DLR Results of the Sixth AIAA Computational Fluid Dynamics Drag Prediction Workshop

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Introduction
- Computational Grids -

Name	WB		WBNP		Δy_1 / [in]
	GG	*SOLAR*	*GG*	*SOLAR*	
Tiny (T)	~20	7.15	25-30	11.8	0.001478
Coarse (C)	~30	14.1	40-45	23.2	0.001285
Medium (M)	~45	26.8	60-70	44.9	0.001118
Fine (F)	~70	39.7	85-100	81.1	0.000972
Extra Fine (X)	~100	×	130-150	×	0.000845
Ultra Fine (U)	~150	×	190-225	×	0.000735

Grid Size Factor: ~1.9×

- **Started Grid Generation from Fine (F) Level.**
- **Derived coarser Grids through scaling of Sources, Factor $1/1.5^{1/3} = 0.873\ldots$**
- **Generated Meshes compliant to Gridding Guidelines, two Exceptions:**
  - **Wing & Nacelle TE Base >> 8 Cells reduced (2 Cells inboard, 7 Cells outboard).**
  - **Wing spanwise Spacing increased from < 0.1%×Semi-Span at Root/Engine to ~0.34%.**

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Introduction
- Test Cases, Grids & Turbulence Models -

Config.	Grid	Case 2	Case 3	Case 5
WB	T	SA-neg, RSM-ω	--	--
	C	SA-neg, RSM-ω	--	--
	M	SA-neg, RSM-ω	SA-neg, RSM-ω	SA-neg
	F	SA-neg, RSM-ω	--	--
WBNP	T	SA-neg, RSM-ω	--	--
	C	SA-neg, RSM-ω	--	--
	M	SA-neg, RSM-ω	--	--
	F	SA-neg, RSM-ω	--	--

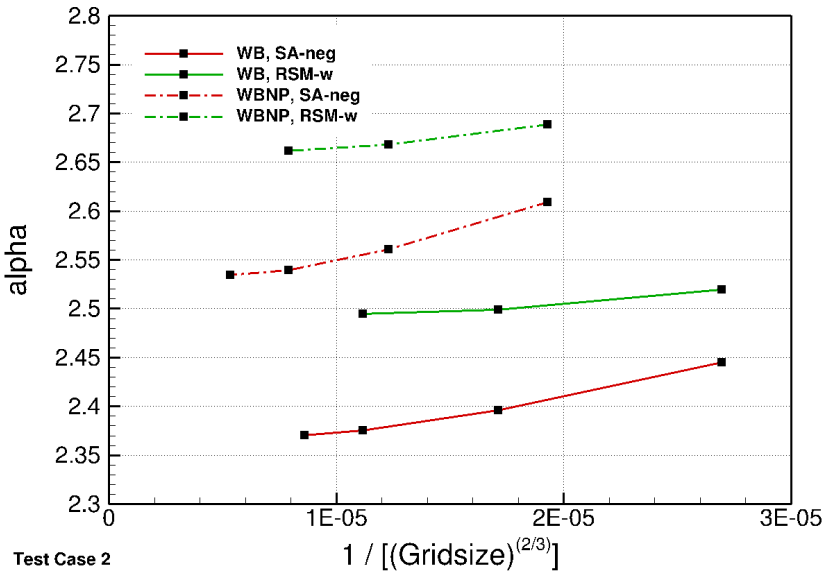
- **Slow Convergence with RSM-ω on fine Grids, not finished yet.**

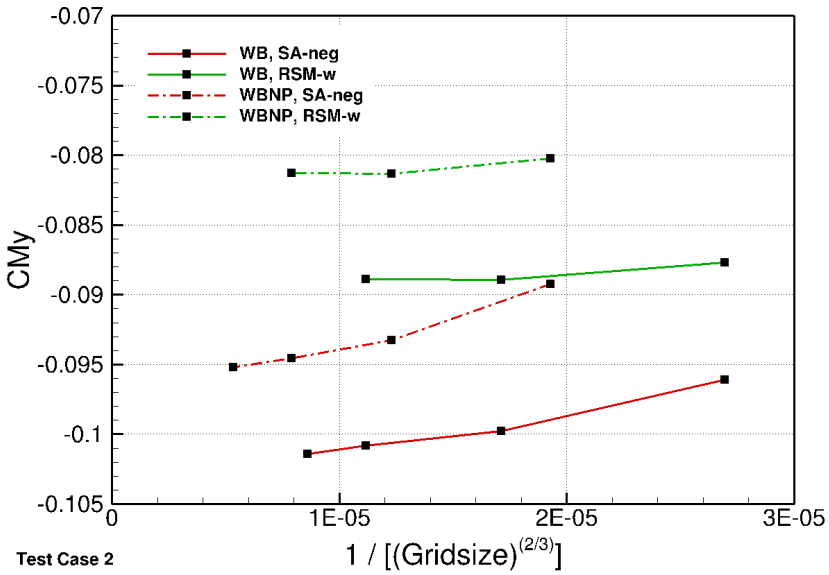
Introduction
- Flow Solver TAU -

- **Finite-Volume**
- **Node-centered**
- **LU-SGS Time Integration**
- **4w Multigrid Cycle**
- **Steady RANS**
- **Central spatial Discretization Scheme**
- **TAU Release 2015.2.0 with new Matrix Dissipation Formulation**

- **Turbulence Models:**
  - **Negative Spalart-Allmaras One-Equation Model (SA-neg), 2012**
  - **SSG/LRR-omega Full Reynolds Stress Model (RSM-ω), 2012**

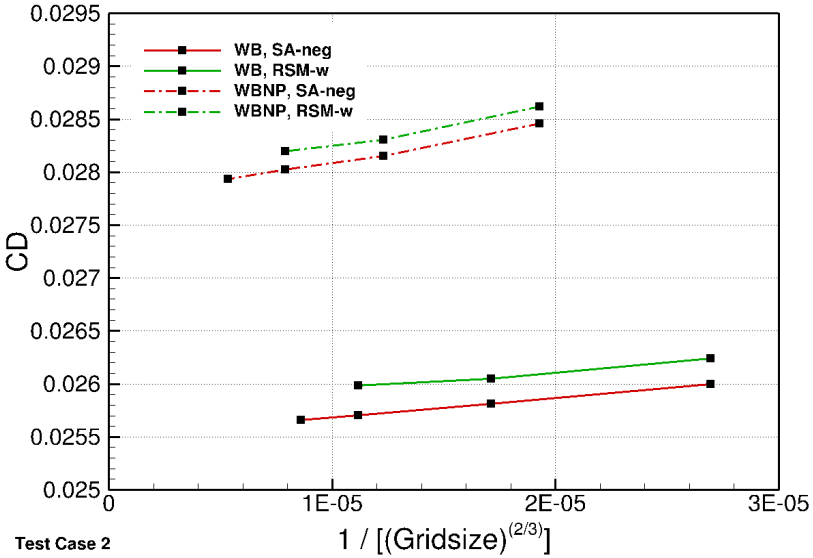
Case 2 - CRM Nacelle-Pylon Drag Increment

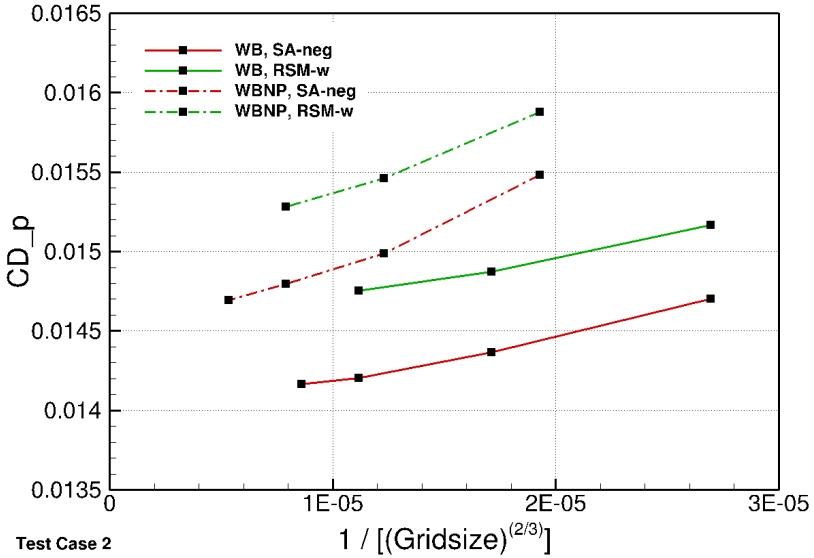


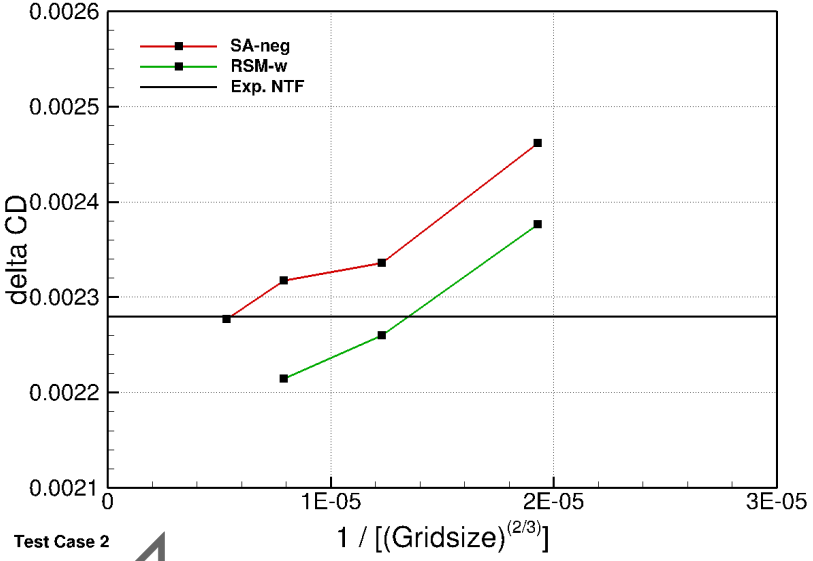


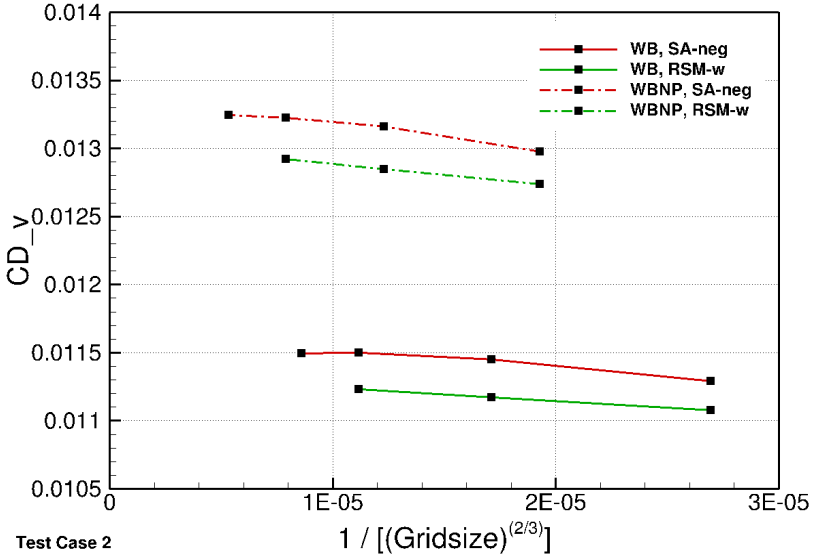
CFD Computations on all Grids fall within the specified Accuracy of C_L = 0.5+/-0.0001.

Case 2 - CRM Nacelle-Pylon Drag Increment









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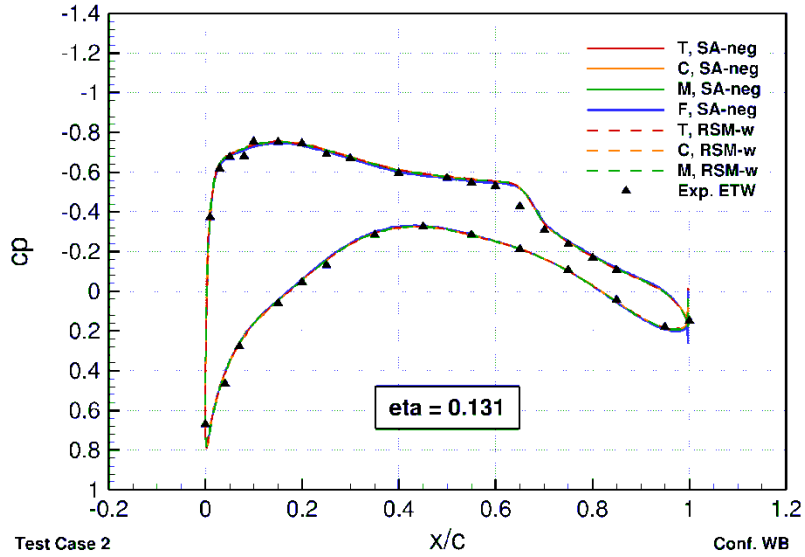
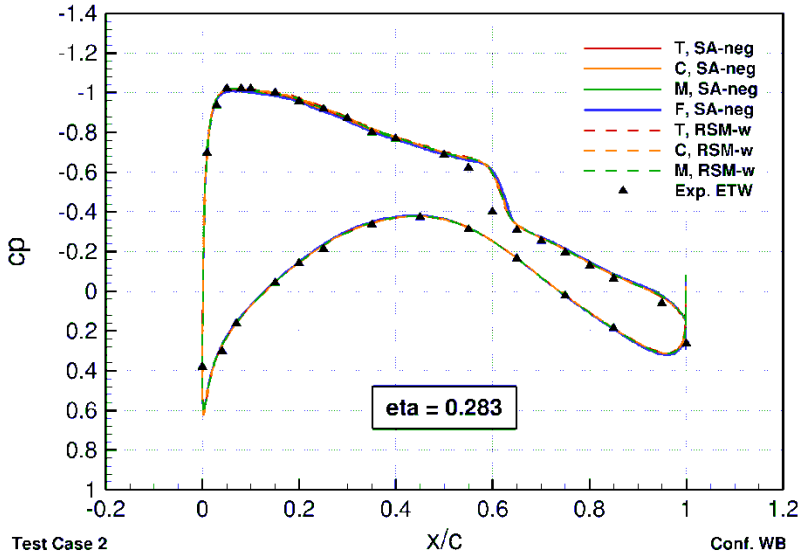
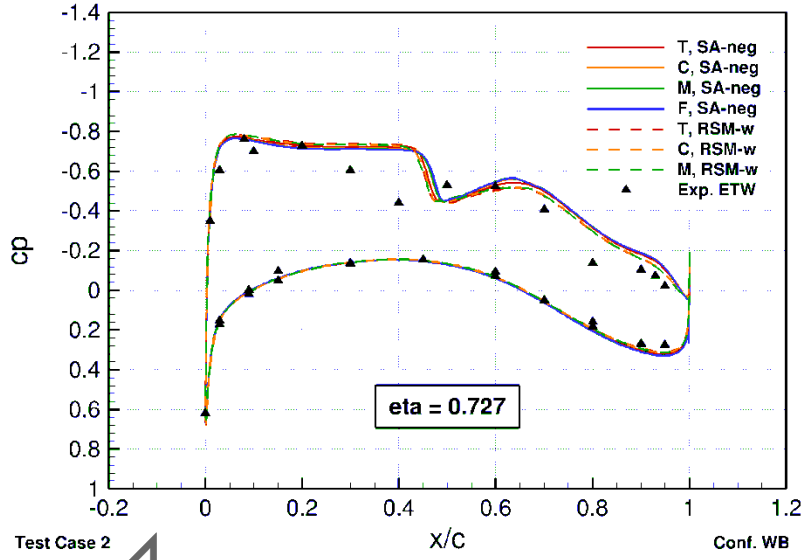
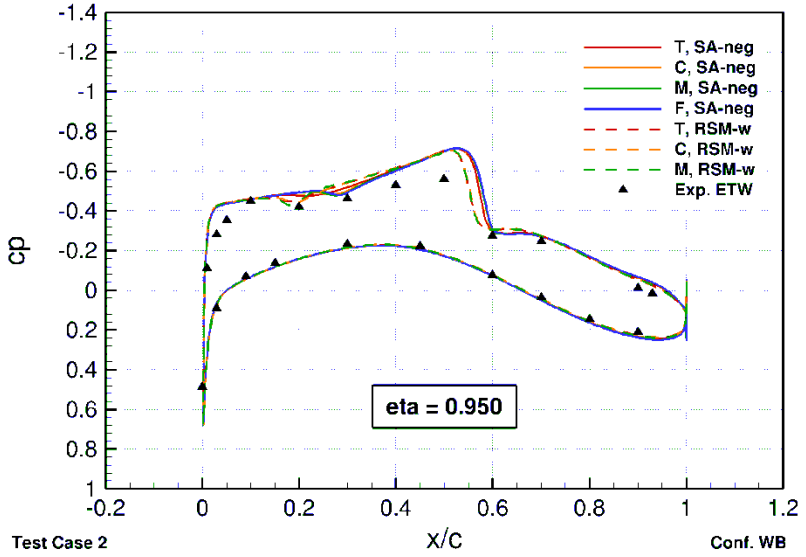
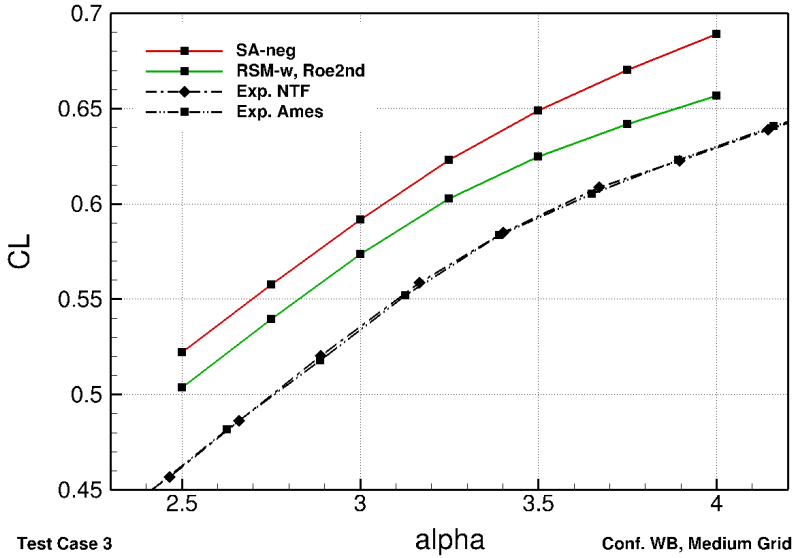


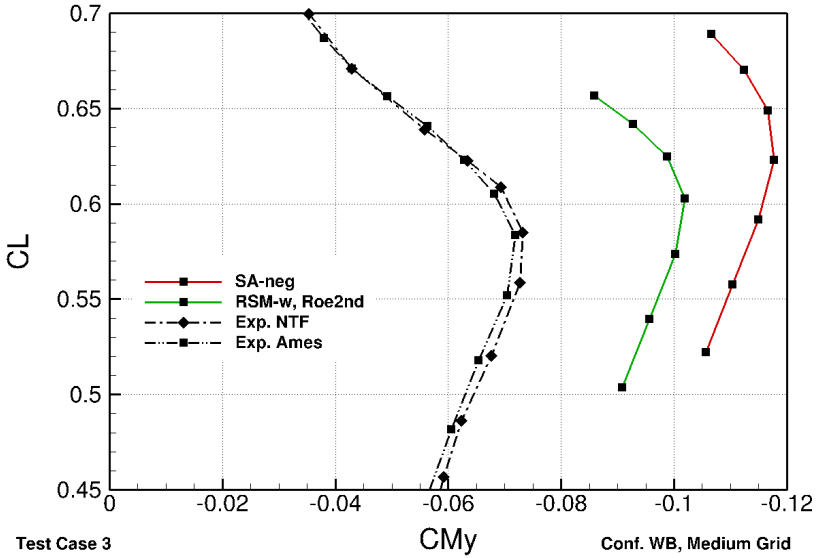


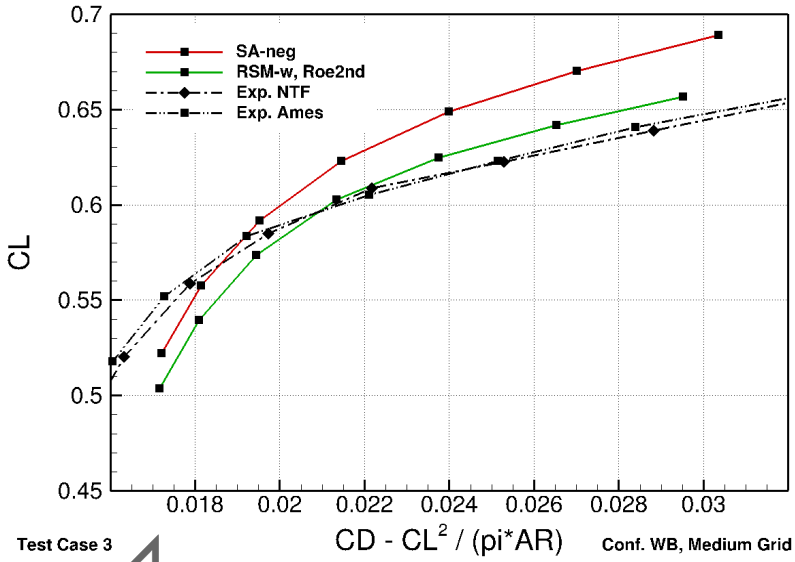


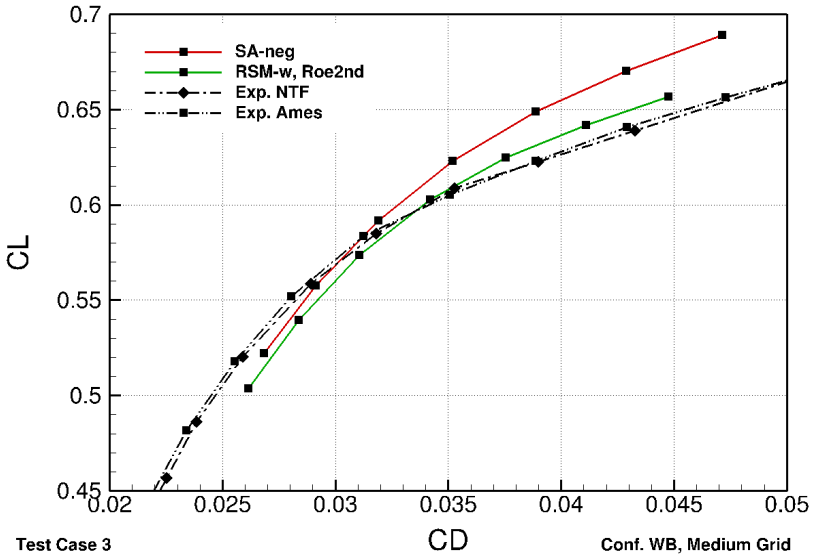


Case 3 - CRM WB Static Aero-Elastic Effect









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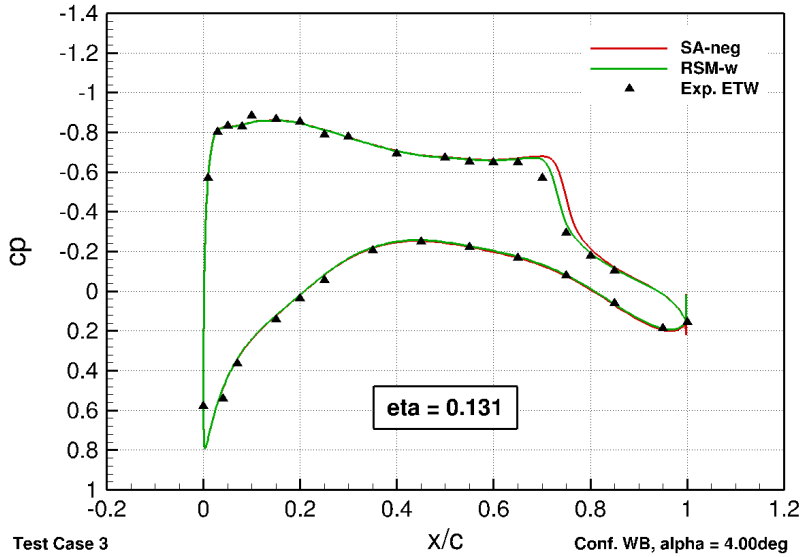
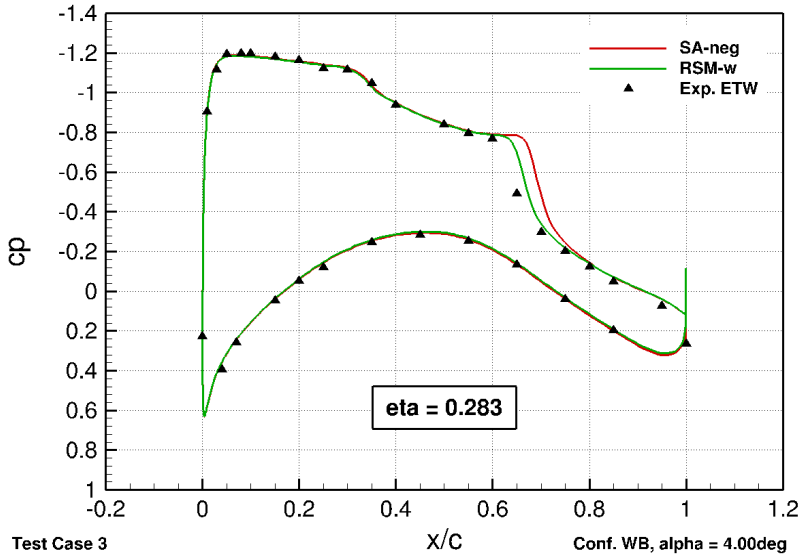
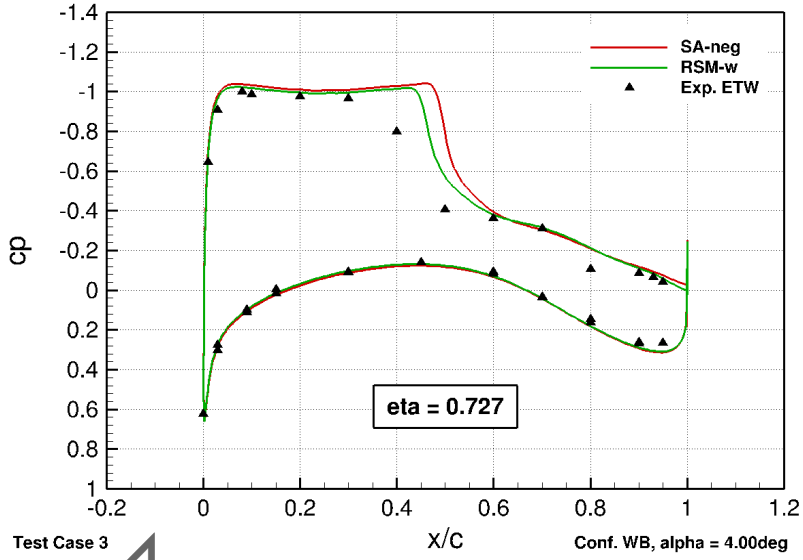
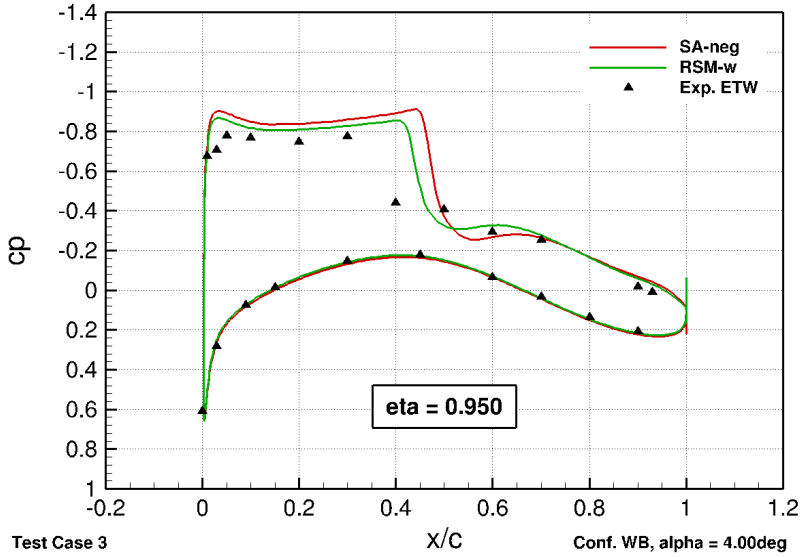


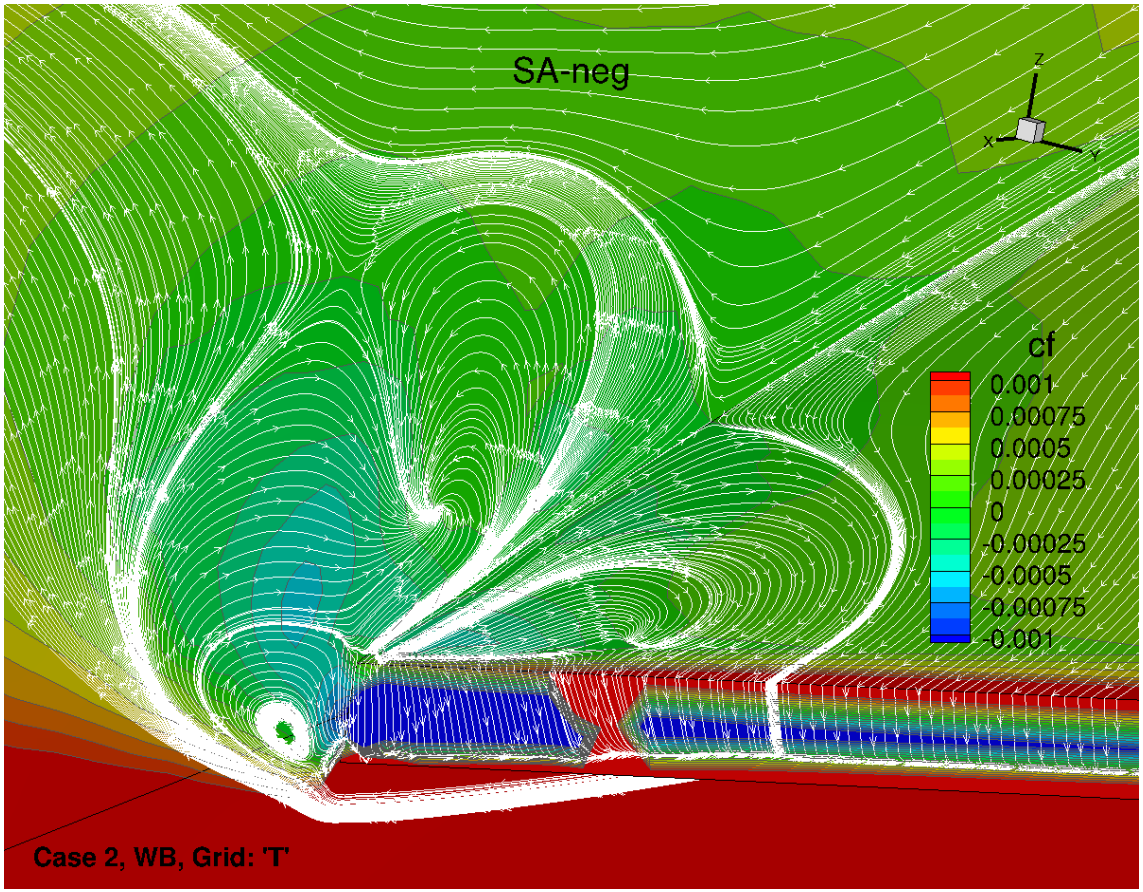






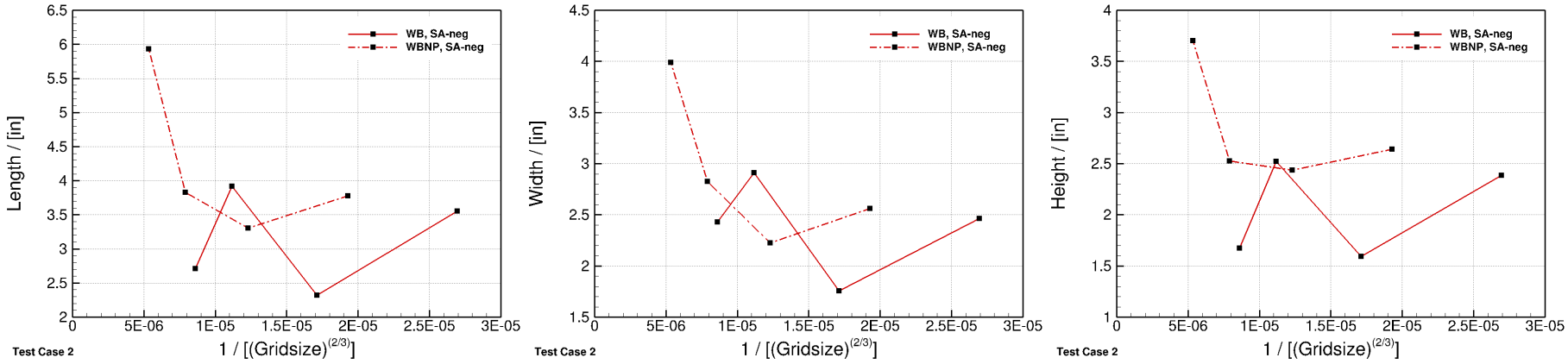
Side-of-Body Flow Separation
- Overview -

- **Predicted by linear Eddy Viscosity Models.**
- **Size reduced when taking into Account non-isotropic turbulent normal Stresses.**
- **Not found with k-ω or RSM Models.**
- **Size depends on:**
  - **numerical Dissipation,**
  - **Angle of Attack,**
  - **Grid Density,**
  - **…**



Side-of-Body Flow Separation

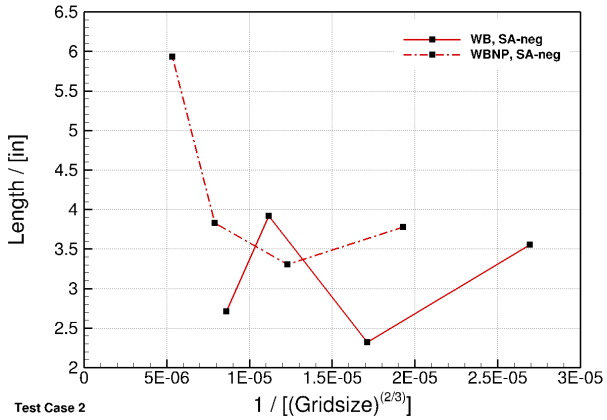
- Variation with Grid Size …

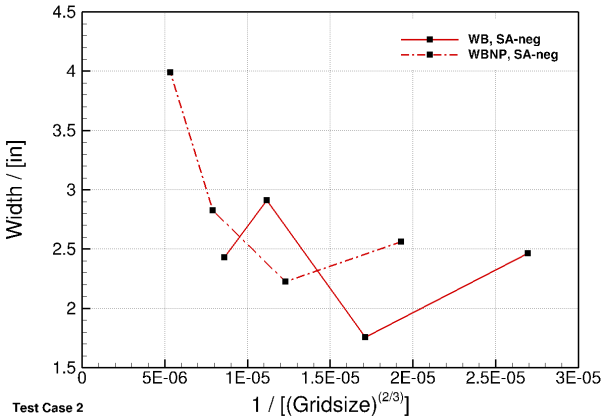


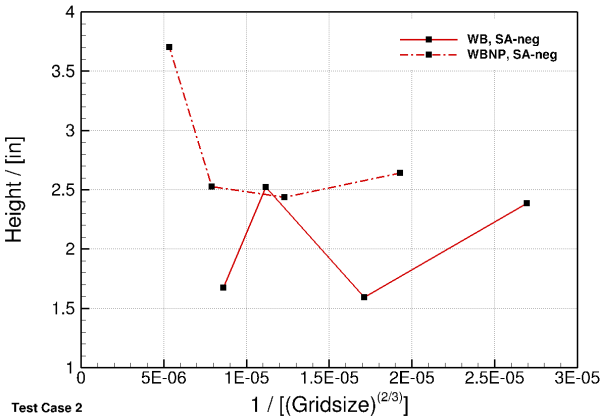
Separation Size increases for finer Meshes.

Side-of-Body Flow Separation

- Variation with Grid Size and Angle of Attack -







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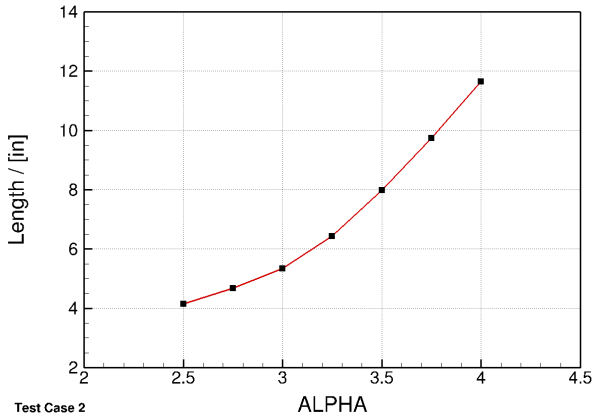
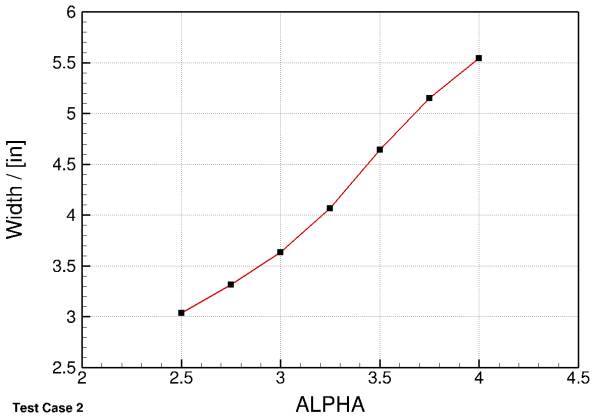
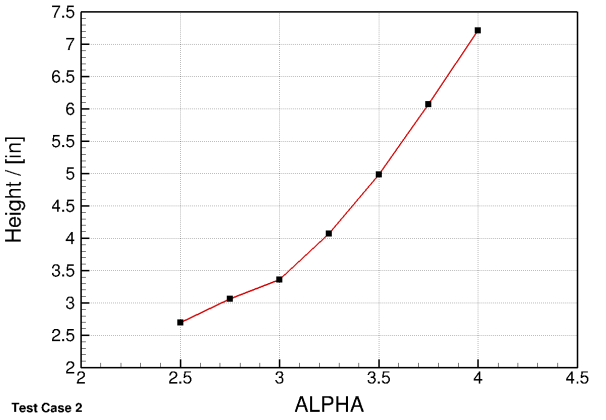
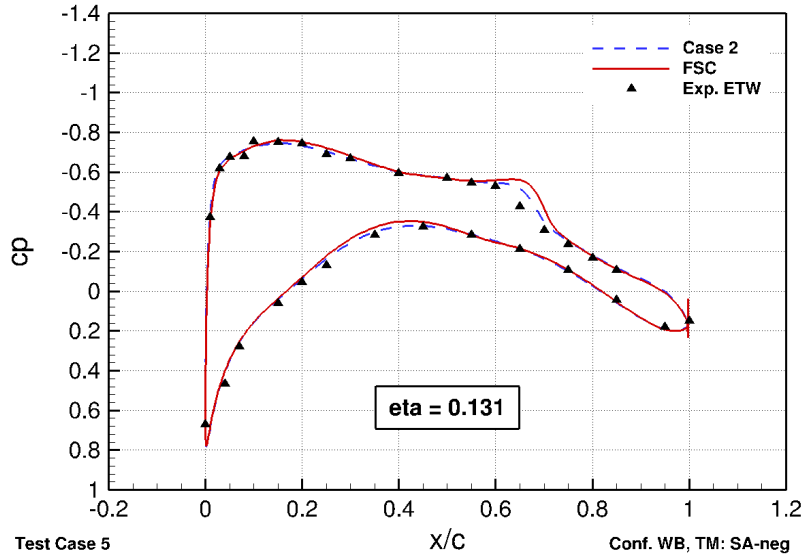


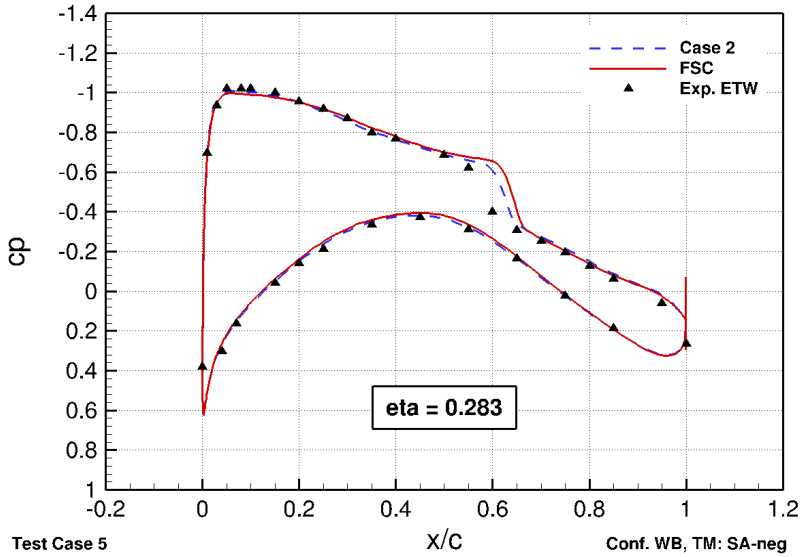


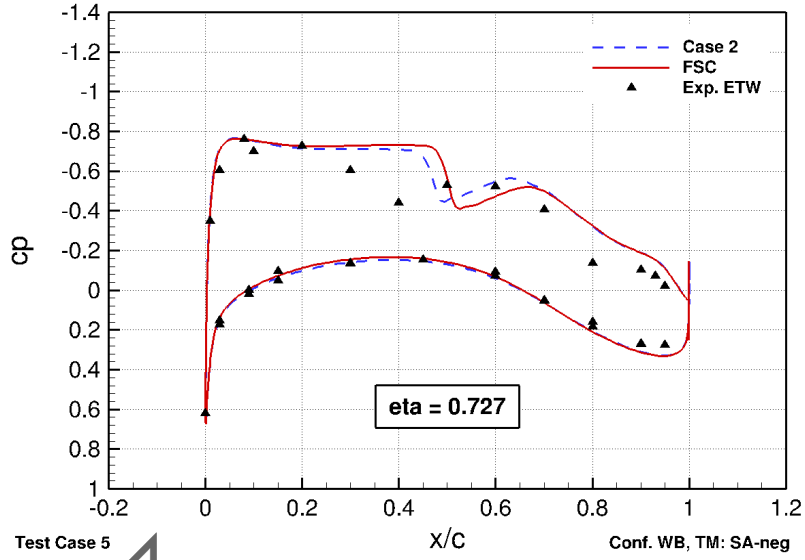


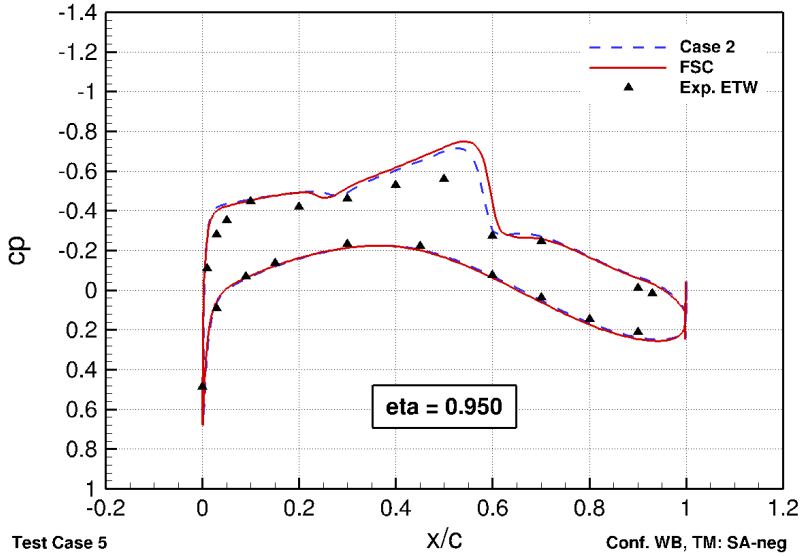
Separation Size increases with Angle of Attack.

Case 5 - CRM WB Coupled Aero-Structural Simulation









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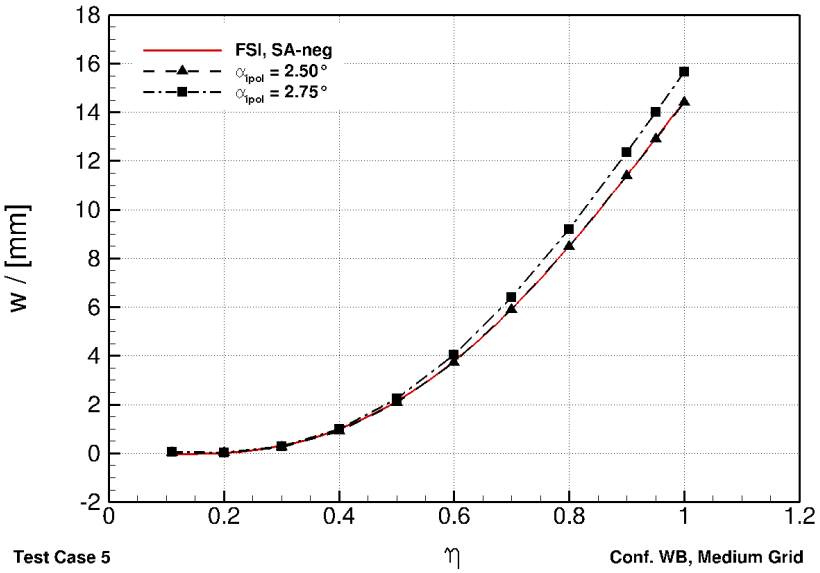

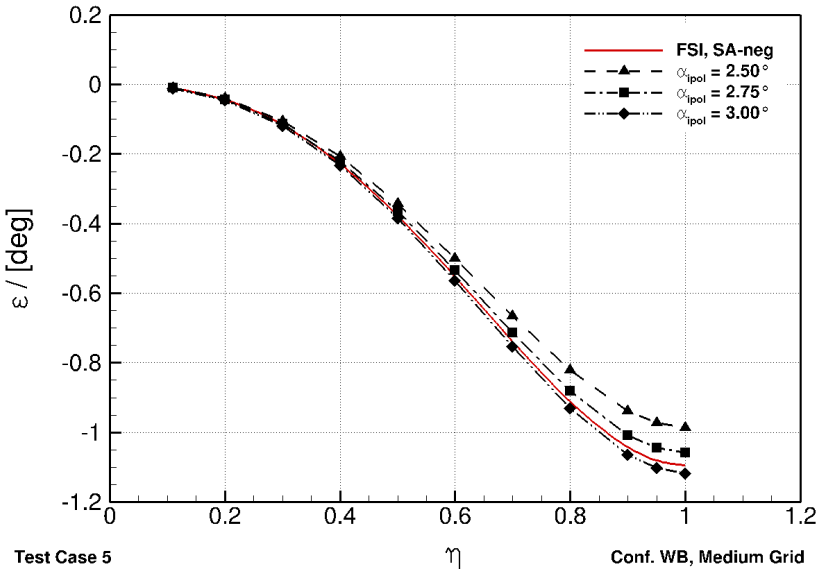

	α / [deg]	C_L	C_D	$C_{D,p}$	$C_{D,f}$	C_{My}
Case 2	2.3753	0.50003	0.02570	0.01420	0.01150	-0.1008
FSI	2.4034	0.50001	0.02604	0.01457	0.01148	-0.1019

Conclusions

- **Family of four SOLAR Grids generated on WB and WBNP Configurations (Tiny to Fine).**
- **Grid Sizes smaller than required by Gridding Guidelines, Size Factor larger.**
- **CFD Data for two Turbulence Models (SA-neg, RSM-ω) available.**
- **Differences between Grid Sizes and Turbulence Models very small.**
- **Deviations in Drag Increment between CFD and NTF Test Data below 2 drag counts.**
- **Deviations in Shock Location between SA-neg and RSM-ω increase with Angle of Attack.**
- **SoB Separation Size increases with both Grid Size and Angle of Attack.**
- **Good Agreement between coupled Simulation and CFD on pre-deformed Geometry.**