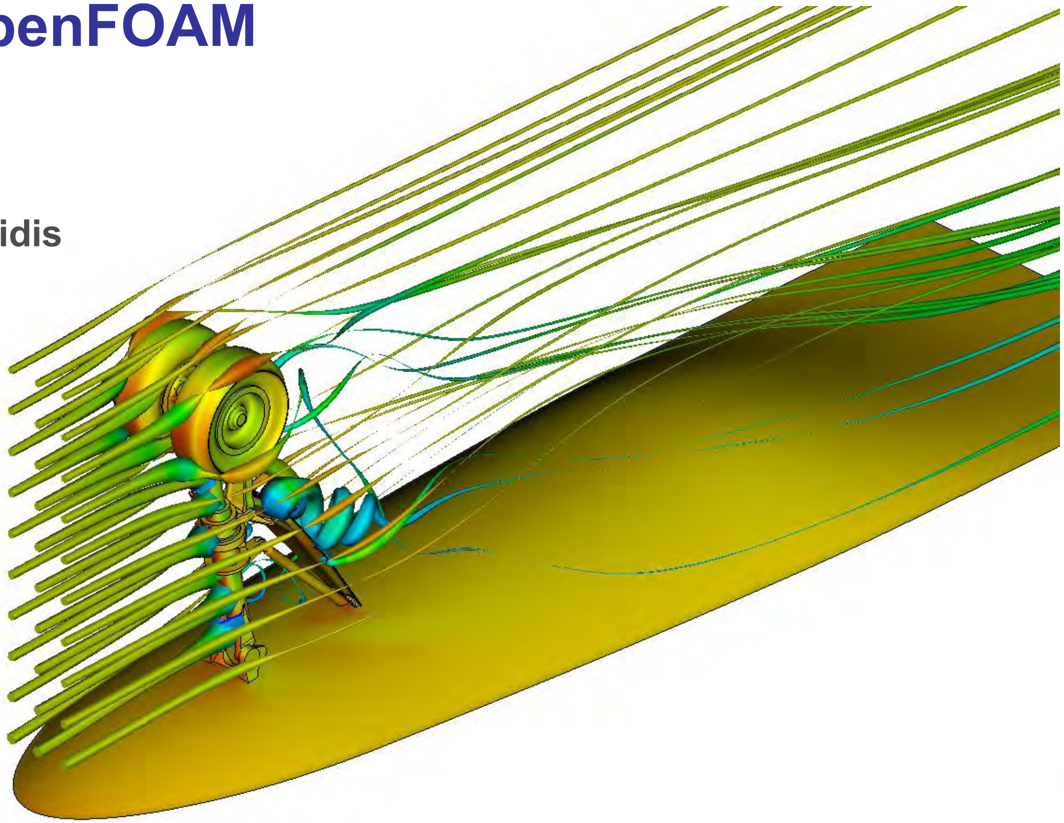
Mesh study for external aerodynamics CFD simulations with OpenFOAM



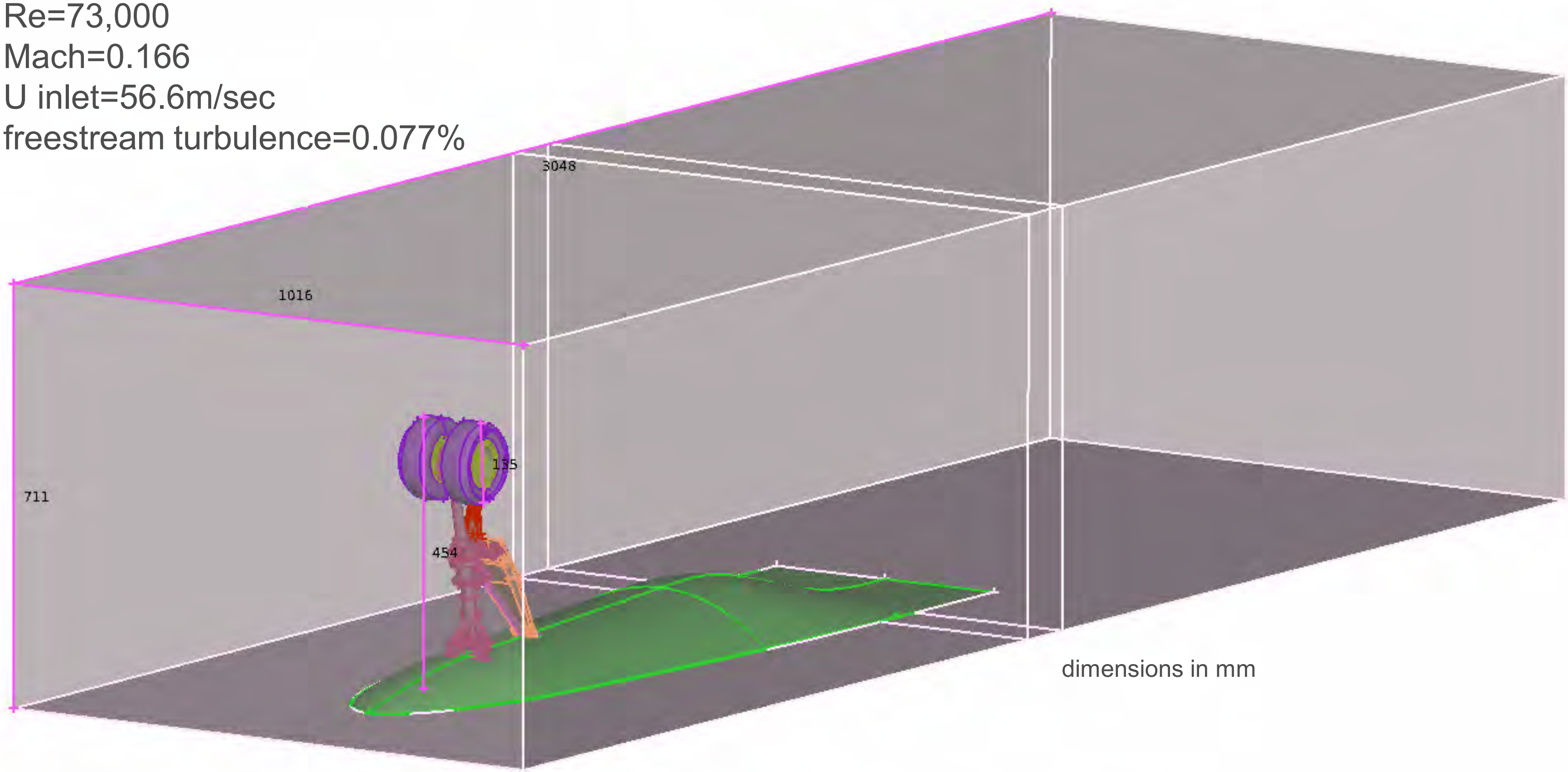
Vangelis Skaperdas, Aristotelis Iordanidis

BETA CAE Systems S.A.

The BANC-I landing gear model

¼ scale model of Gulfstream 550 aircraft nose gear

Re=73,000
Mach=0.166
U inlet=56.6m/sec
freestream turbulence=0.077%



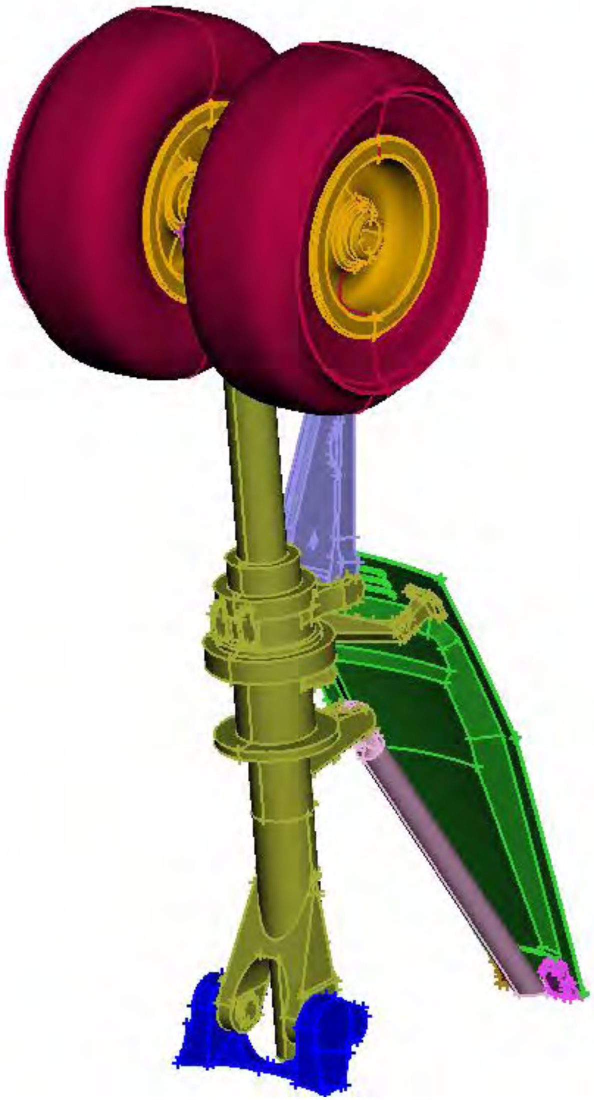
dimensions in mm

Sources:
1) https://nfo.aiaa.org/tac/ASG/FDTC/DG/BECAN_files/Workshop_Announcement.pdf
2) "Aerodynamics of a Gulfstream 550 nose landing gear model" D. Neuhart, M. Khorammi, M. Choudhari, NASA Langley Research Center, Hampton Virginia

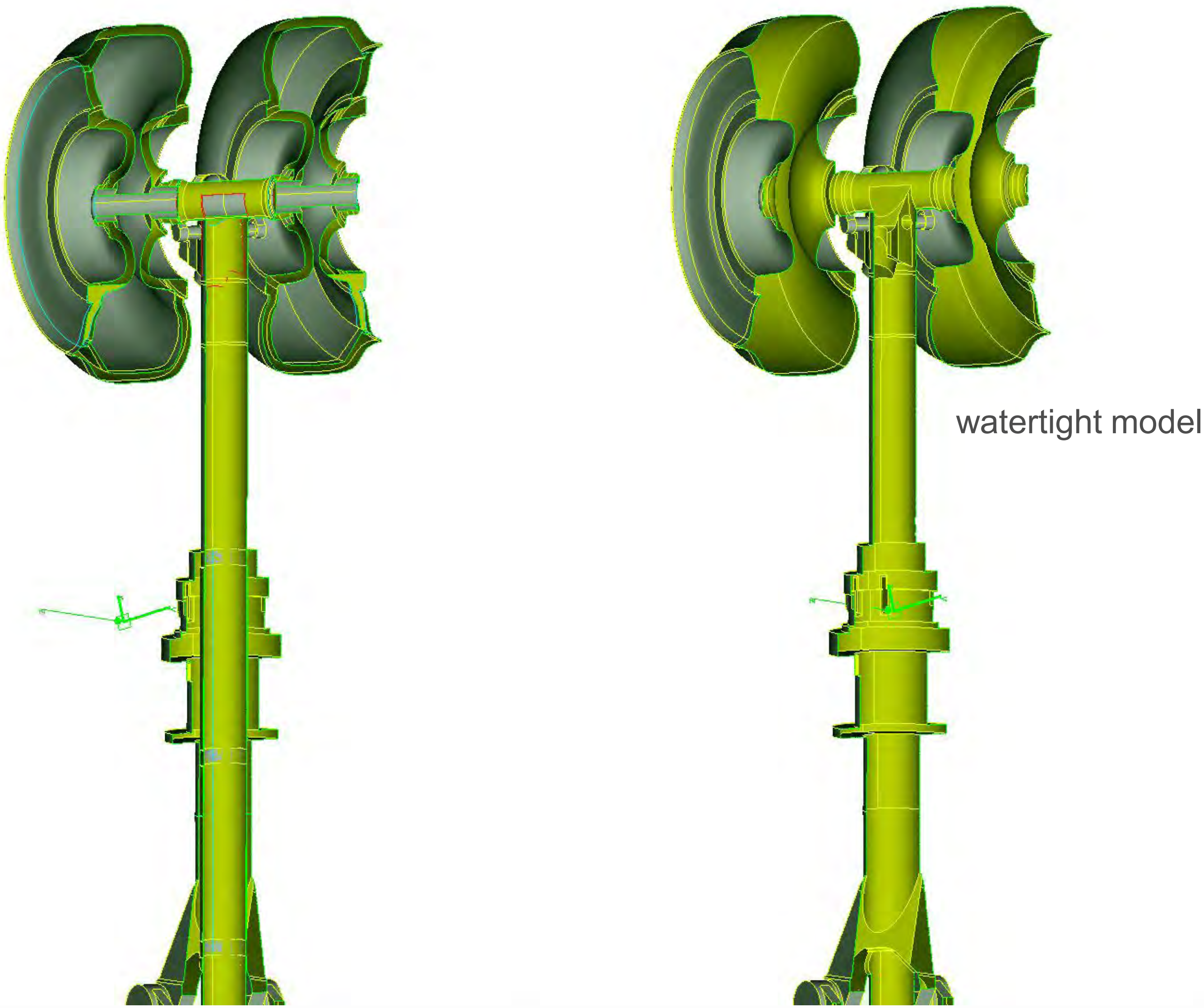
Software used

- ANSA v13.2.3 for pre-processing
- OpenFOAM v2.1.1
- μETA v6.8.2 for post-processing

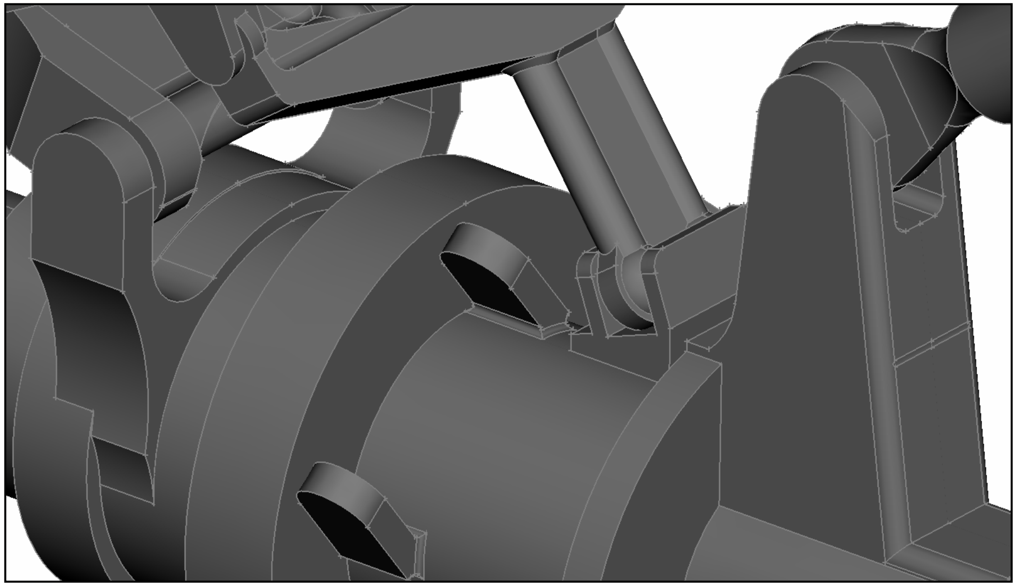
Geometry preparation: STEP file input and separation of parts

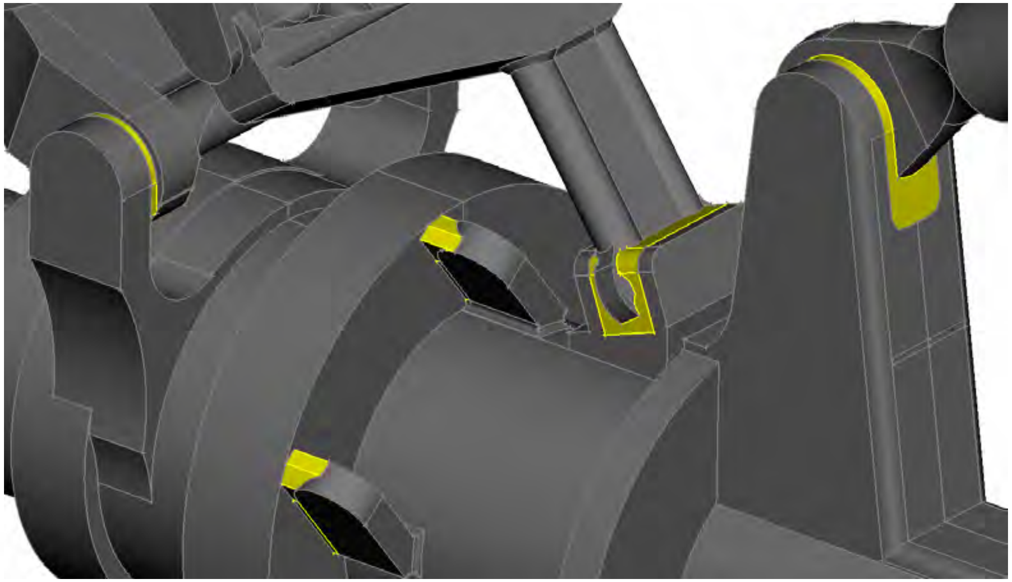


Geometry preparation: removal of unnecessary geometry

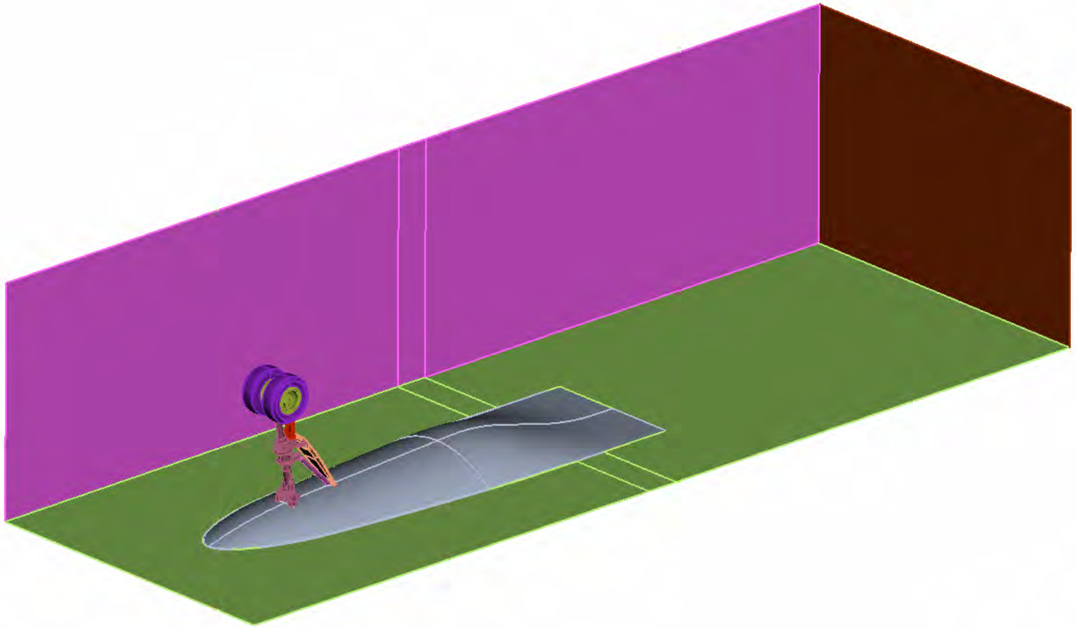


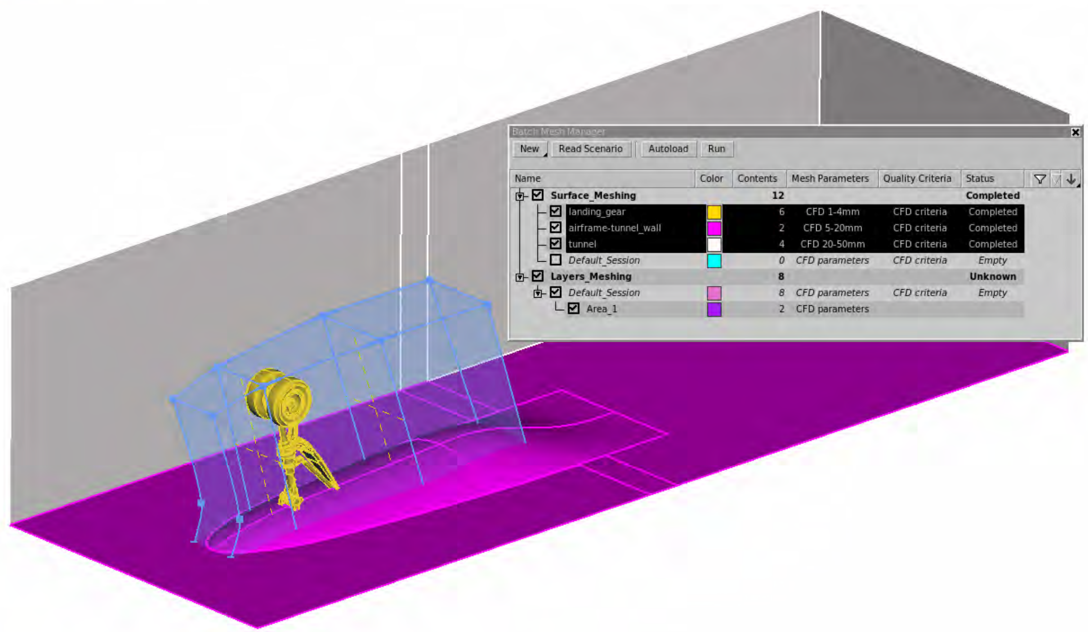
Geometry preparation: closure of small gaps and proximities





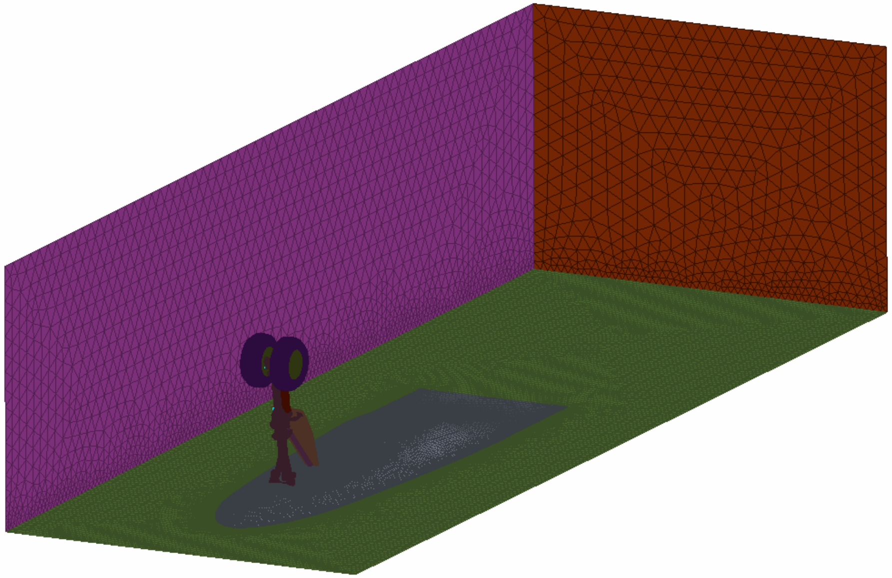
Batch Meshing setup: automation and consistency in meshing

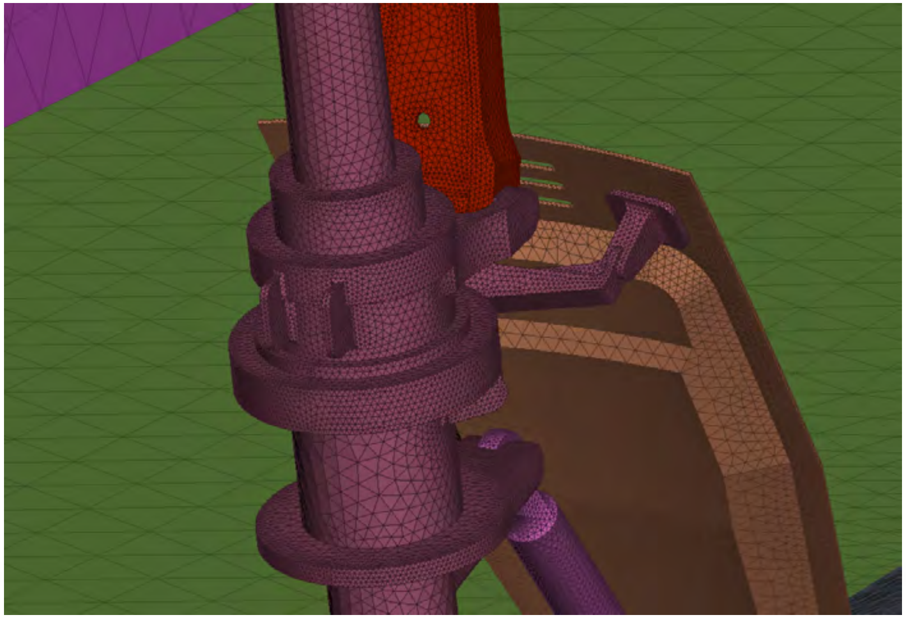




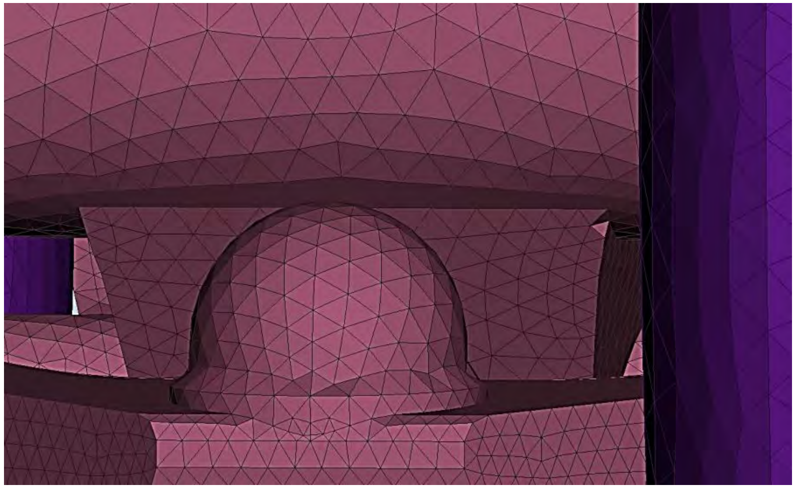
Surface mesh details – coarse mesh 334k trias

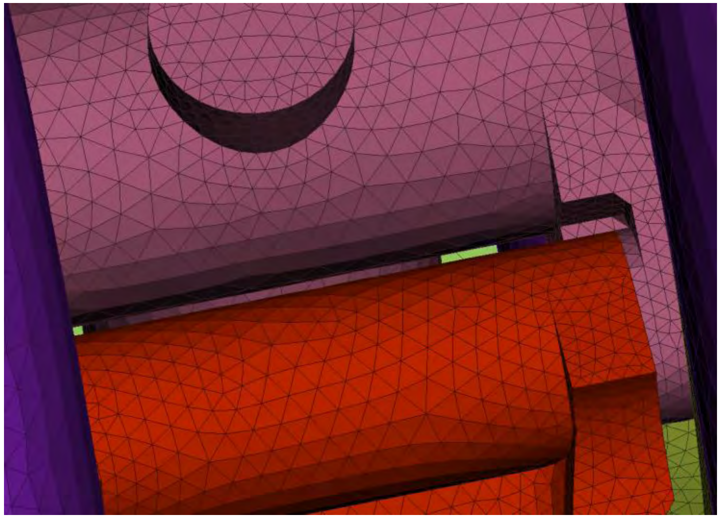
Surface Mesh Fluent skewness<0.4

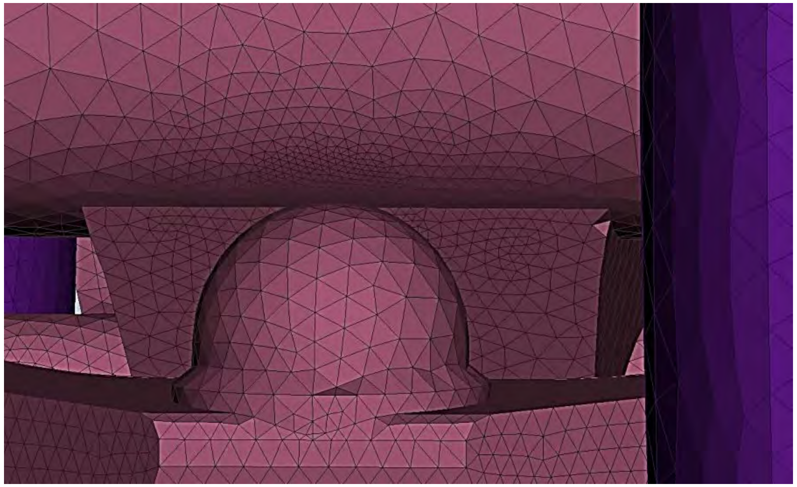


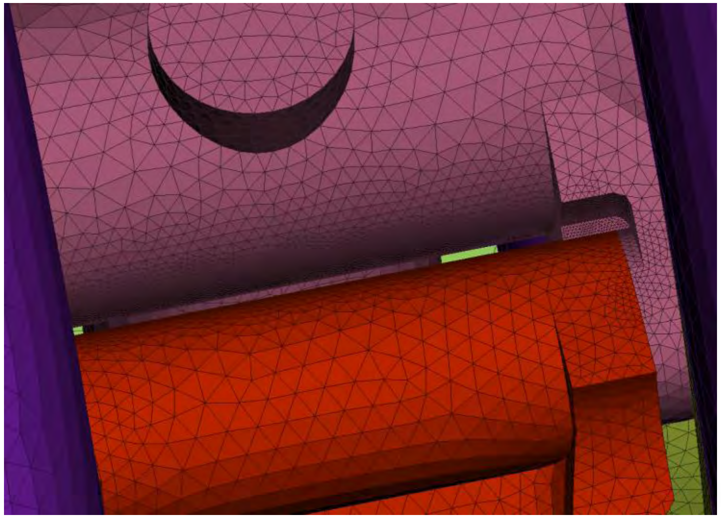


Surface mesh: proximity refinement

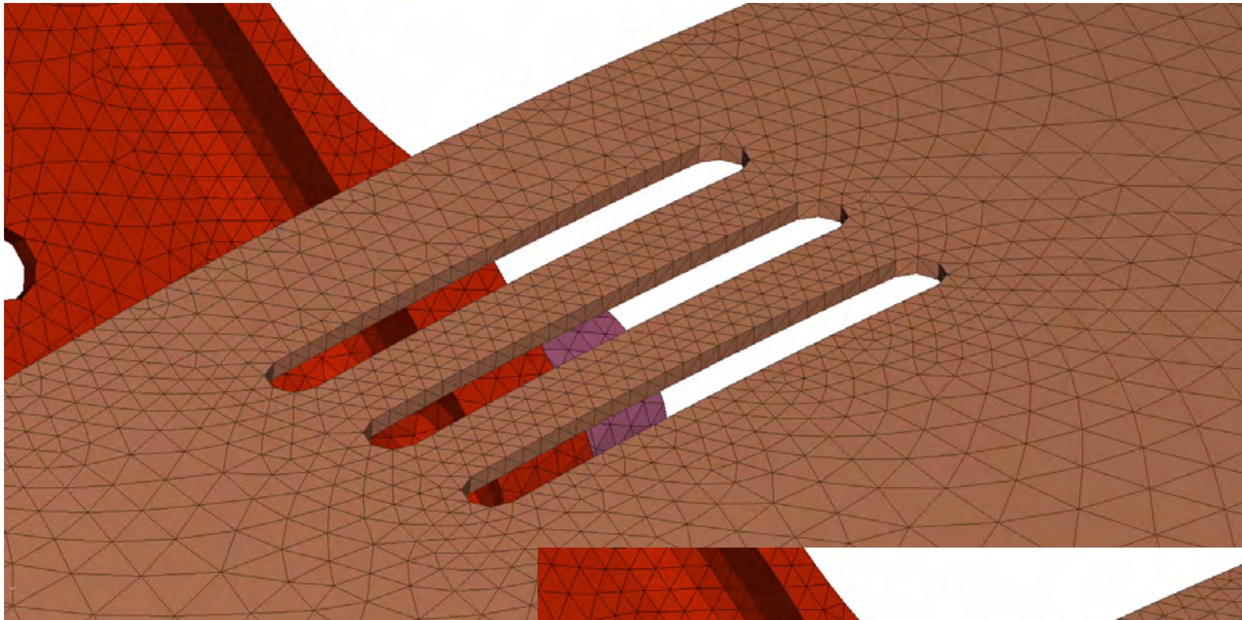


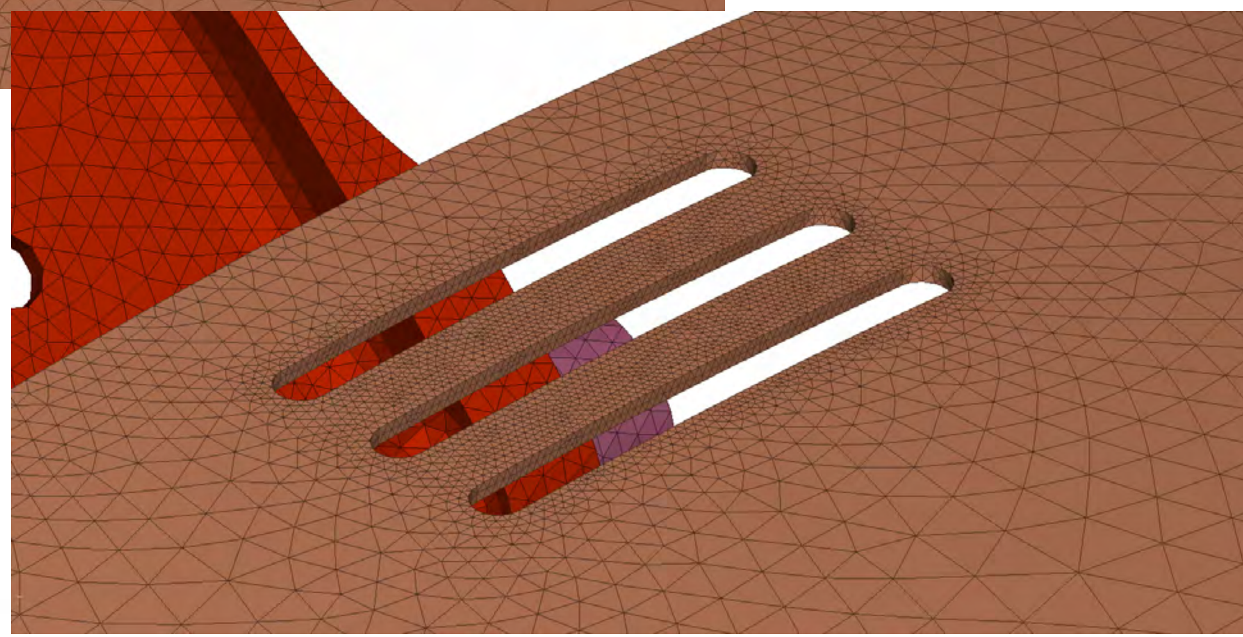




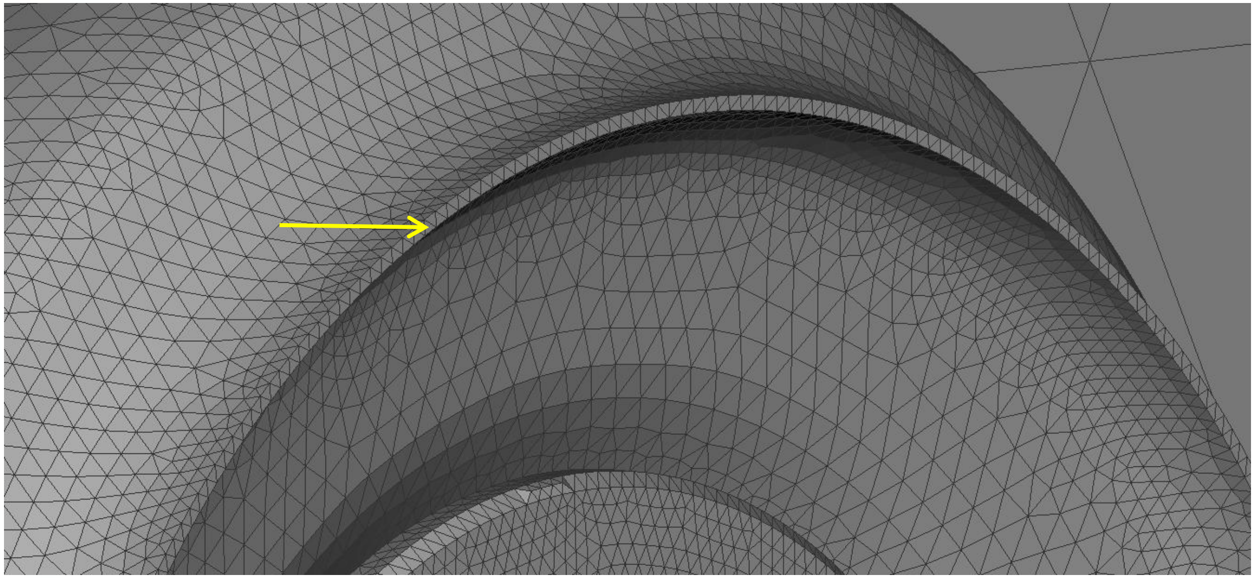


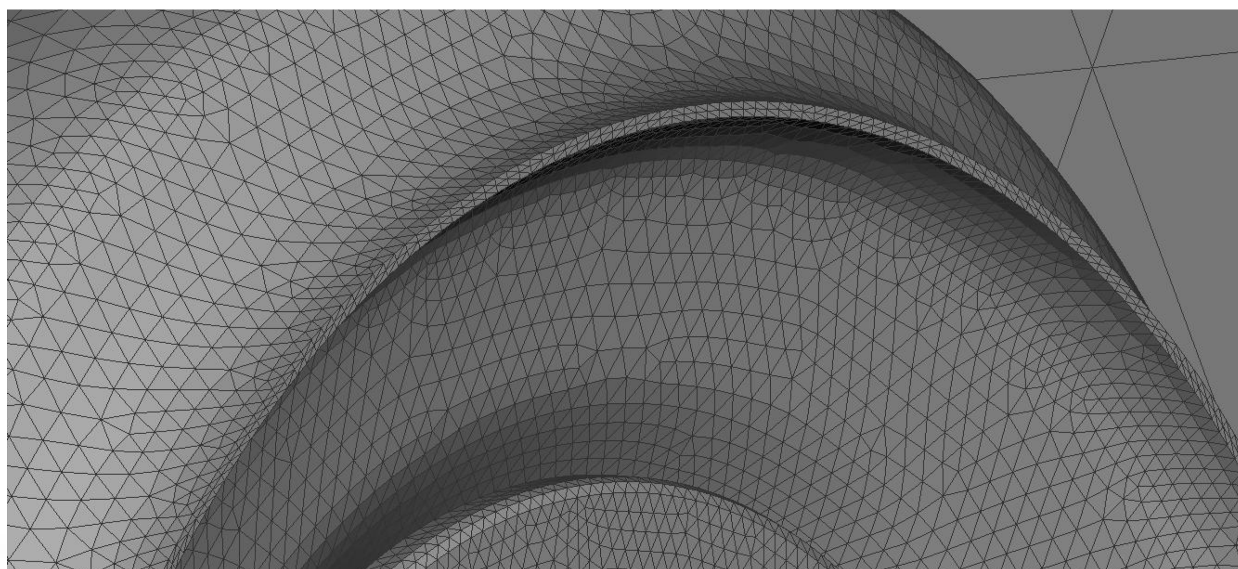
Surface mesh: proximity refinement



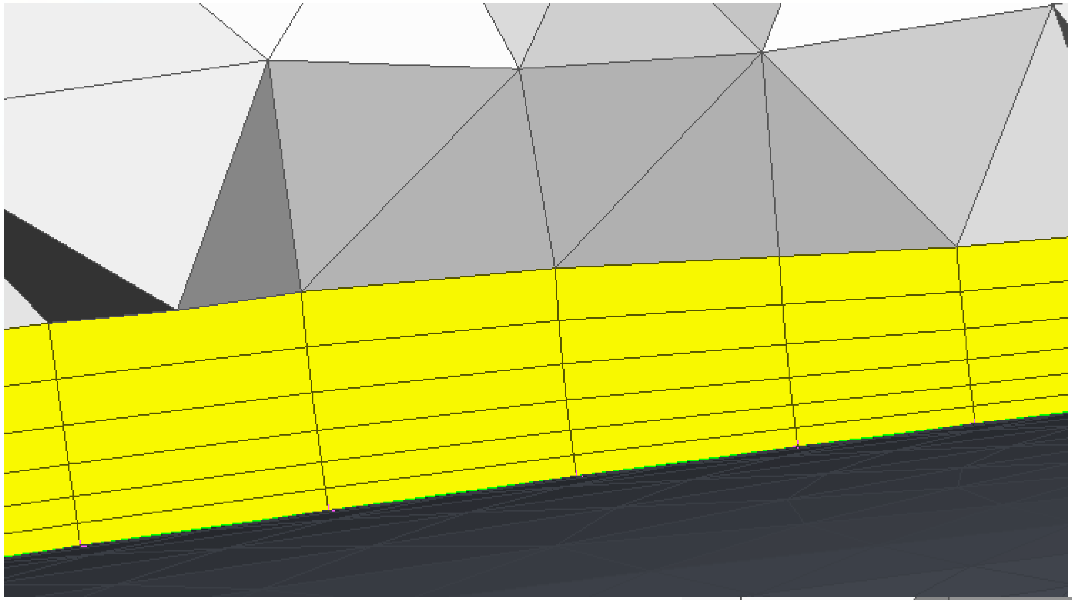


Mesh treatment of narrow thickness faces

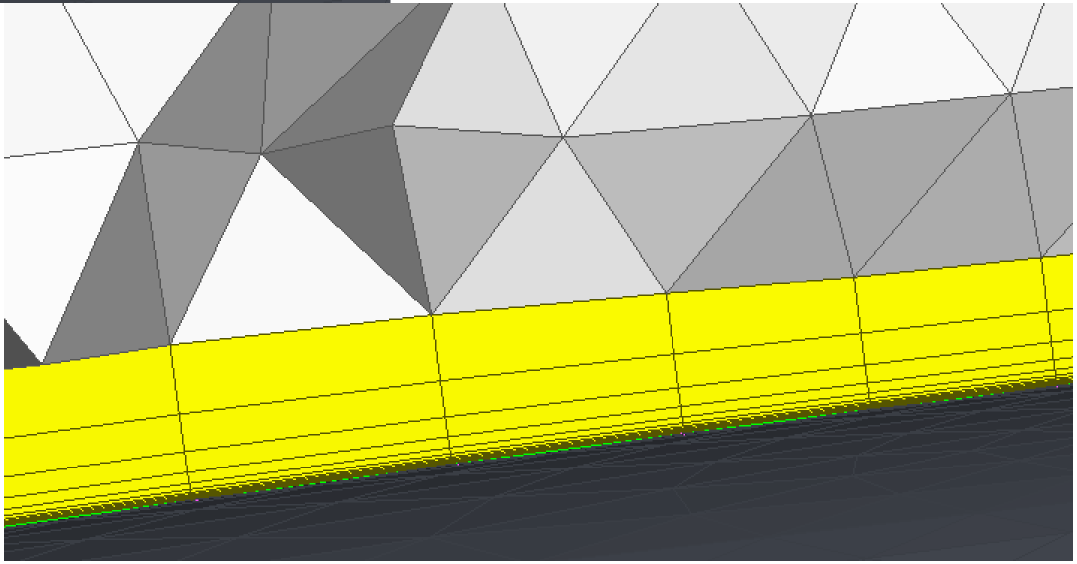




Boundary layer generation

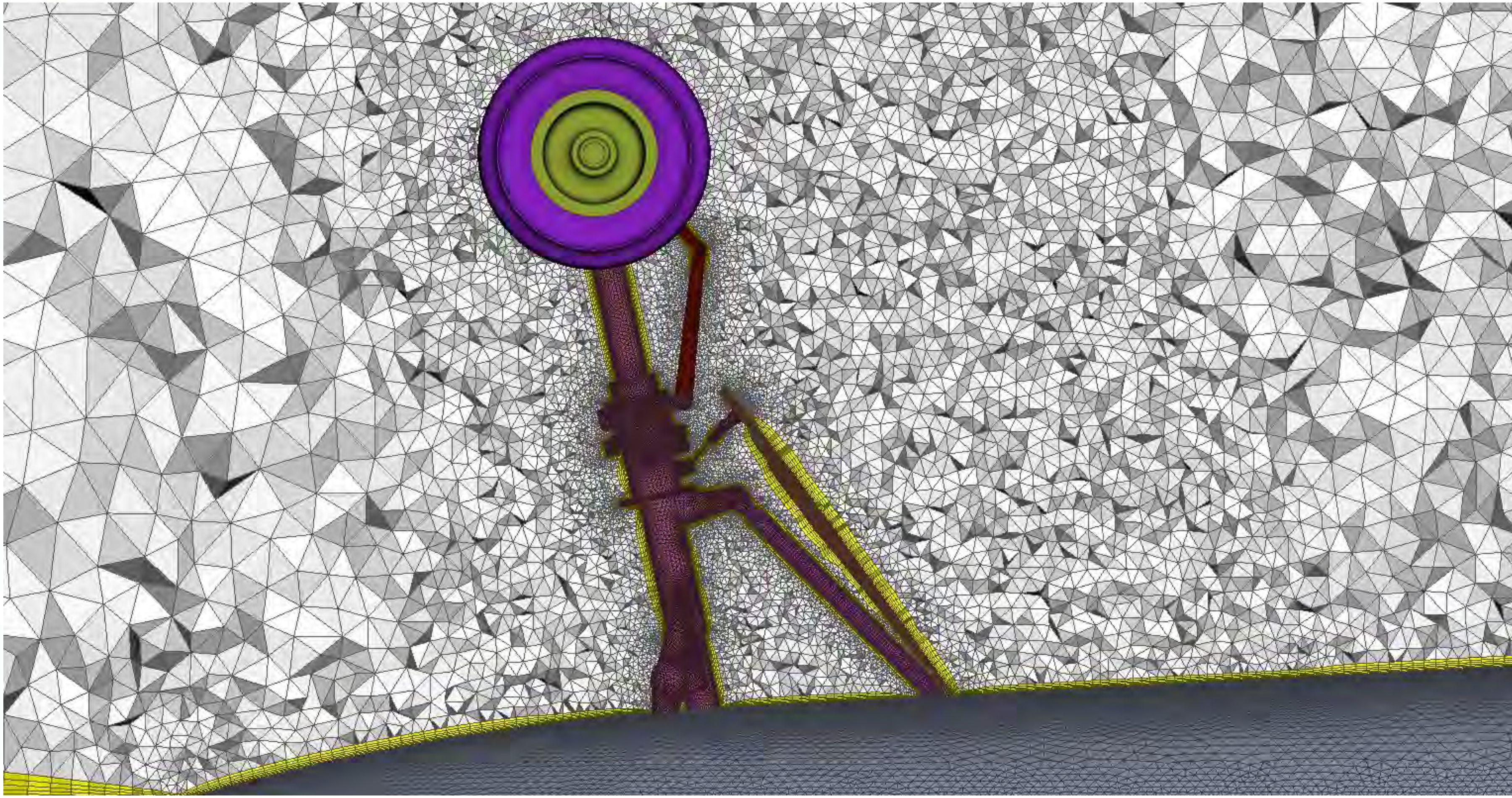


Hi Reynolds layers
first height 20% of local length
growth rate = 1.2
6 layers

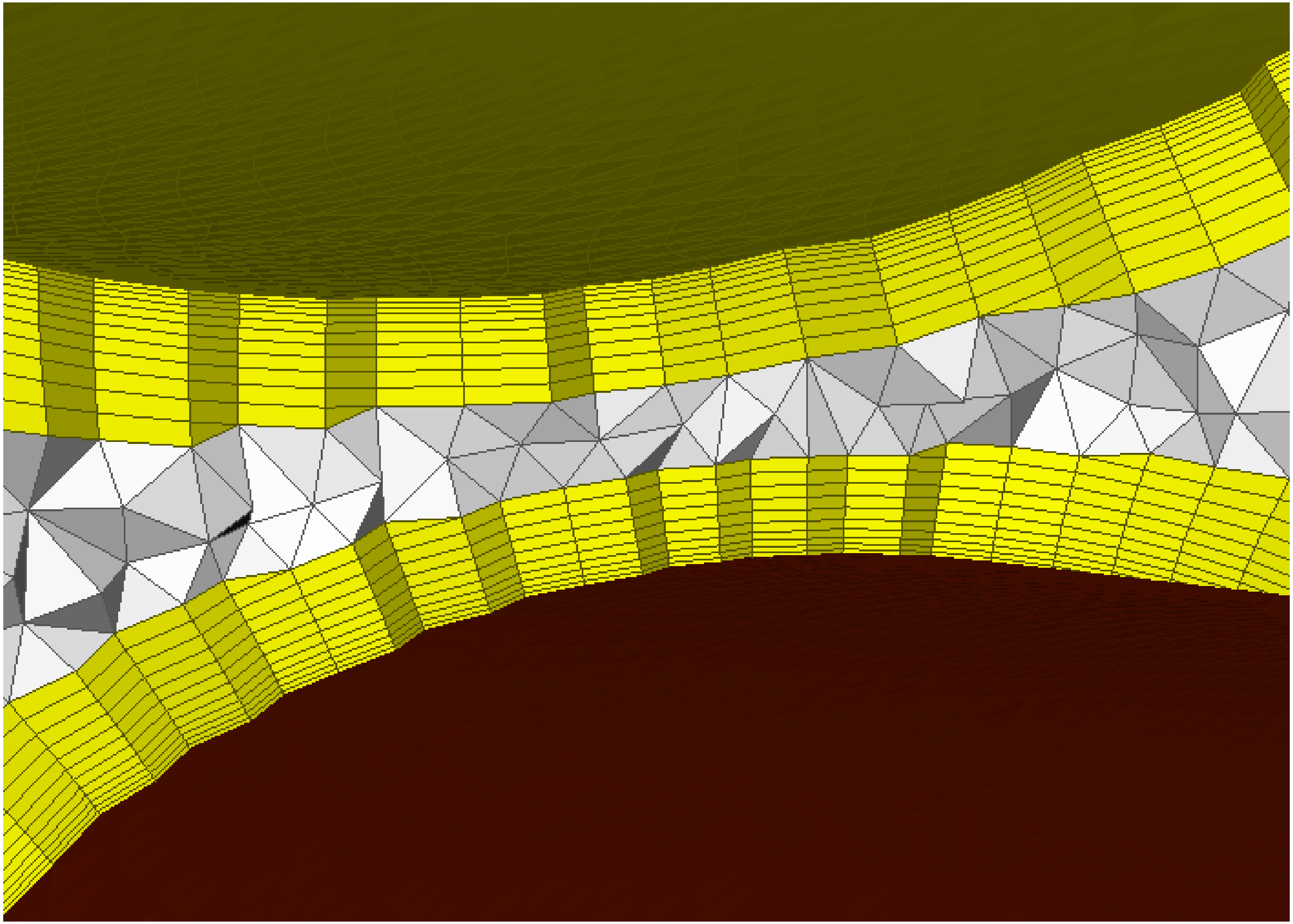


Low Reynolds layers
first height 0.01mm
growth rate = 1.2
6 layers in absolute
+6 layers in aspect mode
last aspect ratio = 0.3

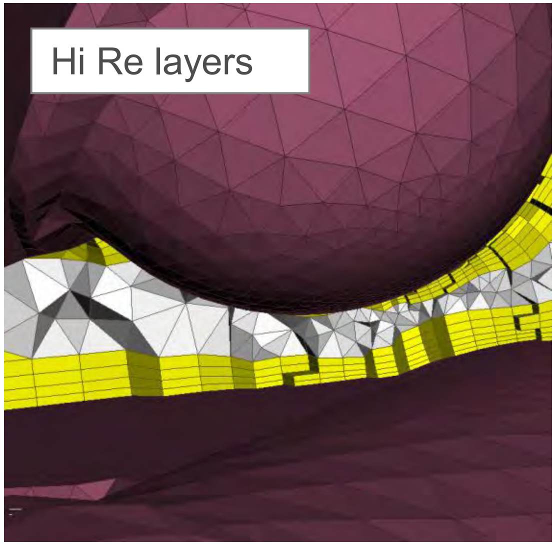
Boundary layer generation: 100% area coverage

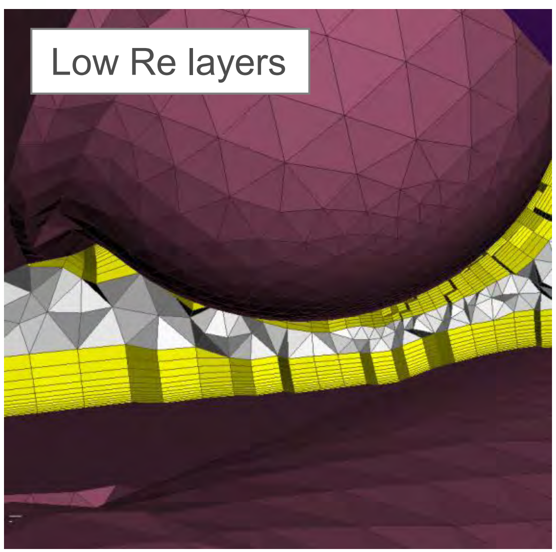


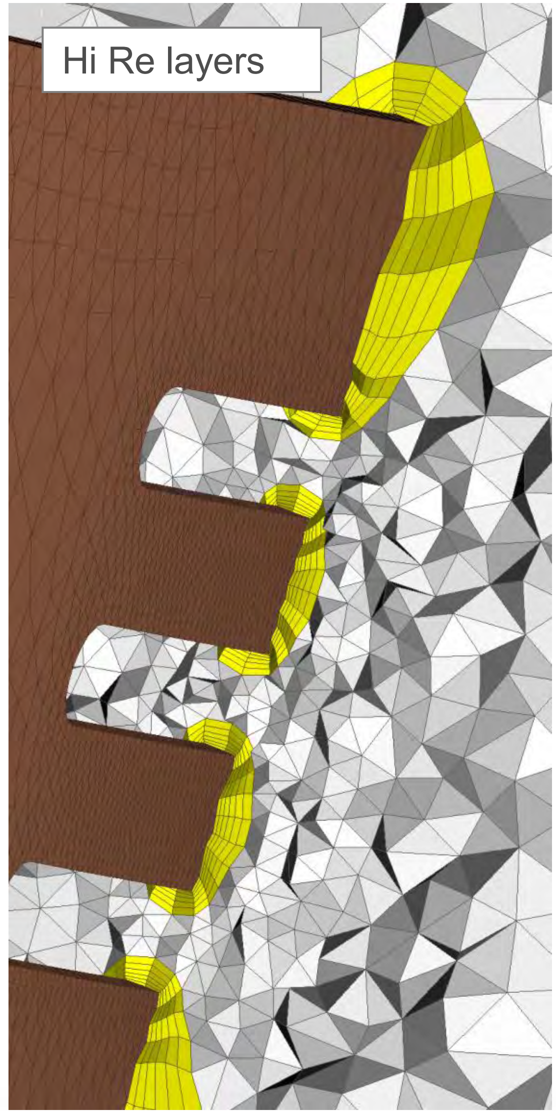
Boundary layer generation: collapsing of layers at proximities

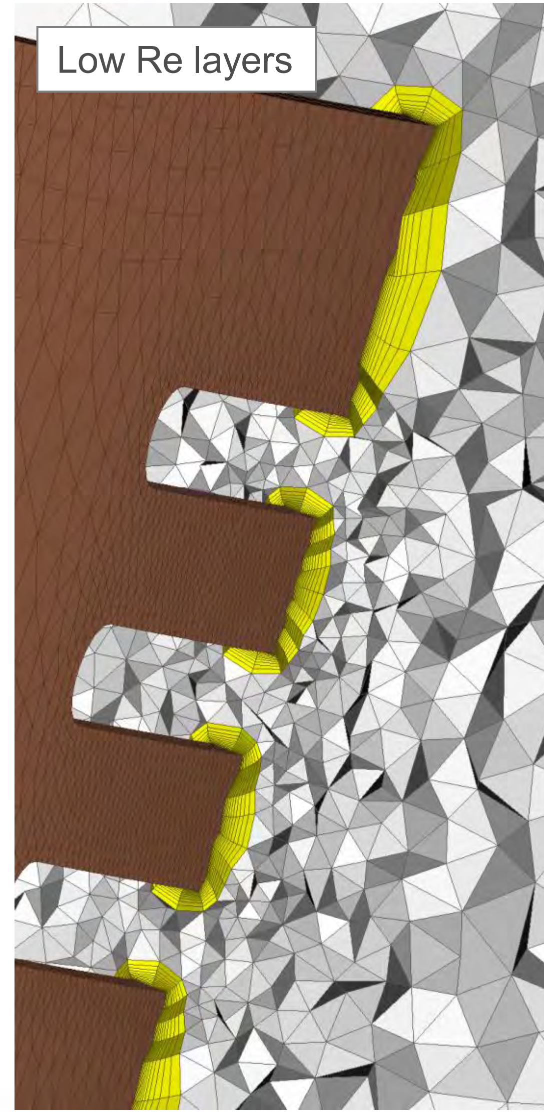


Boundary layer generation: details of Hi and Low Re meshes

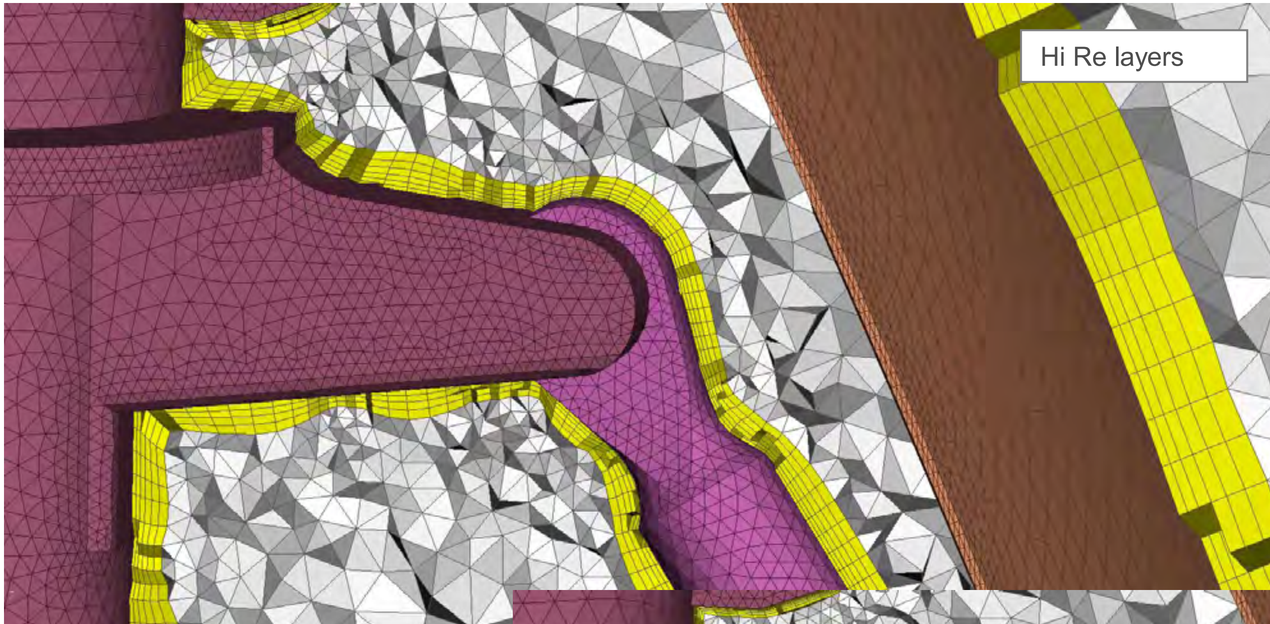


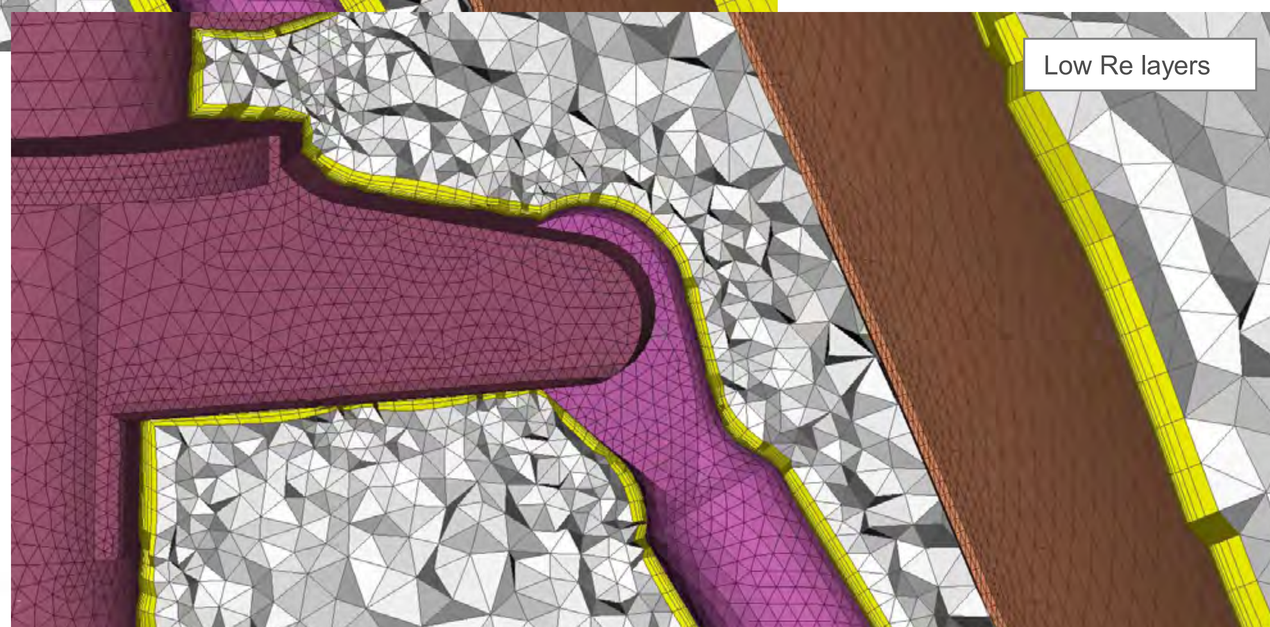




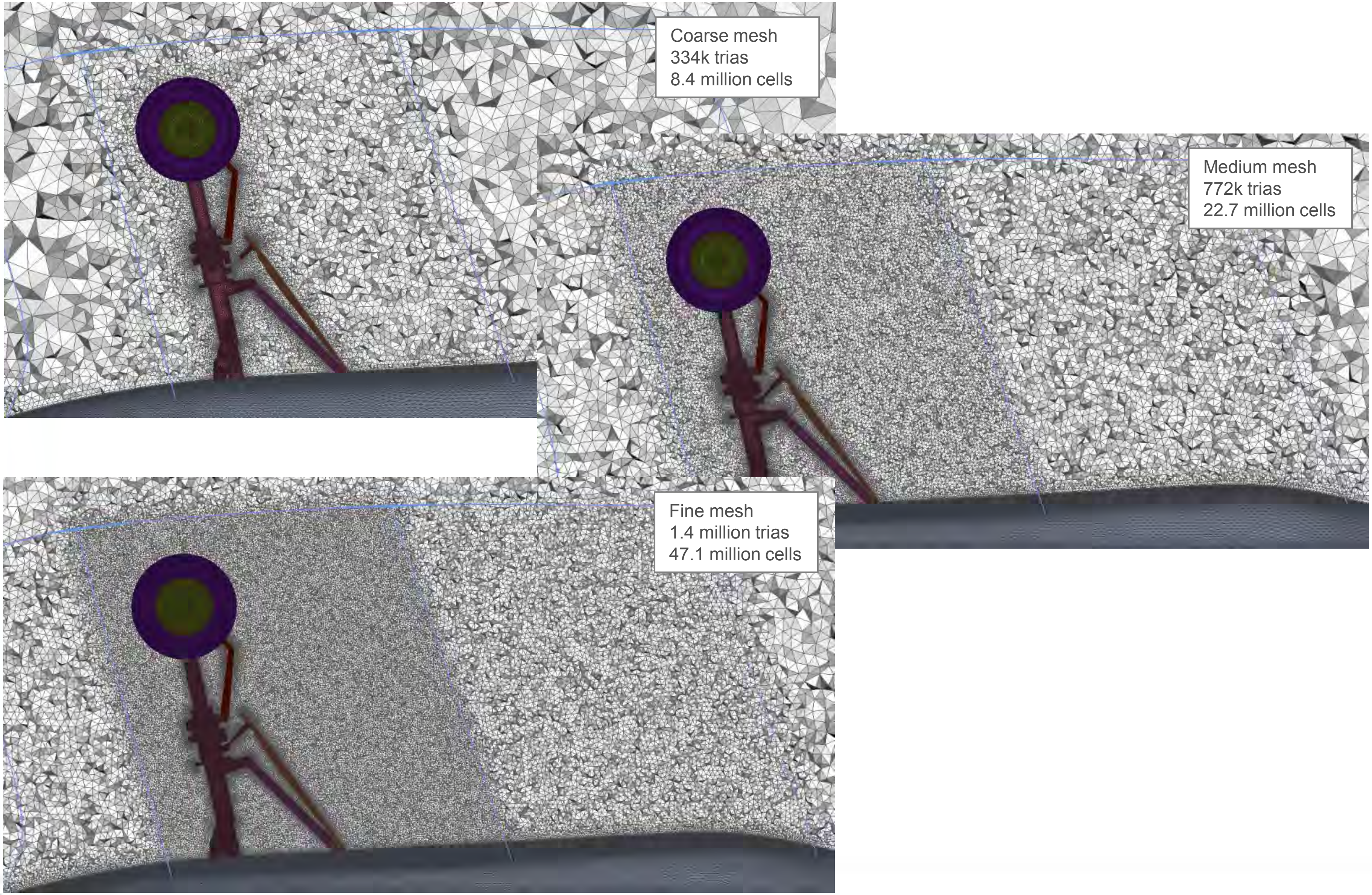


Boundary layer generation: details of Hi and Low Re meshes

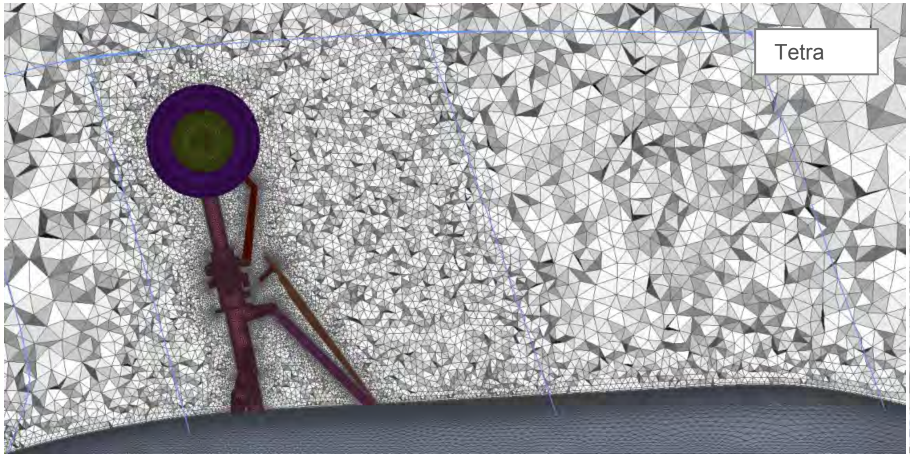


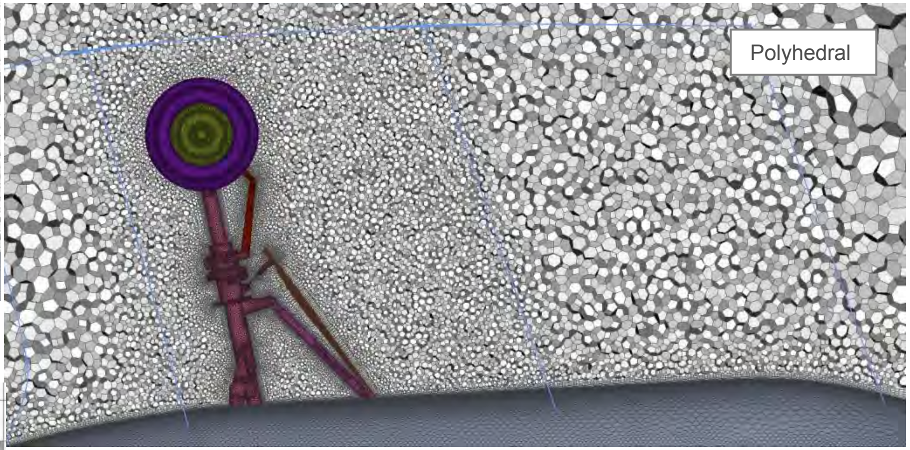


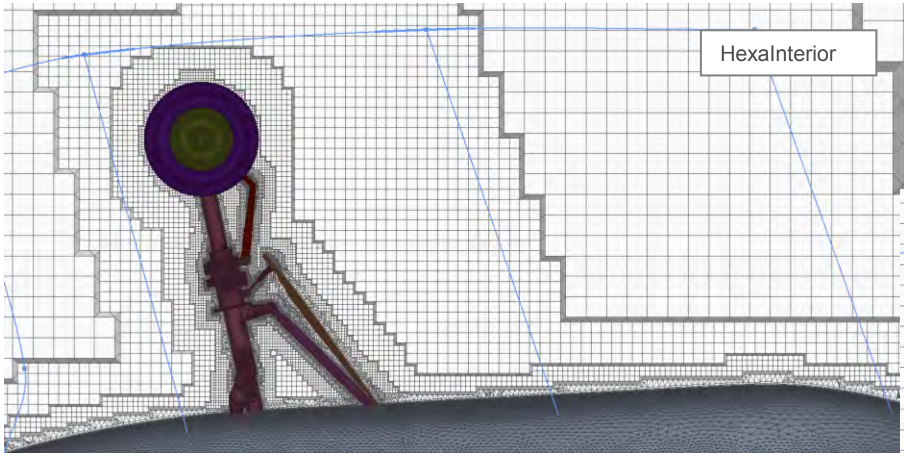
Mesh refinement study for Low Re layer tetra case

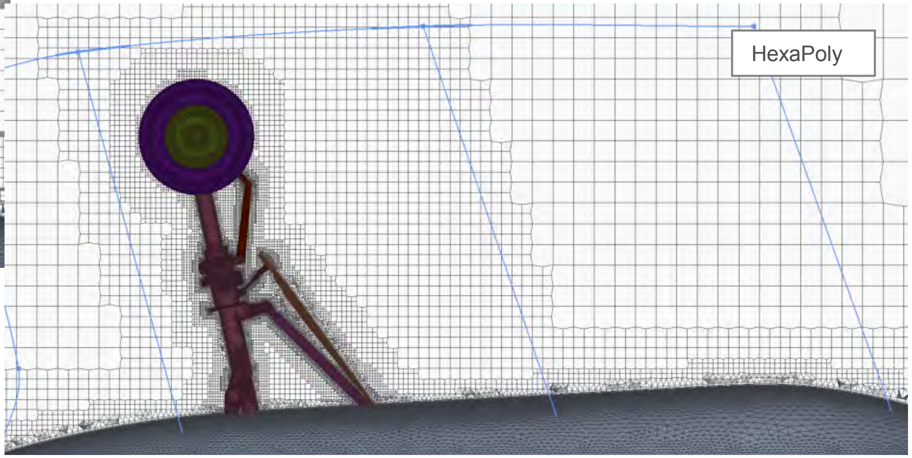


Mesh type variations – Coarse cases









Summary of mesh models

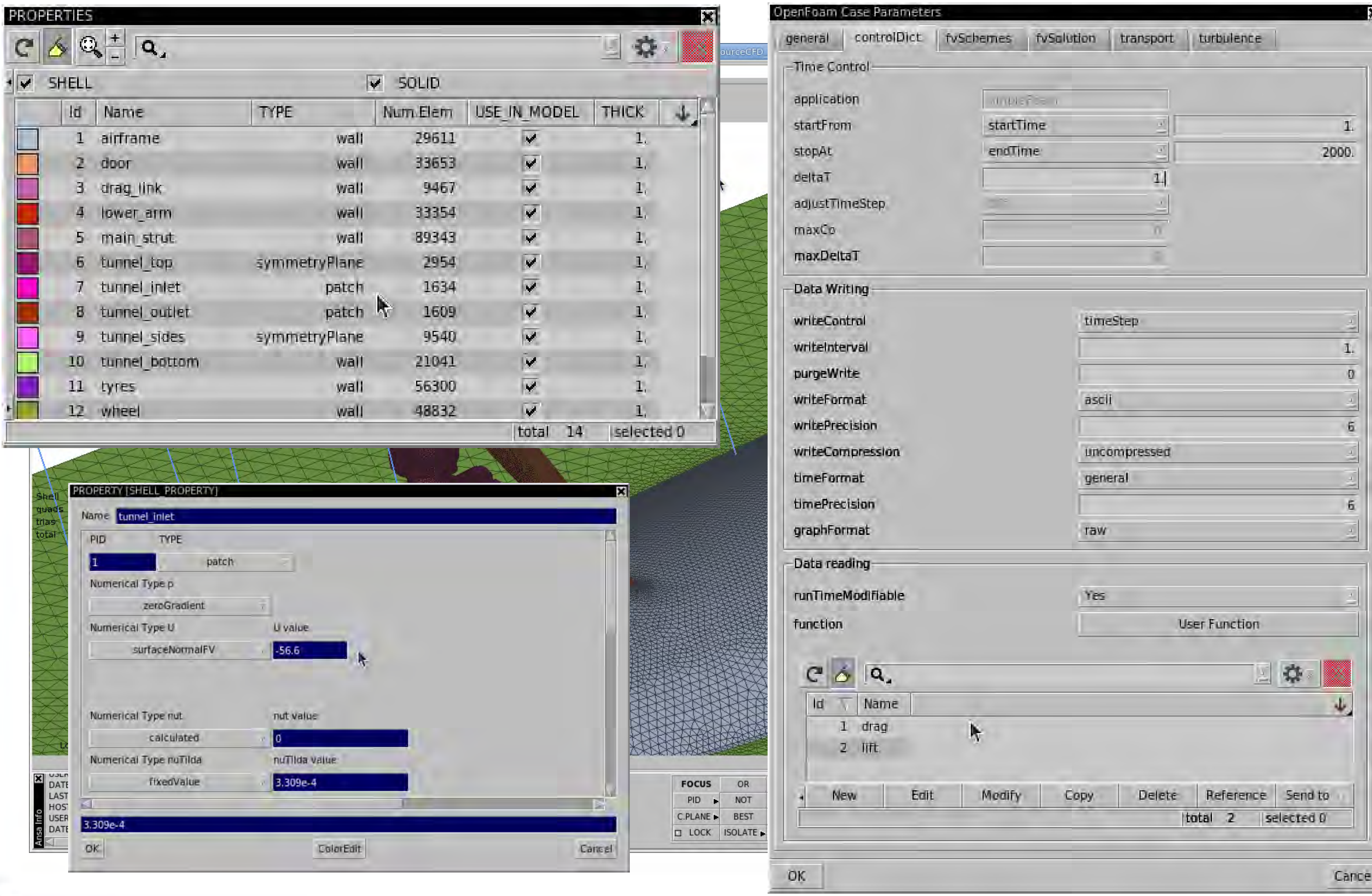
	Coarse	Medium	Fine
No layers	Tetra (5 million)		
Hi Re layers	Tetra (6 million)		
	Polyhedral (3 million)		
Low Re layers	Tetra (8 million)	Tetra (23 million)	Tetra (47 million)
	HexaInterior (8 million)	HexaInterior (19 million)	
	HexaPoly (7 million)	HexaPoly (15 million)	

Indicative mesh quality statistics – Coarse Tetra Low Re

OpenFOAM skewness						
ID of Element with min value					MIN Value	
2891747					0	
ID of Element with max value					MAX Value	
3675472					4.37	
Class					No of Elements	Perc(%)
1	From:	0	To:	1	8236958	97.6
2	From:	1	To:	2	109609	1.2
3	From:	2	To:	3	87140	1.0
4	From:	3	To:	4	5032	0.059
5	From:	4	To:	10	54	0.00063
TOTAL					8438793	

OpenFOAM Non Orthogonality						
ID of Element with min value					MIN Value	
2780942					0	
ID of Element with max value					MAX Value	
602331					70.18	
Class					No of Elements	Perc(%)
1	From:	0	To:	18	2344964	27.7
2	From:	18	To:	36	4859012	57.5
3	From:	36	To:	60	1233095	14.6
4	From:	60	To:	70	1720	0.020
5	From:	70	To:	90	2	2.37001e-05
TOTAL					8438793	

Setup of OpenFOAM cases in ANSA



OpenFOAM case setup

Steady State simulations with simpleFoam

Initializations with potentialFoam

Turbulence models: Spalart Allmaras

LinearUpwind scheme for U
Upwind scheme for turbulence

GAMG solver for p
smoothSolver for U and turbulence

BCs

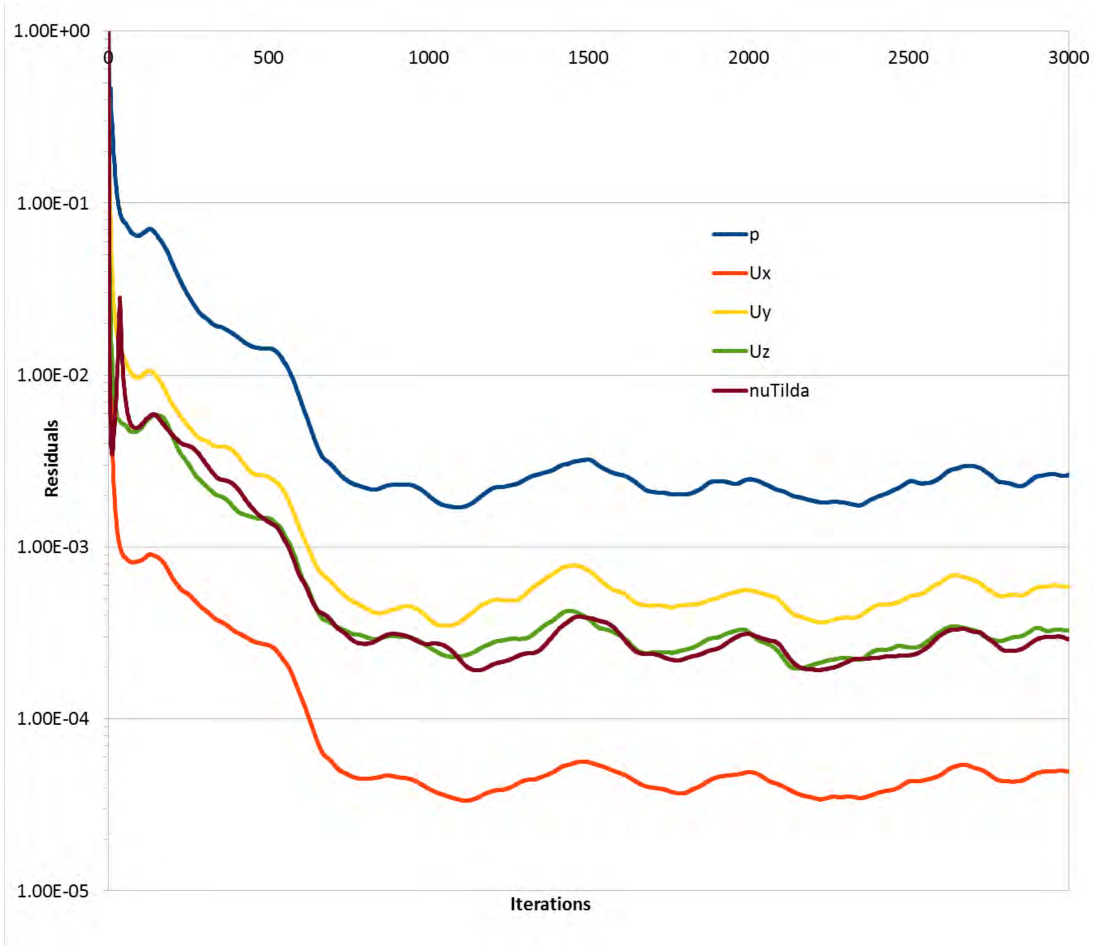
	walls	inlet	Outlet
p	zeroGradient	zeroGradient	fixedValue 0
U	fixedValue 0	fixedValue 56.6	zeroGradient
nuTilda	fixedValue 0	fixedValue 3.3e-4	zeroGradient
nut	fixedValue 0	calculated	calculated

3000 iterations per case

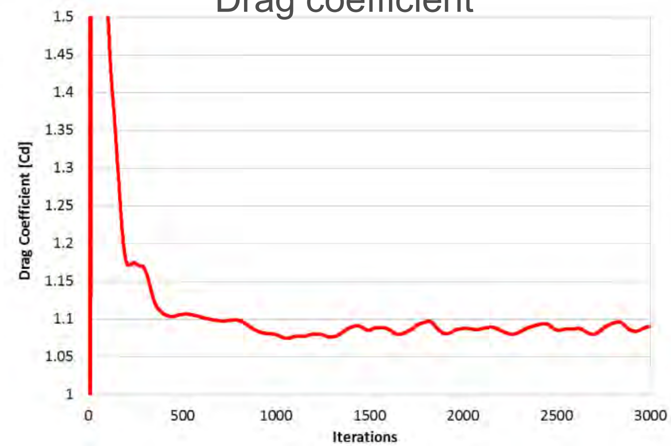
Forces averaged for last 2000 iterations

Mapping of results on different meshes

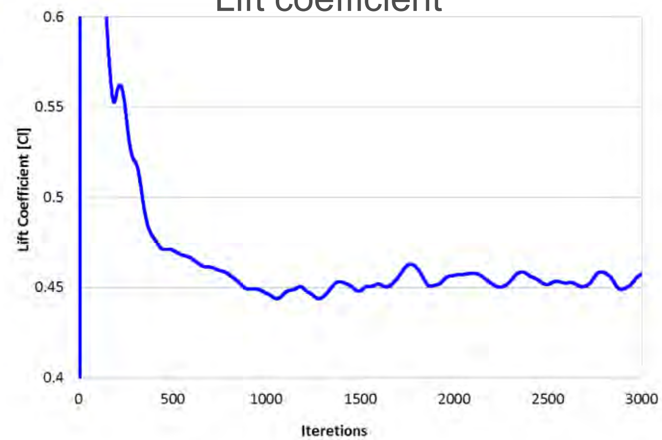
Convergence plots: Coarse Tetra Low Re



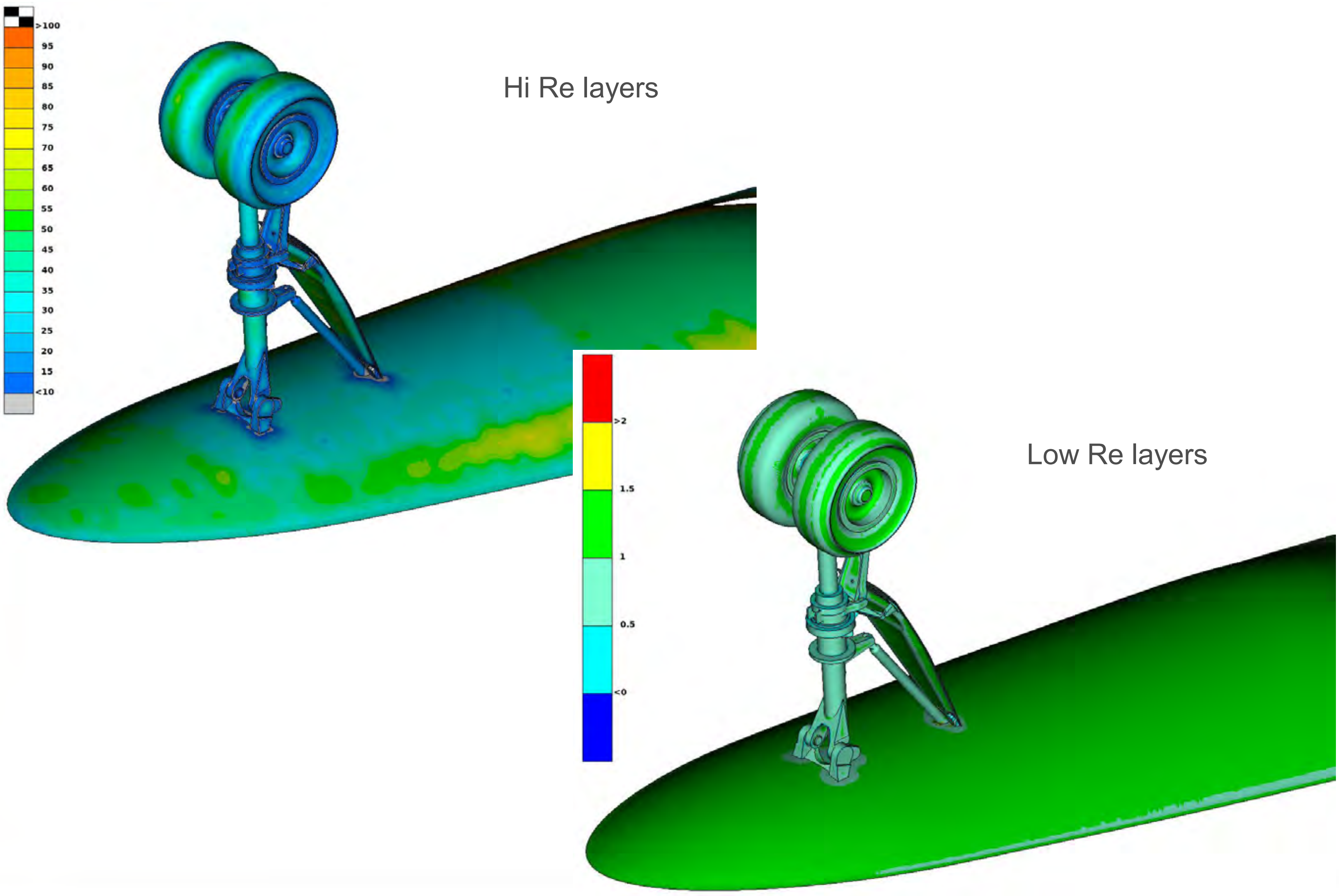
Drag coefficient



Lift coefficient

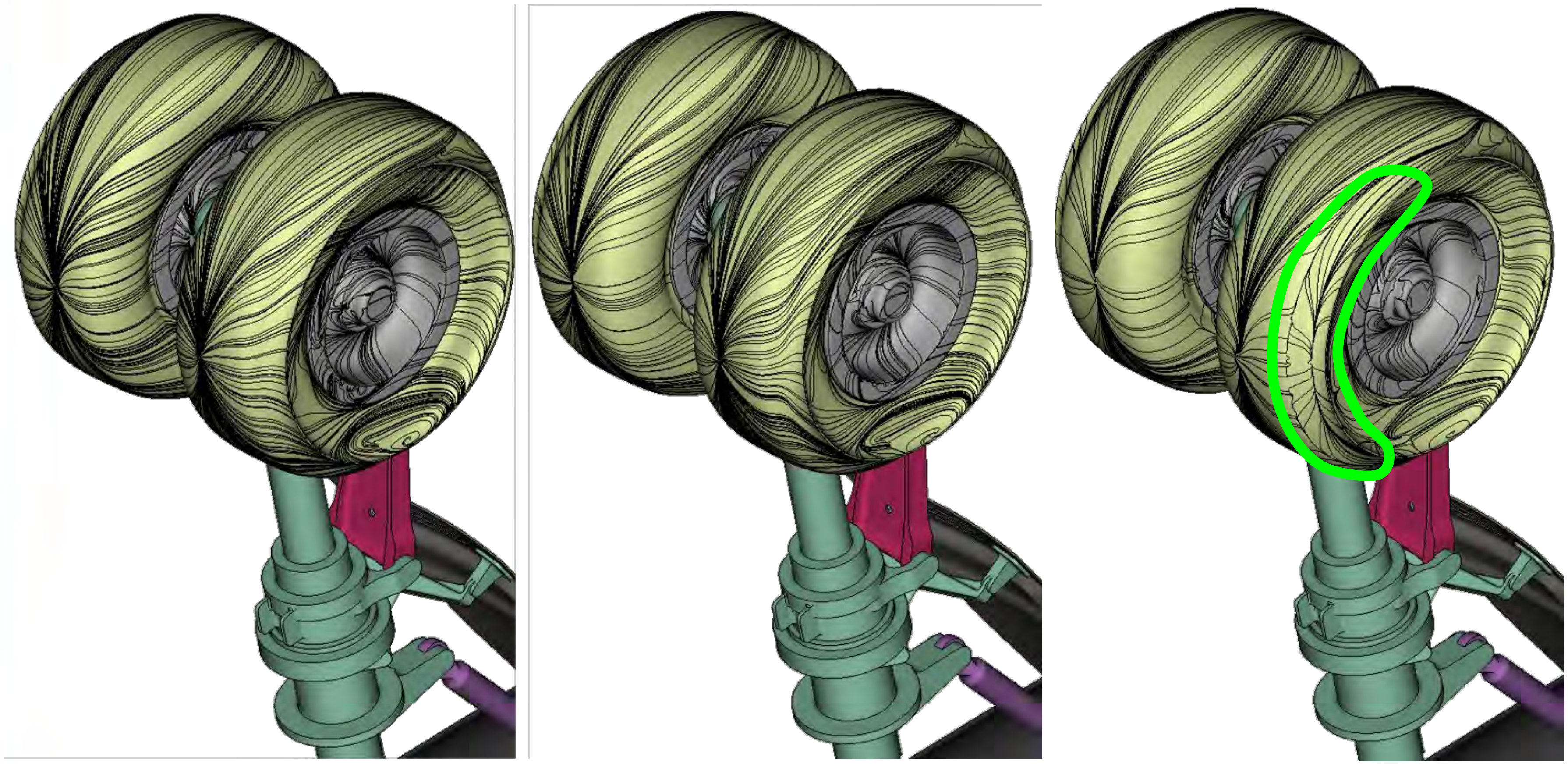


Post-processing in μETA: y+ results for Hi and Low Re meshes



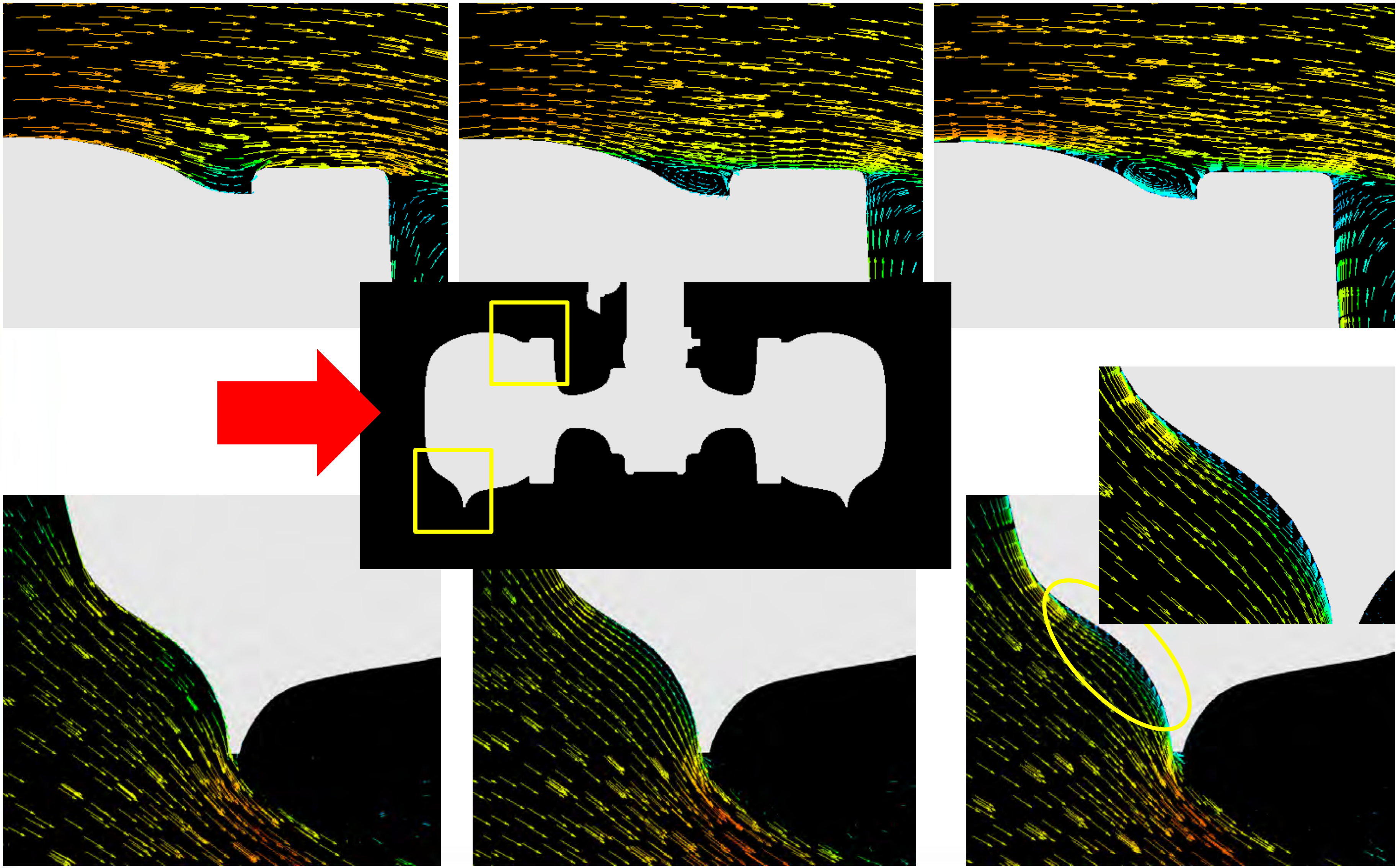
Effect of boundary layers – Tetra Coarse case

No layers | Hi Re layers | Low Re layers

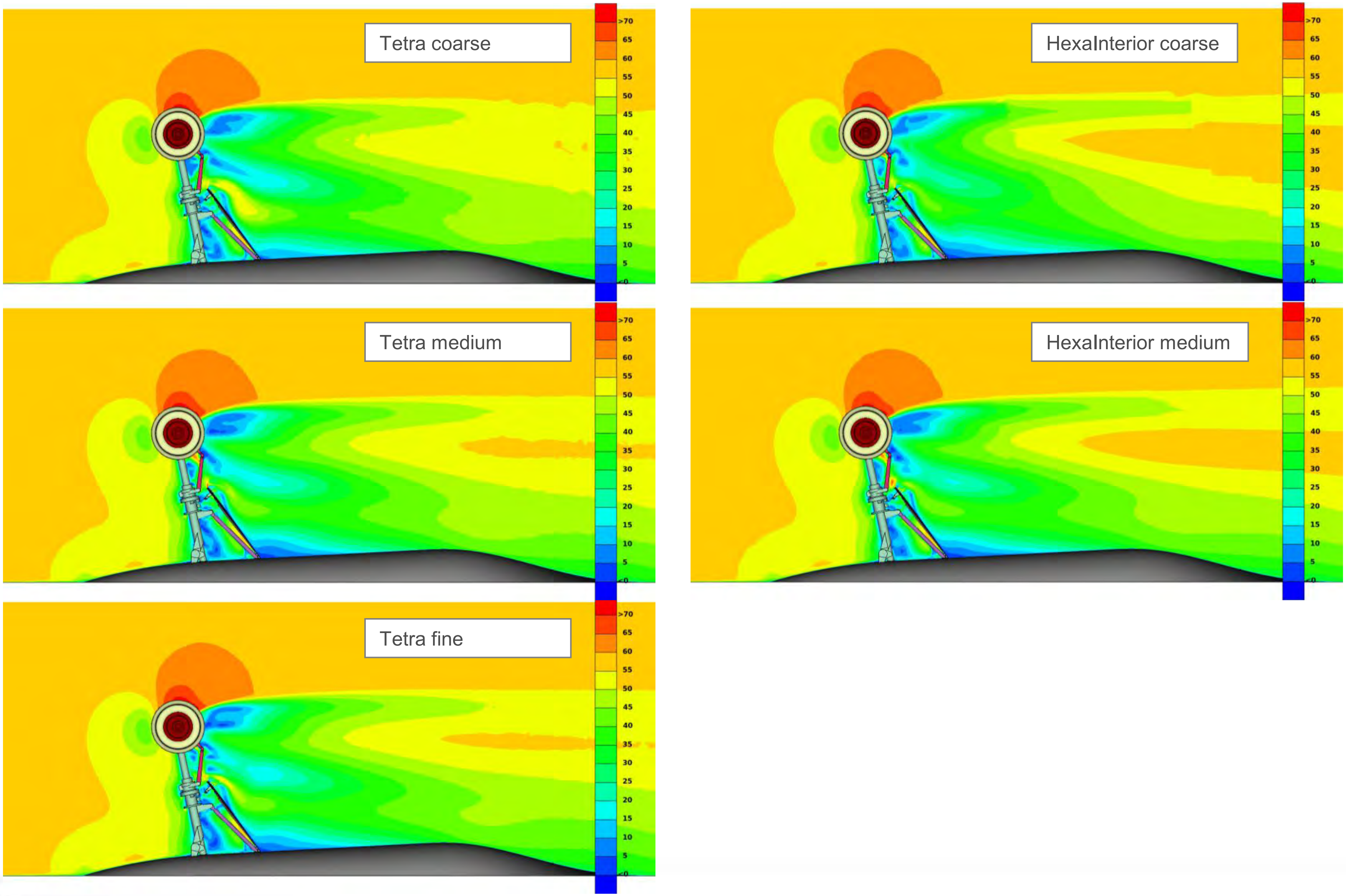


Effect of boundary layers

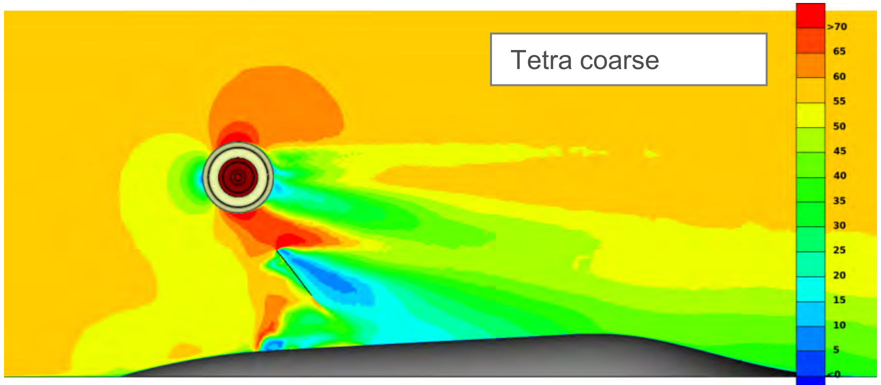
No layers | Hi Re layers | Low Re layers

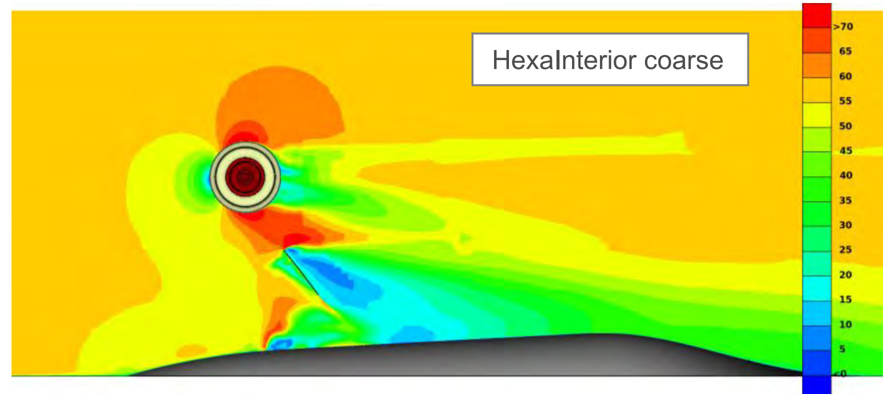


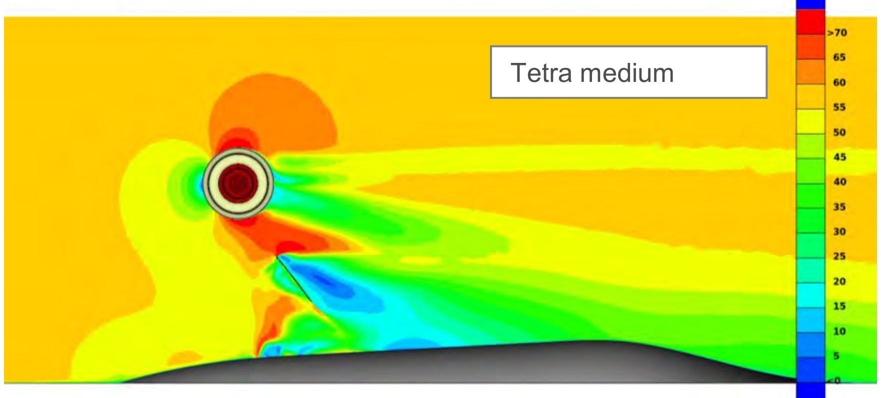
Velocity magnitude at centre line plane for Low Re layer meshes

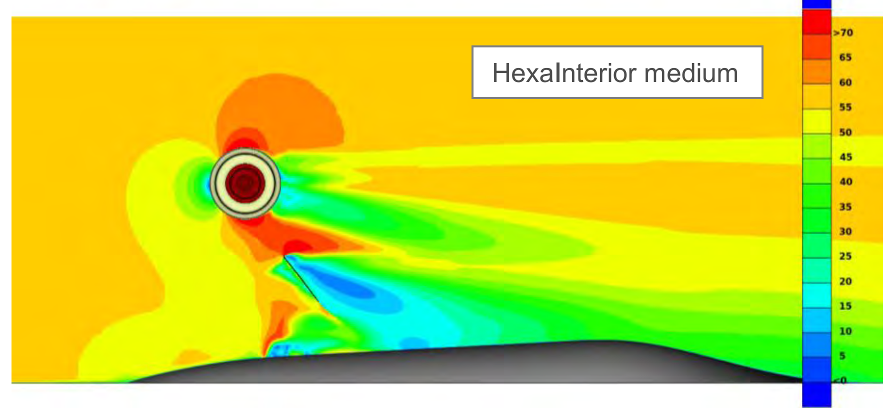


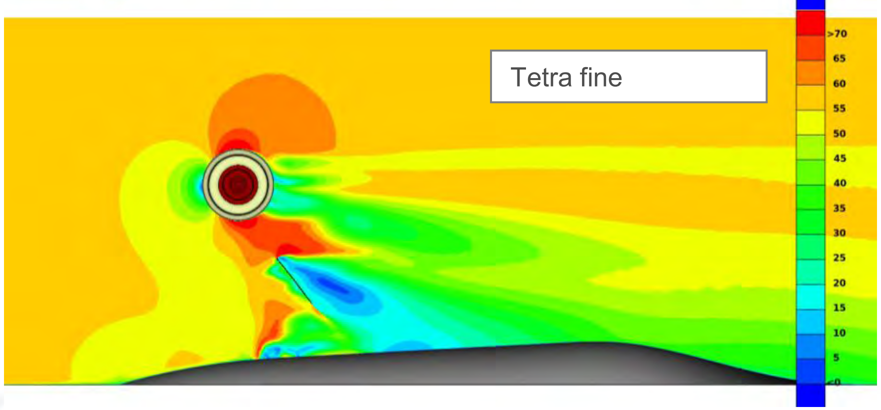
Velocity magnitude at wheel centre line plane (x=-0.04) for Low Re



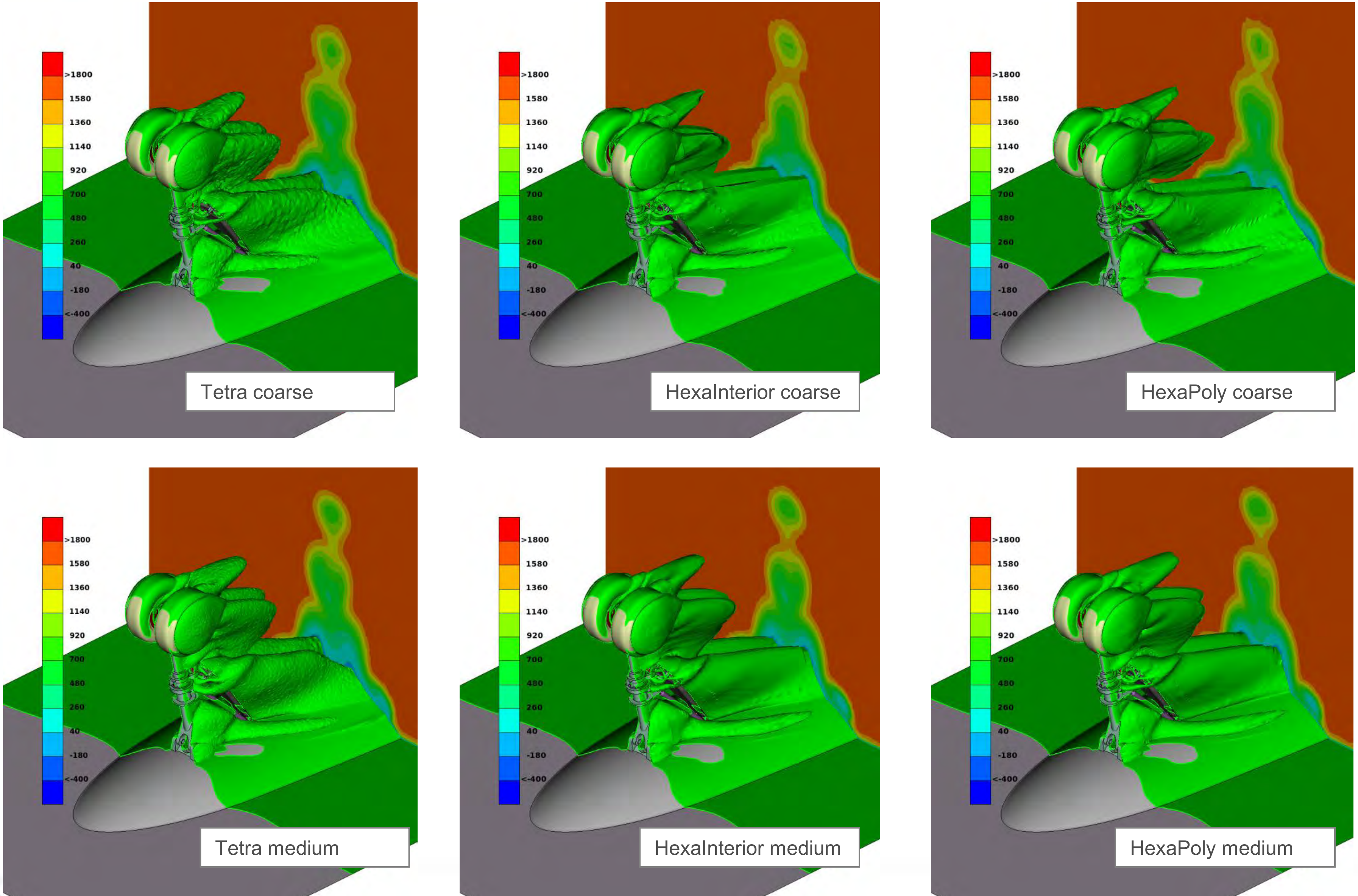




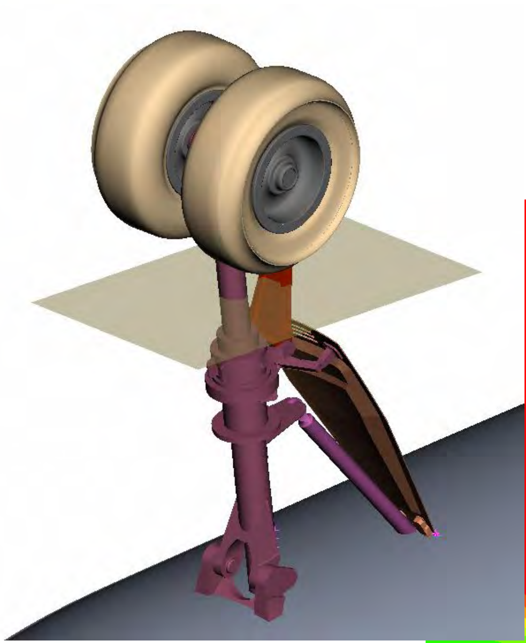


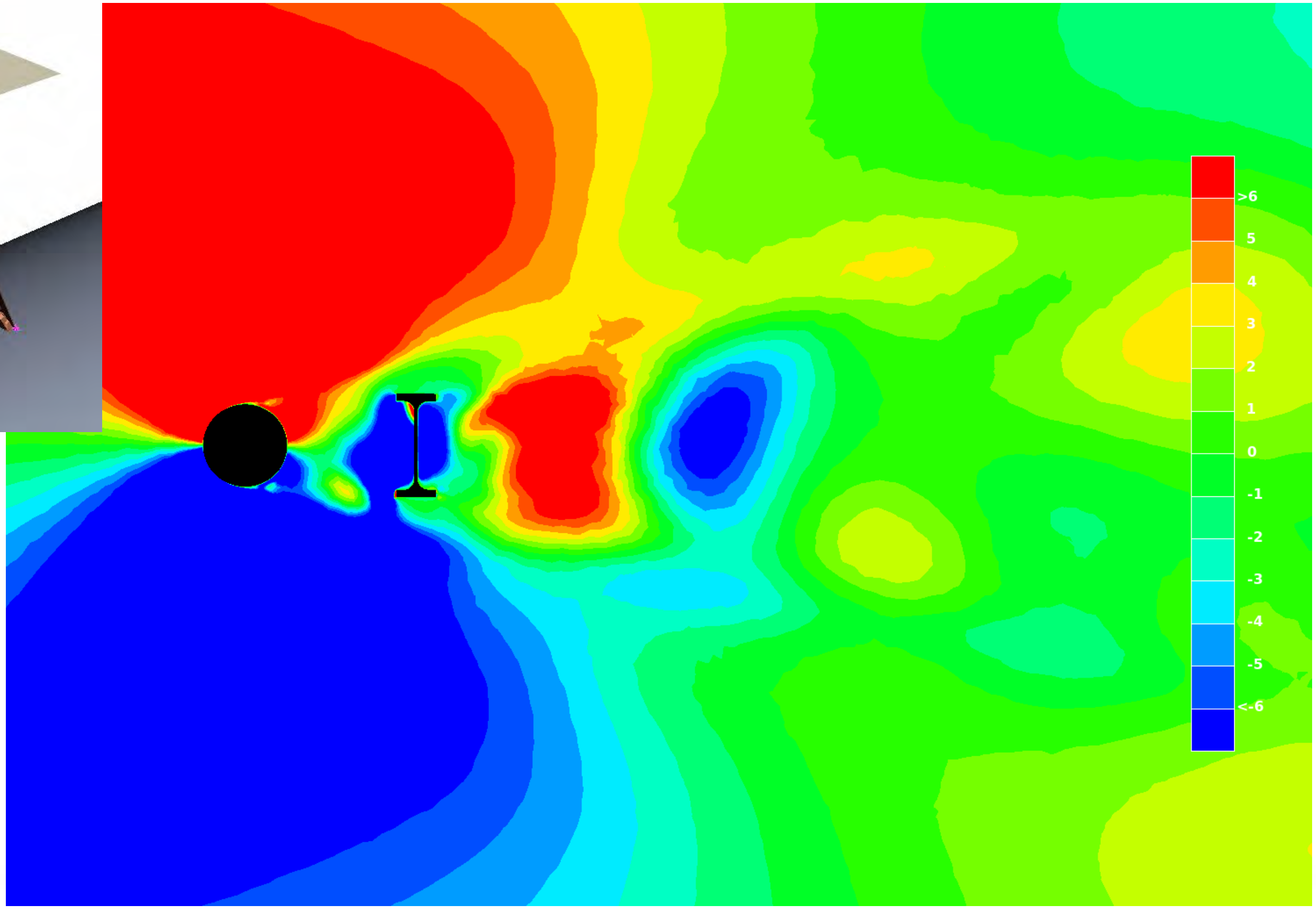


Total pressure =0 iso-surface and cut-plane downstream for Low Re

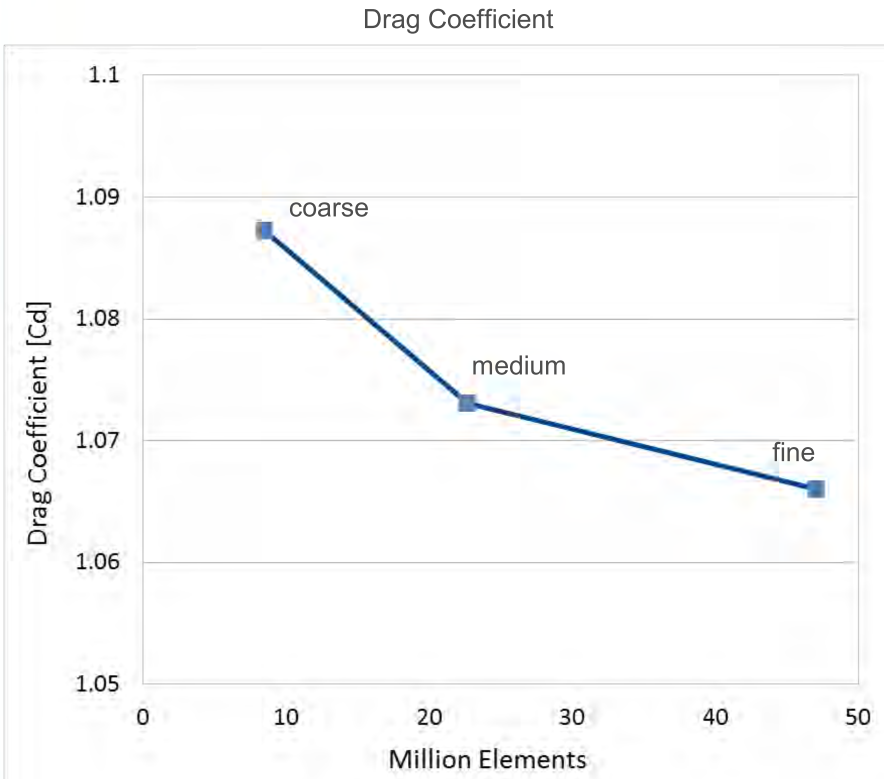


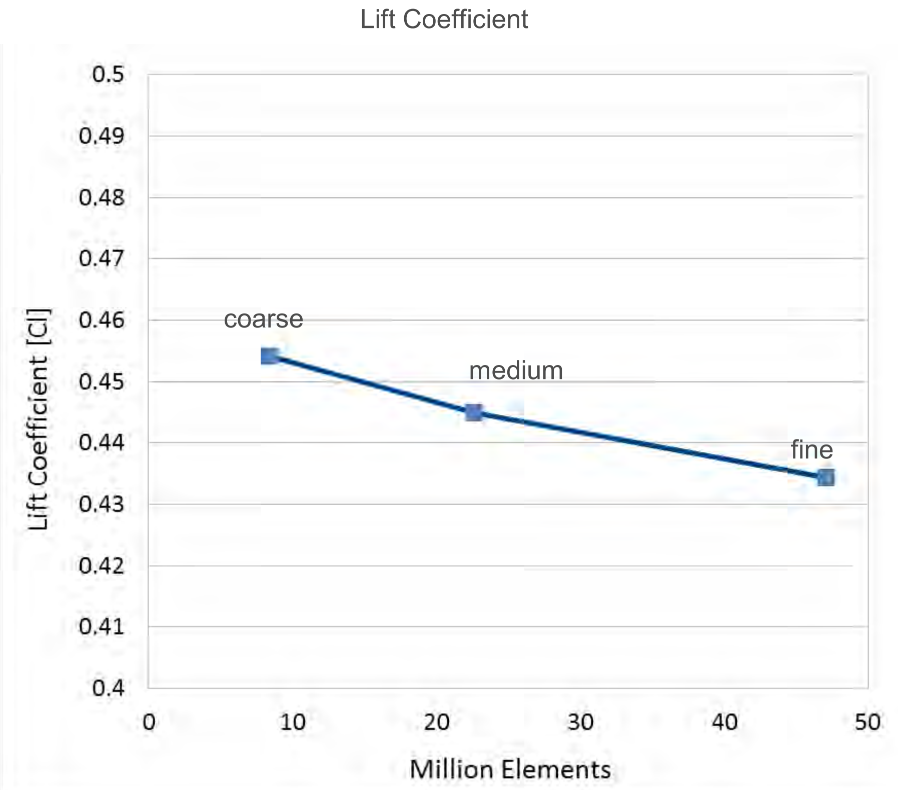
Uy unsteady flow-field at plane cutting the landing gear main strut





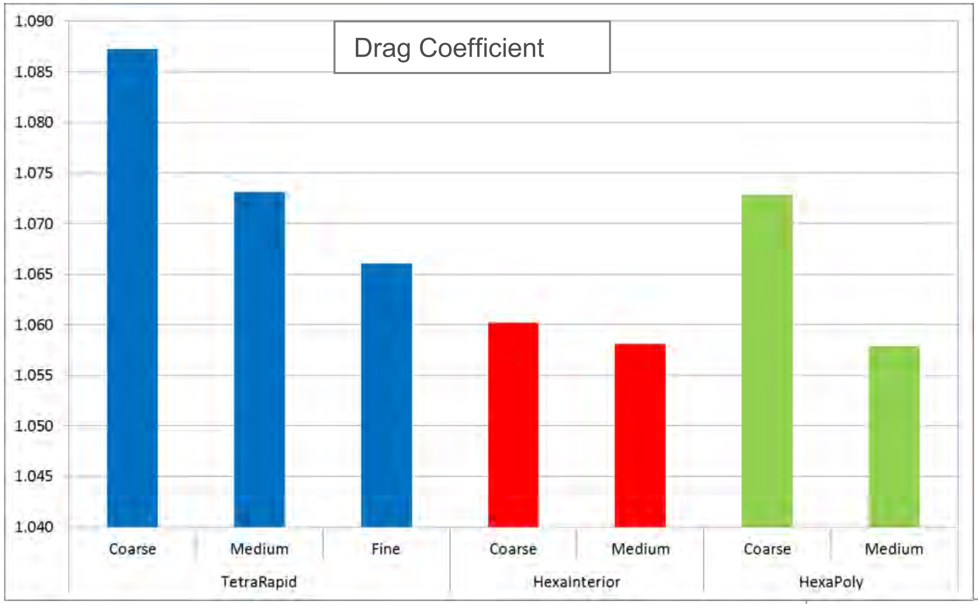
Mesh refinement results for Tetra Low Re layer meshes

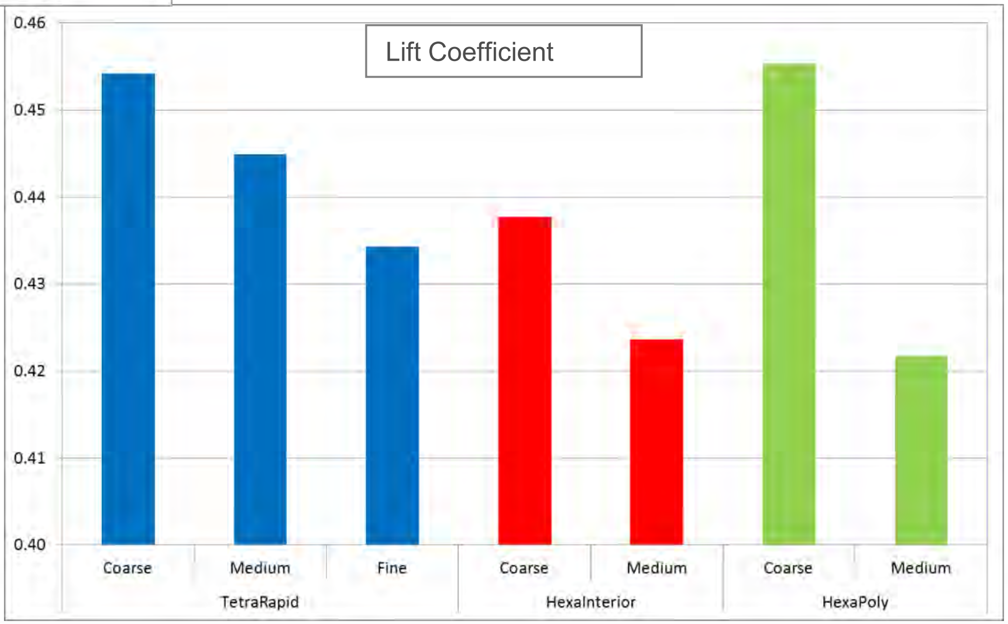




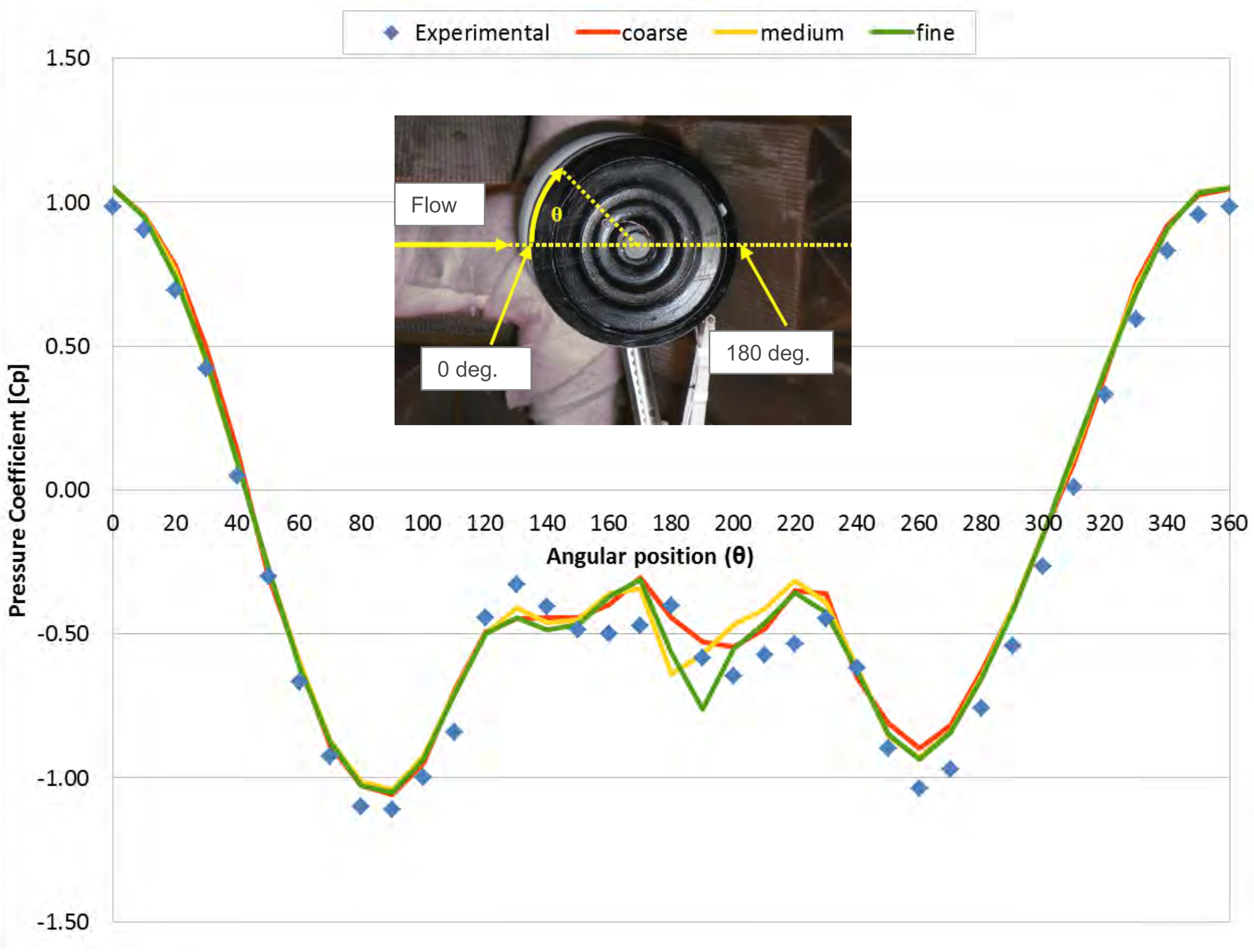
Coefficients calculated based on projected frontal area = 0.03205 m^2

Force prediction of different type Low Re layer meshes

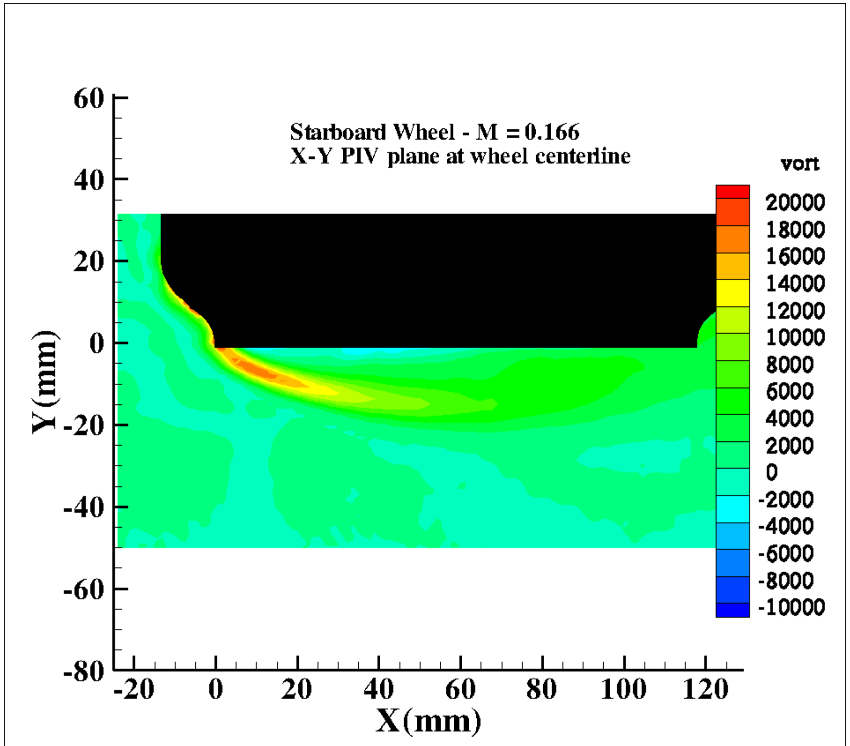


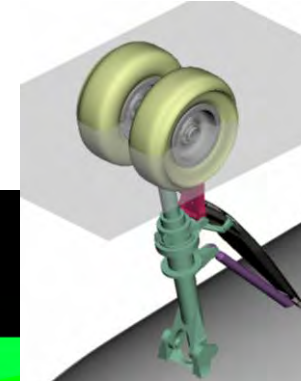


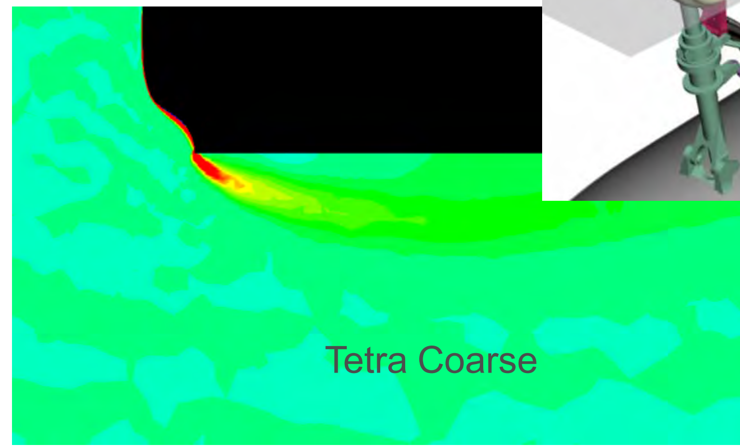
Comparison with experiment: Cp around wheel for Low Re Tetra

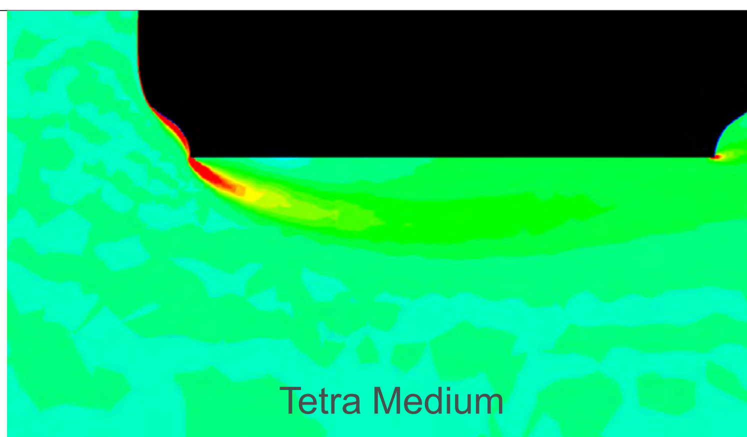


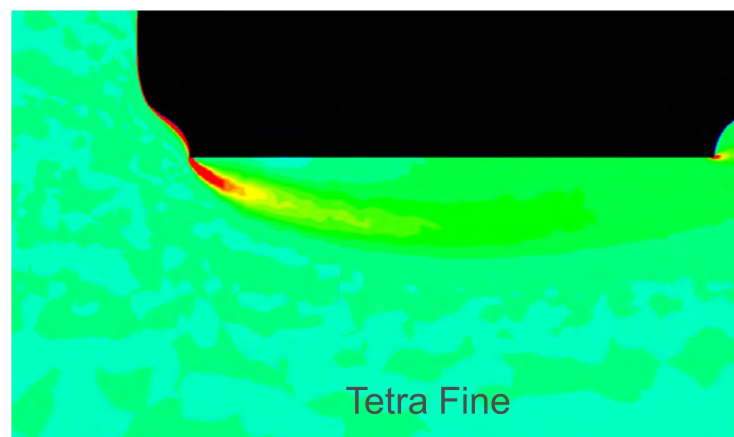
Comparison with experiment: z-vorticity at wheel axis plane



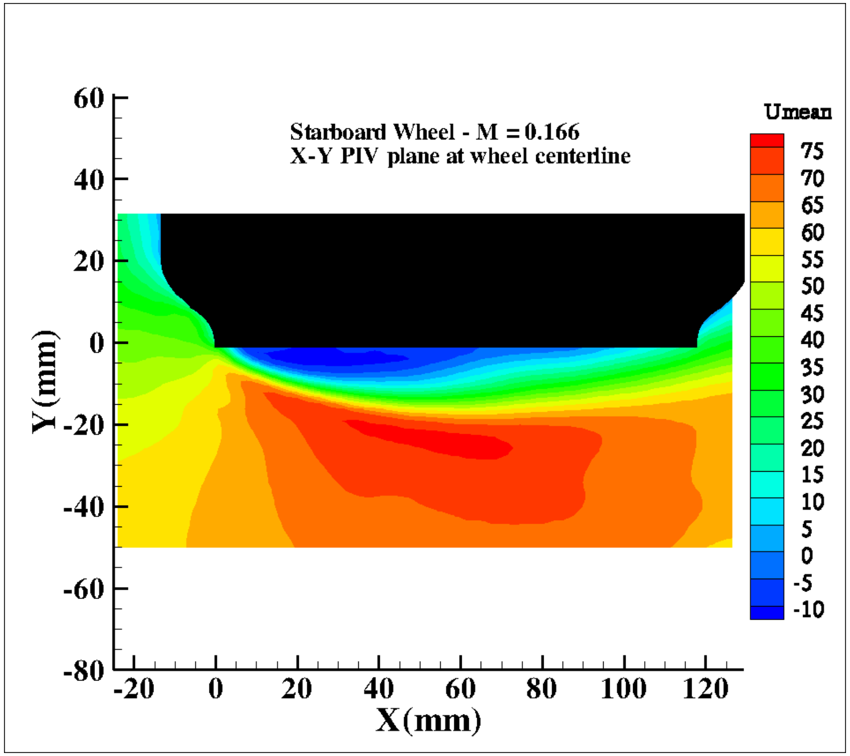


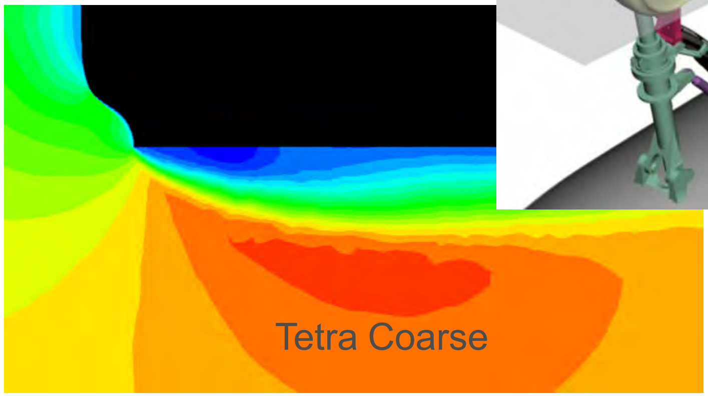


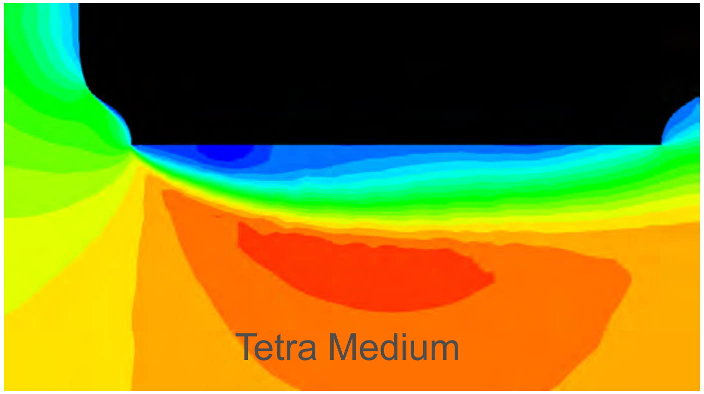


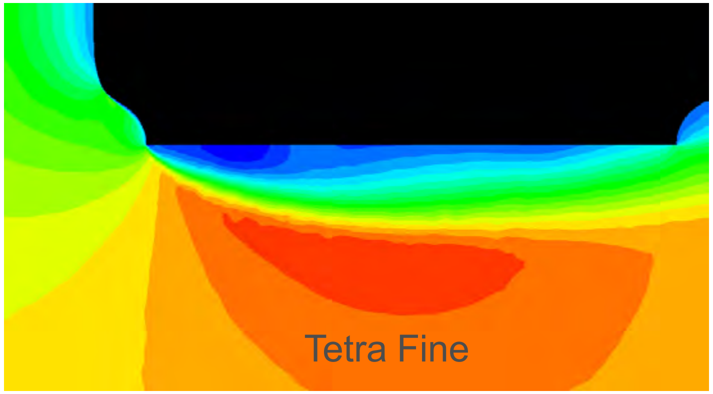


Comparison with experiment: Ux velocity at wheel axis plane

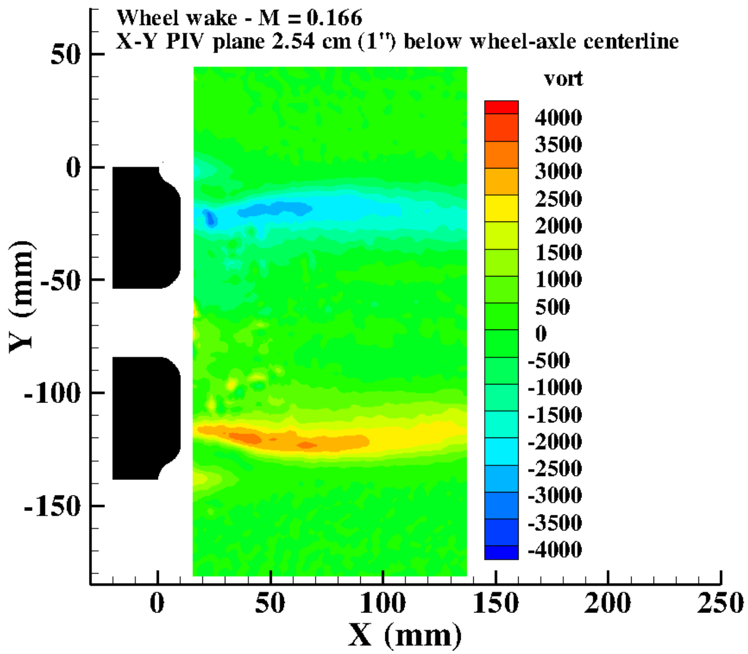


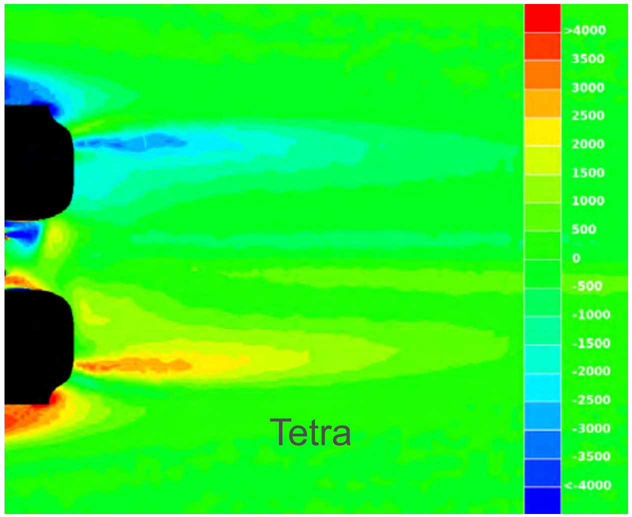


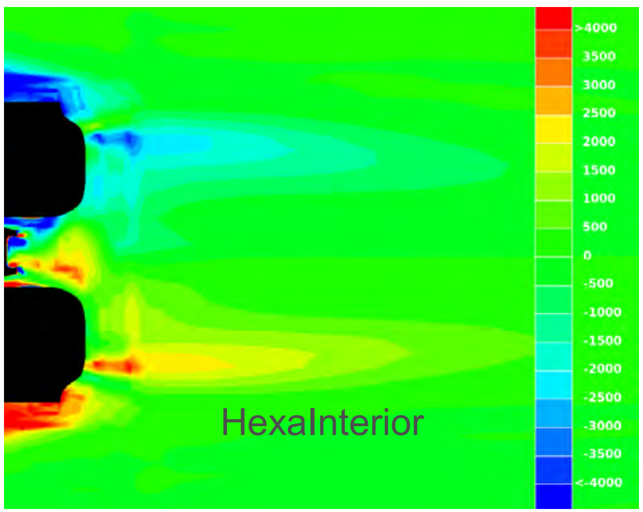


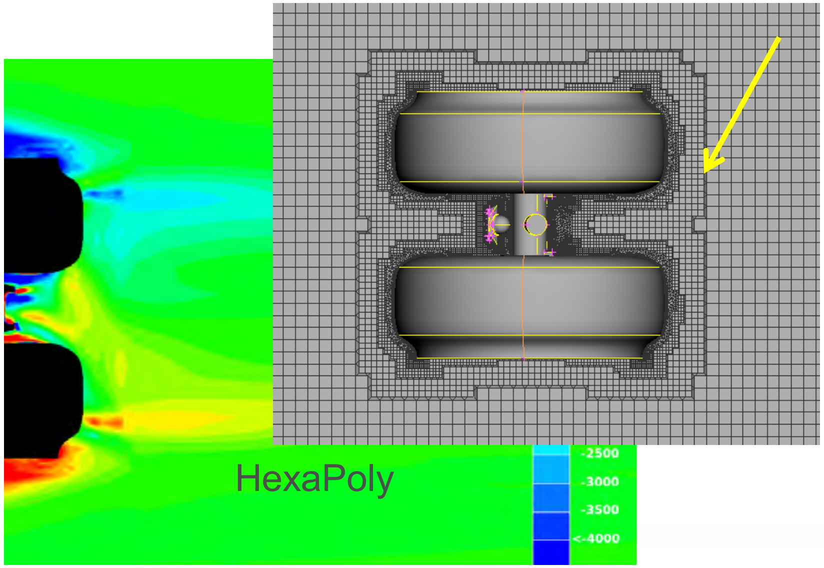


Comparison with experiment: z-vorticity at 1” below axis plane









Conclusions and future work

- ANSA powerful pre-processing for OpenFOAM was demonstrated with key points like:
  - Effective geometry handling for the creation of watertight geometries
  - High quality automated surface and volume meshing meeting OpenFOAM quality criteria
  - High quality generation of low Re type boundary layers on complex geometries
  - Ability to generate various types of volume meshes
  - Built in interface to setup ready to run OpenFOAM cases
- μETA provides powerful automated post-processing for CFD and integrates with ANSA as a complete pre and post-processing solution for OpenFOAM
- Low Re layer meshes predict small separation areas that cannot be predicted from other meshes. On the corresponding model however that displays bluff body aerodynamics with massive recirculation areas which dominate the drag forces, these seem to have small effect.
- All Low Re meshes predicted similar results regardless of density and type to within 3%
- The model selected in this study has a transient flow field and therefore the current steady state approach cannot be expected to yield the best possible results
- Need to examine further the effect of 1:8 volume ratio of transition elements of hexa dominant mesh algorithms on the results
- This study will be repeated in a more thorough manner with a model that has better aerodynamic characteristics and steady state flow field, in order to establish the importance of the mesh on the accuracy of the results

Thank you for your attention!