

### Mesh study for external aerodynamics CFD simulations with OpenFOAM

Vangelis Skaperdas, Aristotelis Iordanidis BETA CAE Systems S.A.

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#### The BANC-I landing gear model

1/4 scale model of Gulfstream 550 aircraft nose gear



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
- $\mu$ ETA v6.8.2 for post-processing



#### Geometry preparation: STEP file input and separation of parts



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#### Geometry preparation: removal of unnecessary geometry





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#### Geometry preparation: closure of small gaps and proximities





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#### Batch Meshing setup: automation and consistency in meshing





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Complete

Unkno

Empty

New Read Scenario Autoload Run

- Surface Meshing

Layers Meshing

Default Session

L M Area 1

Color Contents Mesh Parameters Quality Criteria Status

8 CFD parameters CFD criteria

CFD criteri

CFD parameters

CFD parameters

12



#### Surface mesh details – coarse mesh 334k trias

Surface Mesh Fluent skewness<0.4







### **Surface mesh: proximity refinement**





### **Surface mesh: proximity refinement**



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#### Mesh treatment of narrow thickness faces





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#### **Boundary layer generation**



Hi Reynolds layers first height 20% of local length growth rate = 1.26 layers

Low Reynolds layers first height 0.01mm growth rate = 1.26 layers in absolute +6 layers in aspect mode last aspect ratio = 0.3



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#### **Boundary layer generation: 100% area coverage**



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#### Boundary layer generation: collapsing of layers at proximities





#### Boundary layer generation: details of Hi and Low Re meshes



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## Boundary layer generation: details of Hi and Low Re meshes



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#### Mesh refinement study for Low Re layer tetra case



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#### **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 E	MIN	Value					
		0						
	ID of El	MAX Value						
		3675472			4	37		
		Class			No of Elements	Perc(%)		
1	From: 0 To: 1				8236958	97.6		
2	From:	109609	1.2					
3	From:	87140	1.0					
4	From:	5032	0.059					
5	From:	4	To:	10	54 0.00063			
		8438793						

OpenFOAM Non Orthogonality								
	ID of El	MIN	Value					
		0						
	ID of El	MAX Value						
		70	.18					
		Class			No of Elements Perc(%)			
1	From:	0	To:	18	2344964	27.7		
2	From:	18	To:	4859012	57.5			
3	From:	1233095	14.6					
4	From:	1720	0.020					
5	From:	70	To:	90	2 2.37001e-0			
		8438793						



#### Setup of OpenFOAM cases in ANSA

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6	tunnel top	symmetryPlane	29	4 1	L		maxDeltaT			
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	and the second se				±					
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#### **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
	р	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**



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



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#### **Effect of boundary layers – Tetra Coarse case**









#### Velocity magnitude at centre line plane for Low Re layer meshes



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



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















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



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#### Mesh refinement results for Tetra Low Re layer meshes



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#### Force prediction of different type Low Re layer meshes





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#### **Comparison with experiment: Cp around wheel for Low Re Tetra**





#### Comparison with experiment: z-vorticity at wheel axis plane







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#### Comparison with experiment: Ux velocity at wheel axis plane







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

Wheel wake - M = 0.166 X-Y PIV plane 2.54 cm (1") below wheel-axle centerline









#### **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!