DLR Results of the 7th AIAA Computational Fluid Dynamics Drag Prediction Workshop (DPW-7)

Stefan Keye, Olaf Brodersen
Department of Transport Aircraft

Institute for Aerodynamics and Flow Technology
German Aerospace Center (DLR)
Lilienthalplatz 7
38108 Braunschweig
GERMANY

Contents

Numerical Methods
- Flow Solver TAU -

- **Flow Solver:**
  - Finite-Volume, unstructured, Reynolds-averaged Navier-Stokes CFD Code TAU.
  - Release 2020.1.0.

- **Solver Settings:**
  - steady RANS CFD Simulations.
  - central 2nd Order spatial Discretization Scheme.
  - Lower-Upper Symmetric Gauss-Seidel (LU-SGS) Time Integration.
  - 2v Multigrid Cycle.

- **Turbulence Model:**
  - SSG/LRR Full Reynolds Stress Model, $\ln(\omega)$-based.

    (B. Eisfeld et al.: "Reynolds-Stress Model Computations of NASA Juncture Flow Experiment", Published Online: 22 Nov 2021, https://doi.org/10.2514/1.J060510.)

Numerical Methods
- Computational Grids -

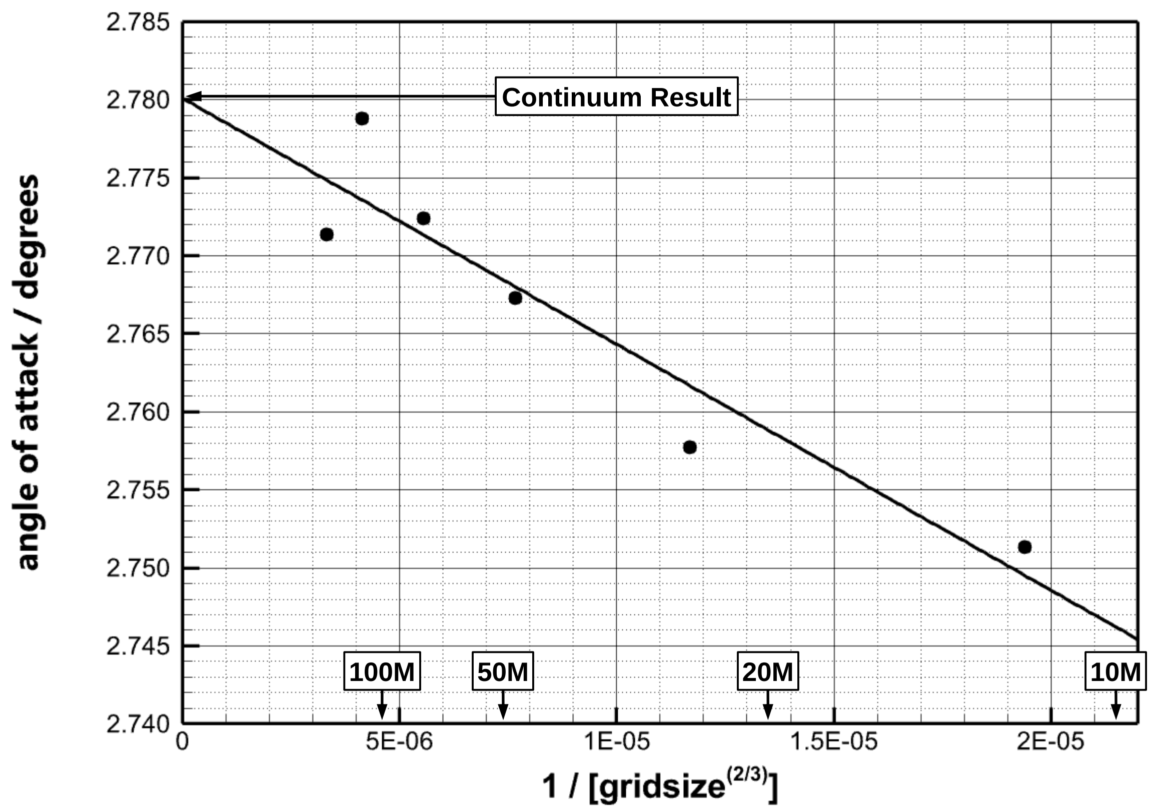
Grid	Points /[10^6]	Elements /[10^6]	Surface Points /[10^6]	y_1/[m]	# Layers	# constant Cells @ Wall	BL Stretching Ratio
T	11.70	31.59	0.506	6.560E-06	53	2	1.2
C	25.01	64.33	0.837	4.374E-06	53	3	1.2
M	47.06	130.7	1.317	3.280E-06	52	4	1.2
F	76.51	224.1	1.931	2.624E-06	52	5	1.2
X	118.8	367.9	2.726	2.187E-06	52	6	1.2
U	164.5	534.2	3.485	1.874E-06	53	7	1.2

- **modified 'SOLAR' Mesh Generating Software.**
- **originally developed by Aircraft Research Association Ltd., Bedford, UK.**
- **hybrid unstructured Meshes, Hex-dominant Boundary Layer.**
- **Grid Points Spacing Ratio smaller than Gridding Guidelines.**
- **Grids available for Download from DPW-7 Website:** https://dpw.larc.nasa.gov/DPW7/DLR_Grids.REV00/

Results Test Case 1a - Grid Convergence Study
- Grid Convergence of aerodynamic Coefficients -

- **CRM Wing/Body Configuration**
- **3.00deg LoQ AE Wing Geometry**

- **Flow Conditions:**
  - Mach Number: Ma = 0.85
  - Chord Reynolds Number: Re = 20×10^6
  - constant Lift Coefficient: $C_L = 0.58 \pm 0.0001$



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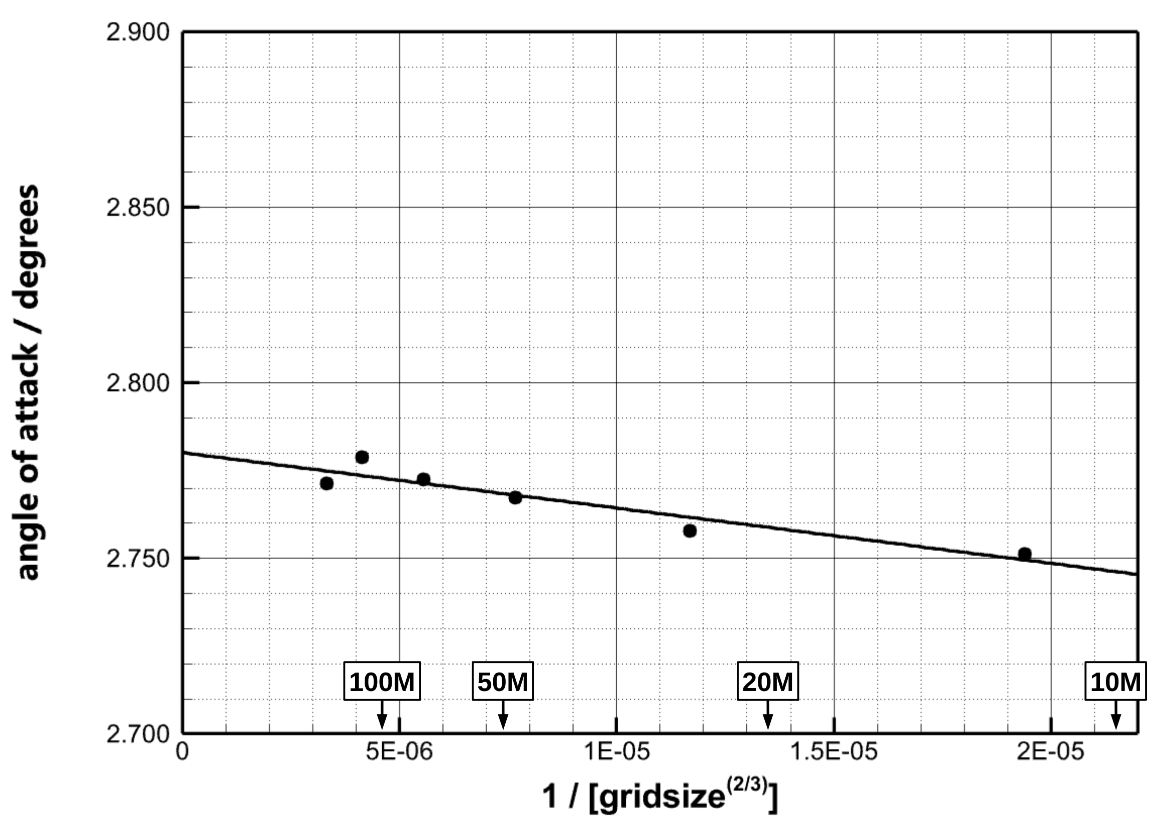

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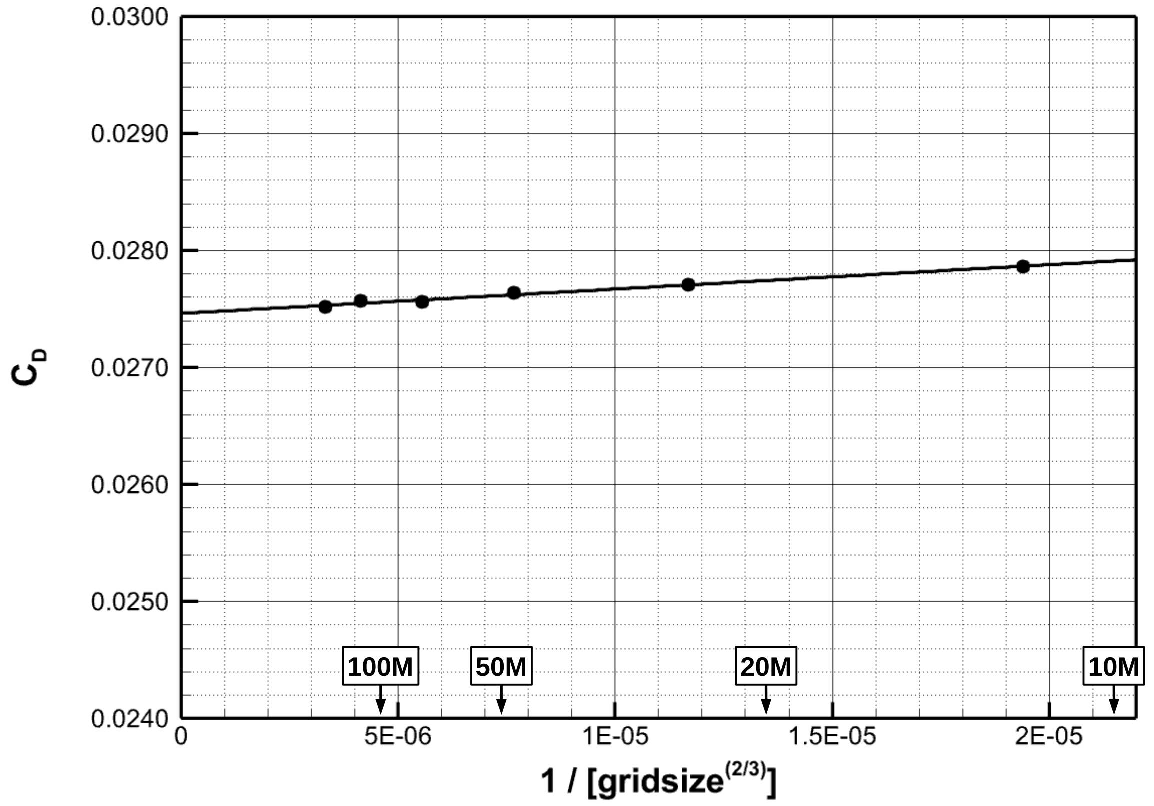

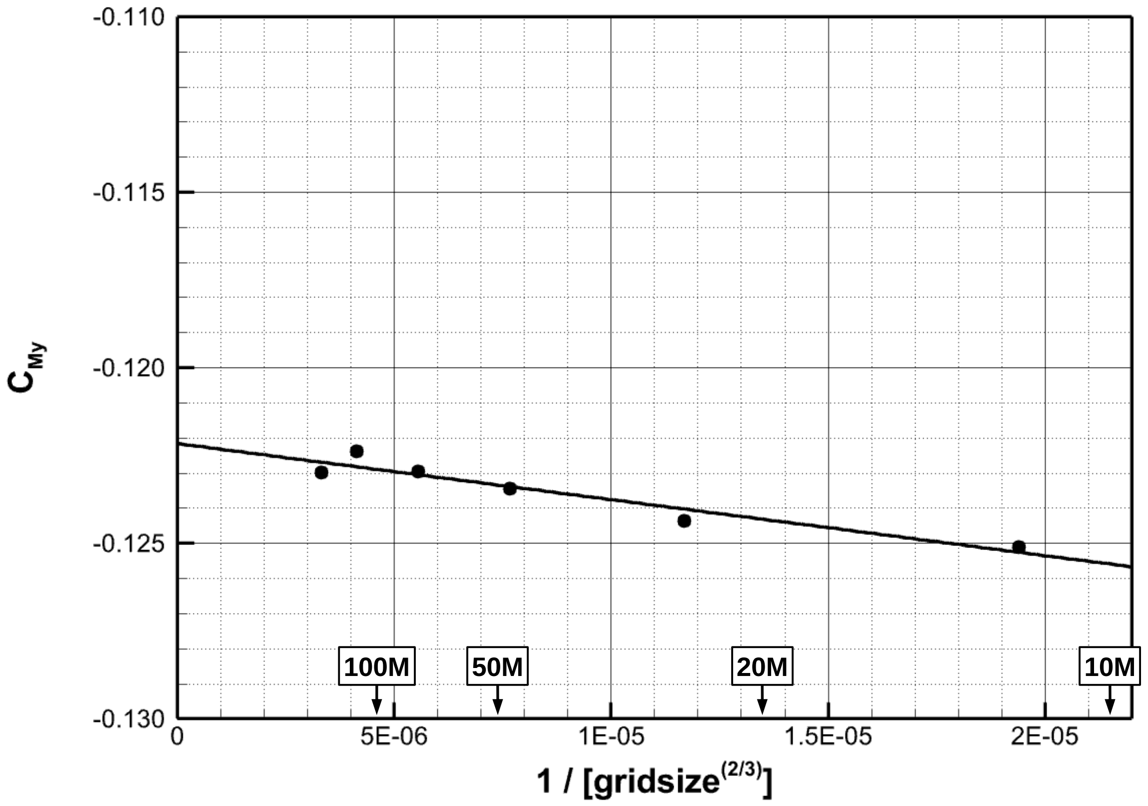

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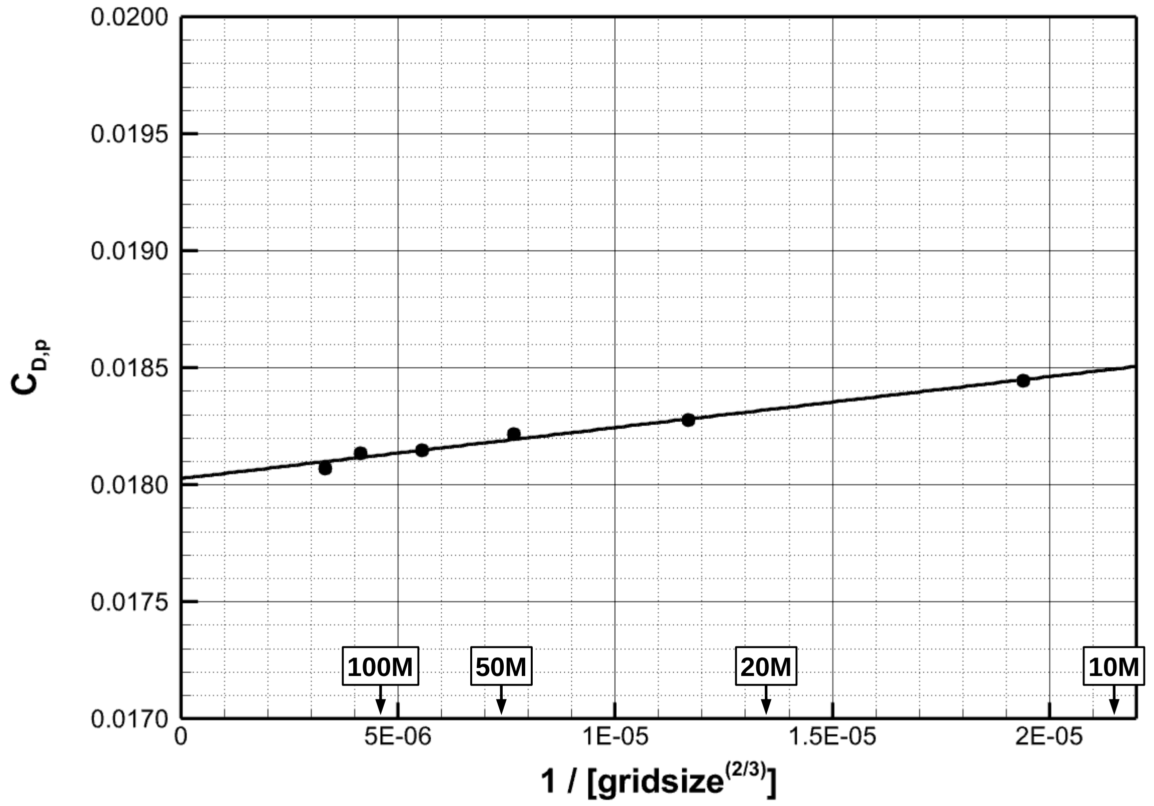
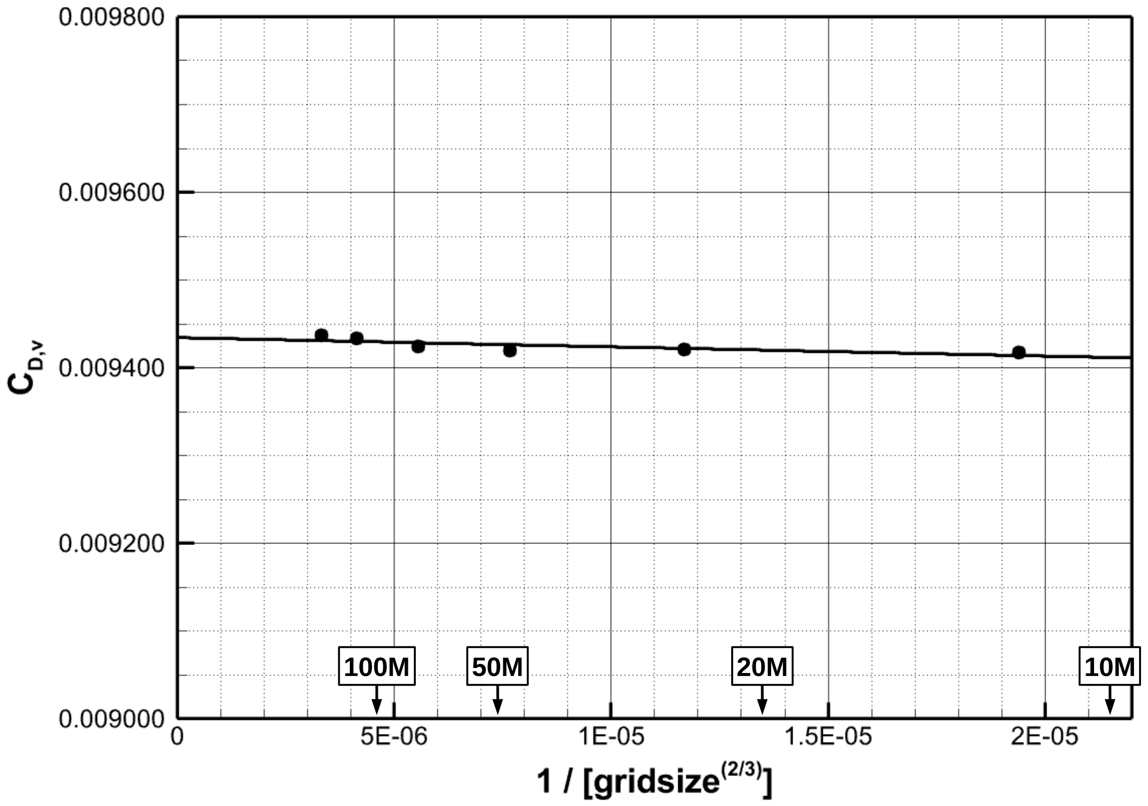
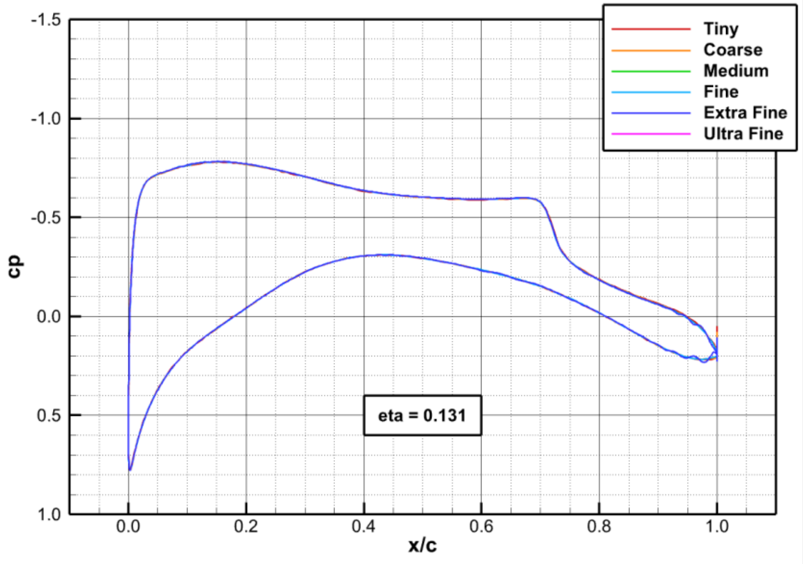
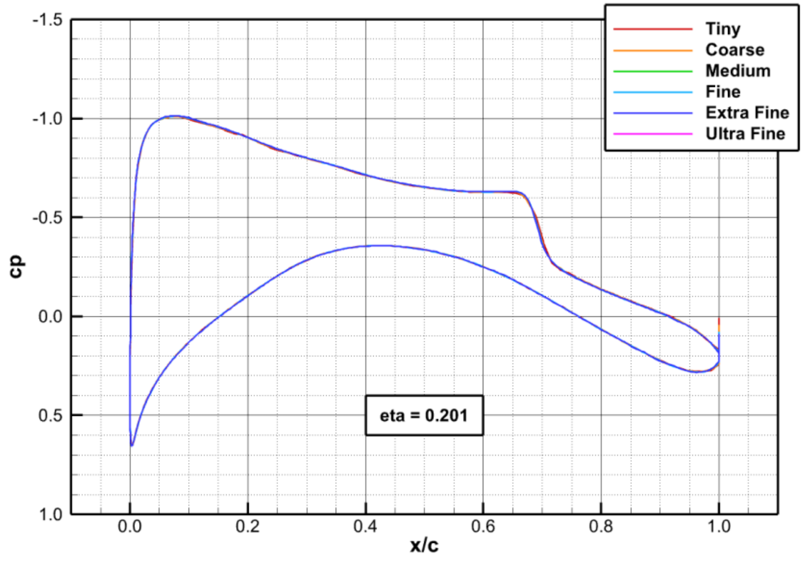
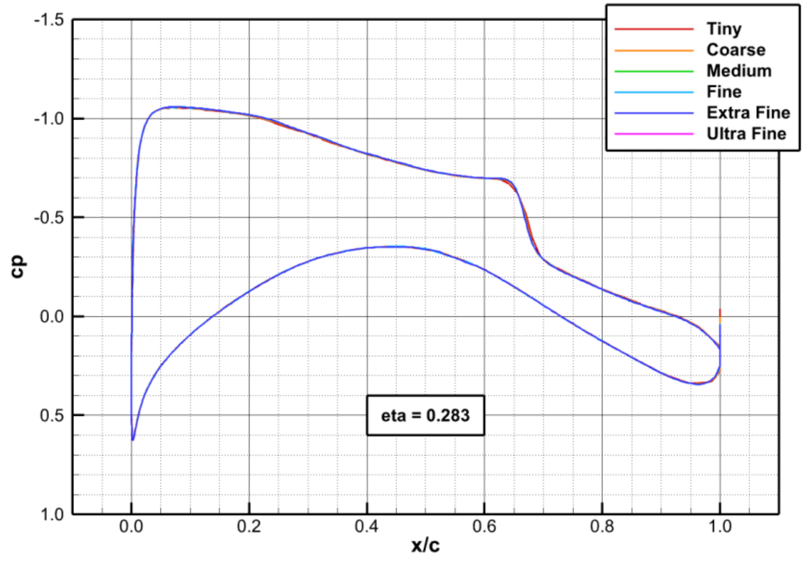




Results Test Case 1a - Grid Convergence Study
- Wing static Pressure Distribution -







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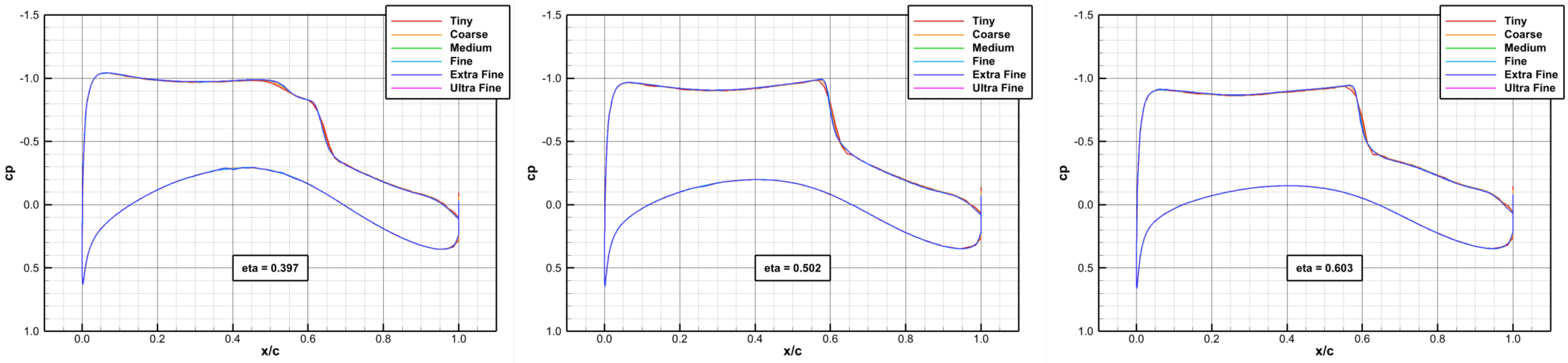

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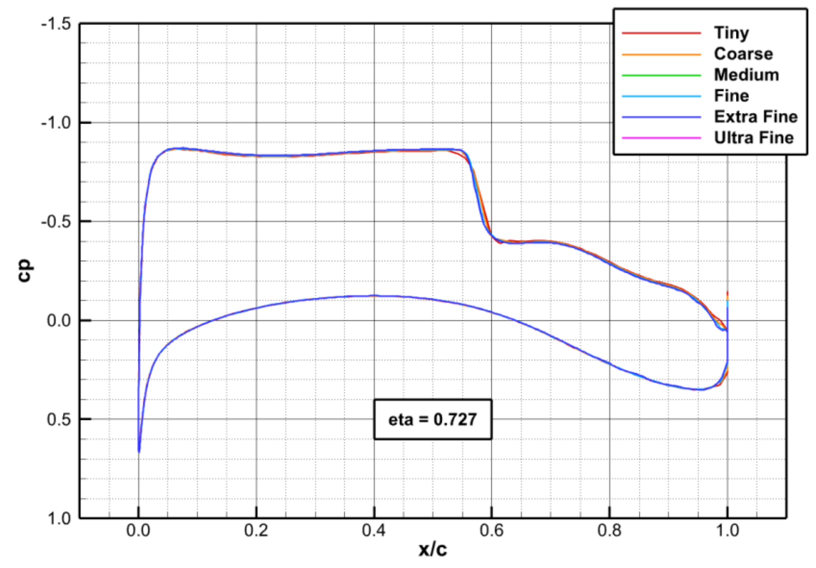
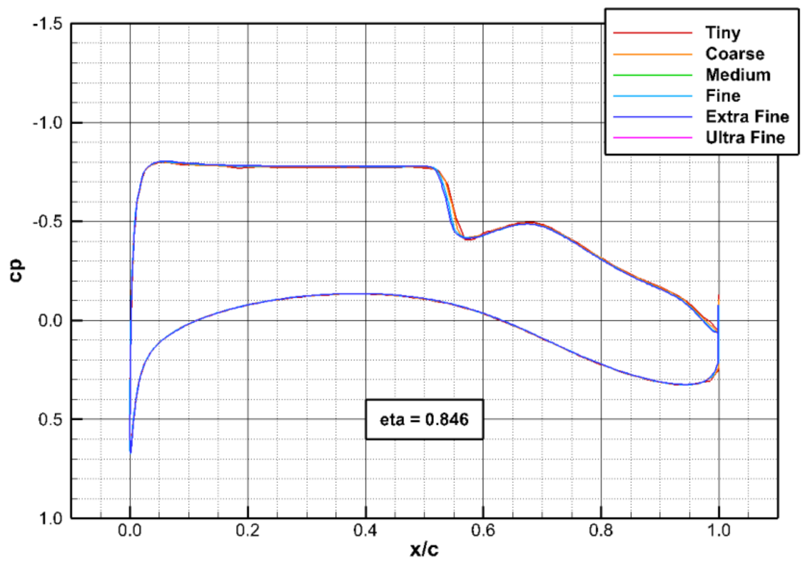
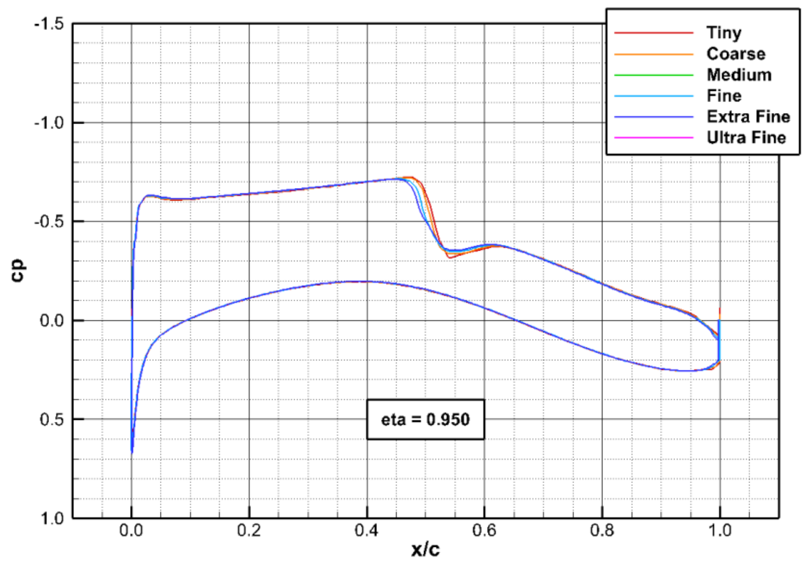
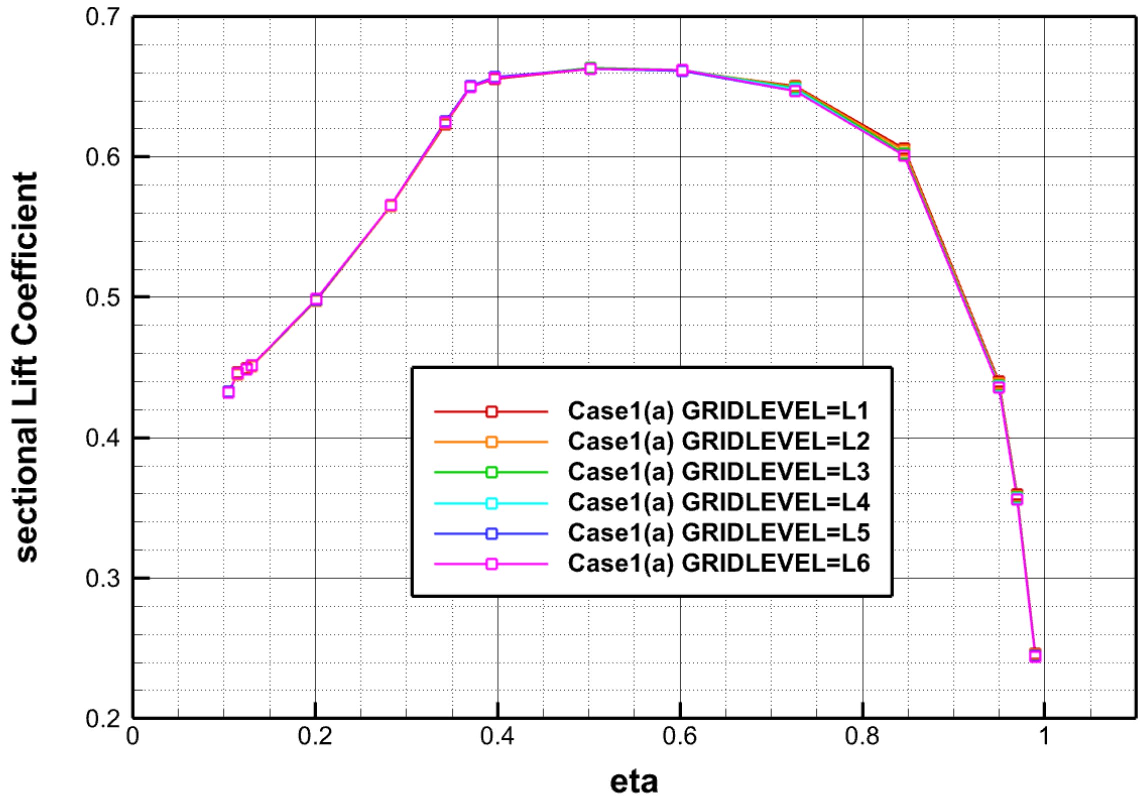
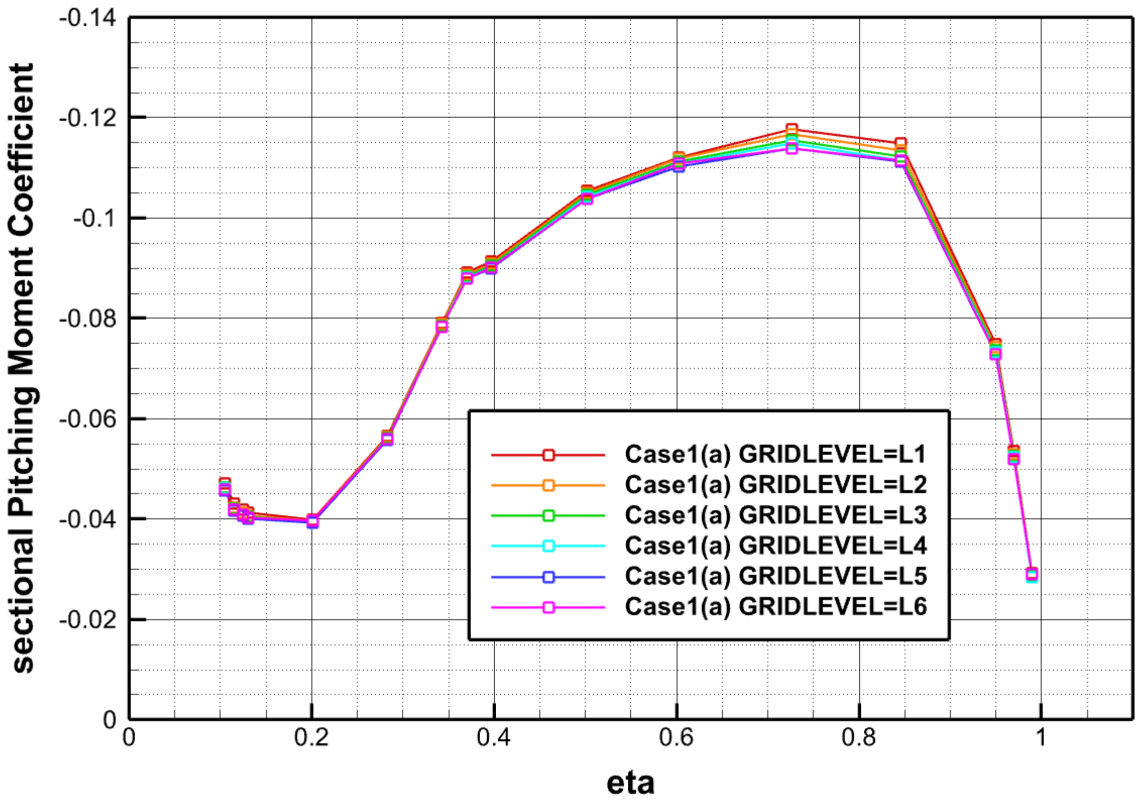






Results Test Case 1a - Grid Convergence Study
- Integral aerodynamic Coefficients -

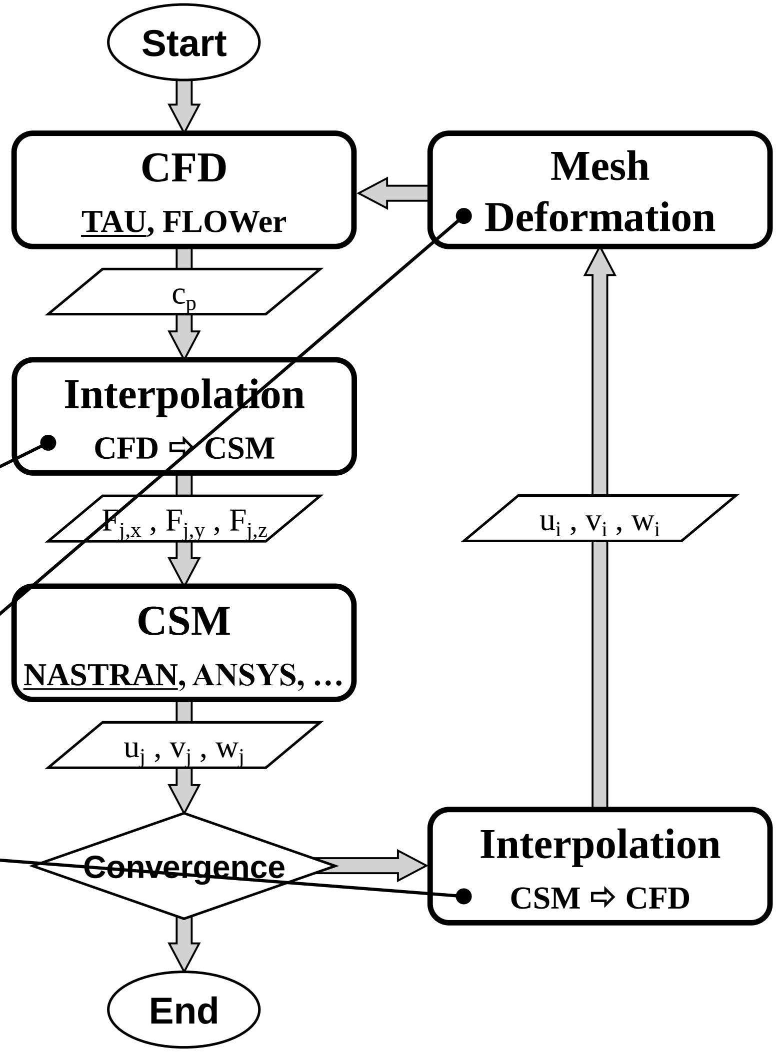




Results Test Case 6 - Coupled Aero-Structural Simulation

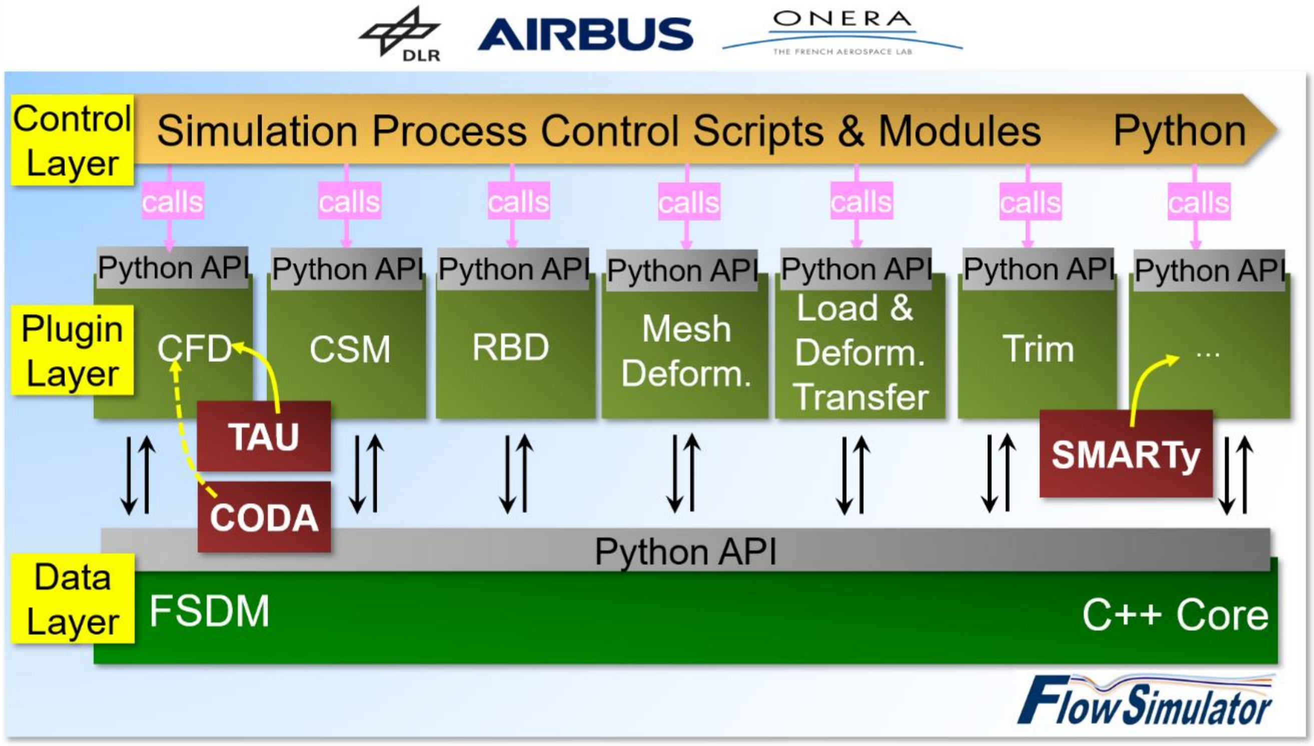
- Static aero-elastic Simulation Method -

- **direct Coupling of CFD Simulation and Structural Analysis Methods to determine the static aero-elastic Equilibrium State.**
- **simultaneous Interaction between outer Fluid Flow and flexible Aircraft Structure simulated through:**
  1. alternating Computation of Solutions of the RANS Equations and the Structural Mechanics Equations,
  2. repeated Interpolation of aerodynamic Loads and structural Deformations.
     - **'nearest-Neighbor' Search Algorithm** for Interpolation of aerodynamic Forces.
     - **Radial Basis Functions Approach** for Interpolation of structural Deflections and CFD Volume Mesh Deformation.
- **start from initial RANS CFD Solution, computed on the undeformed Grid.**
- **proceed until user-defined Convergence Criteria are accomplished.**

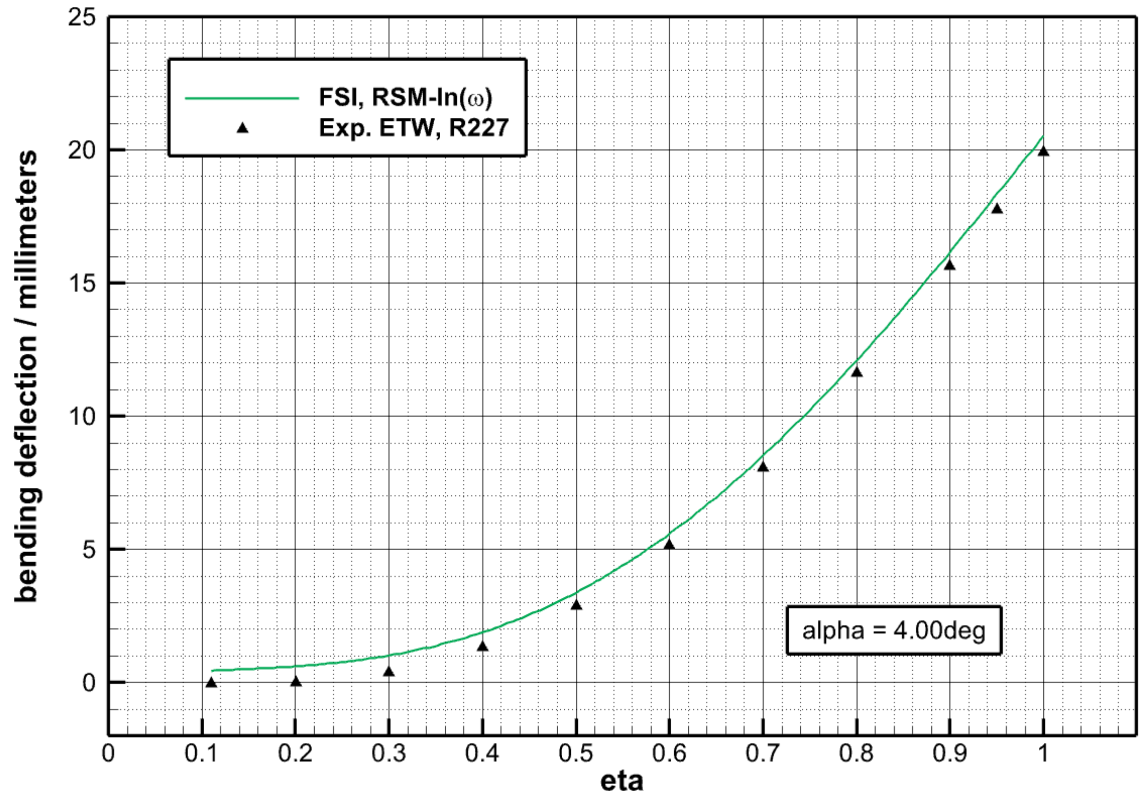


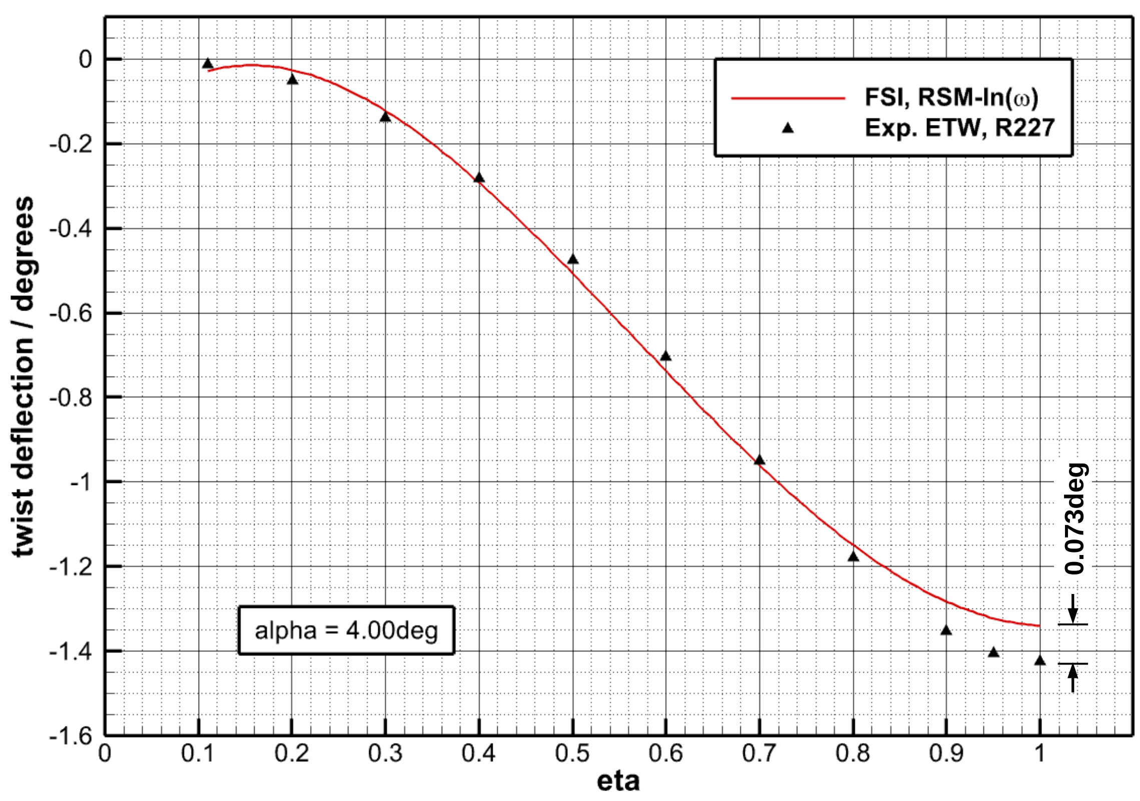
Results Test Case 6 - Coupled Aero-Structural Simulation
- Static aero-elastic Simulation Method -

- **Multi-Disciplinary Simulation Framework 'FlowSimulator'.**
- **useable for MDA, MDO & virtual Flight Testing.**
- **common Development Effort of Airbus, DLR & ONERA.**
- **Simulation Environment for multi-disciplinary Analyses, Optimizations & virtual Flight Tests.**
- **new CFD Code CODA embedded.**



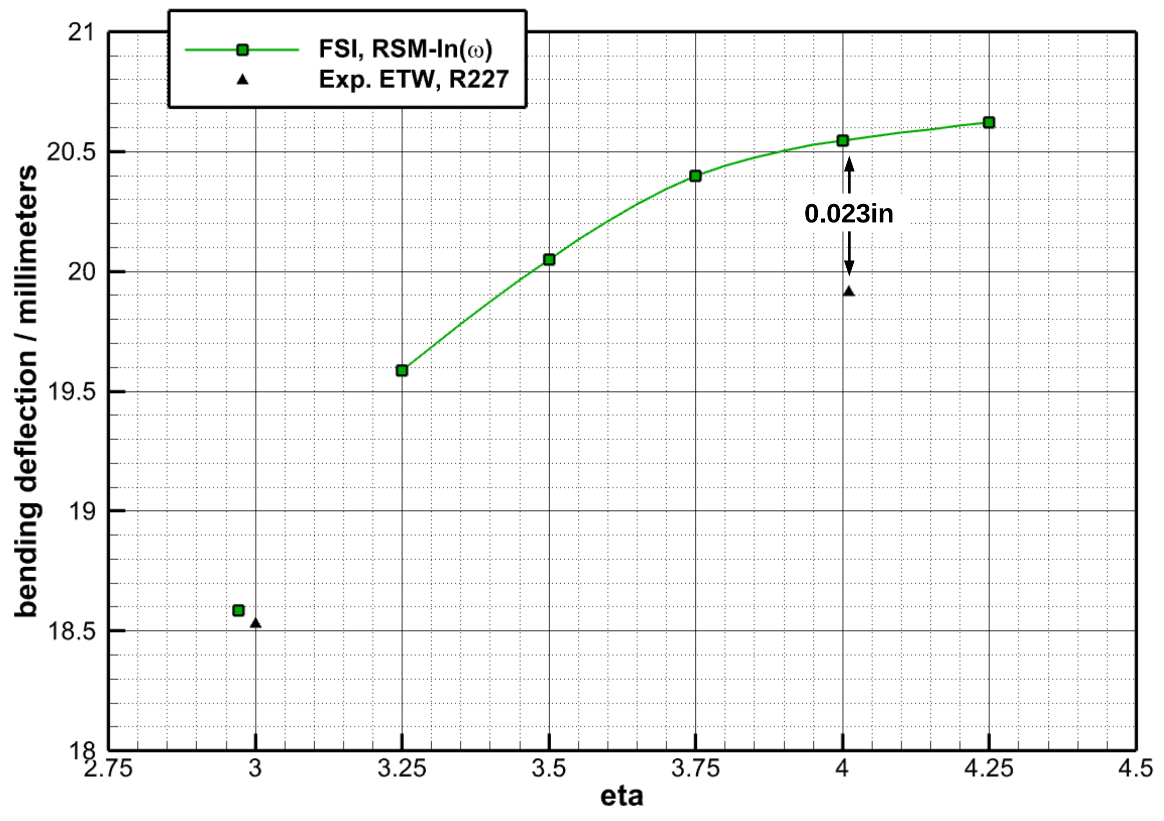
Results Test Case 6 - Coupled Aero-Structural Simulation
- Wing Deformations -

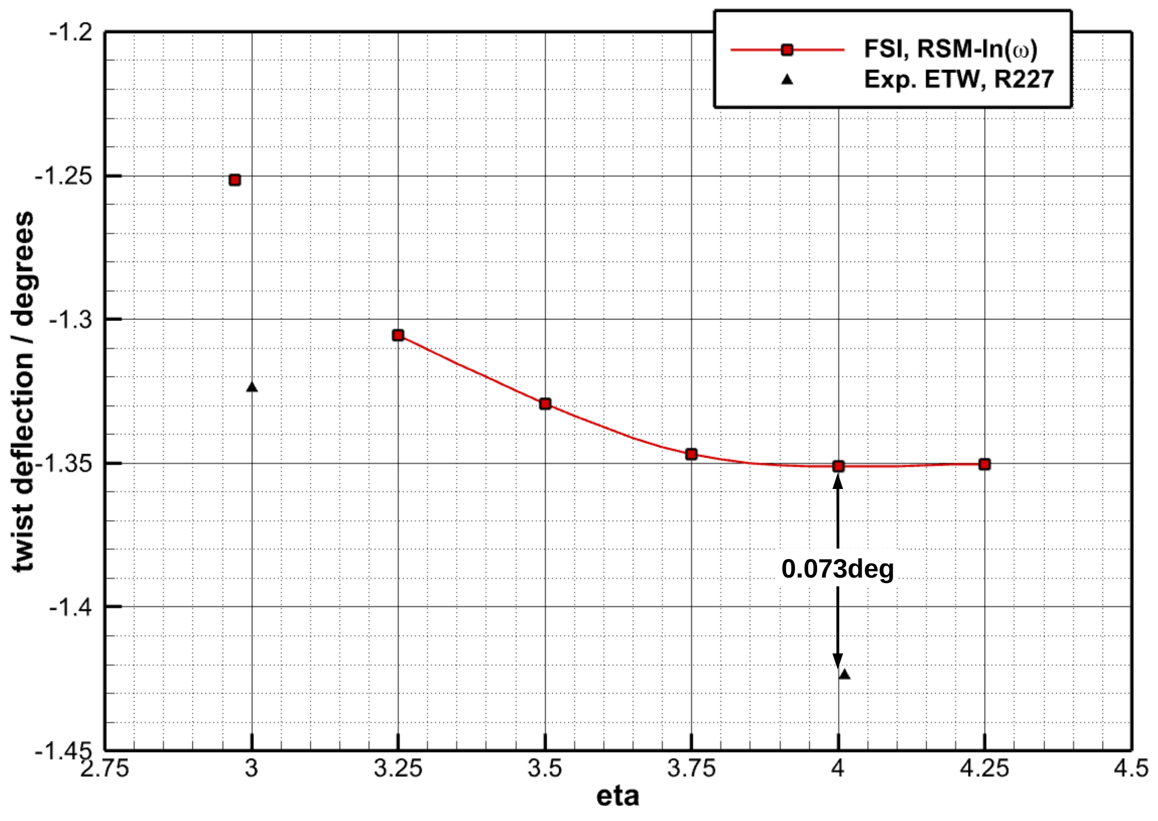




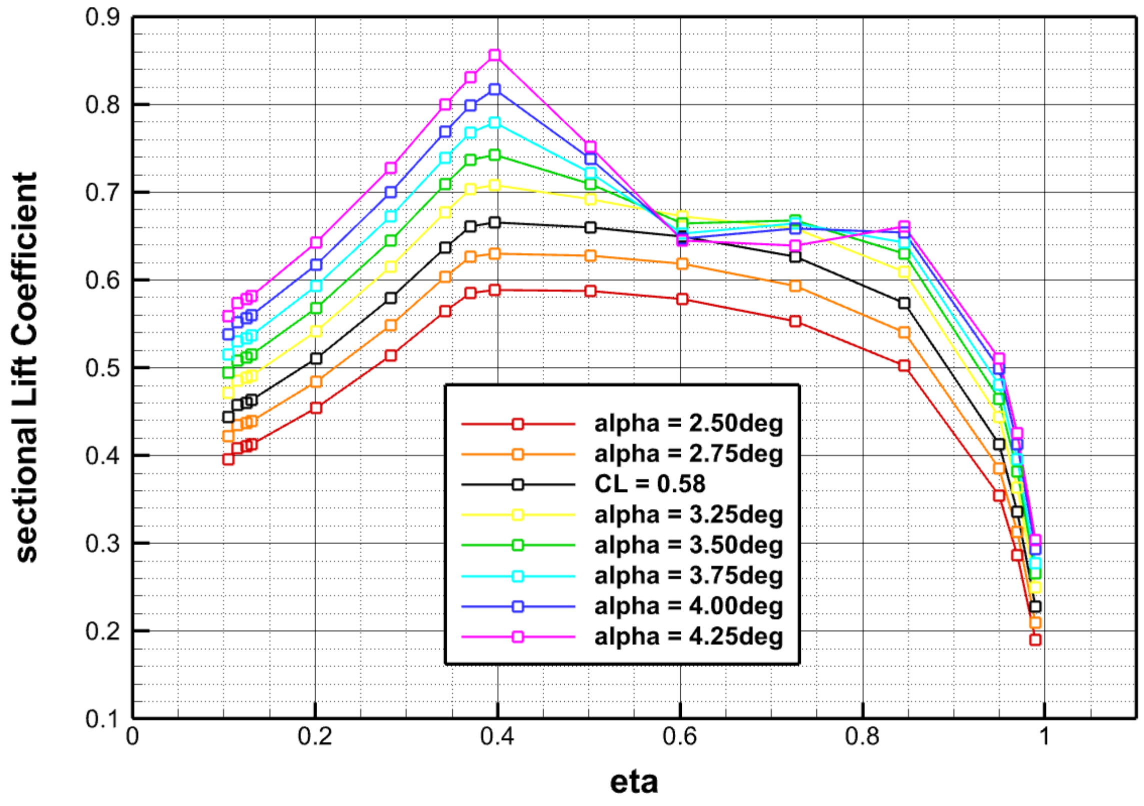
- Deformation Data obtained from the Trans National Access (TNA) Test Campaign (2012), European Transonic Wind Tunnel (ETW), Cologne, Germany.
- kindly provided by T. Lutz, Institute for Aerodynamics and Gas Dynamics, University of Stuttgart.

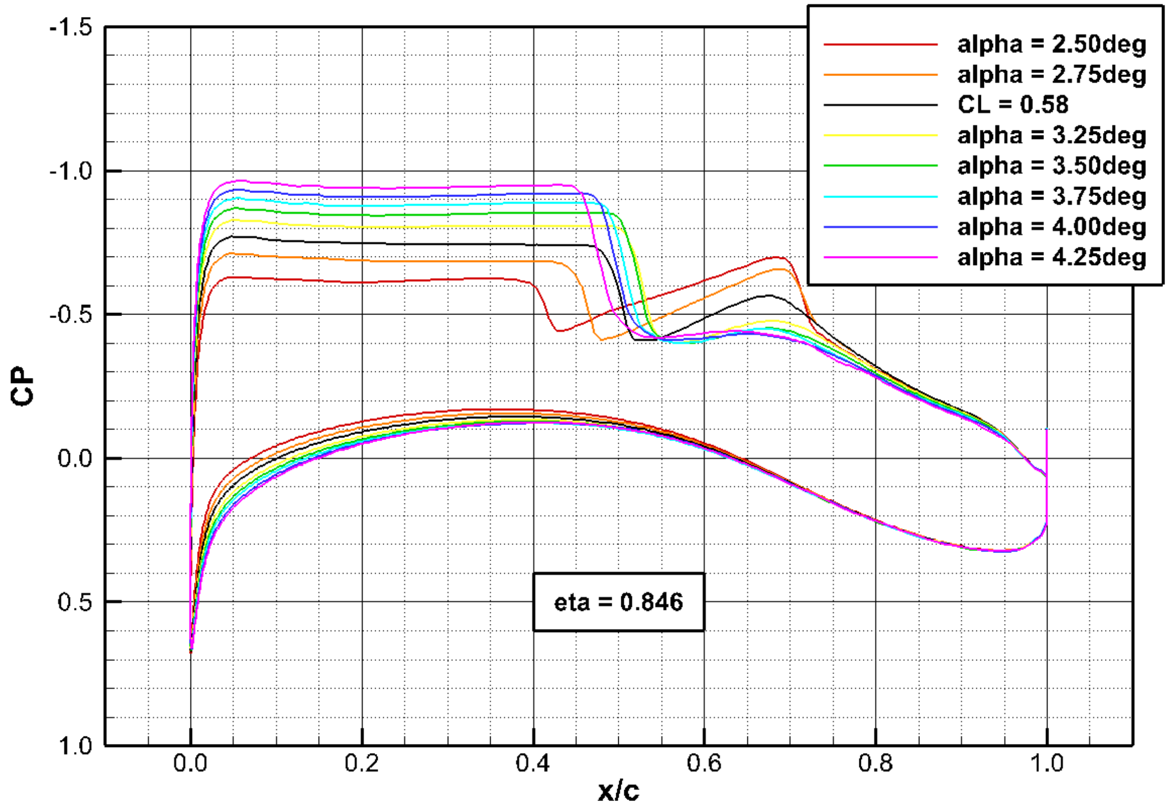
Results Test Case 6 - Coupled Aero-Structural Simulation
- Wing Deformations -





Results Test Case 6 - Coupled Aero-Structural Simulation
- Spanwise Lift Coefficients & Static Pressure Distributions -





Summary

- **Test Cases 1a and 6 covered by DLR Braunschweig.**

- **Grid Convergence Study:**
  - very small Variations in overall aerodynamic Parameters over complete Range of Grid Resolutions (e.g. ΔC_D < 3.5d.c. for 12mio. → 165mio. Points Grids).
  - good Linearity vs. Grid Factor $N^{-2/3}$.
  - Wing static Pressure and spanwise Lift Distributions nearly indistinguishable for all Grid Levels.

- **Aero-elastic Simulation:**
  - good Agreement of computed Deformations to ETW Measurements found for all Angles-of-Attack (max. Twist Deflection Error: $\Delta\varepsilon$ < 0.73deg at α = 4.00deg).

- **Comparison to experimental Data for both Test Cases remains to be performed.**