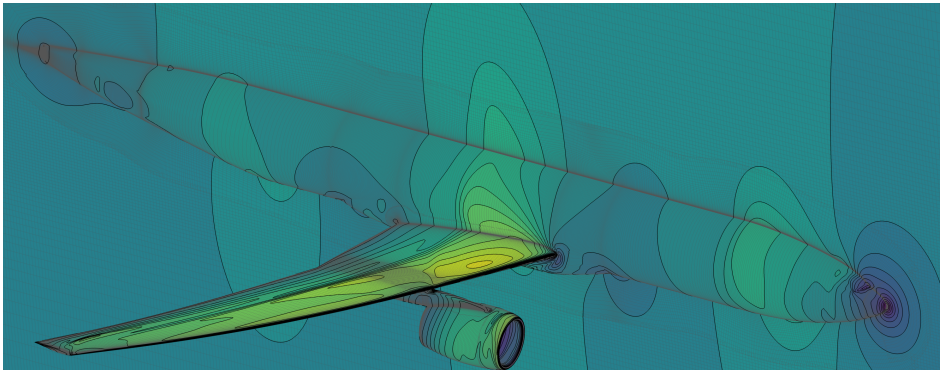


Drag Prediction Workshop VI: SUMad Results

Gaetan K. W. Kenway, Ney Secco and Joaquim R. R. A.
Martins

June 16th, 2016



Test Cases

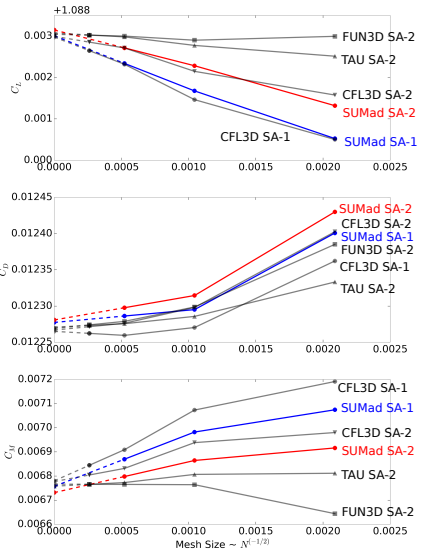
- Case 1: Verification Study 2D NACA0012 airfoil
- Case 2: CRM Nacelle-Pylon Drag Increment
- Case 3: Wing-Body Static Aero-elastic Effect

Flow Solver: SUMad

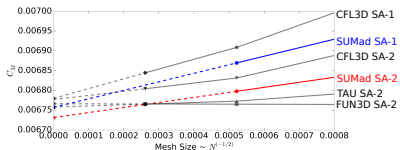
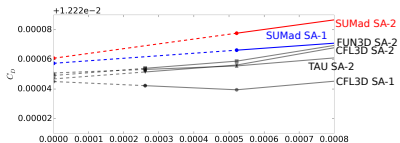
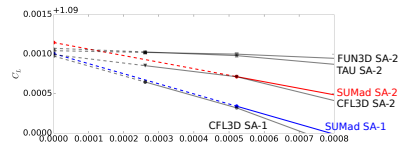
- Structured multi-block solver with overset capability
- Second-order finite volume method
- Implicit hole cutting approach with zipper mesh for force integration
- Central scheme with scalar/matrix JST dissipation
- Three solution algorithms:
 - Explicit Runge–Kutta
 - Diagonally dominant Alternating direction implicit (DDADI)
 - Fully coupled Newton–Krylov
- Spalart–Allmaras (SA) 1-equation model

Case 1 - 2D NACA 0012 airfoil

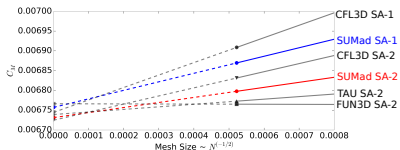
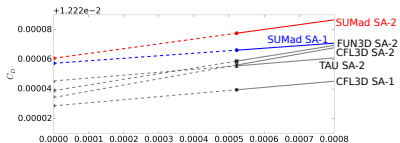
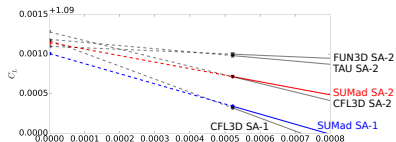
- TMR Family II grids
- First and second order SA turbulence model
- Linear wall pressure extrapolation
- Converged results for Levels 2-7



Converged results are within range of other codes, except for drag

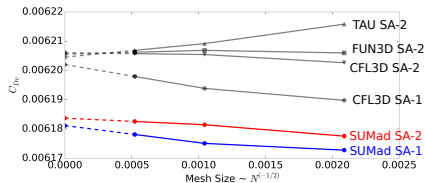
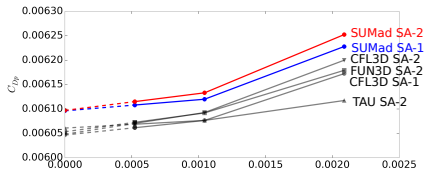
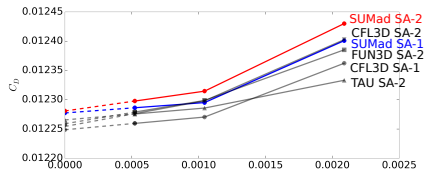


With Level 1

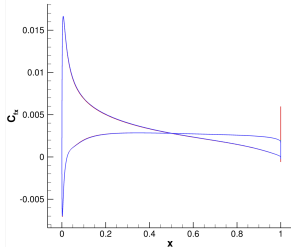
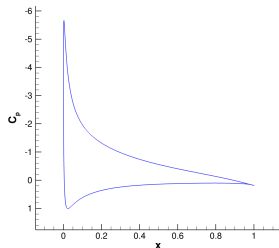
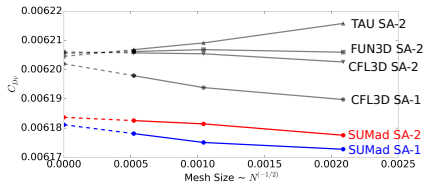
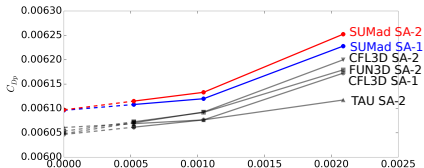
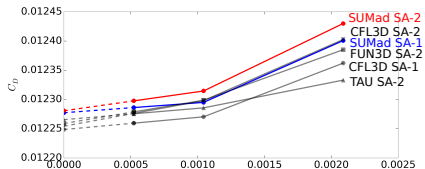


Without Level 1

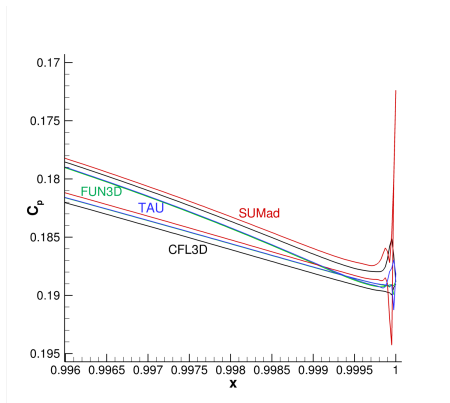
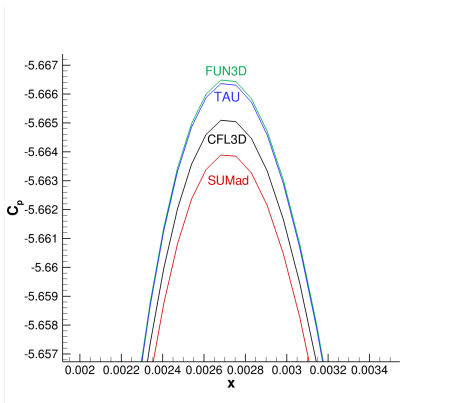
Differences in drag components cancel each other



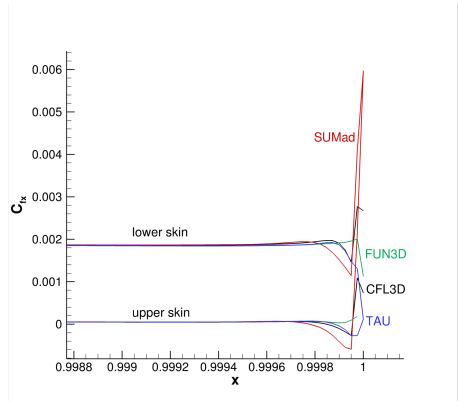
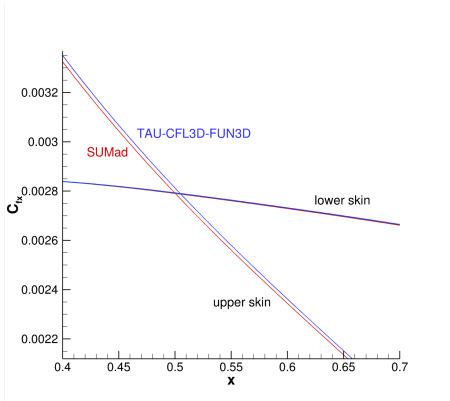
Differences in drag components cancel each other



Underestimate of pressure at trailing edge

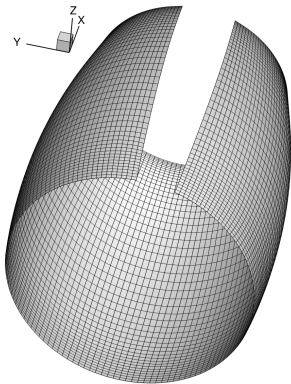


C_f underestimated over 60% of the upper skin

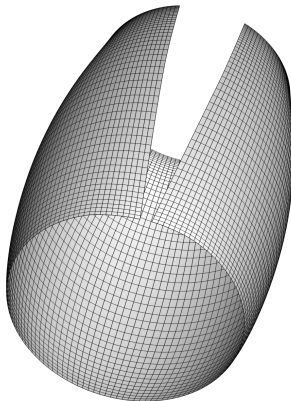


Overset Grid Information

- Most near-field surface meshes are identical to Boeing overset grids
- Surfaces re-extruded using in-house hyperbolic generator
- Background meshes are identical except for pylon block
- WB mesh blocks are a subset of WBNP mesh blocks



Original



Modified

Grid Size Information

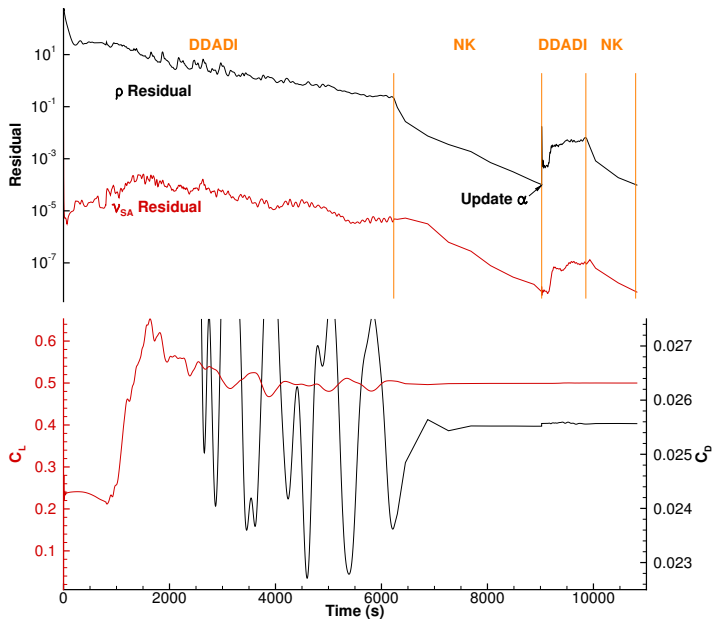
Overset: Cell counts not consistent with guidelines, but are consistent with Boeing meshes

Grid	WBNP Cells	WB Cells	WB $N^{-2/3}$	1 st cell size	Ratio
Tiny	11 560 960	7 159 808	2.69×10^{-5}	0.001478	1.204
Coarse	22 287 600	13 984 000	1.72×10^{-5}	0.001182	1.159
Medium	38 498 688	24 164 352	1.20×10^{-5}	0.000985	1.131
Fine	60 980 304	38 372 096	8.79×10^{-6}	0.000739	1.111
XFine	91 896 832	57 278 464	6.72×10^{-6}	0.000657	1.096

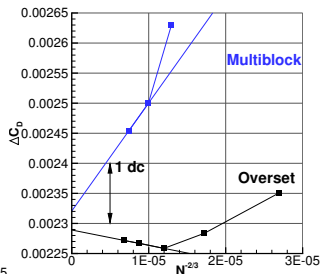
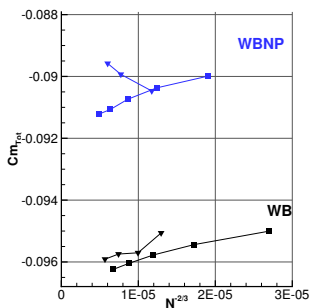
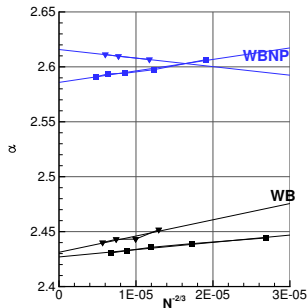
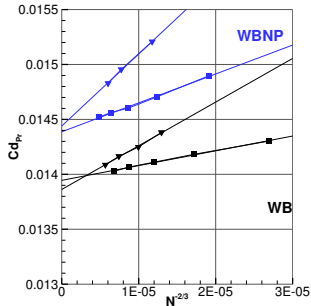
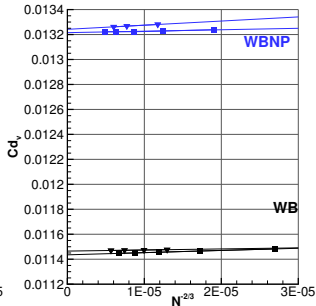
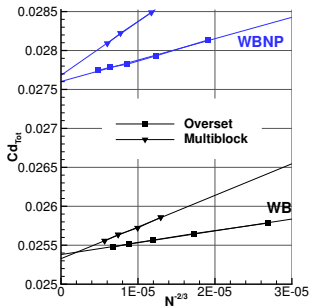
MB: Cell counts consistent with gridding guidelines
Meshes are slightly modified CFSE WBNP meshes and Embraer WB meshes

Grid	WBNP Cells	WB Cells	WB $N^{-2/3}$	1 st cell size	Ratio
Tiny	24846784	21437440	1.29×10^{-5}	0.001481	1.166
Coarse	46554752	31825920	9.96×10^{-6}	0.001288	1.133
Medium	62274880	49437824	7.42×10^{-6}	0.001120	1.111
Fine	-	74136448	5.67×10^{-6}	0.000974	1.096
XFine	-	110932736	4.33×10^{-6}	0.000847	1.085

Convergence Behavior for Overset WB Medium Mesh



Grid convergence



Overset Side of Body Mesh

Tiny



Coarse

Medium

Fine

XFine

Tiny



MB Side of Body Mesh

Tiny



Coarse



Medium



Fine



XFine



Tiny



Bubble behavior of Overset WB meshes

Tiny

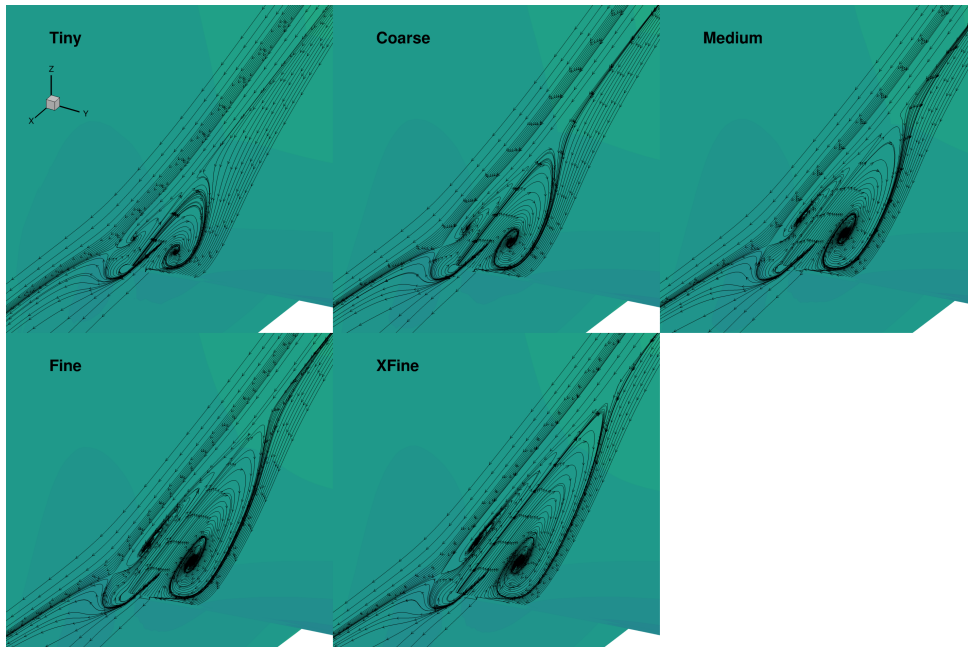


Coarse

Medium

Fine

XFine



Bubble behavior of Multiblock WB meshes

Tiny

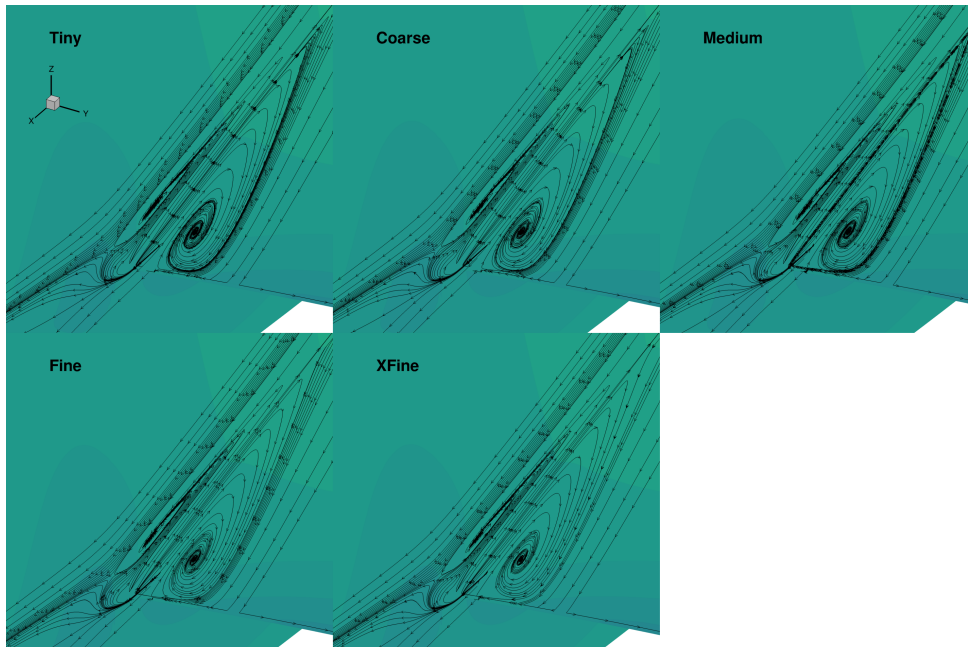


Coarse

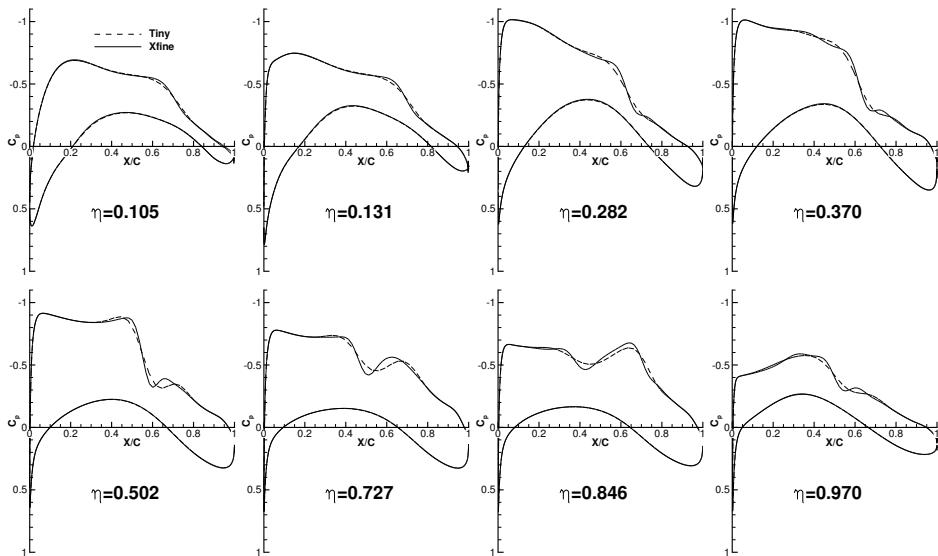
Medium

Fine

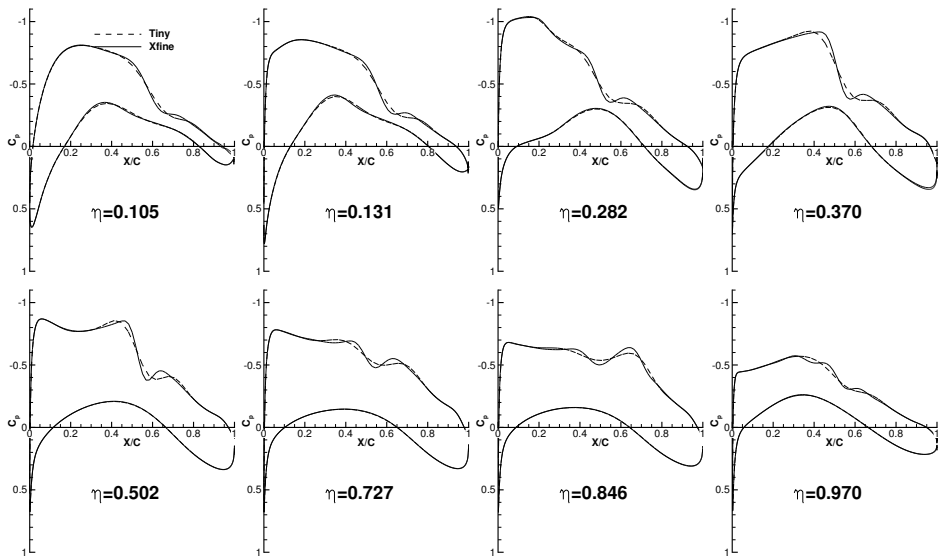
XFine



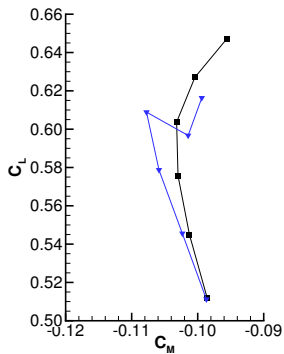
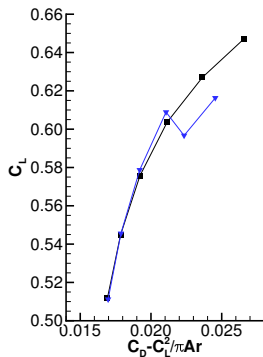
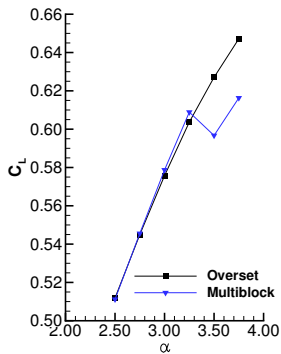
C_P for WB Overset Grids



C_P for WBNP Overset Grids



Case 3: Drag Polar



Case 3: Bubble Growth, Overset Meshes

$\alpha=2.75^\circ$



$\alpha=3.00^\circ$



$\alpha=3.25^\circ$



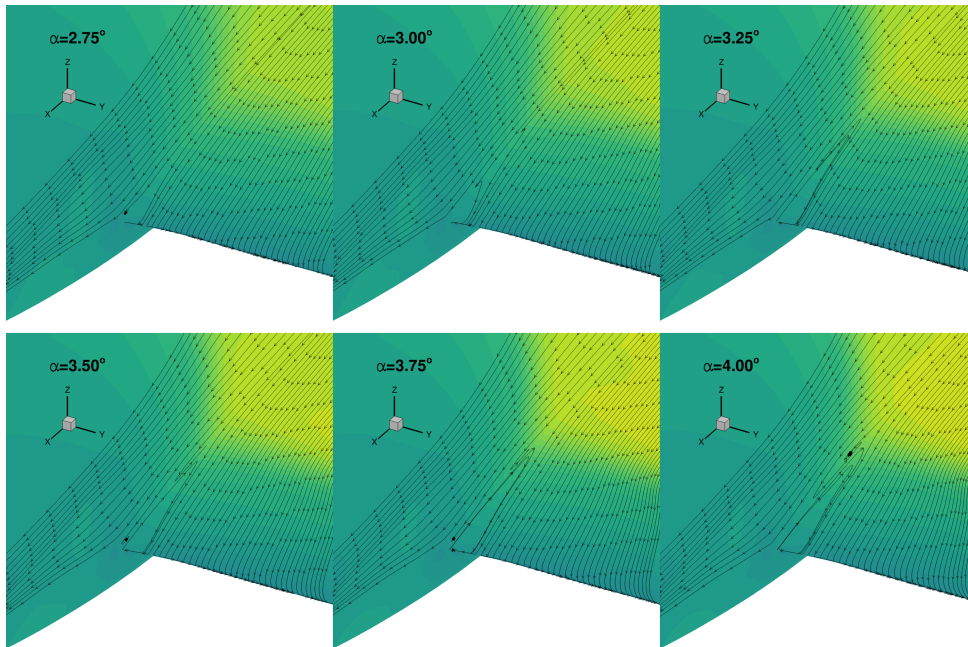
$\alpha=3.50^\circ$



$\alpha=3.75^\circ$



$\alpha=4.00^\circ$



Case 3: Bubble Growth, Multiblock Meshes

$\alpha = 2.75^\circ$



$\alpha = 3.00^\circ$



$\alpha = 3.25^\circ$



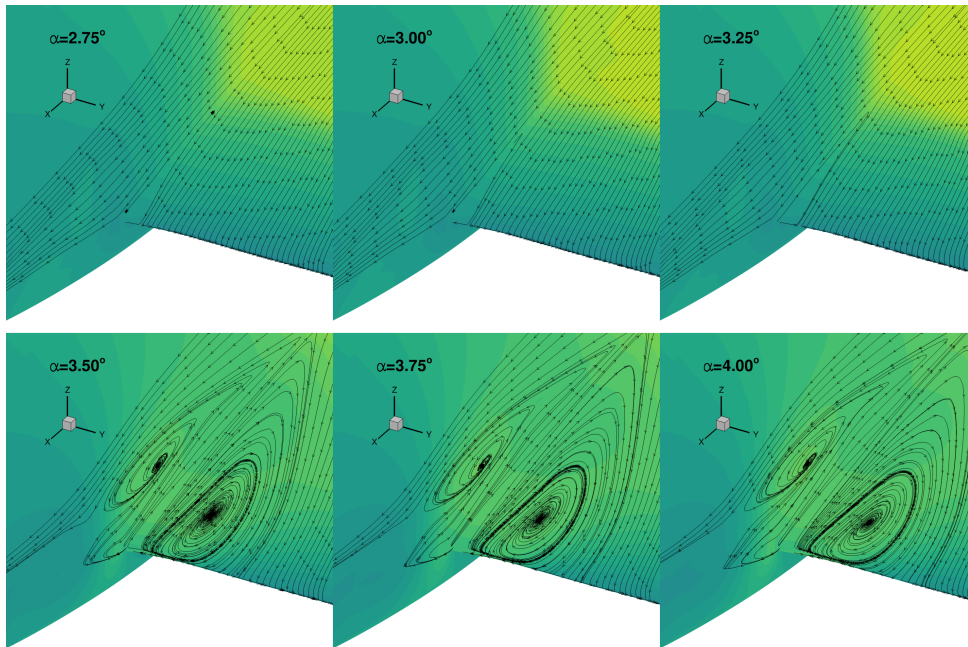
$\alpha = 3.50^\circ$



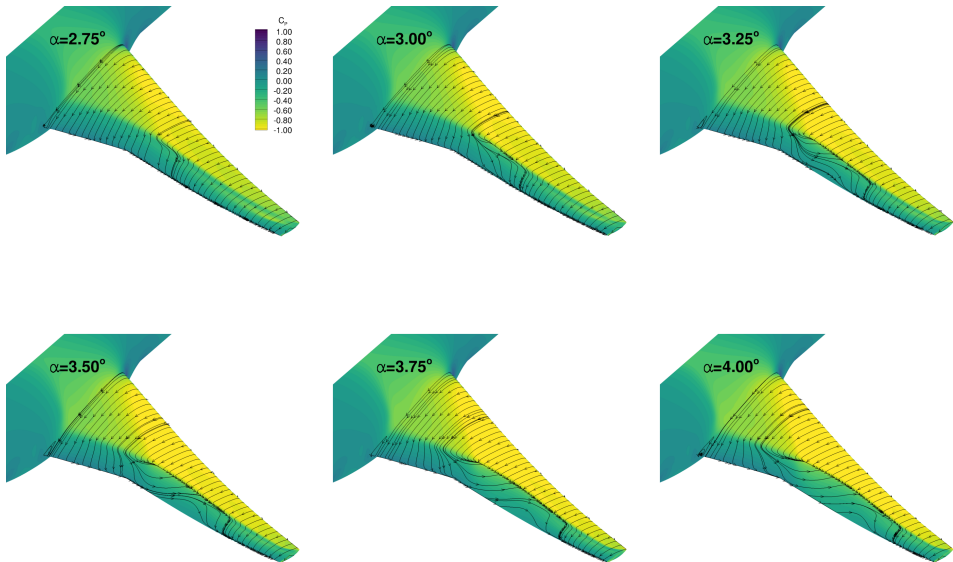
$\alpha = 3.75^\circ$



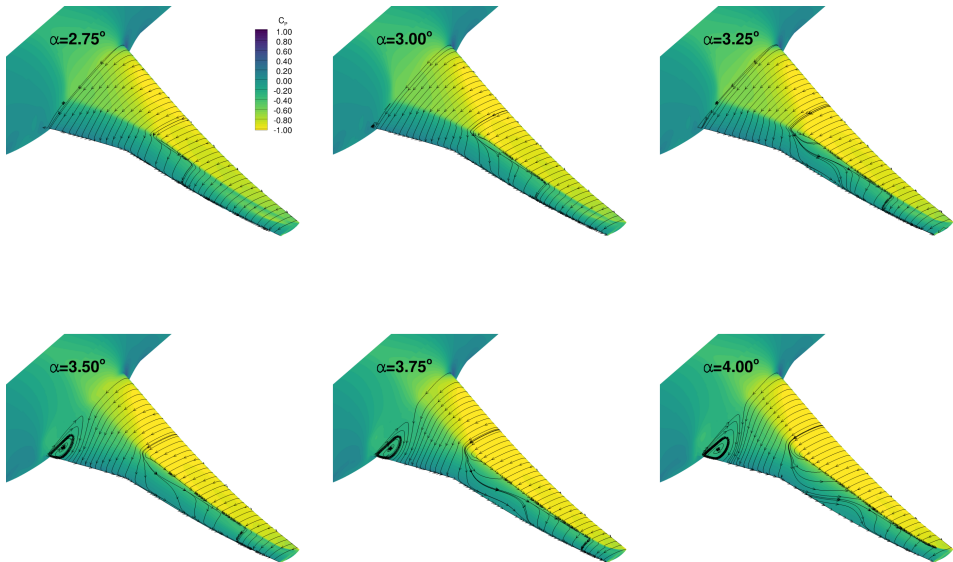
$\alpha = 4.00^\circ$



Case 3: Separation, Overset Meshes



Case 3: Separation, Multiblock Meshes



- Case 1
 - Similar overall trends
 - Slight discrepancy in pressure and viscous drag components
- Case 2
 - Overset grids show expected convergence trends
 - Multiblock meshes have higher drag values
 - Drag increment values are better predicted with the overset meshes
- Case 3
 - No large separation bubble on medium overset meshes
 - Multiblock mesh shows larger separation bubble at $\alpha \geq 3.5^\circ$

Questions

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`mdolab.engin.mich.edu`

