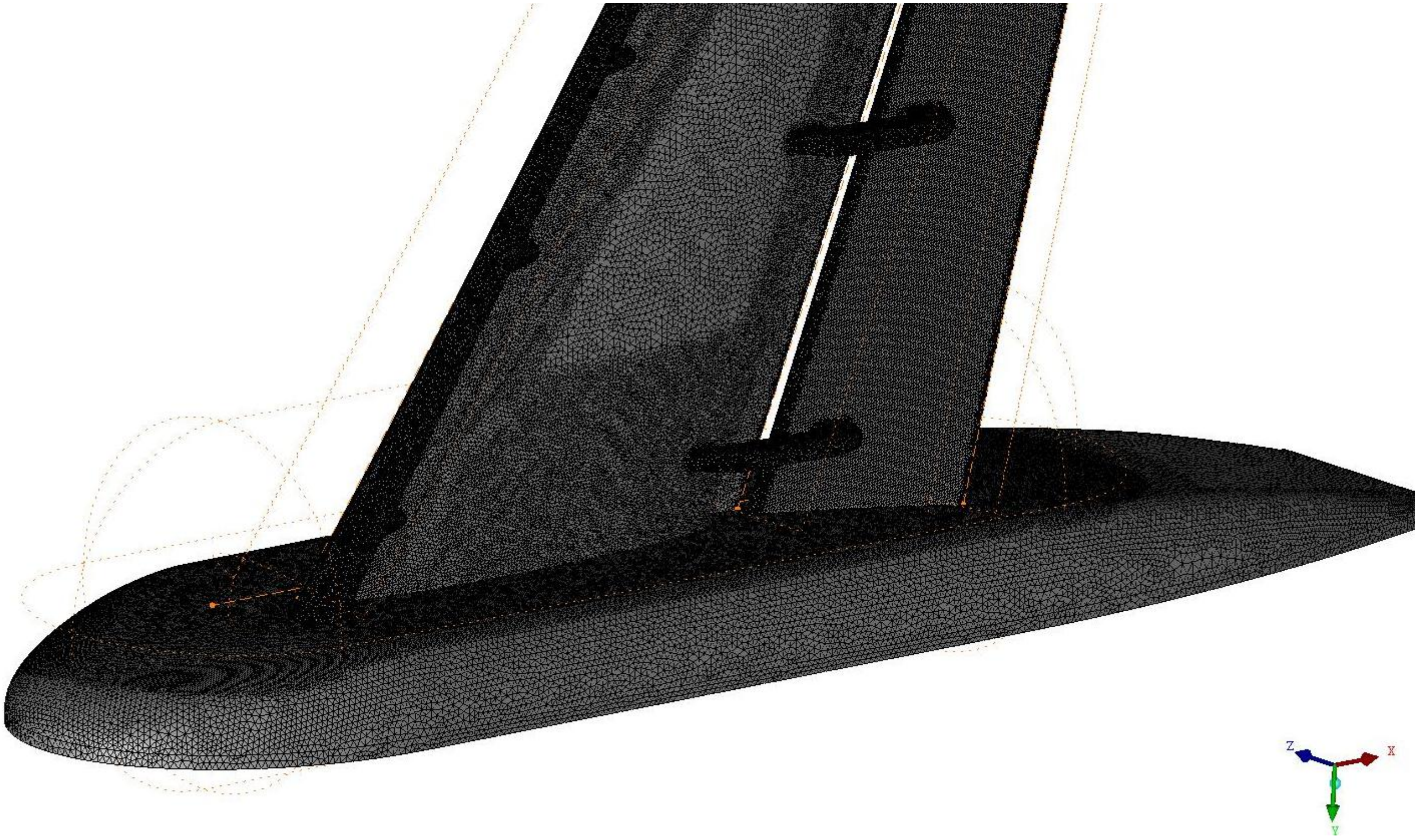
Mesh Generation – Volumetric Refinement

Regions where volumetric refinement is performed.



Mesh Generation – Volumetric Refinement

Regions where volumetric refinement is performed.



Outline

- Objectives
- Theoretical and Numerical Formulations
- High-Lift Configuration
- Mesh Generation
- Results
- Conclusions

Outline

- Objectives
- Theoretical and Numerical Formulations
- High-Lift Configuration
- Mesh Generation
- **Results**
- Conclusions

Results

The following tables show the simulations performed.

	Hybrid Mesh	SA	SST
No-Brackets From-Scratch	Coarse	X	
	Medium		
	Fine		

Previous result.

The flow to be considered as fully turbulent.

	Hybrid Mesh	SA	SST
Brackets From-Scratch	Coarse	X	
	Medium	X	X
	Fine	X	

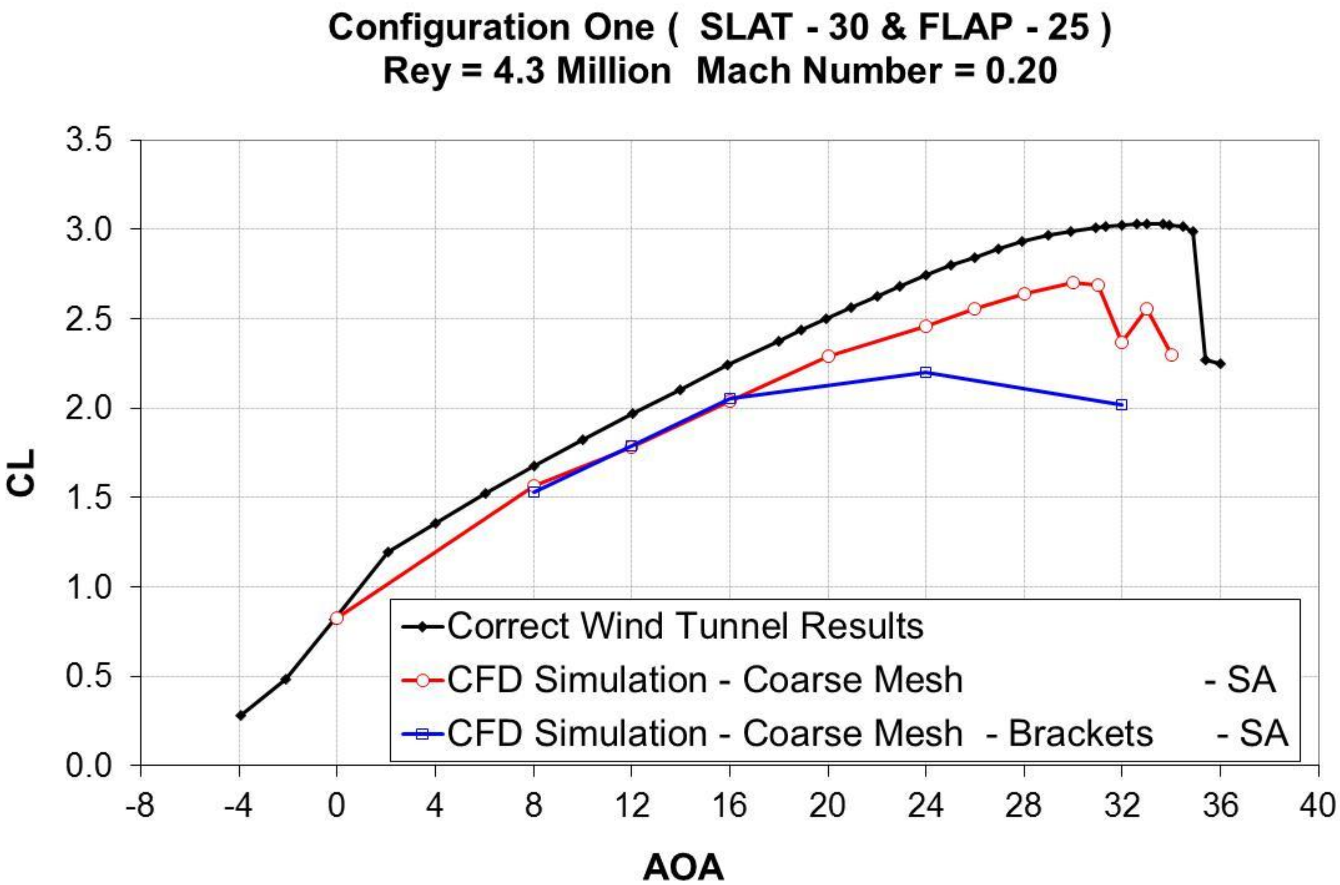
	Hybrid Mesh	SA	SST
Brackets Restart	Coarse		
	Medium	X	
	Fine		

Outline

- Objectives
- Theoretical and Numerical Formulations
- High-Lift Configuration
- Mesh Generation
- **Results**
  - **Coarse Mesh**
  - **Medium Mesh**
  - **Fine Mesh**
- Conclusions

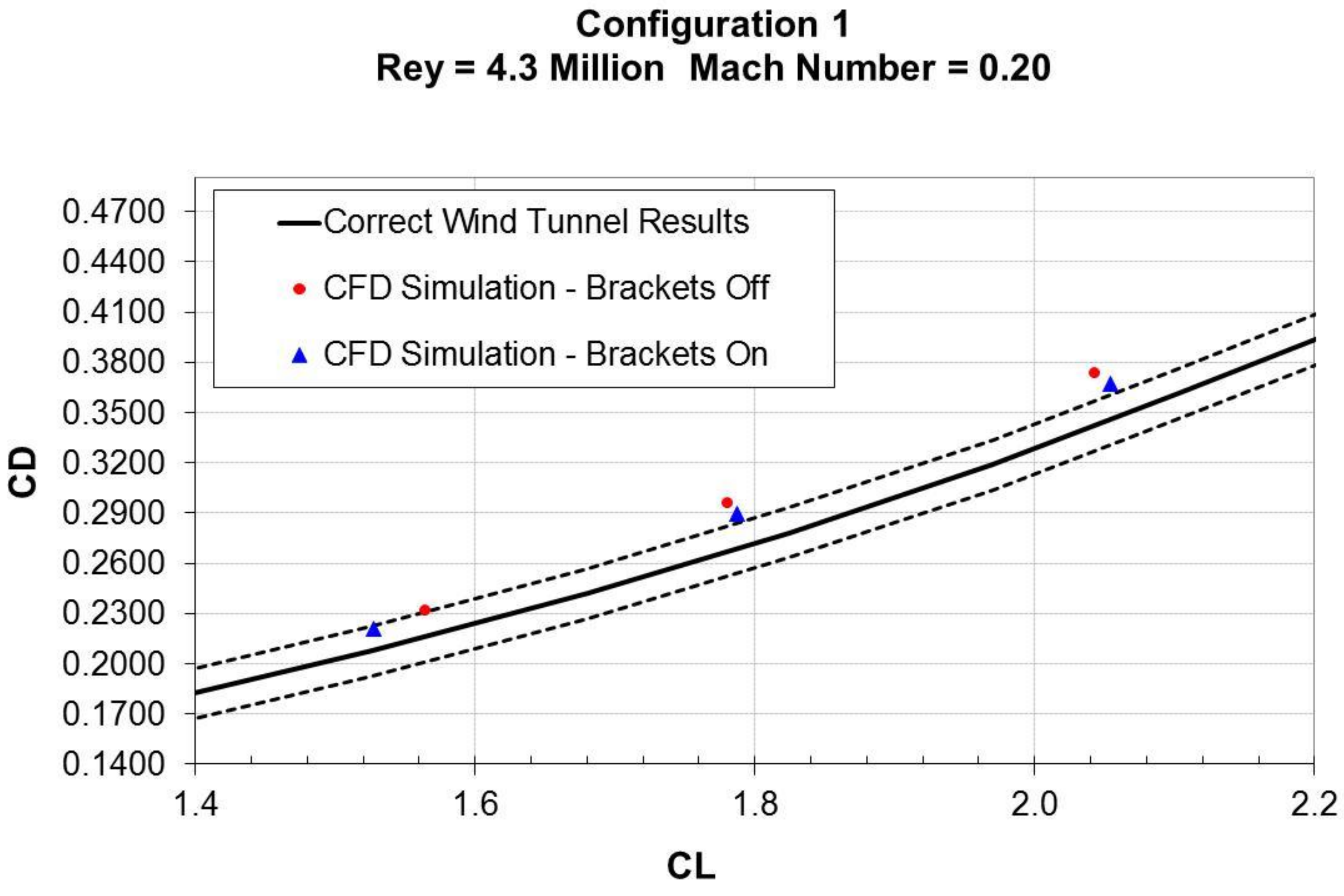
Results – Coarse Meshes

Comparison between the results with and without the brackets for the coarse mesh



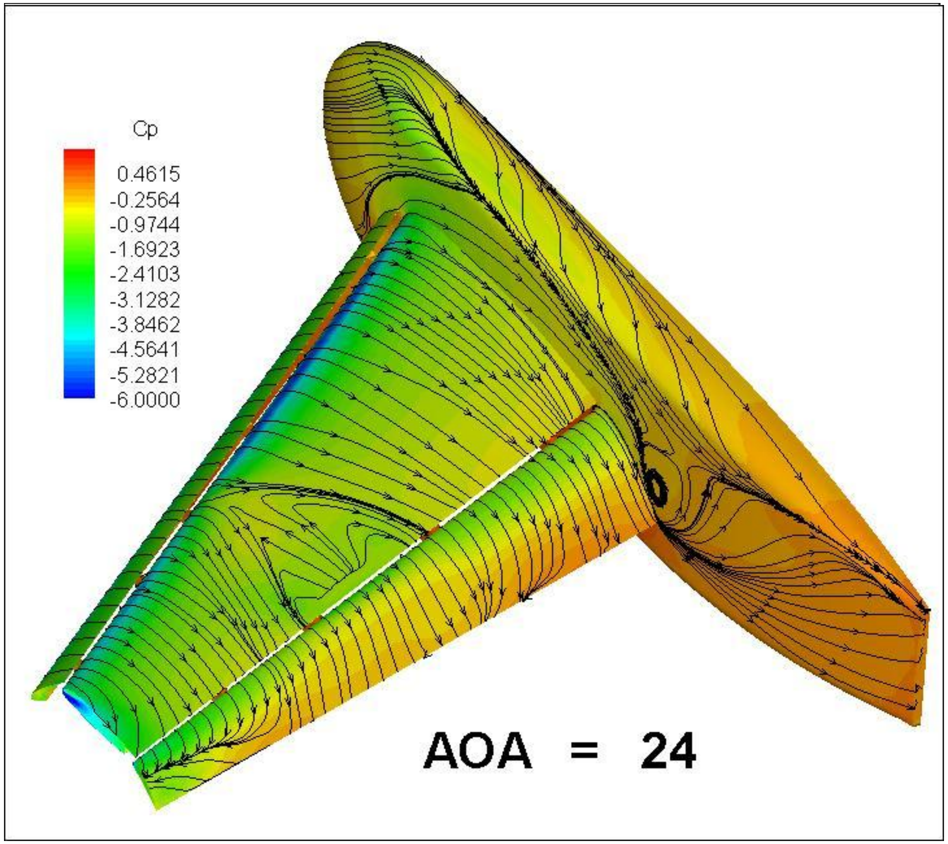
Results – Coarse Meshes

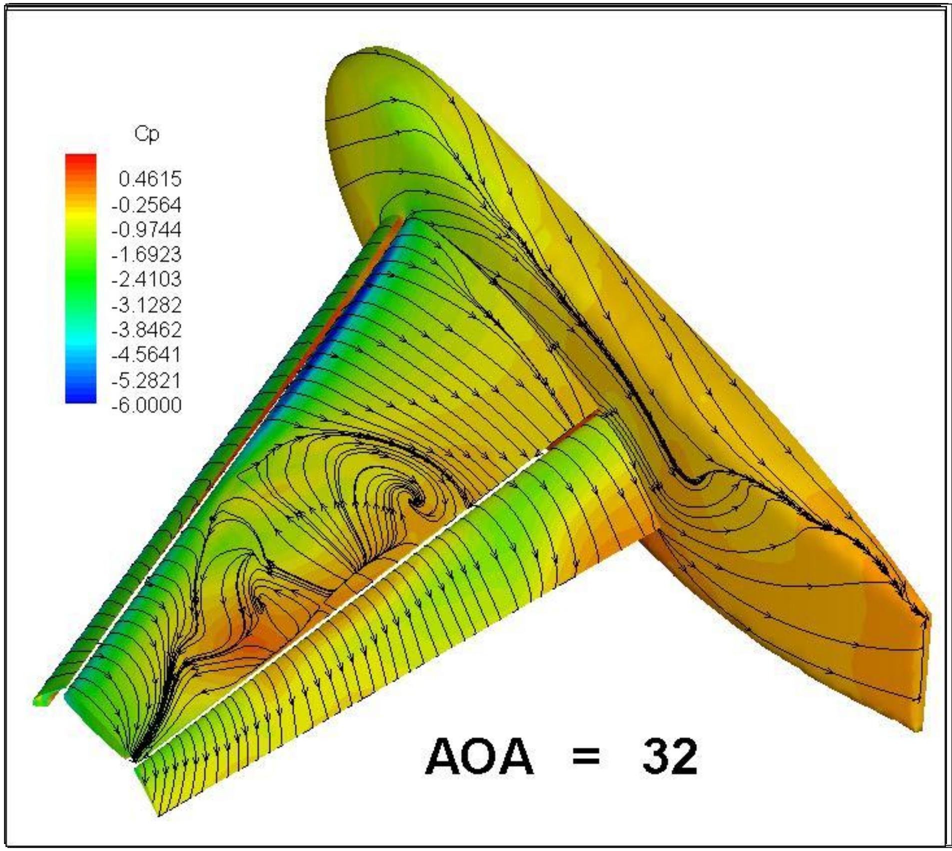
Drag polar comparison for both configurations.



Results – Coarse Meshes

Cp distribution with the shear lines.



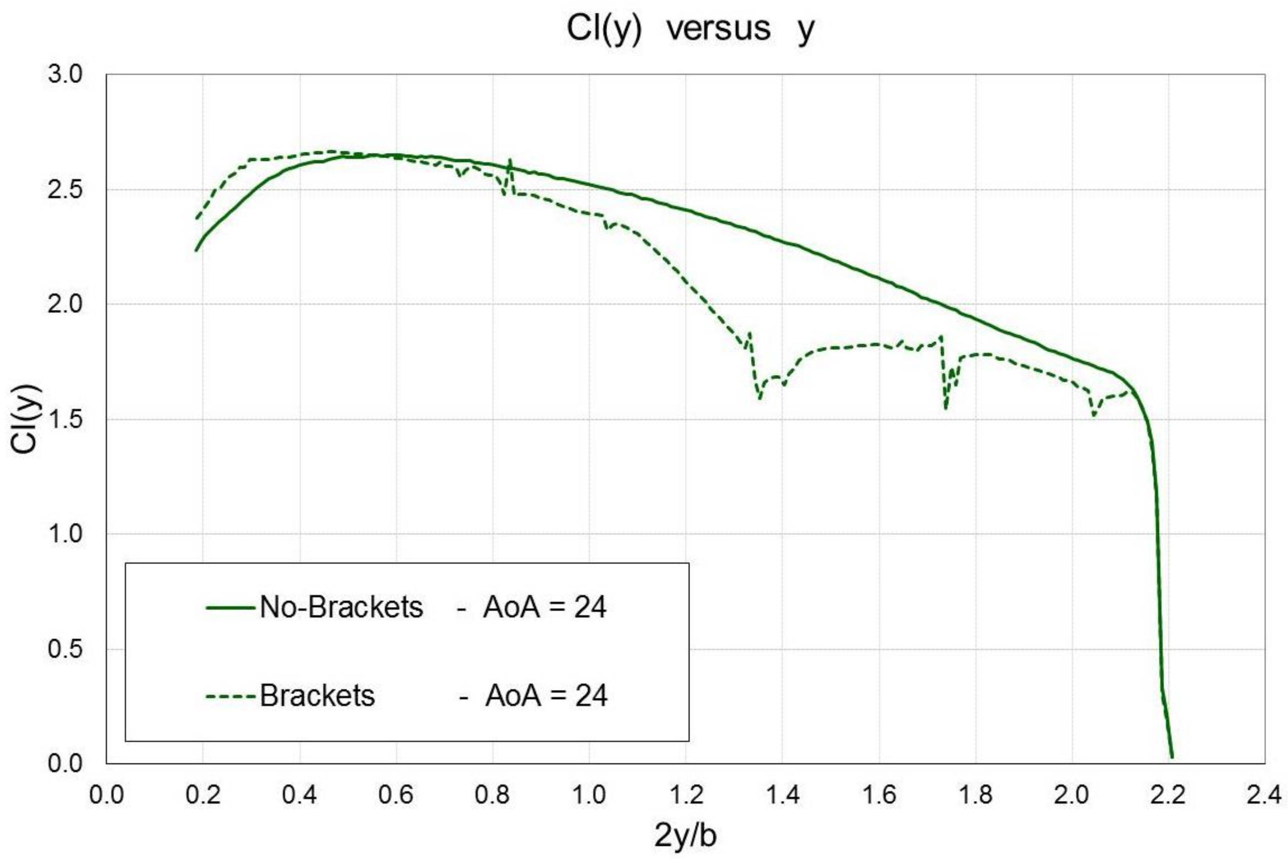


CL = 2.20

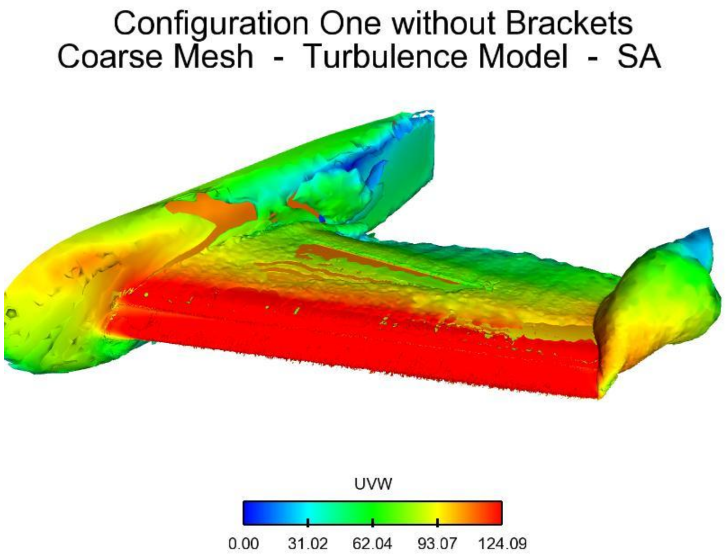
CL = 2.37

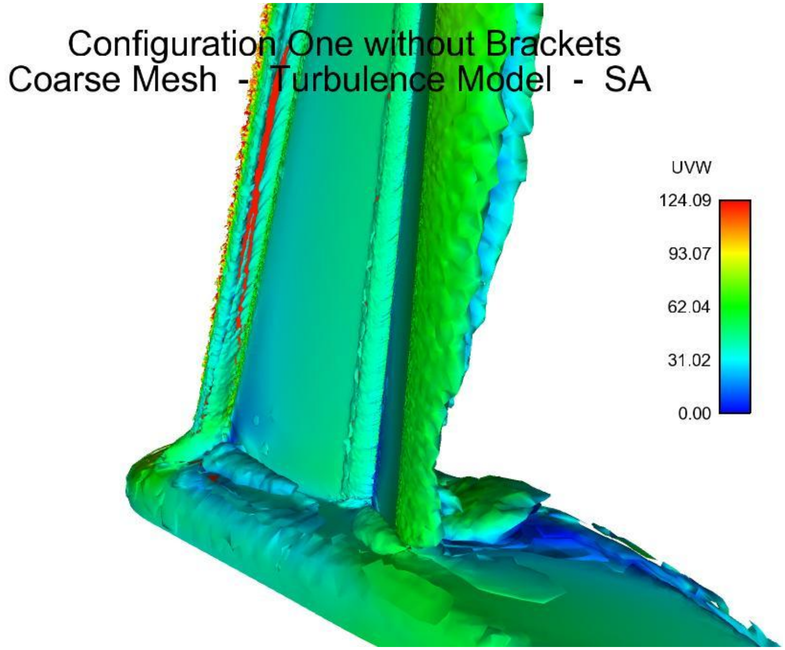
Results – Coarse Meshes

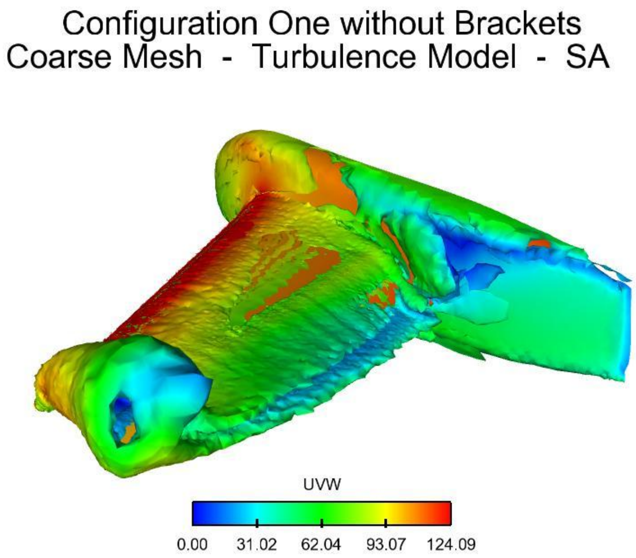
The integration of the pressure coefficient over the chordwise direction yields the load distribution. In the mid-span region there is good agreement between the two configurations.



Results – Coarse Mesh wt. Brackets



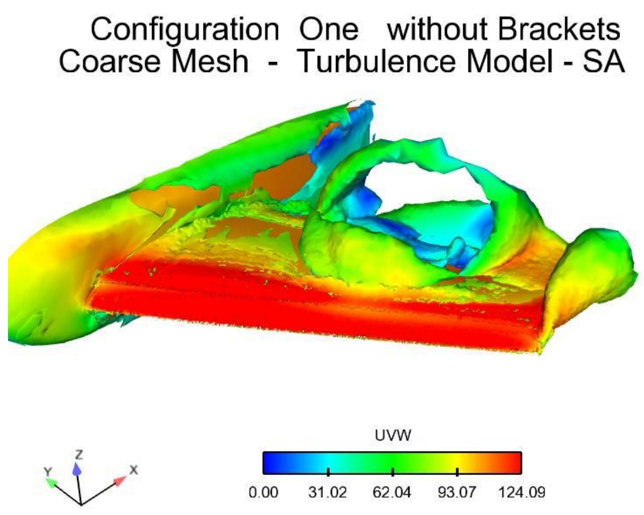


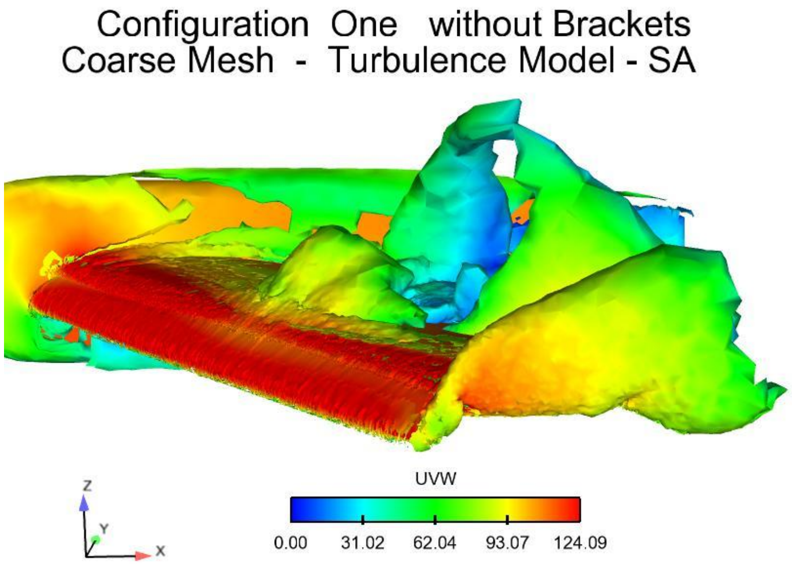


Vorticity iso-surfaces colored by the magnitude of the velocity.

AoA = 30 deg.

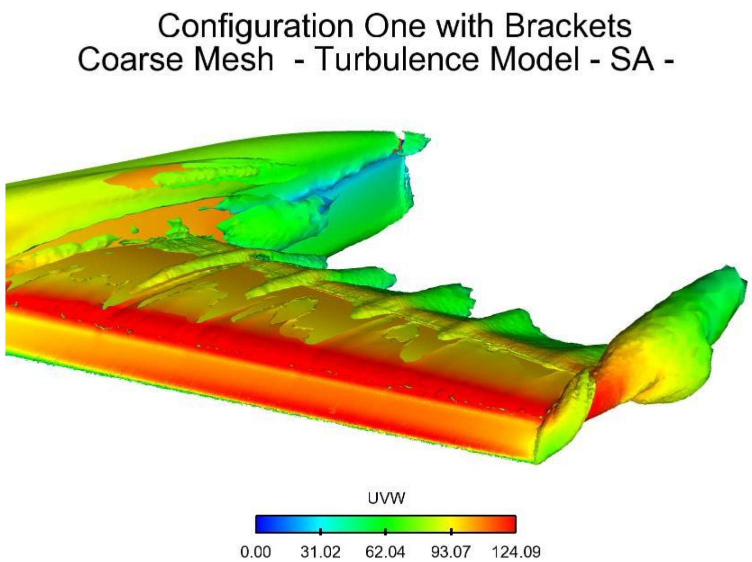
Results – Coarse Mesh wt. Brackets

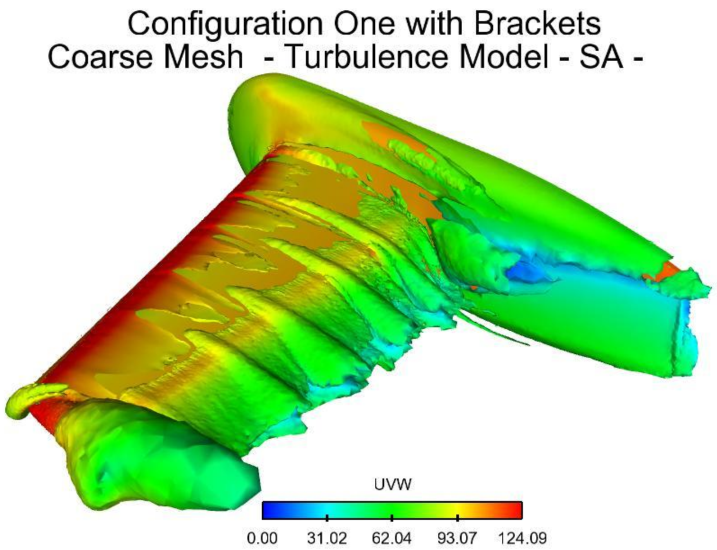


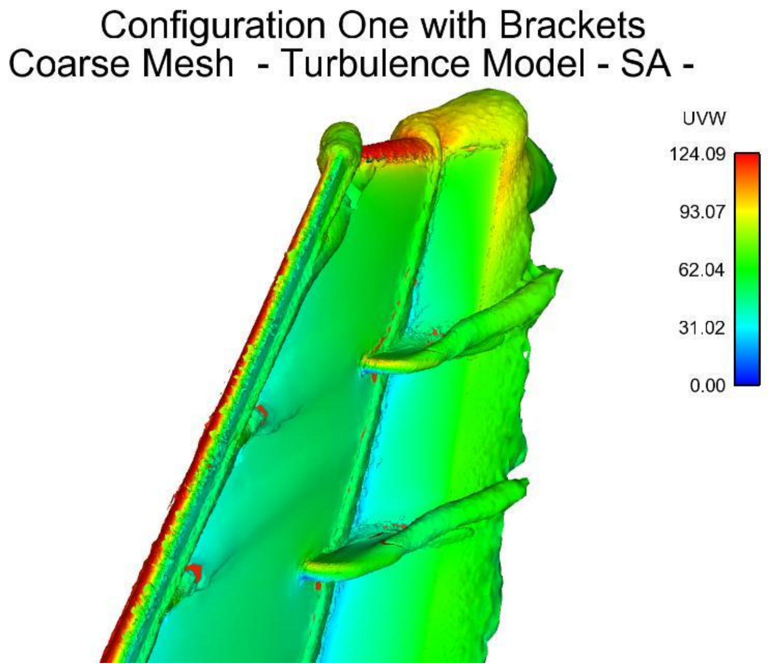


At mid-span region of the wing main element, a massive flow detachement is observed AoA = 32 deg.

Results – Coarse Mesh w. Brackets



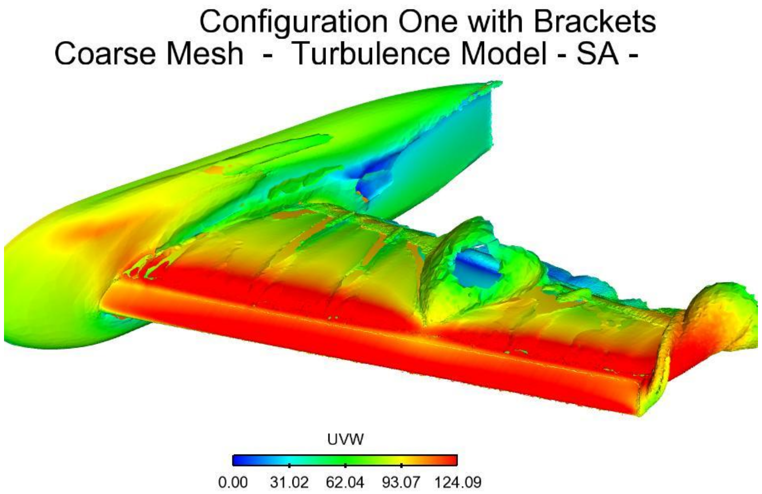


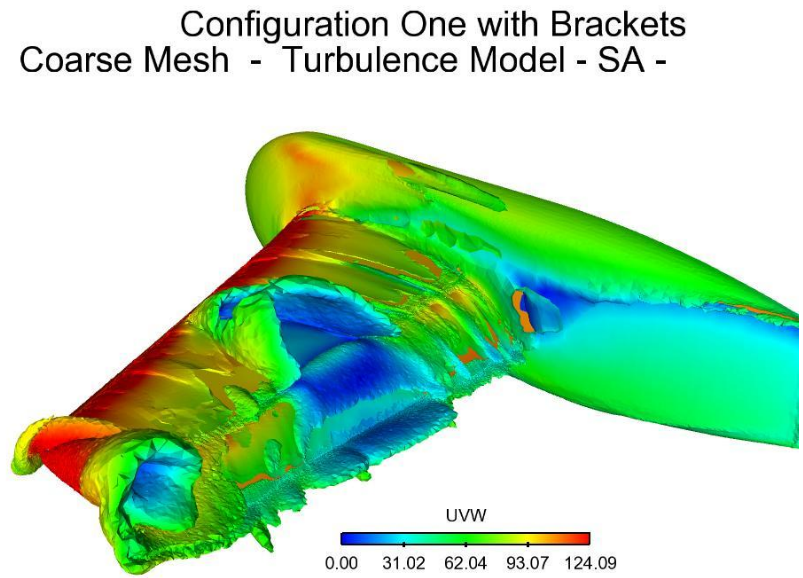


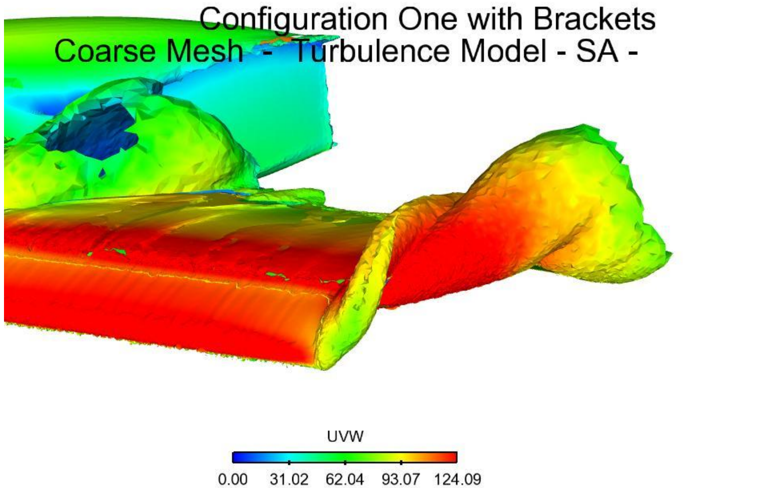
Vorticity iso-surfaces colored by the magnitude of the velocity.

AoA = 16 deg.

Results – Coarse Mesh w. Brackets







At mid-span region of the wing main element, a massive flow separation is observed

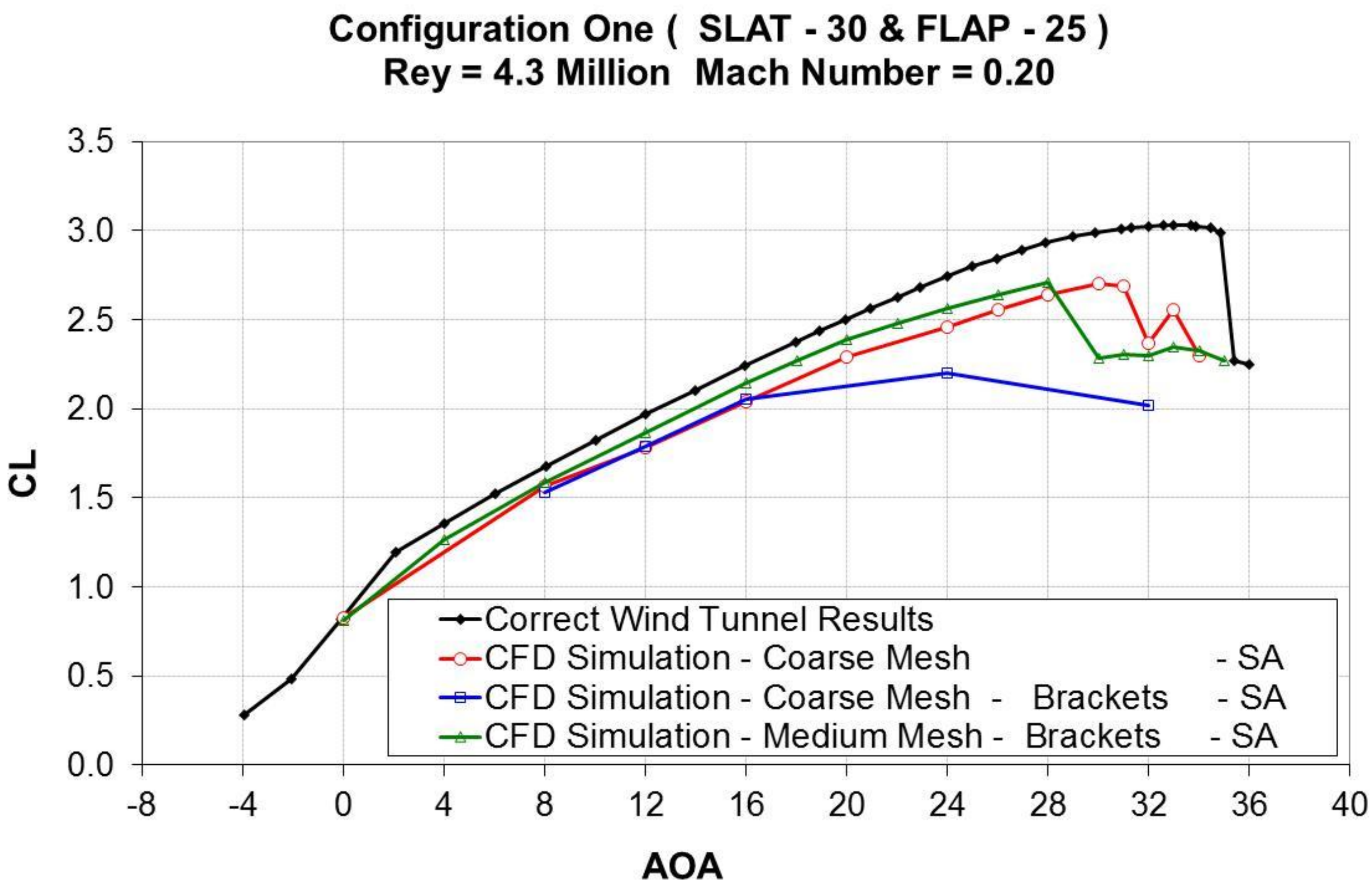
AoA = 24 deg.

Outline

- Objectives
- Theoretical and Numerical Formulations
- High-Lift Configuration
- Mesh Generation
- **Results**
    - **Coarse Mesh**
    - **Medium Mesh**
    - **Fine Mesh**
- Conclusions

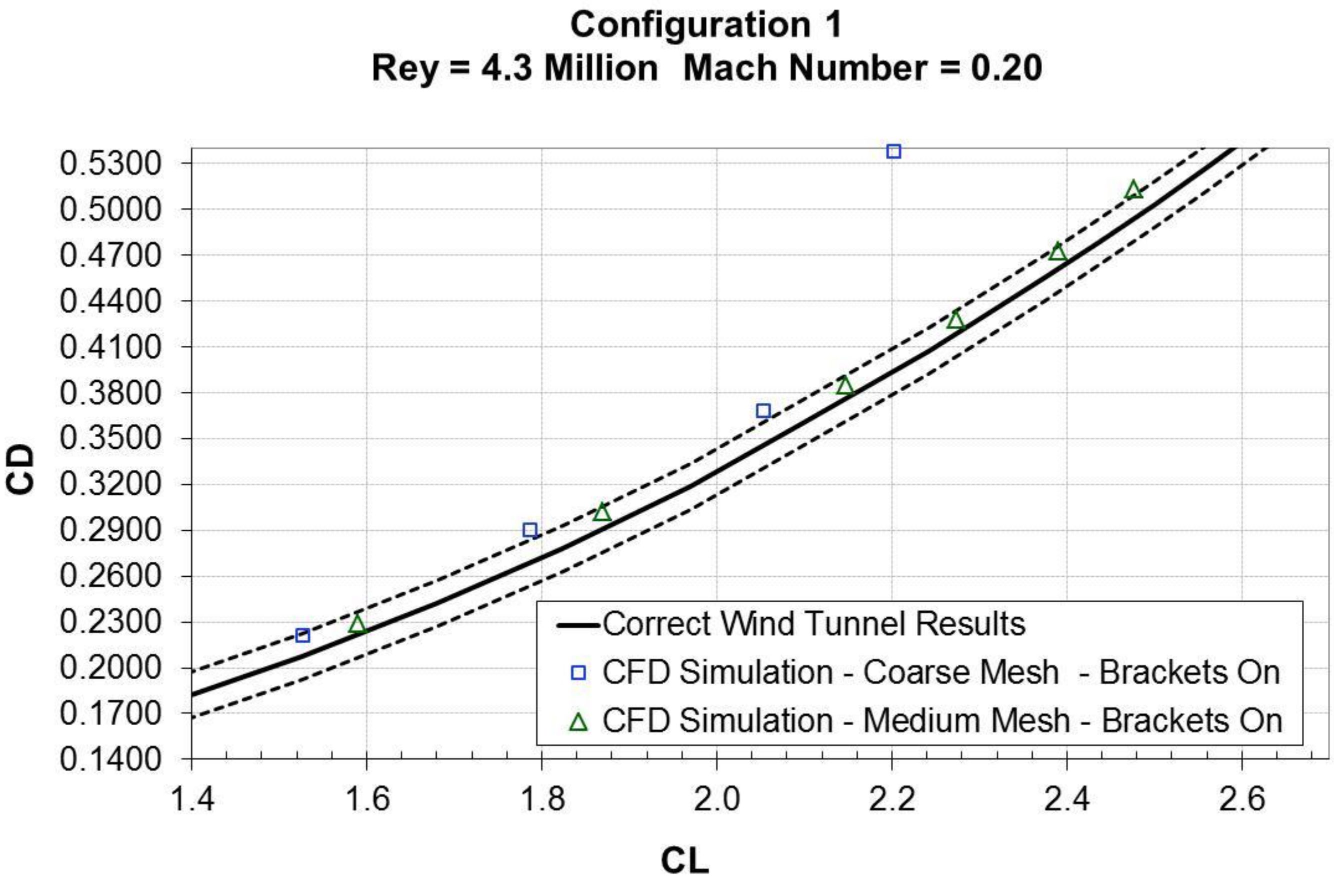
Results – Medium Meshes

Comparison between the coarse and the medium mesh.



Results – Medium Meshes

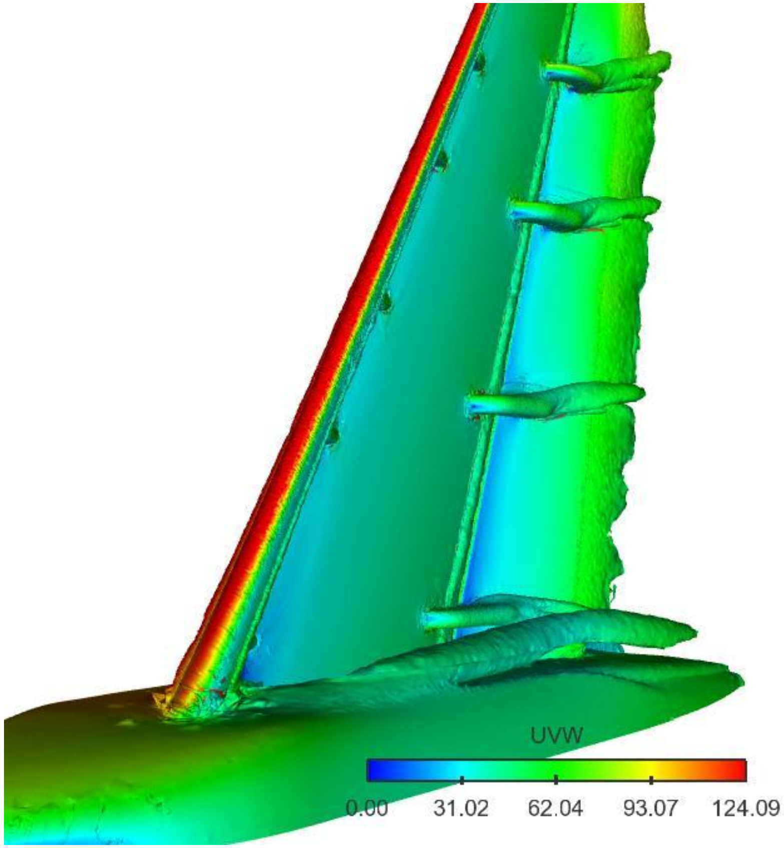
Drag polar for the coarse and medium meshes. An improvement is observed over the coarse mesh results.



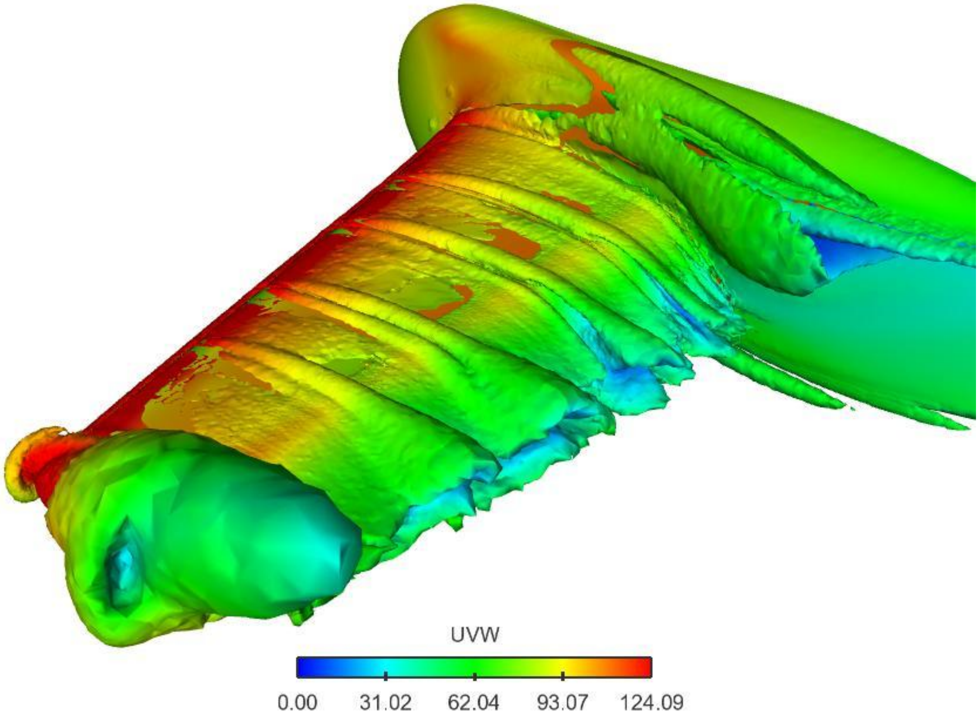
Results – Medium Mesh w. Brackets

Vorticity iso-surfaces colored by velocity magnitude, AoA = 24 deg.

Configuration One with brackets
Medium Mesh – Turbulence Model - SA

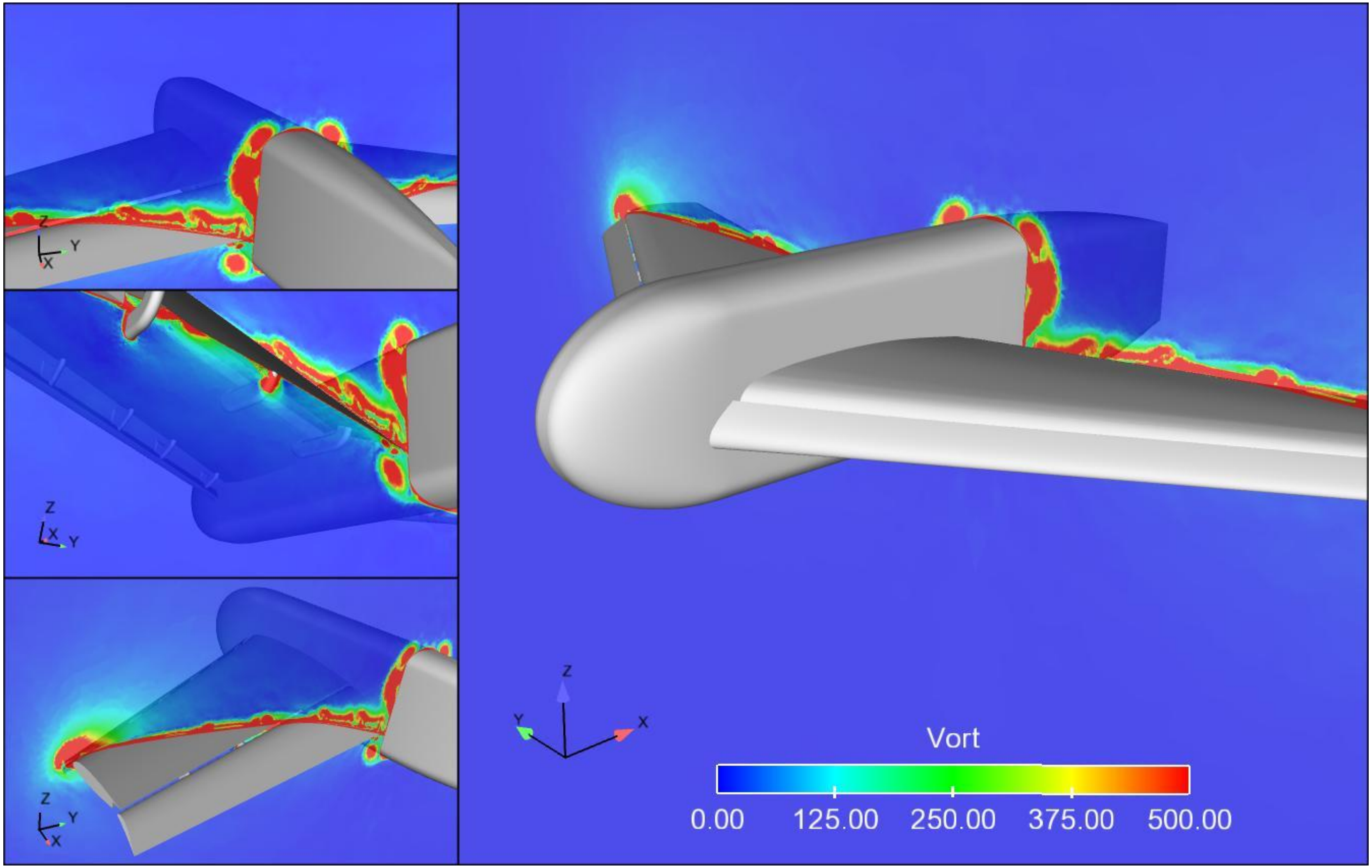


Configuration One with brackets
Medium Mesh – Turbulence Model - SA



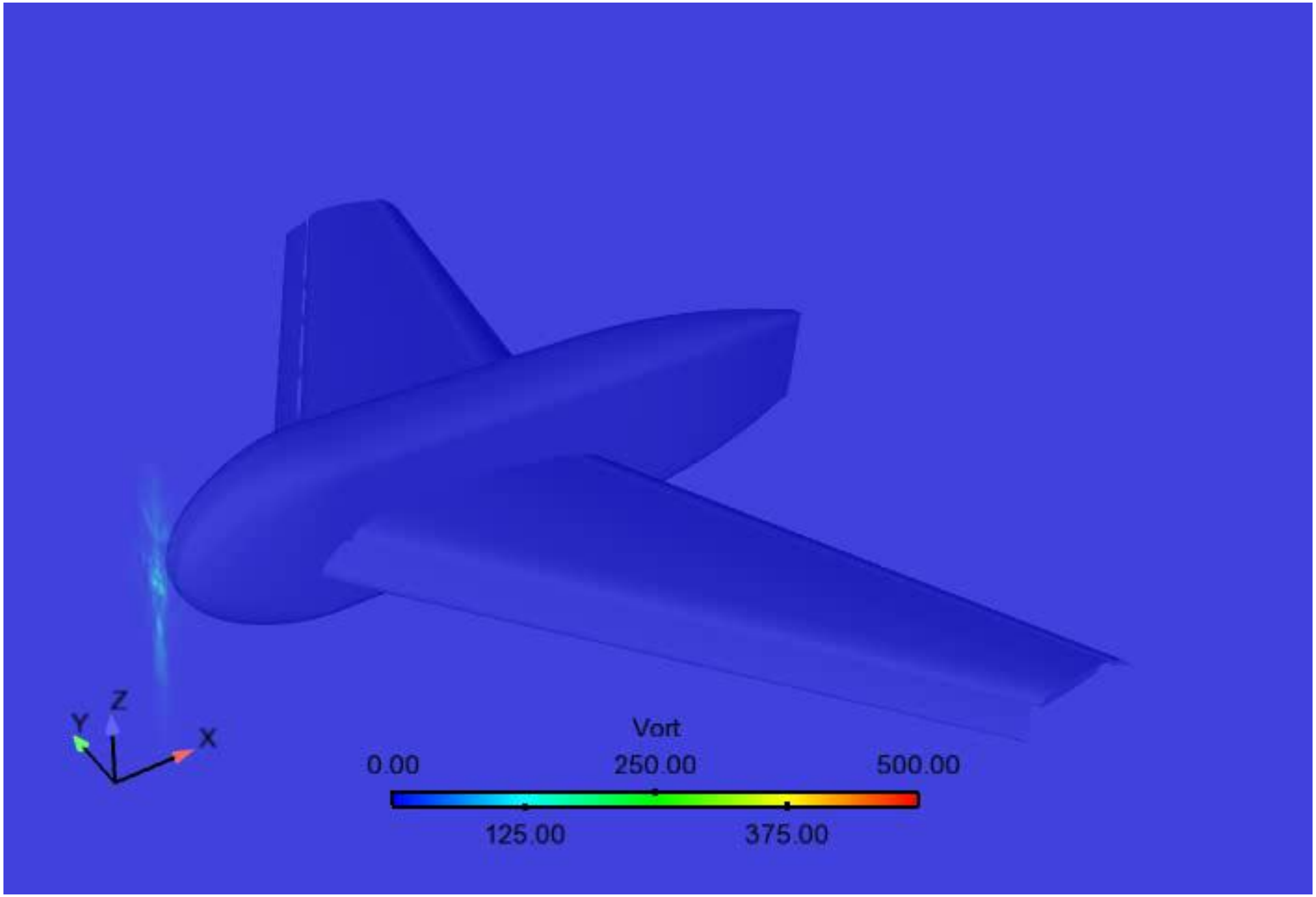
Results – Medium Mesh w. Brackets

Vorticity planes, AoA = 24 deg.



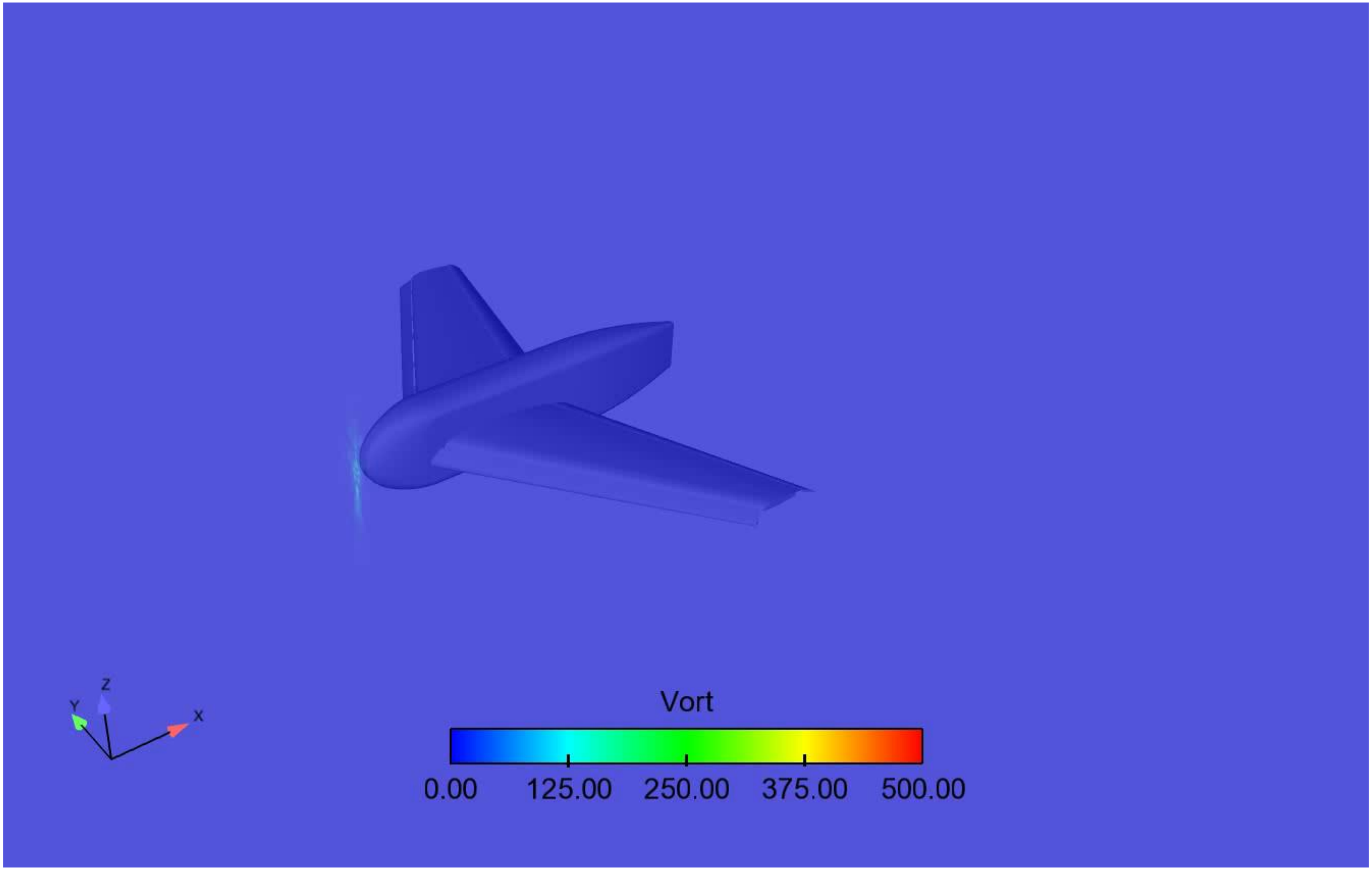
Results – Medium Mesh w. Brackets

AoA = 24 deg.



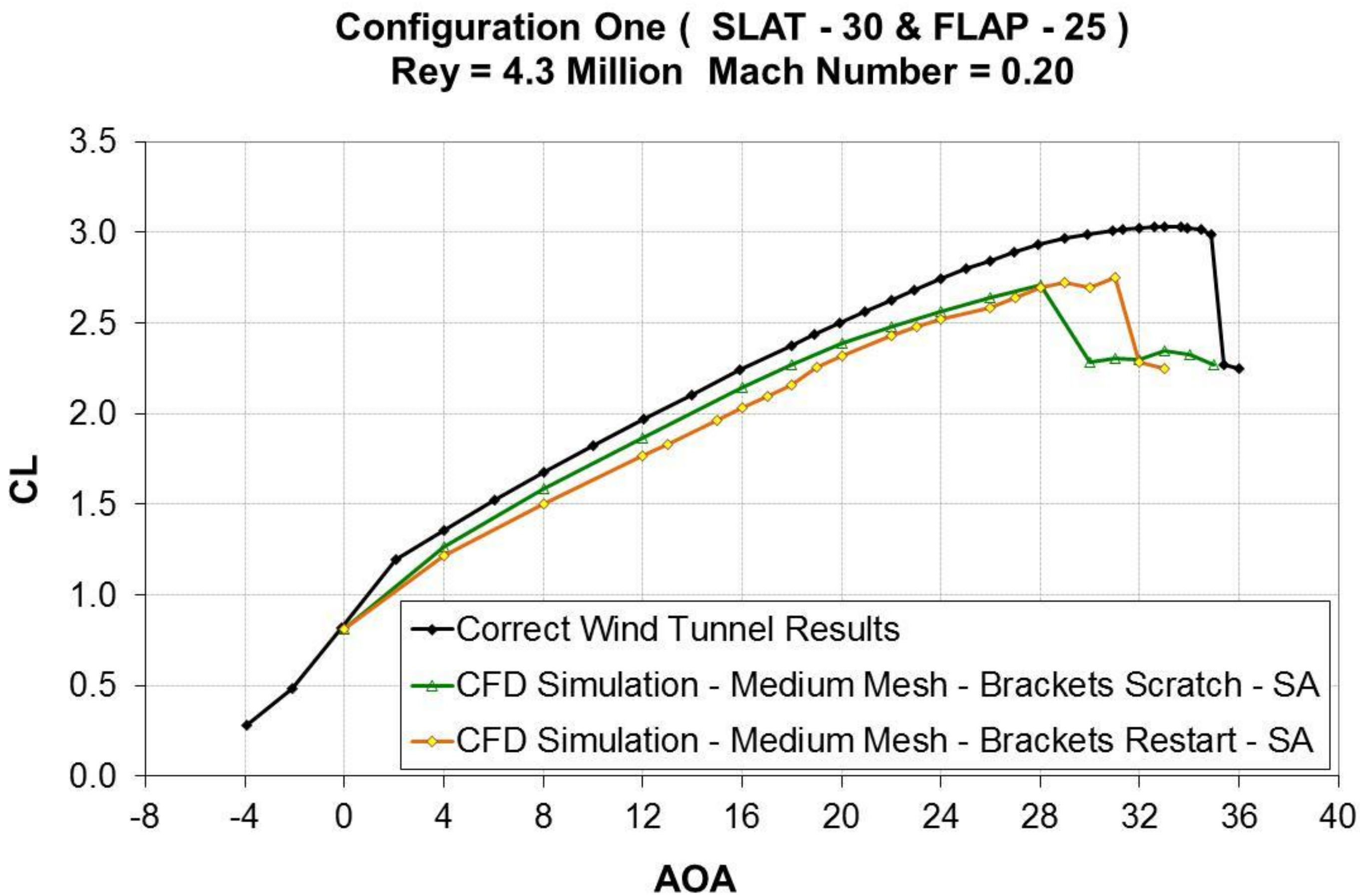
Results – Medium Mesh w. Brackets

AoA = 32 deg.



Results – Medium Mesh w. Brackets

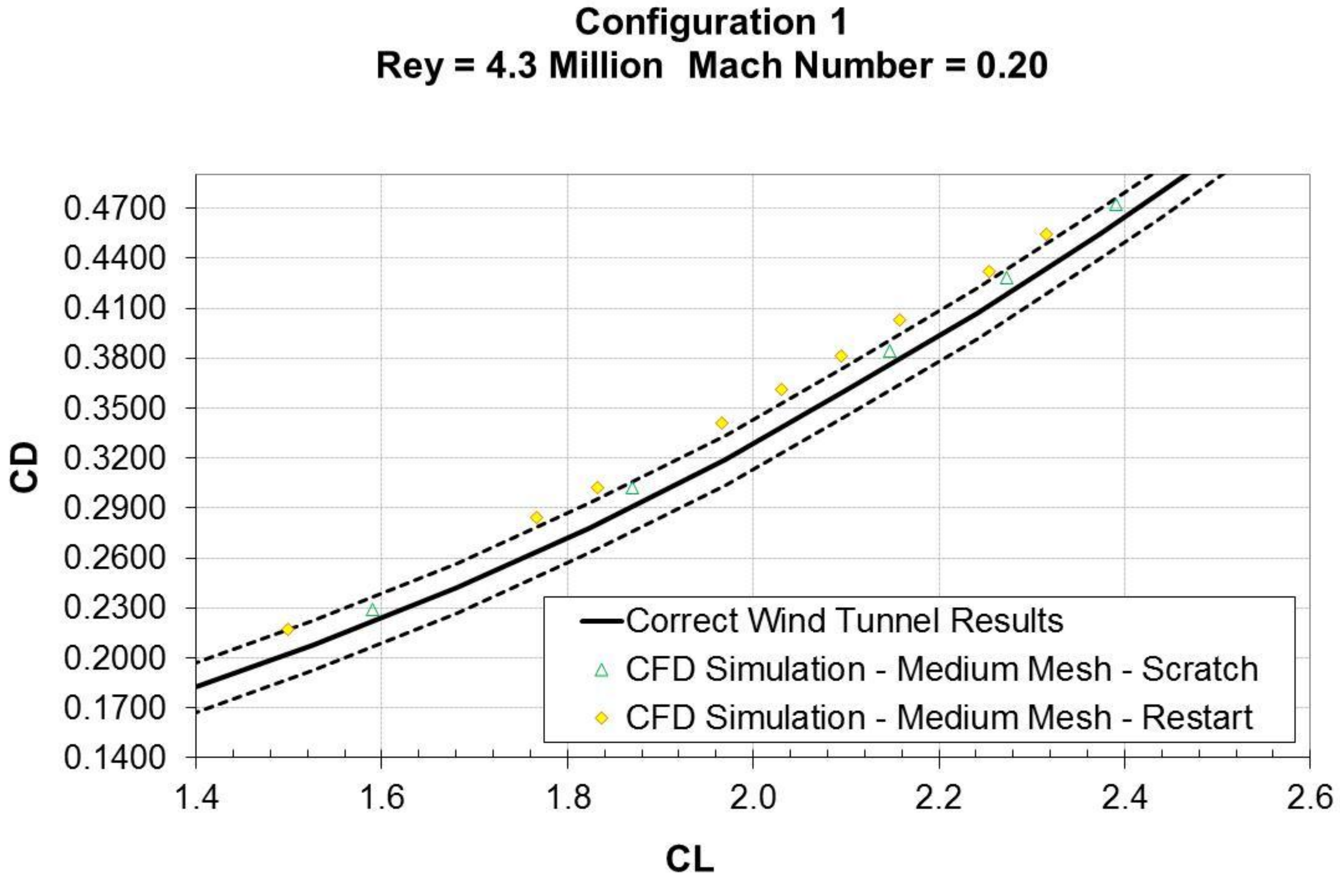
Lift coefficient comparison. No hysteresis analysis was conducted in order to decrease the angle of attack after the maximum achieved CL.



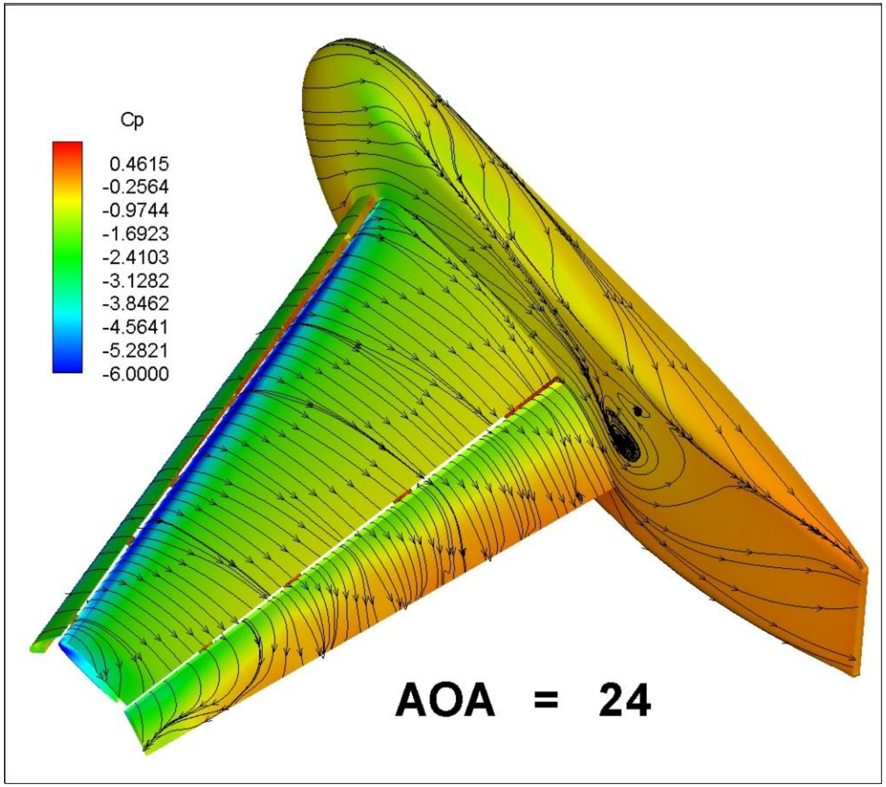
Results – Medium Mesh w. Brackets

The drag polar indicates a worse comparison of the restart procedure in relation to the ‘from-scratch’ approach.

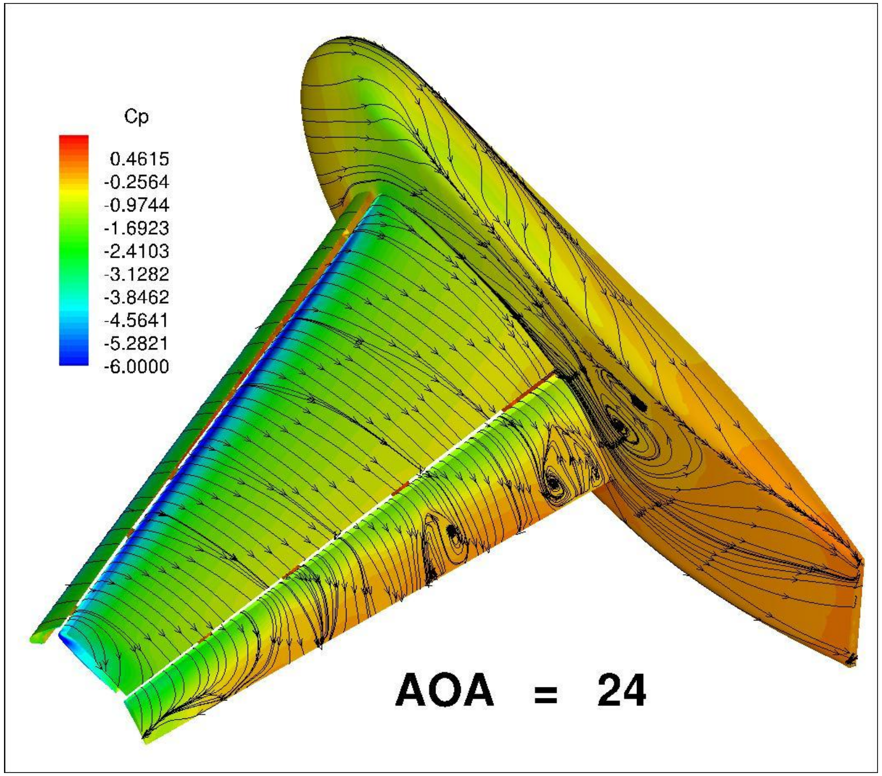
.



Results – Medium Mesh w. Brackets



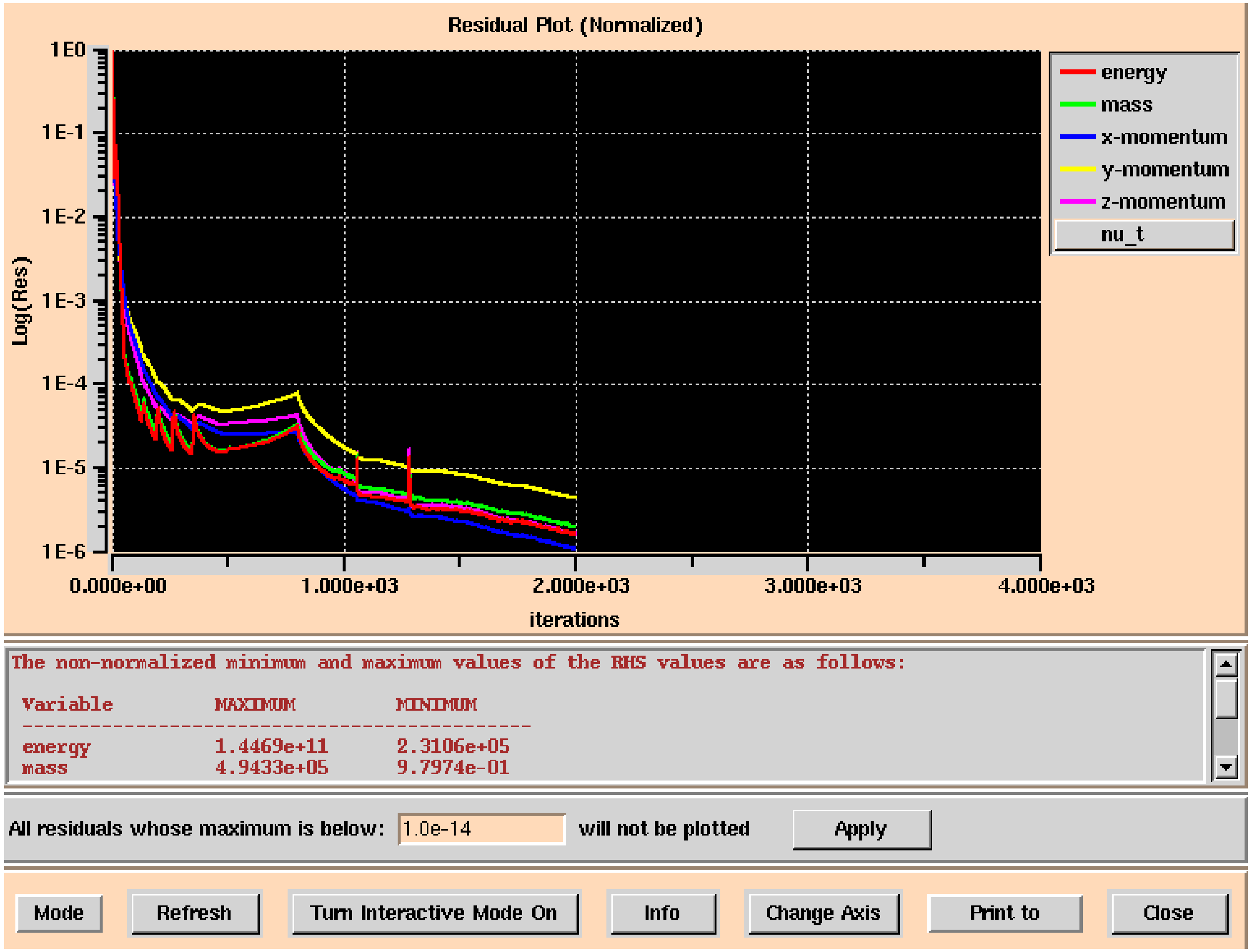
From-Scratch



Restart

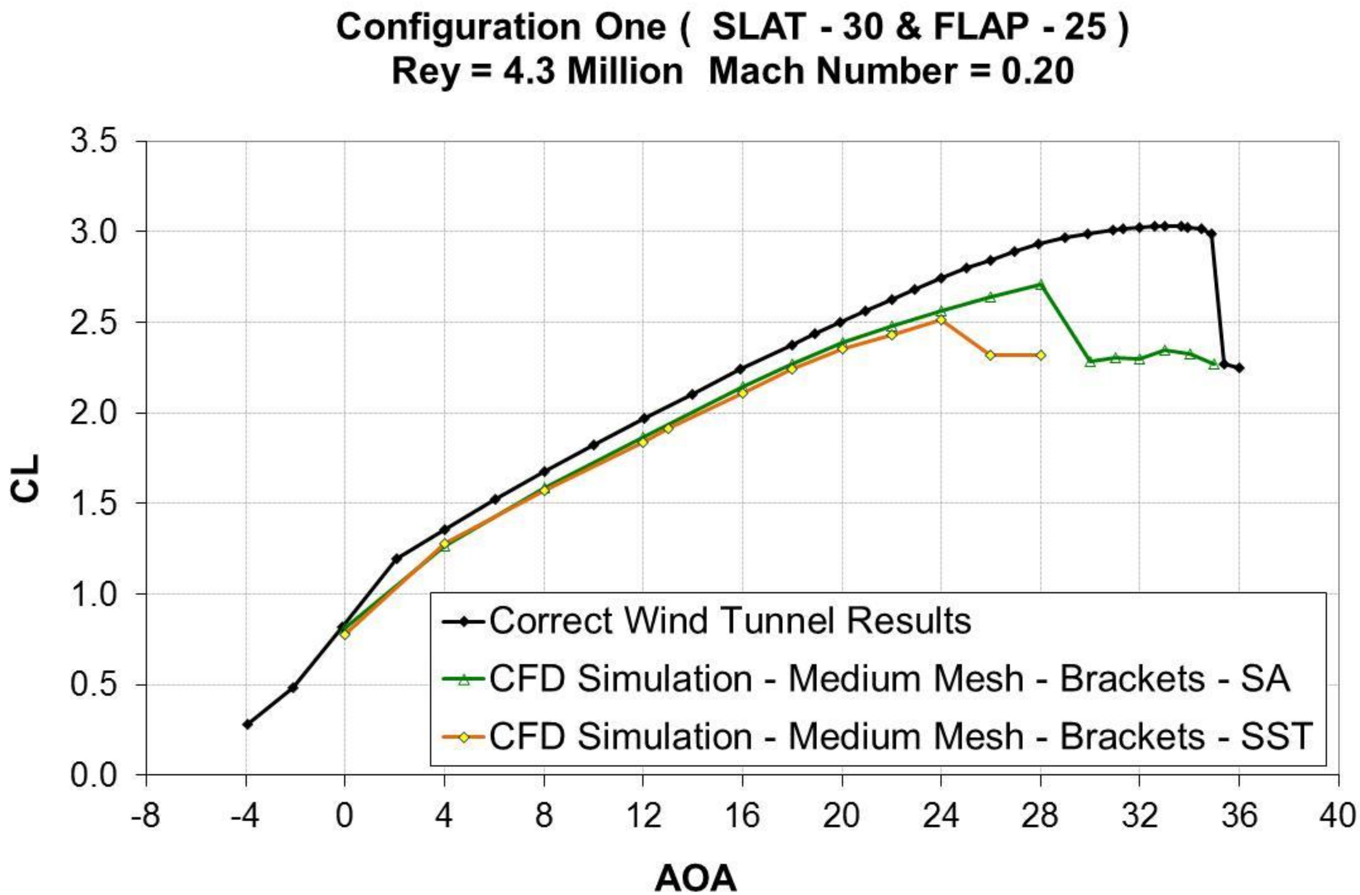
Results – Medium Mesh w. Brackets

The forces are quite converged after 2000 ite.



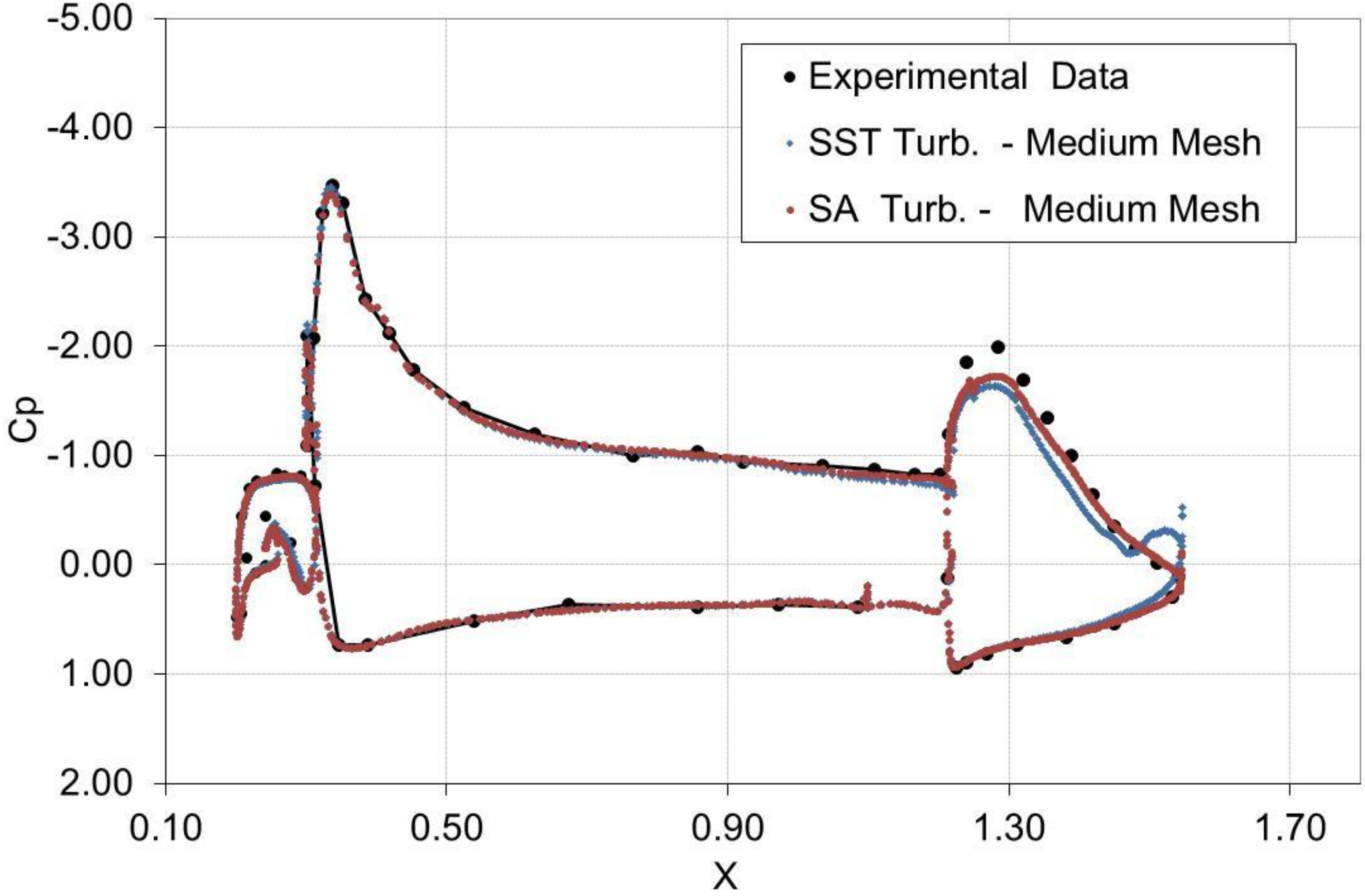
Results – Medium Mesh w. Brackets

Comparison between the SA and the SST turbulence models.



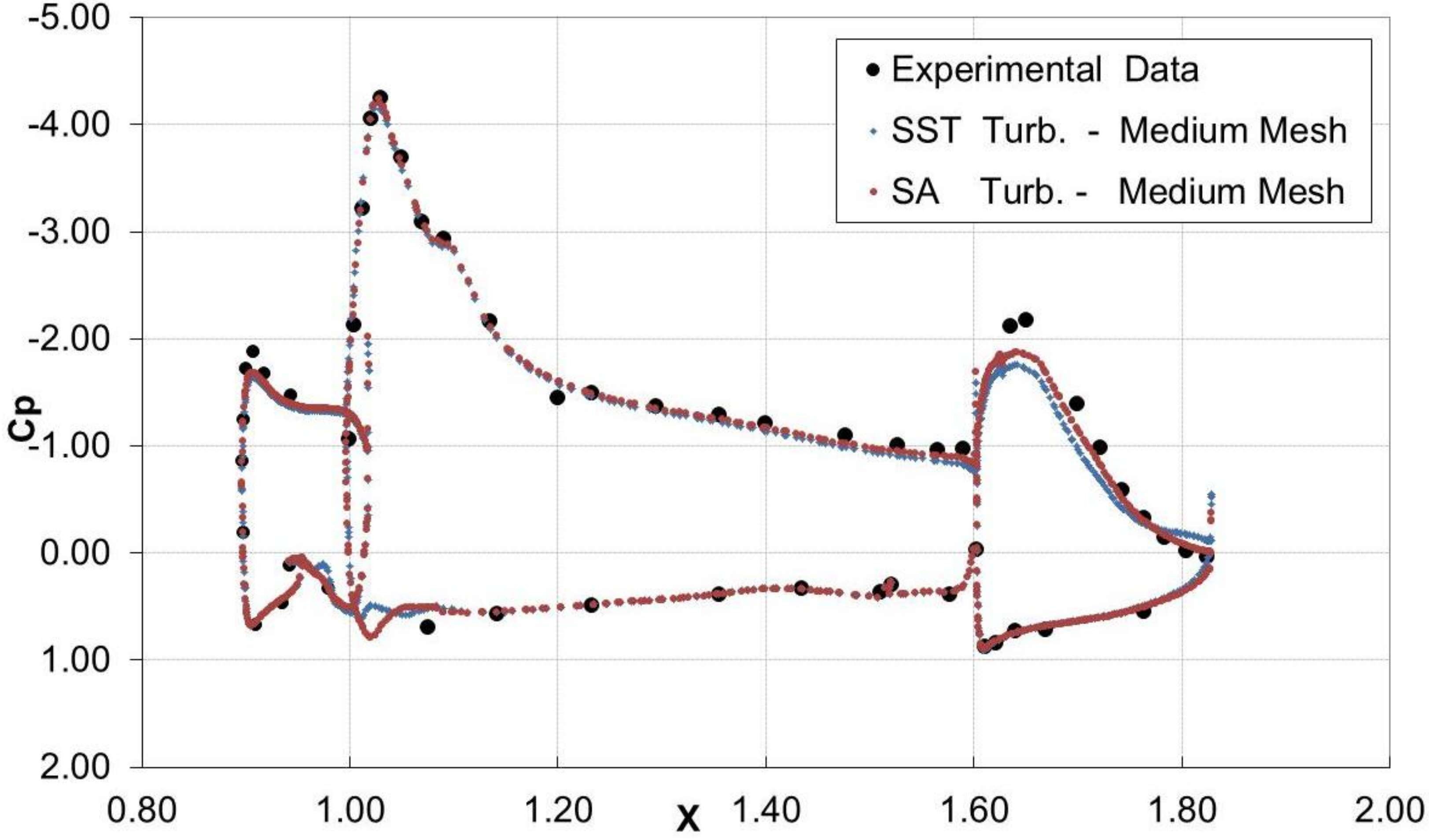
Results – Medium Mesh w. Brackets

Comparison Cp distribution SA X SST @ Eta = 0.17 - AoA =13



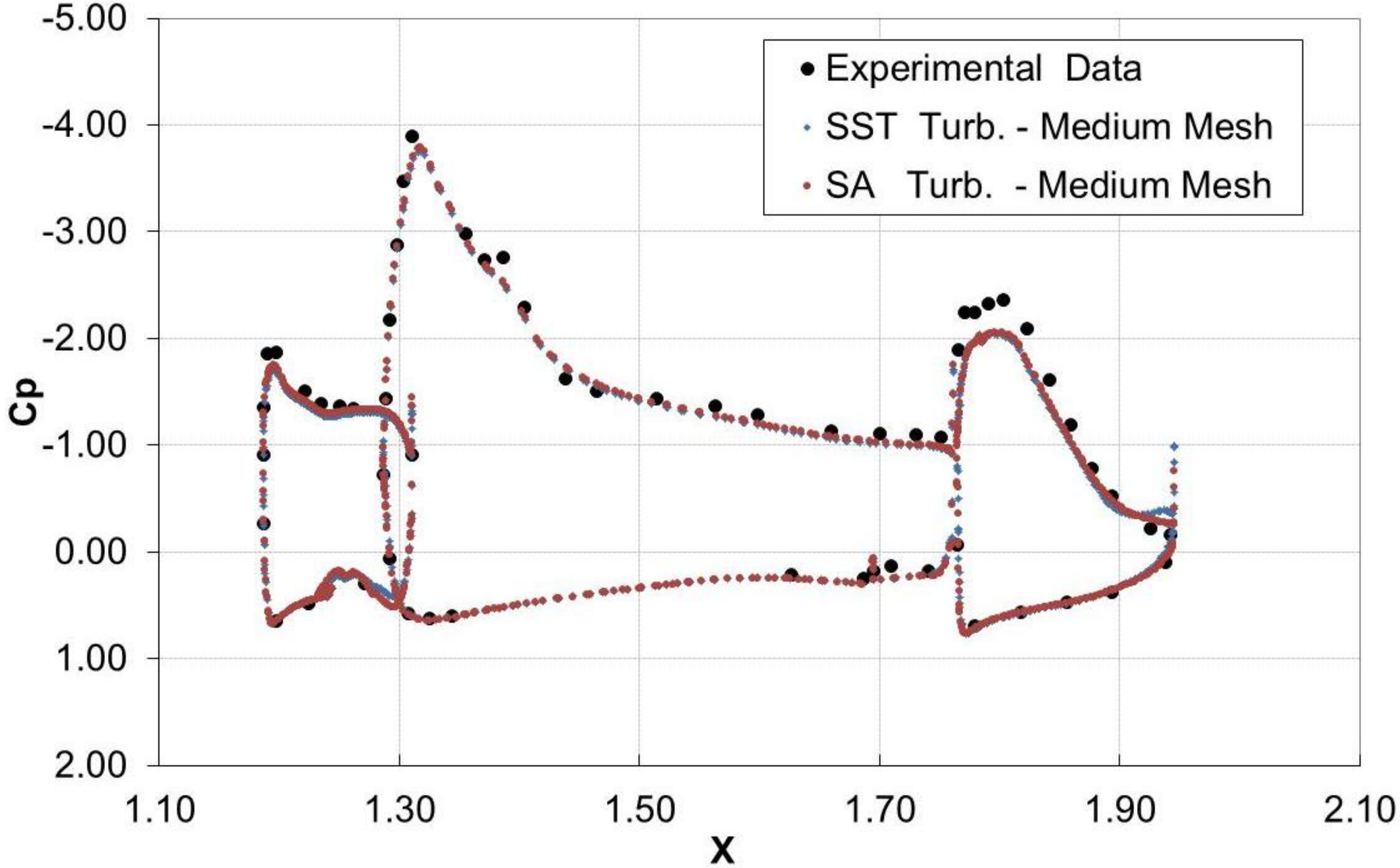
Results – Medium Mesh w. Brackets

Comparison Cp distribution SA X SST @ Eta = 0.65 – AoA = 13



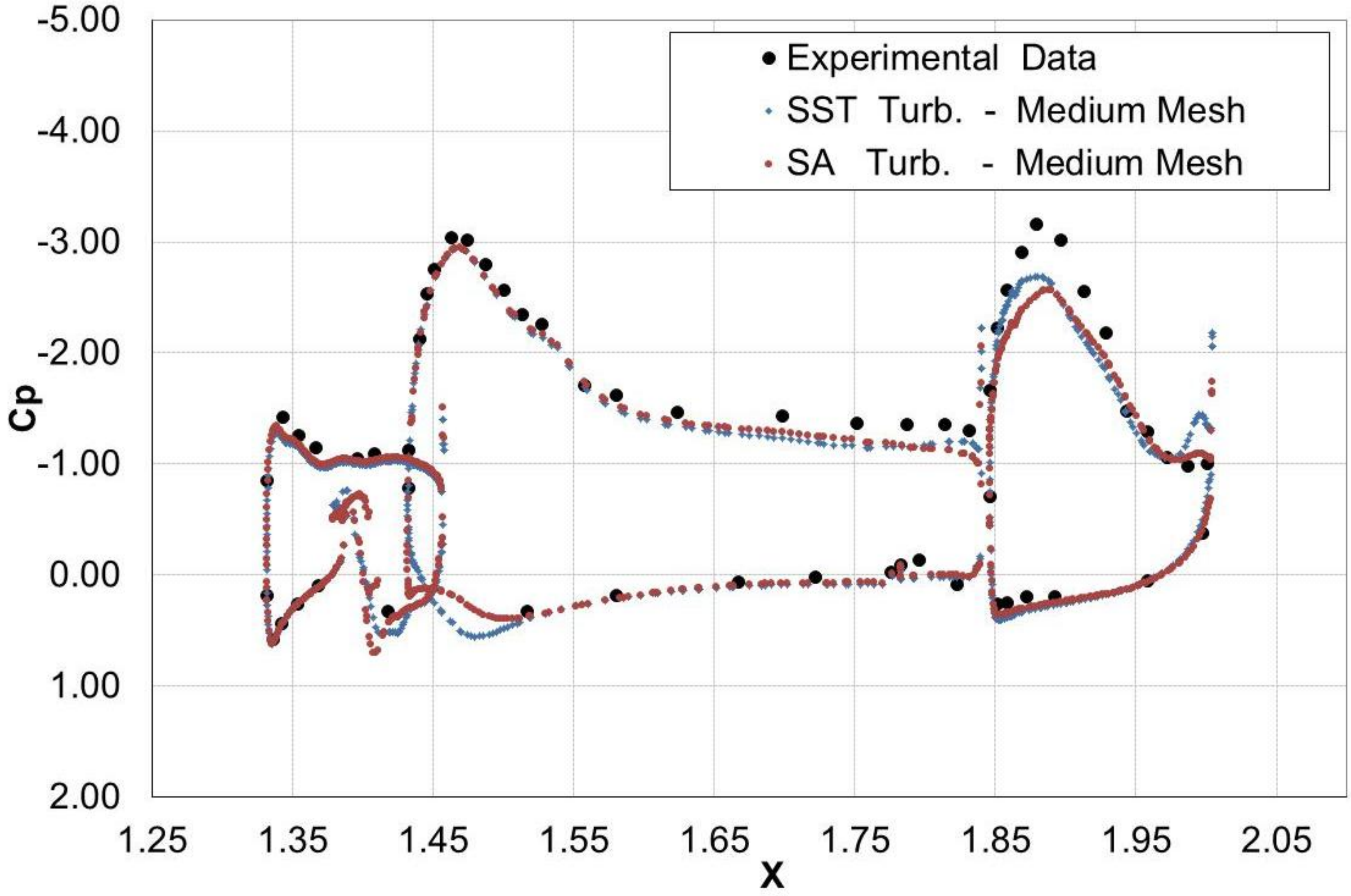
Results – Medium Mesh w. Brackets

Comparison Cp distribution SA X SST @ Eta = 0.85 – AoA =13



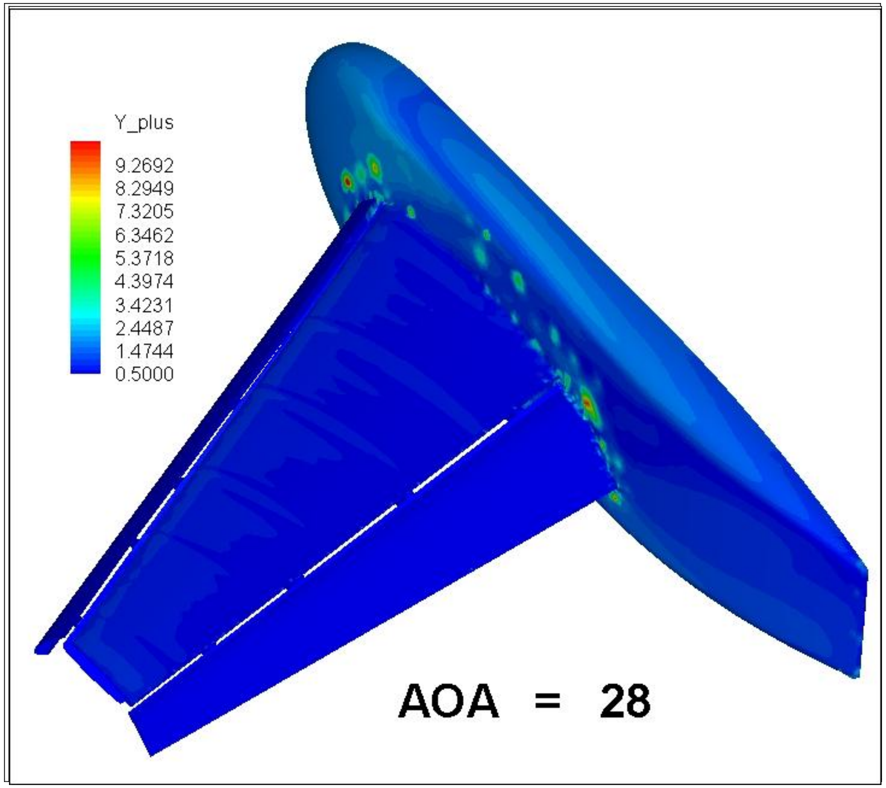
Results – Medium Mesh w. Brackets

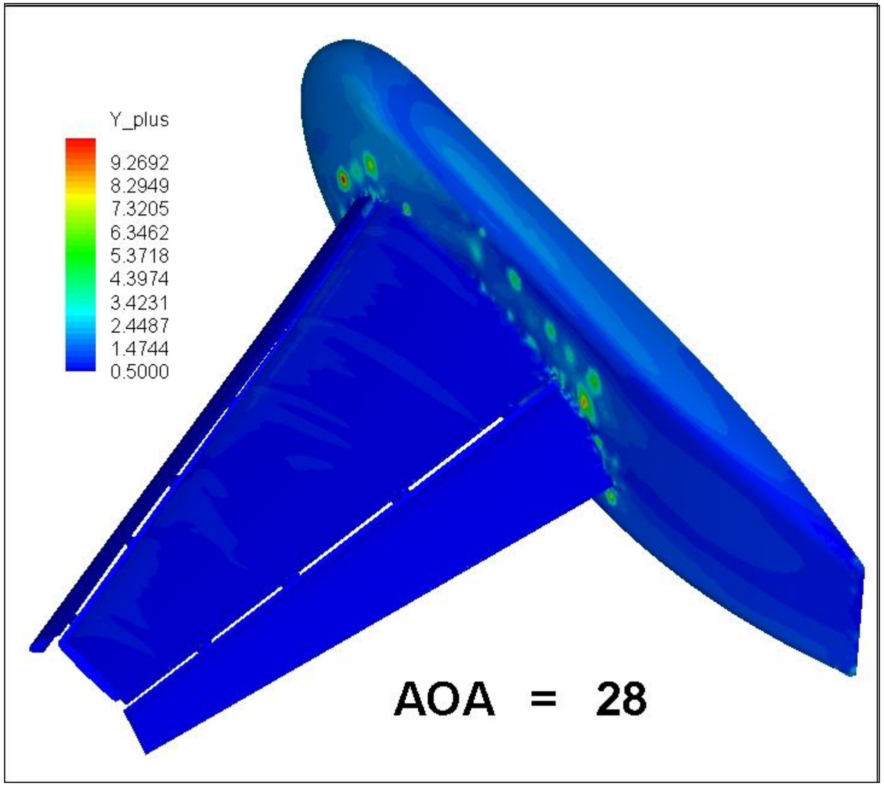
Comparison Cp distribution SA X SST @ Eta = 0.95 – AoA =13



Results – Medium Mesh w. Brackets

Comparison between the SA and the SST turbulence models.



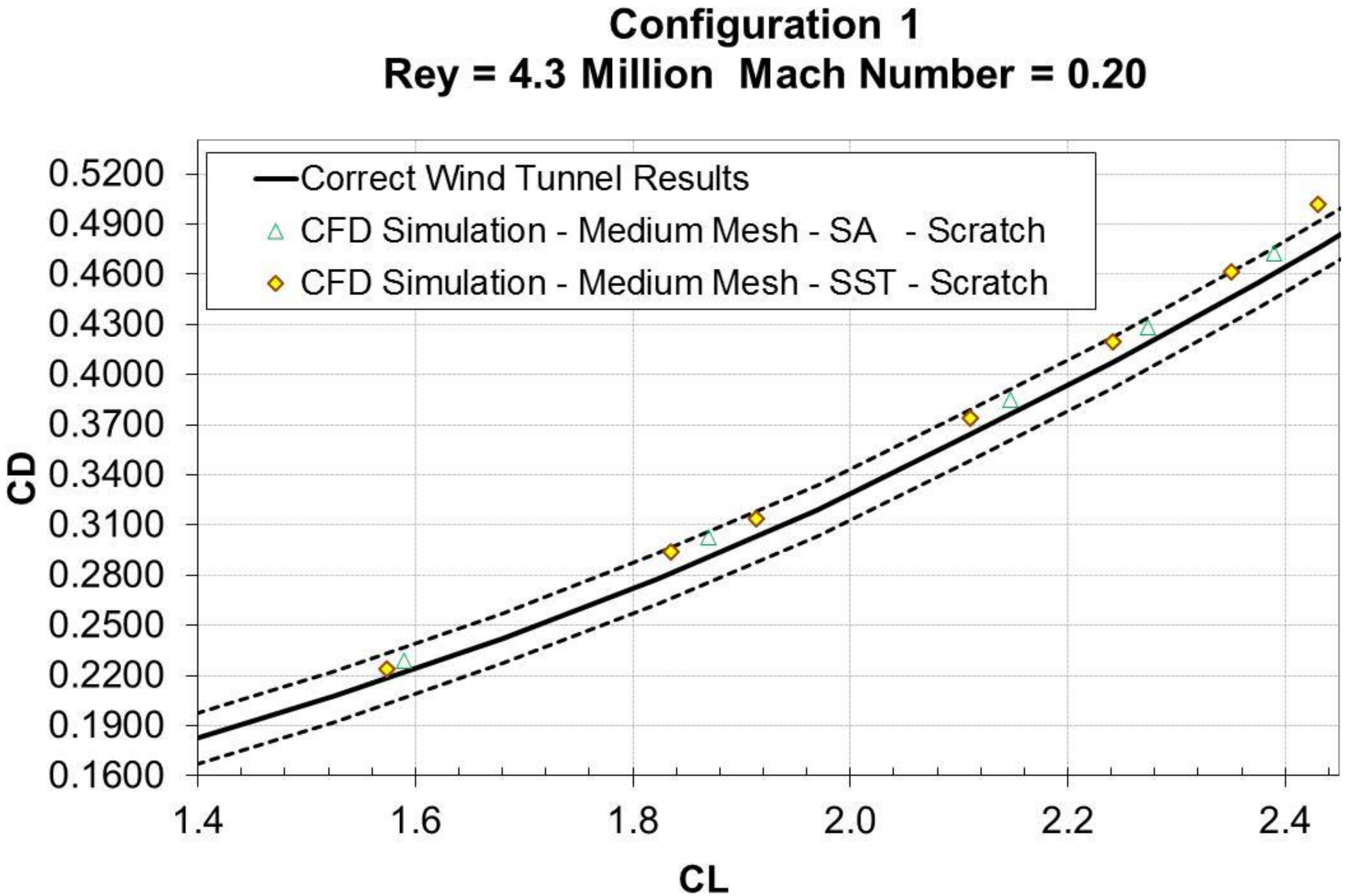


SA

SST

Results – Medium Mesh w. Brackets

In terms of drag coefficient the two obtained solutions are close to each other.

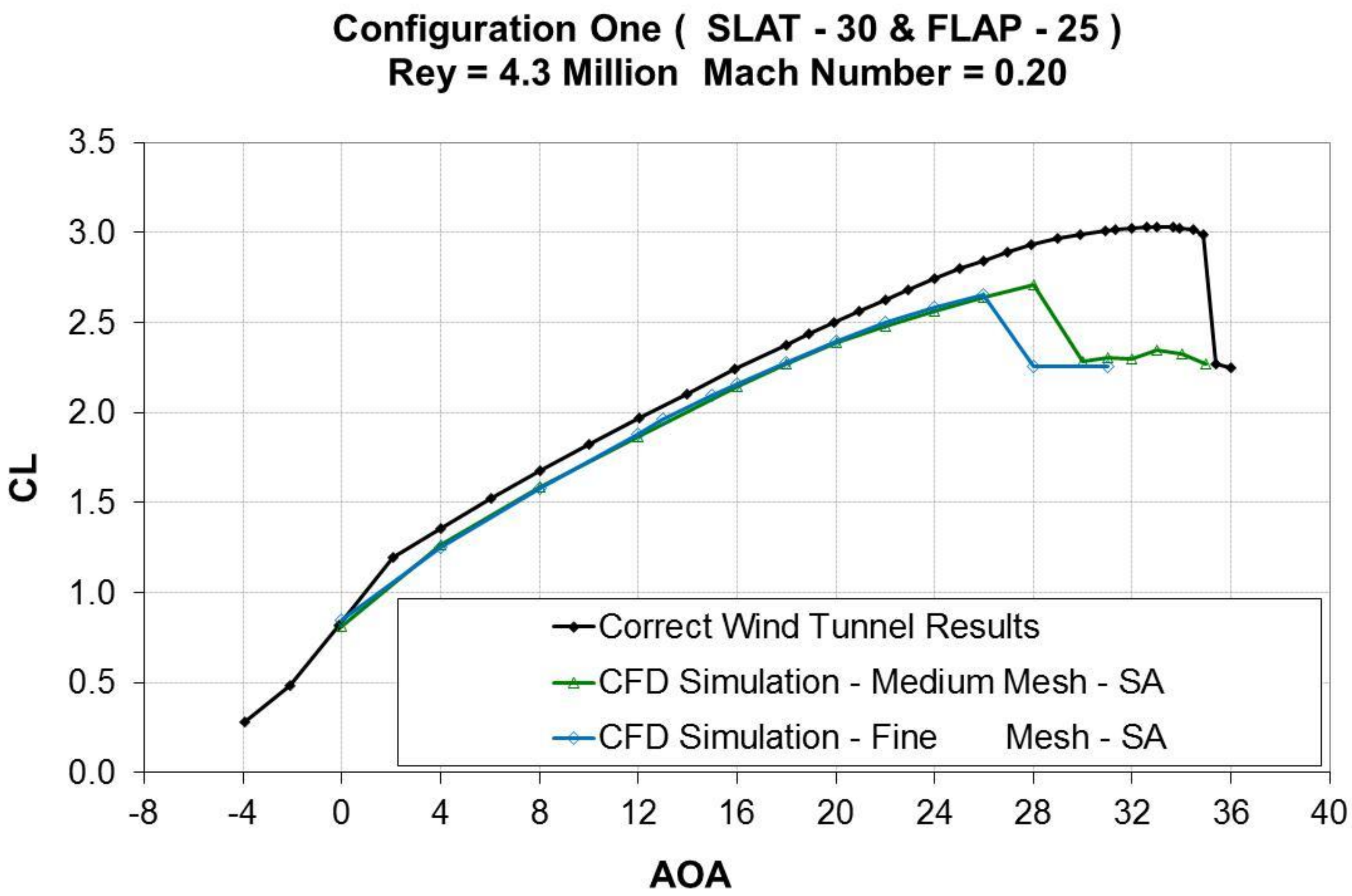


Outline

- Objectives
- Theoretical and Numerical Formulations
- High-Lift Configuration
- Mesh Generation
- **Results**
  - **Coarse Mesh**
  - **Medium Mesh**
  - **Fine Mesh**
- Conclusions

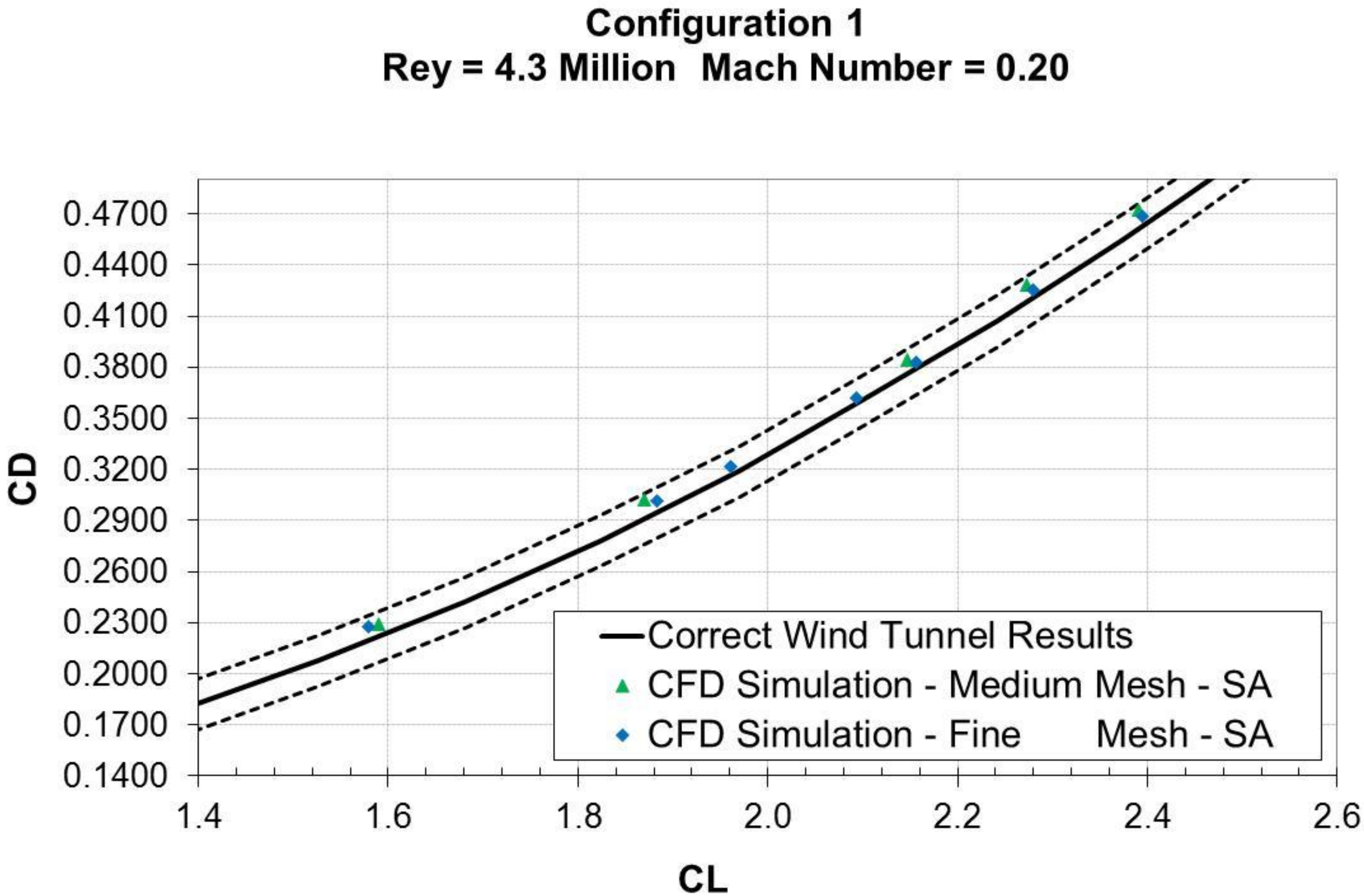
Results – Fine Mesh w. Brackets

Not expected...



Results – Medium Meshes

However, the drag results have a better comparison with the experimental results.

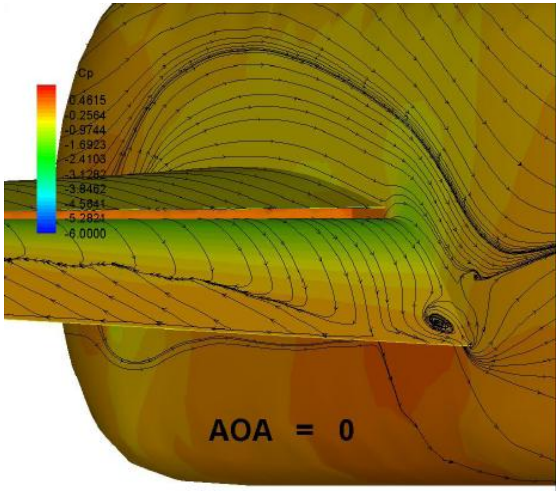


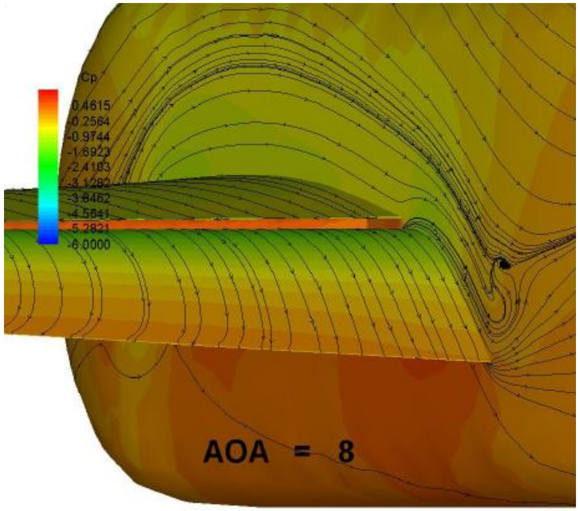
Conclusions

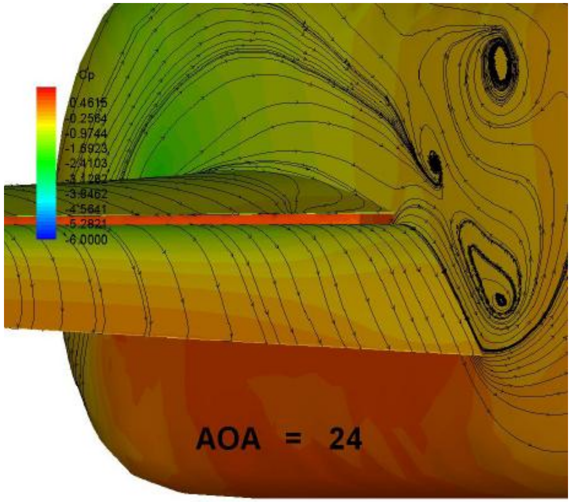
- The mesh assumed as coarse presented a very premature stall.
- The surface mesh refinement provided an improvement in the aerodynamic coefficients.
- The volumetric refinement presented an unexpected result which decreased the stall angle of attack and the maximum CL.
- The different turbulence models are generating very different flow pattern.
- There is a need to continue the studies with a more systematic procedure to perform the mesh generation.

Backup Slides

hybrid mesh - SA Model







hexahedral mesh - SA Model