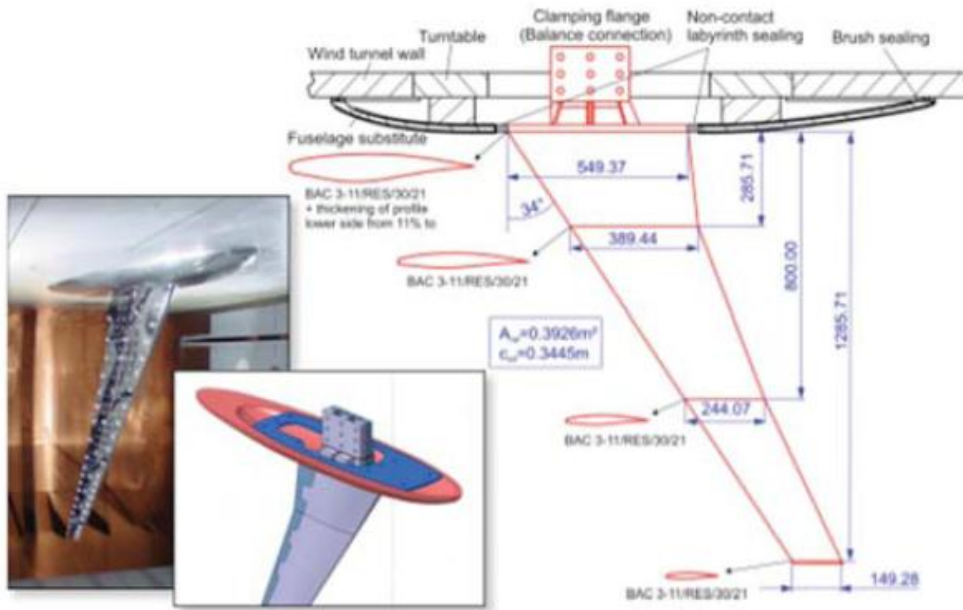


STEADY AND UNSTEADY AEROELASTIC COMPUTATIONS OF HIRENASD WING FOR LOW AND HIGH REYNOLDS NUMBERS

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22 April 2012, Honolulu, HI

Outline

- ▶ 1. Test Cases for HIRENASD Wing
- ▶ 2. ZEUS Software
- ▶ 3. Computational Model Information
- ▶ 4. Unsteady Computation Data
- ▶ 5. Analysis Set-(1)
- ▶ 6. Analysis Set-(2)
- ▶ 7. Conclusions and Future Work

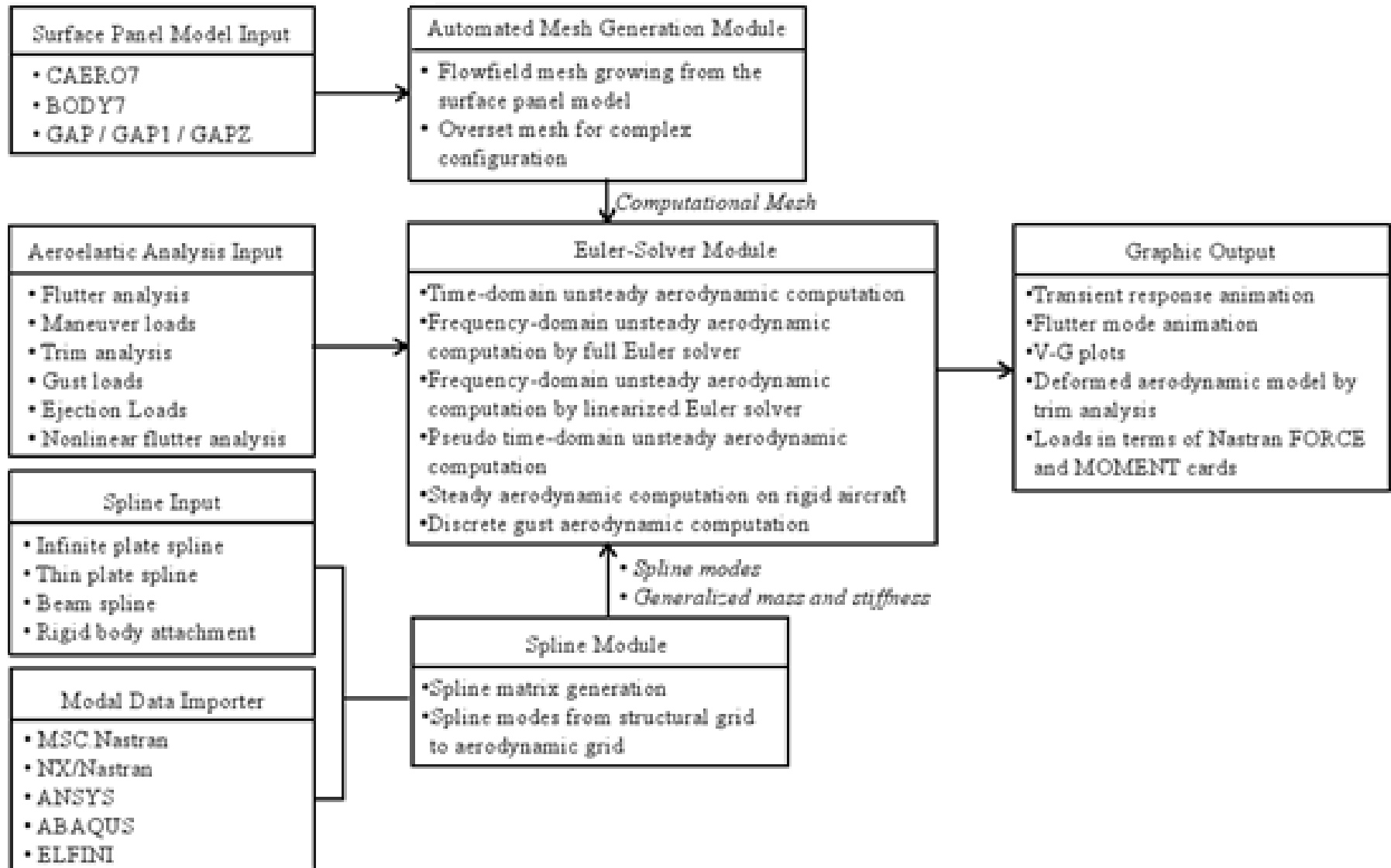
Test Cases for HIRENASD Wing

- ▶ $M=0.80$ and test medium: nitrogen
- ▶ **Steady (Static) Cases:**
 - ▶ a) $Re_c = 7.0$ million, $\alpha = 1.5^\circ$, (exp. 132)
 - ▶ b) $Re_c = 23.5$ million, $\alpha = -1.34^\circ$, (exp. 250)
- ▶ **Unsteady (Dynamic) Cases:** Forced oscillations in 2nd bending mode
 - ▶ a) $Re_c = 7.0$ million, $\alpha = 1.5^\circ$, $f= 78.9$ Hz (exp. 159)
 - ▶ b) $Re_c = 23.5$ million, $\alpha = -1.34^\circ$, $f=80.4$ Hz (exp. 271)
- ▶ Analyses are performed by using ZEUS Software developed by ZONA Technology.

ZEUS Software

- ▶ ZEUS is ZONA's Euler unsteady aeroelastic solver to provide solutions for complex configurations. It uses Cartesian grid and employs boundary layer coupling.
- ▶ Uses modal data importer and ZAERO 3D spline module.
- ▶ Constructs structured grids.
- ▶ **Turbulence Model:** Green's Integral Boundary Layer Method
- ▶ **Flux Construction:** Central difference with JST (Jameson-Schmidt-Turkel) Artificial Dissipation Scheme

Program Architecture of ZEUS



Computational Model Information

- ▶ Modal analysis is performed in Nastran and then imported to ZEUS for steady and unsteady calculations.
- ▶ Two sets of analyses are performed based on two different FEM models and compared to experimental data.
- ▶ **1) HIRENASD FEM Structured Wing (with hollow wing body)**
 - ▶ This model was used by ETW in 2008.
 - ▶ Steady results will be presented.
 - ▶ Unsteady results were not comparable.
- ▶ **2) HIRENASD Nov2011 FEM Model**
 - ▶ Current coarse FEM model provided AEPW committee.
 - ▶ Steady and unsteady results will be presented.

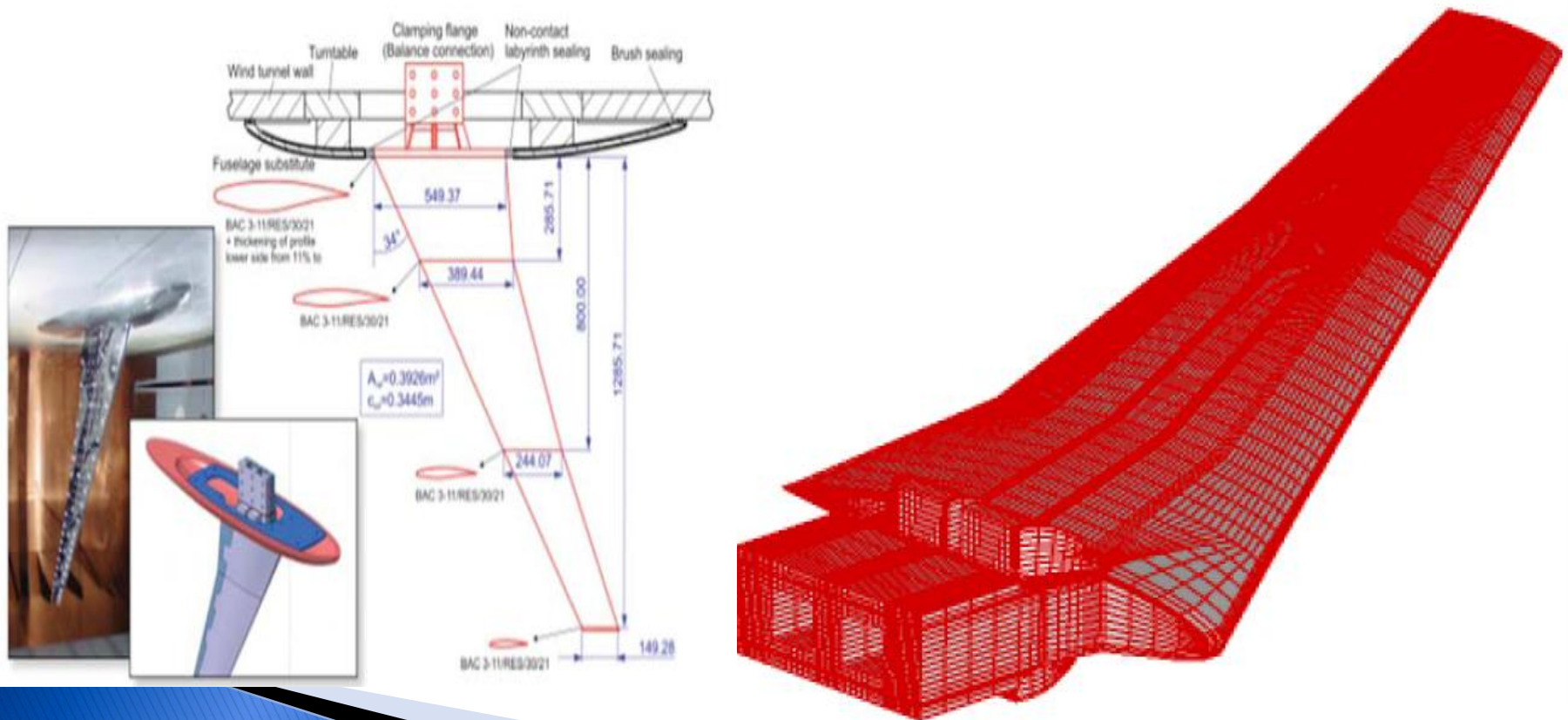
Unsteady Computation Data

- ▶ **For HIRENASD Nov2011 FEM Model**
- ▶ **1st Case (Low Re Case for Exp.159) (Processing Freq: 78.9 Hz)**
- ▶ **Time record: 0.0253485 sec**
- ▶ **Time step-size: 0.0001 sec**
- ▶ **Number of sub-iteration per global time step: 30**
- ▶ **Nsteps/cycle: 256**

- ▶ **2nd Case (High Re Case for Exp.271) (Processing Freq: 80.4 Hz)**
- ▶ **Time record: 0.00248756 sec**
- ▶ **Time step-size: 0.00009717 sec**
- ▶ **Number of sub-iteration per global time step: 30**
- ▶ **Nsteps/cycle: 128**

Analysis Set-(1)

- ▶ **FEM Model:** HIRENASD FEM Structured Wing (with hollow wing body)
- ▶ Set-1 is analyzed by ITU.



Aerodynamic Model Information

Set-1

- ▶ **Aerodynamic Model is generated in ZEUS.**
- ▶ **Grid Type:** Structured
- ▶ **Element Type:** Quadrilateral
- ▶ **Computational Mesh:** (135 x 71 x 55)
- ▶ **Solver:** Cell Based
- ▶ **Platform:** Intel Core 2 CPU Processor ~ 1.5 hours (for steady analysis)

- ▶ **Fluid-Structure Interaction (FSI) is provided by ZEUS.**
- ▶ Splines between structural and aerodynamic grids are generated by ZEUS.
- ▶ After constructing surface mesh, ZEUS automatically generated block elements.

Results of Steady Analyses Set-1

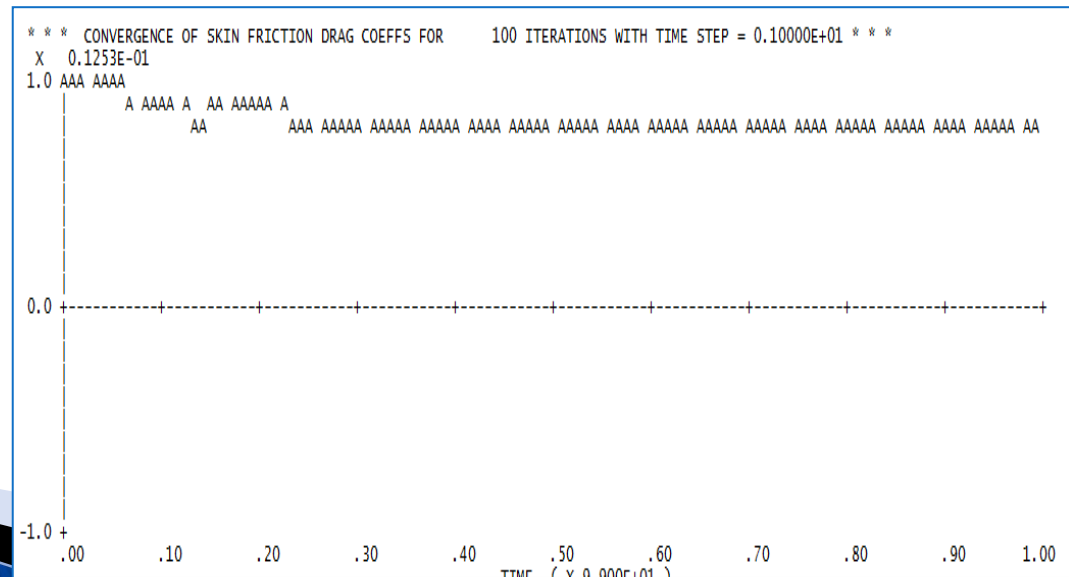
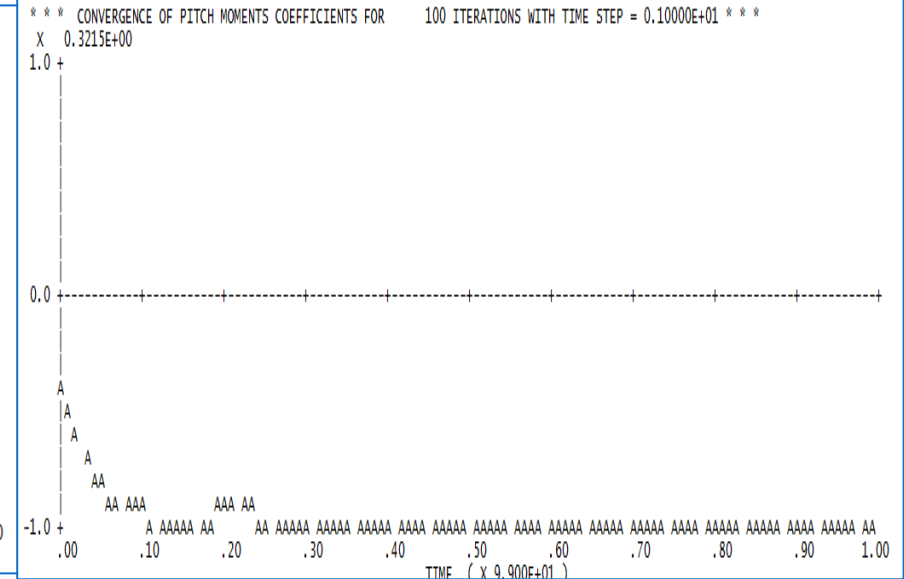
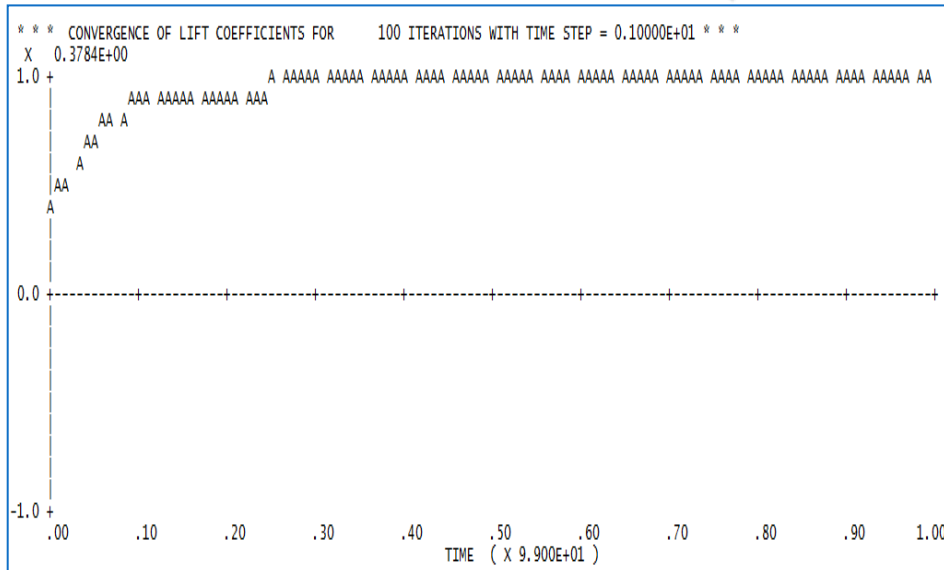
Low Re Case (for exp.132)

Quantity	Calculated
C_L	0.35704
C_M	-0.59870
C_D	0.01784

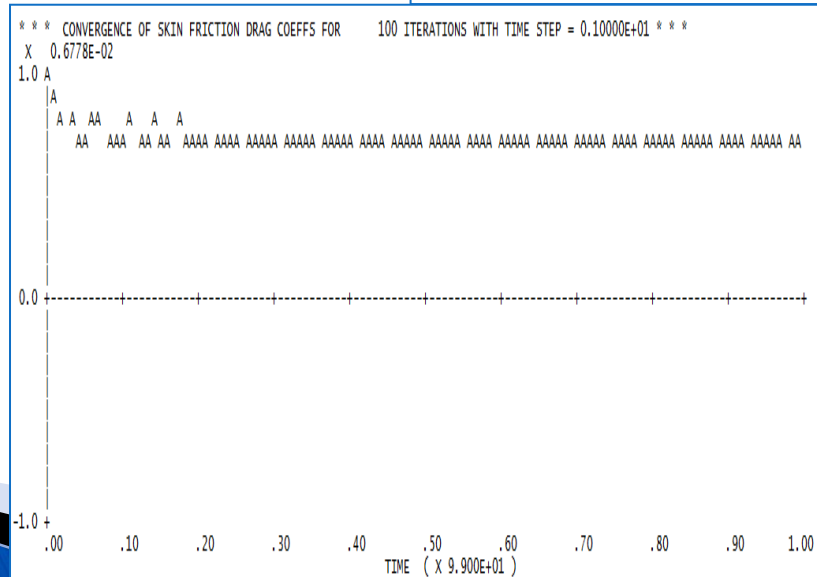
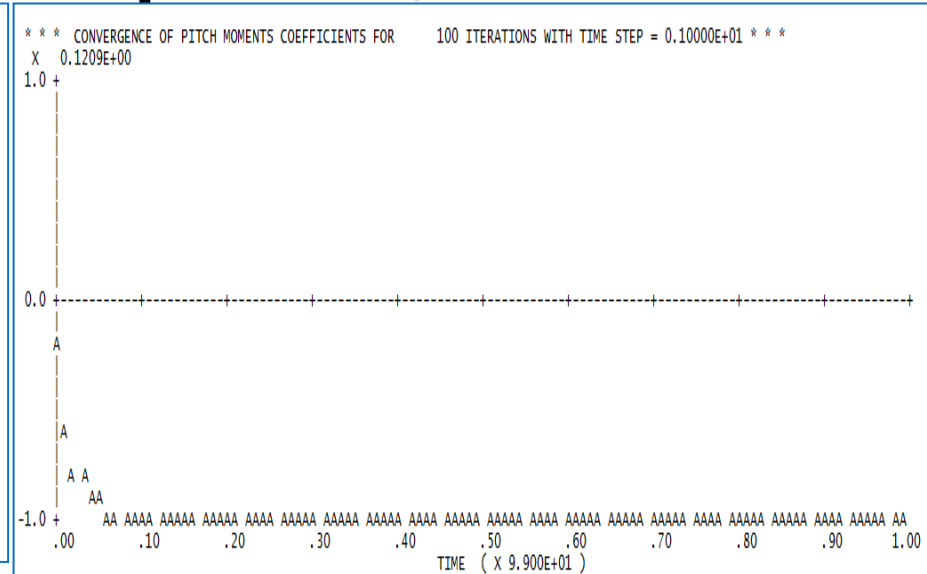
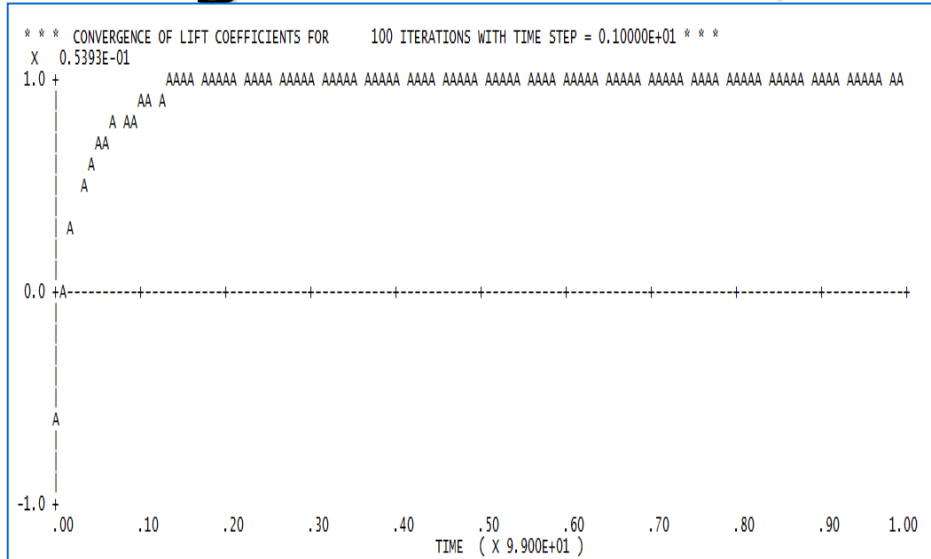
High Re Case (for exp.250)

Quantity	Calculated
C_L	0.05370
C_M	-0.23513
C_D	0.01283

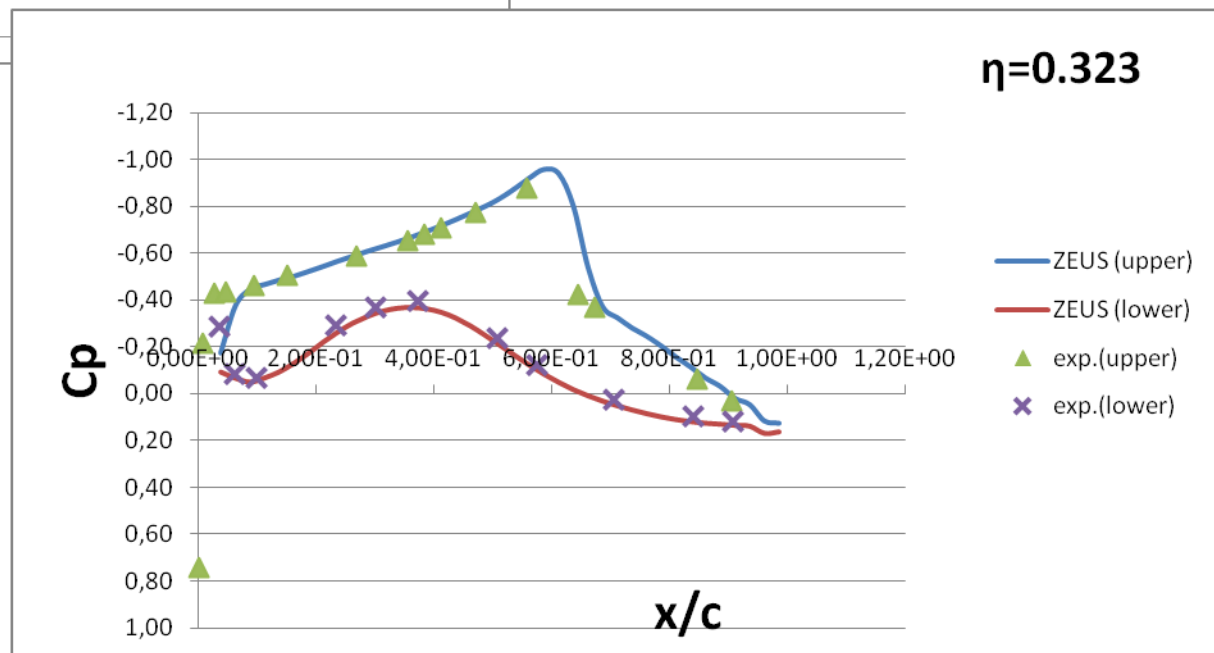
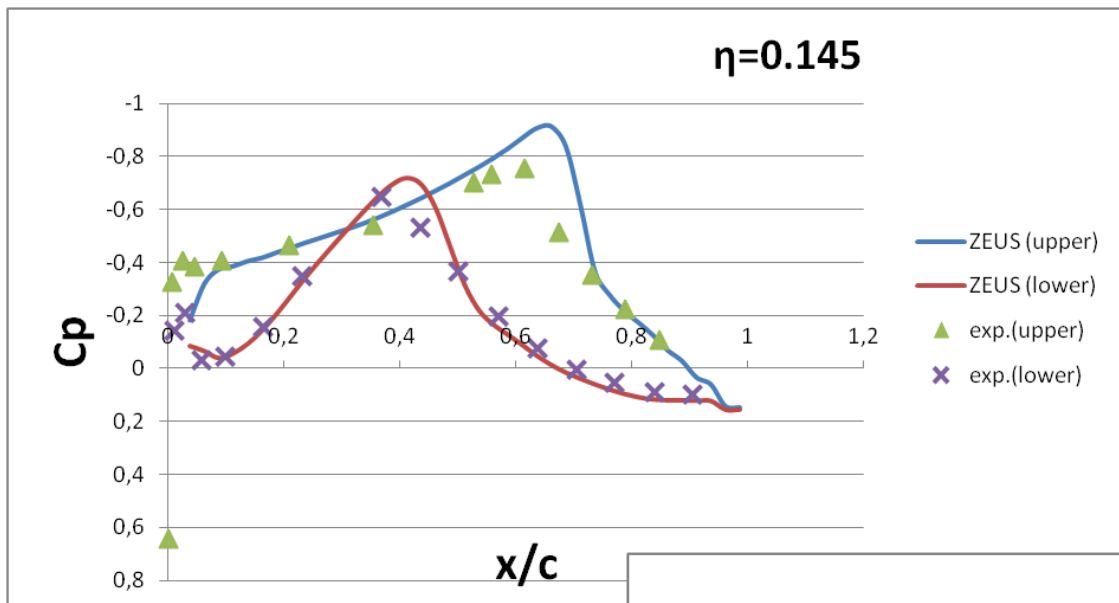
Convergence for Steady Analyses – Low Re Case (for exp 132)

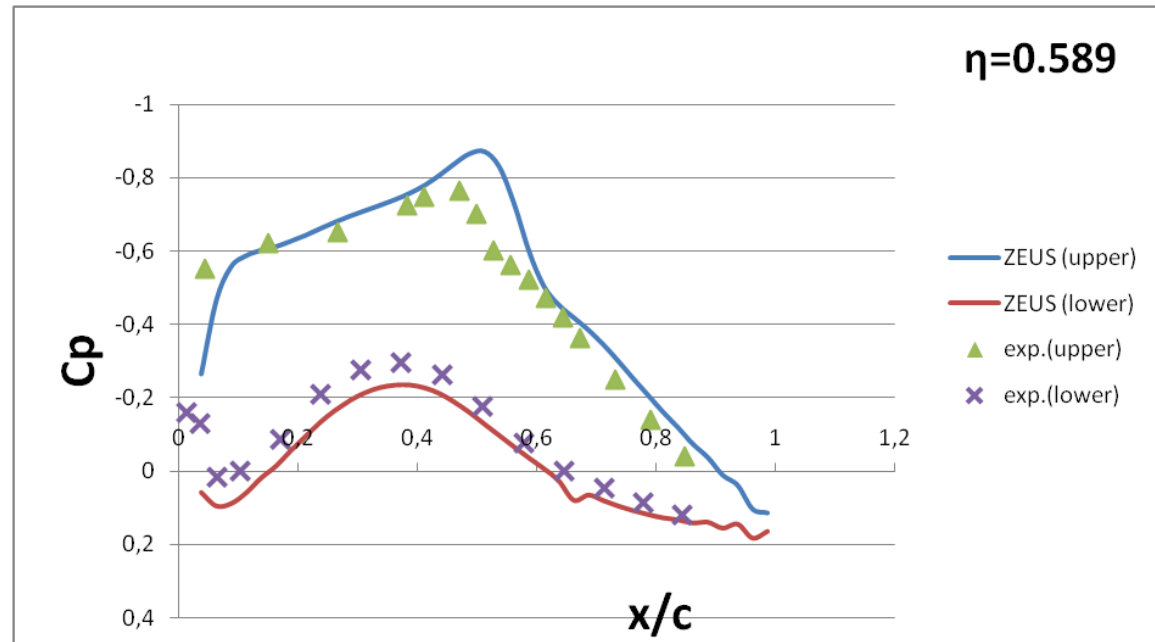
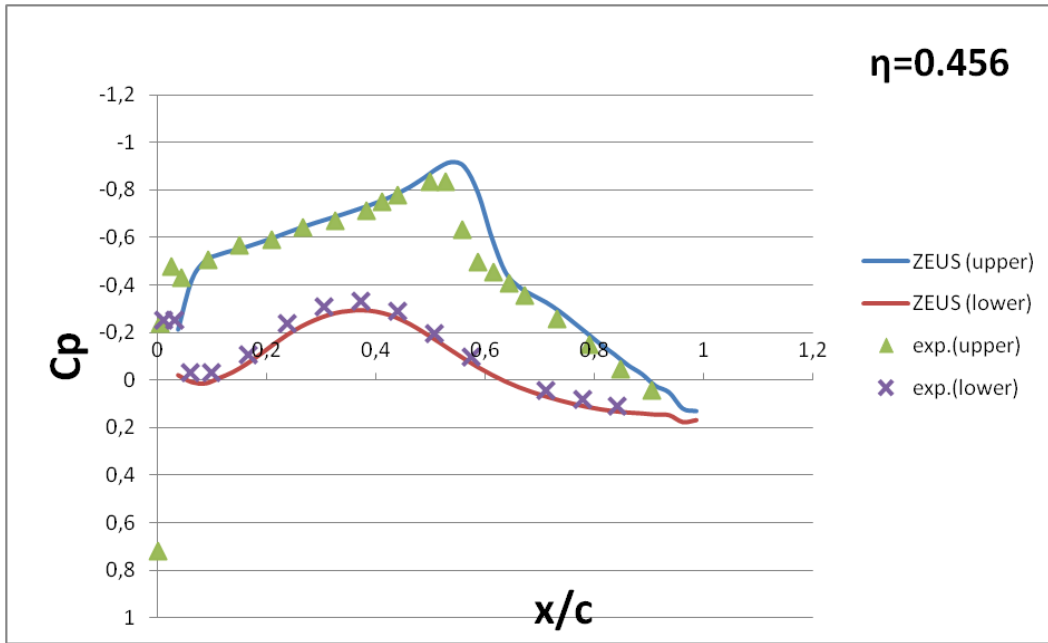


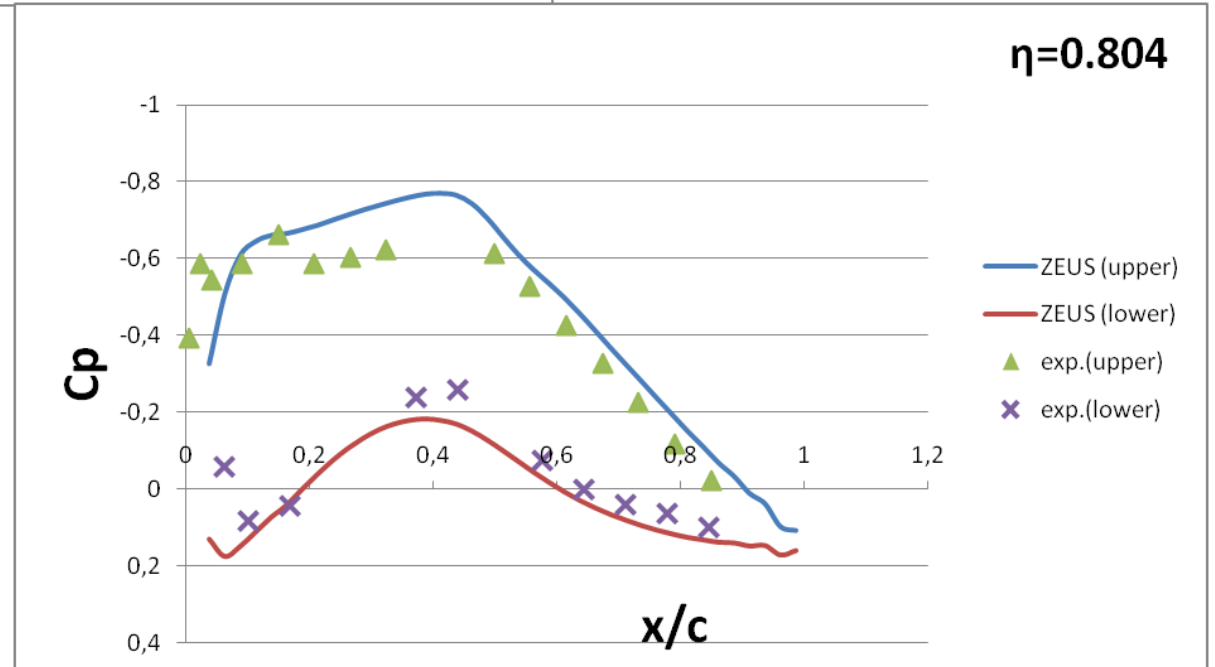
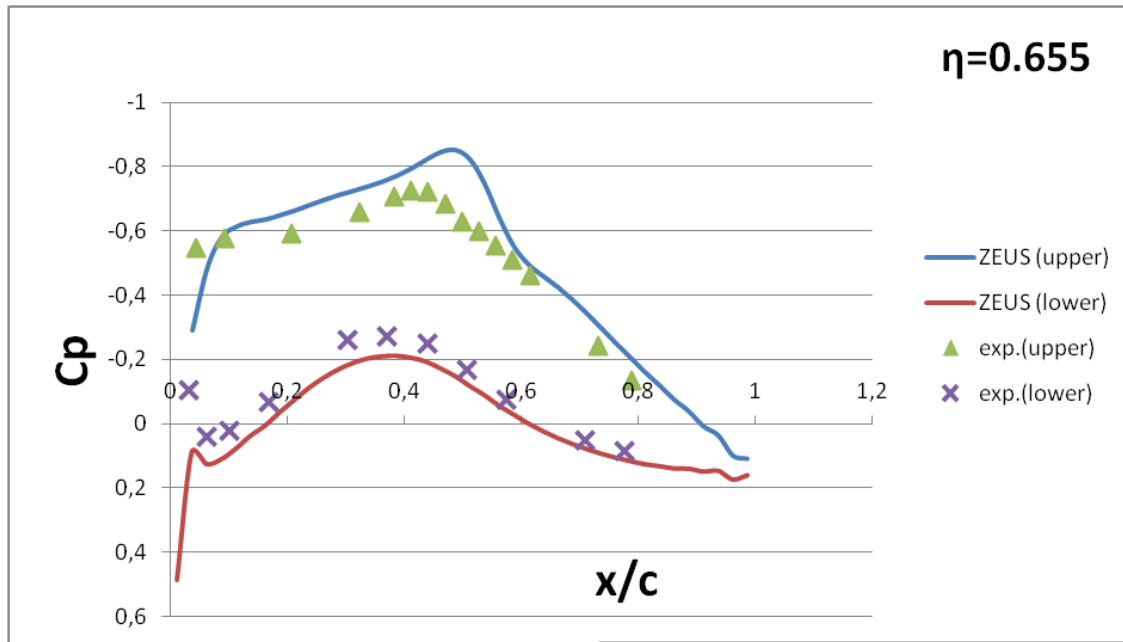
Convergence for Steady Analyses – High Re Case (for exp 250)



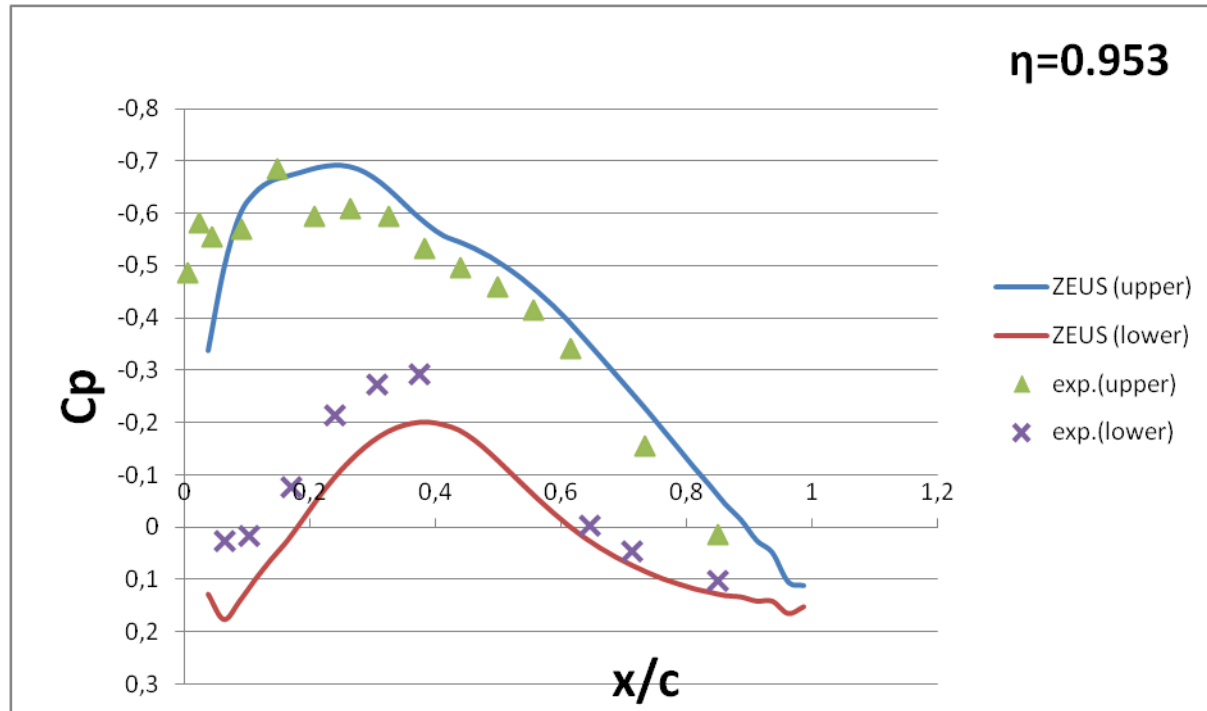
Results for exp.132 Set-1



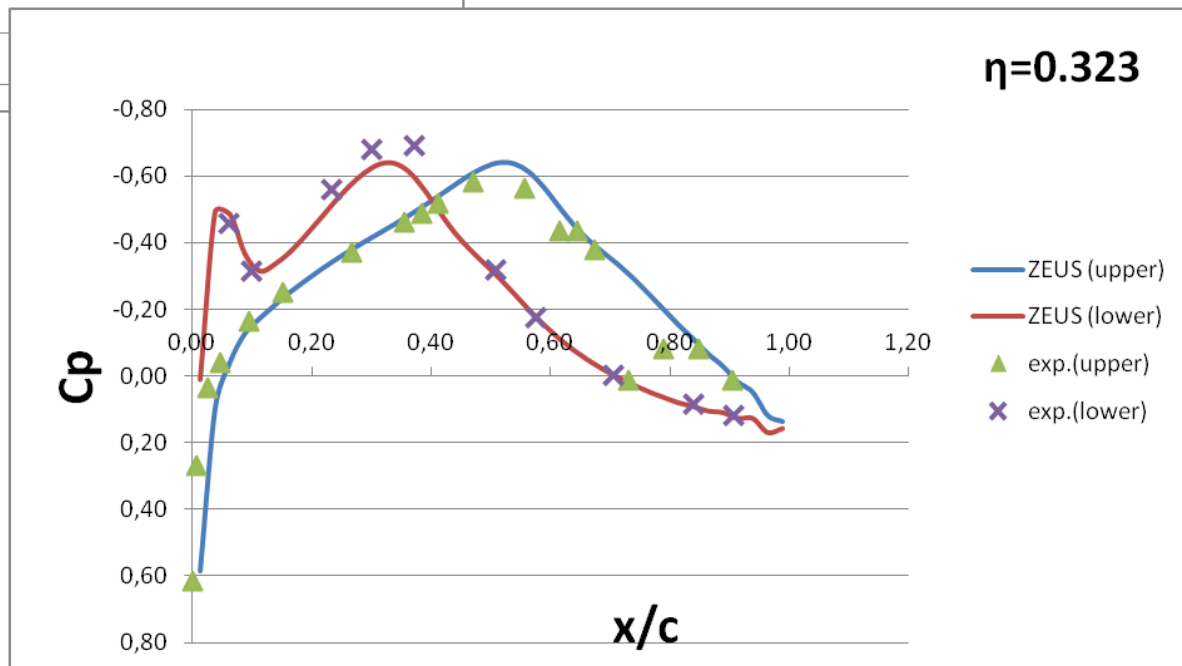
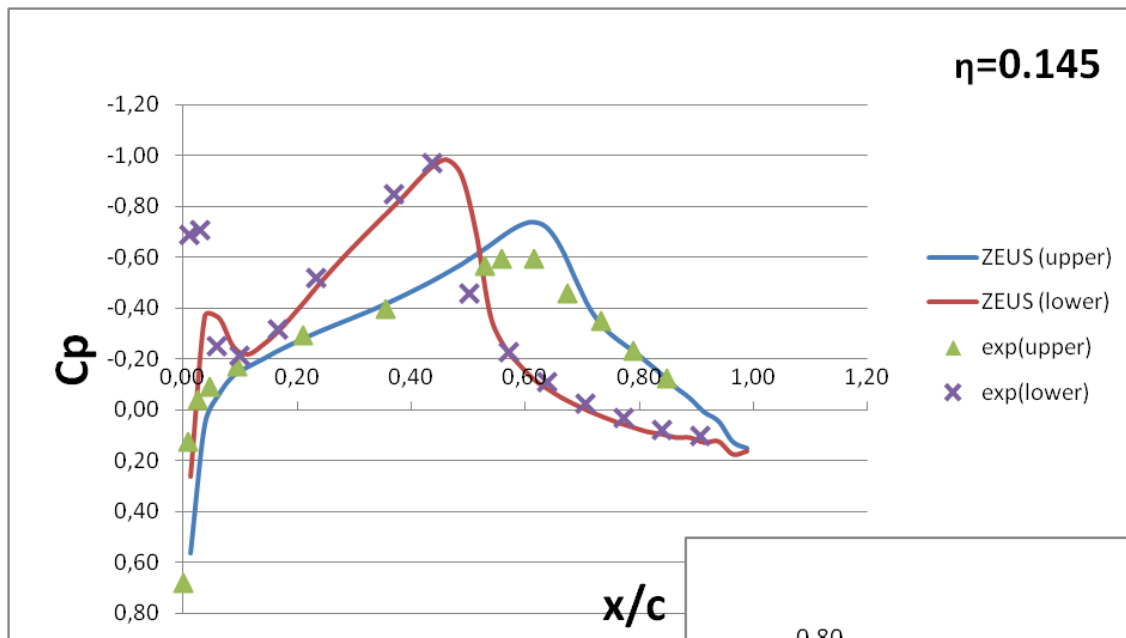




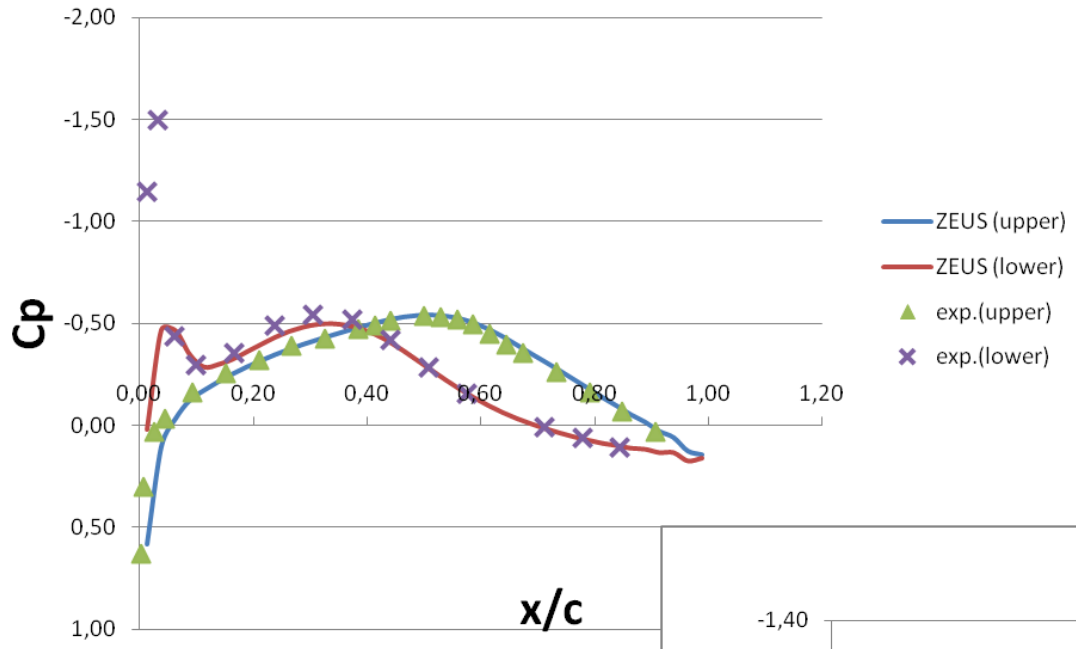
Results for exp.132 Set-1



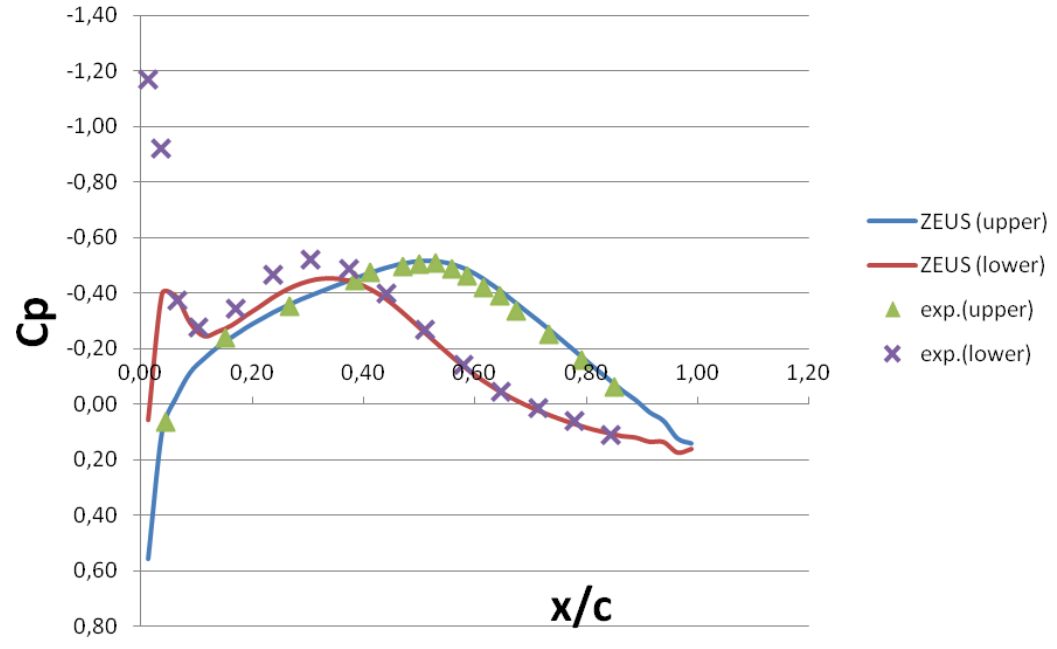
Results for exp.250 Set-1

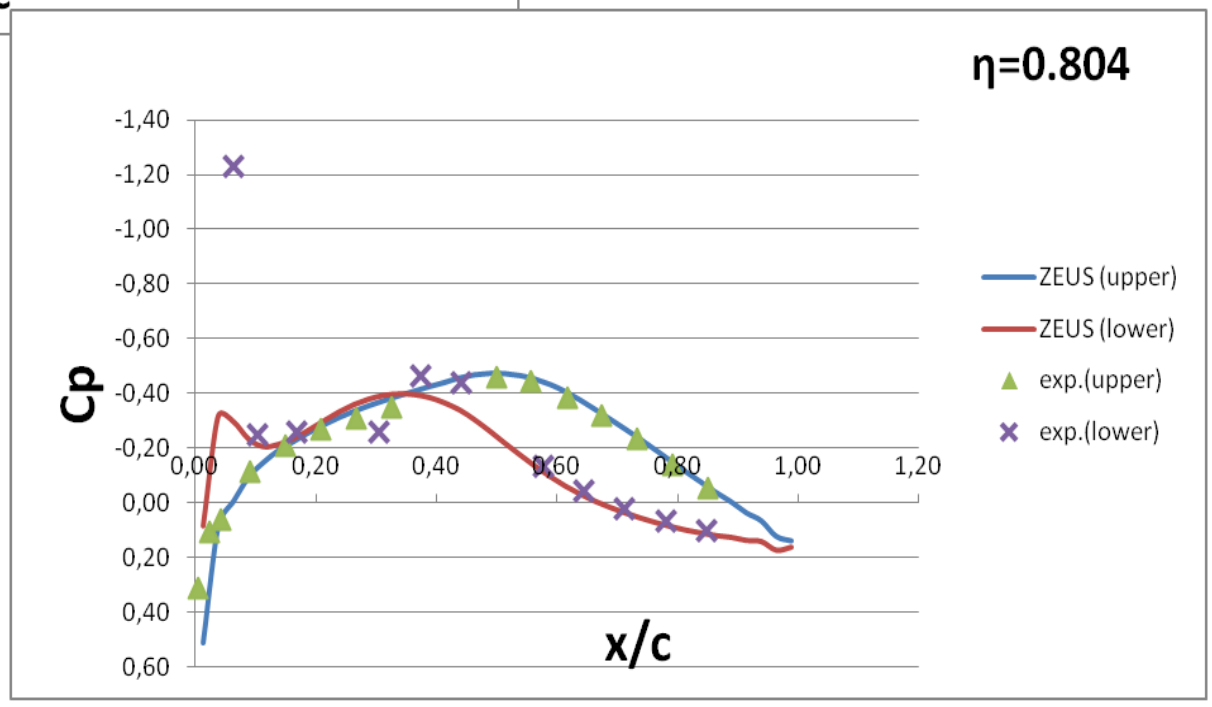
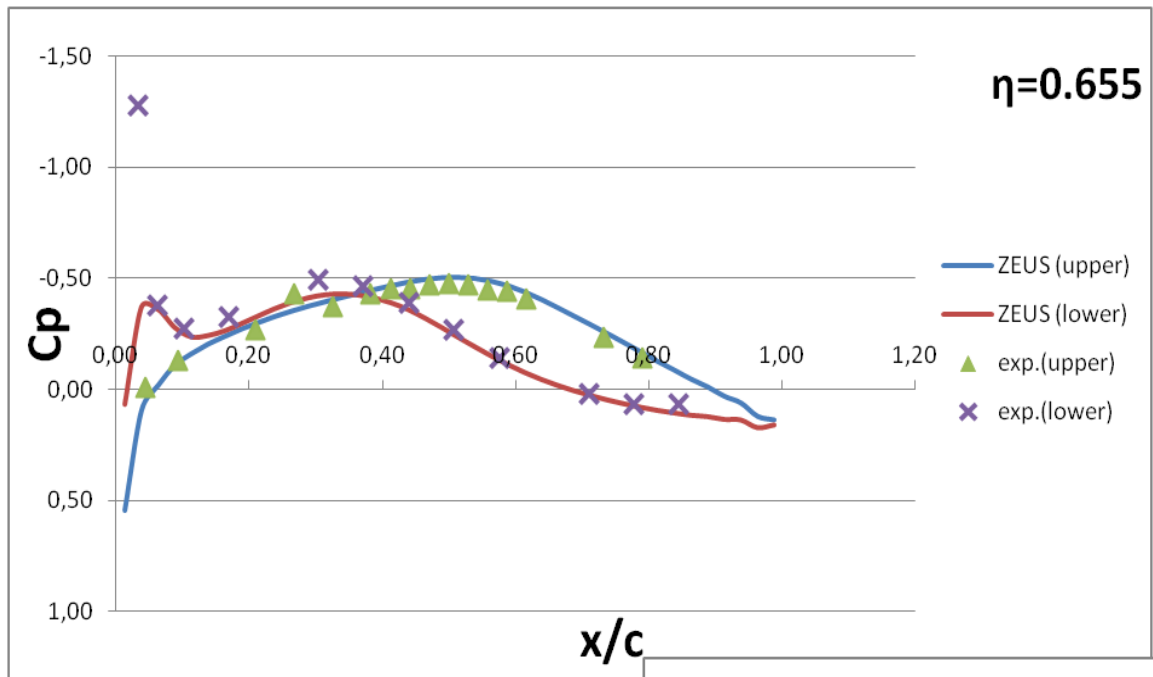


$\eta=0.456$

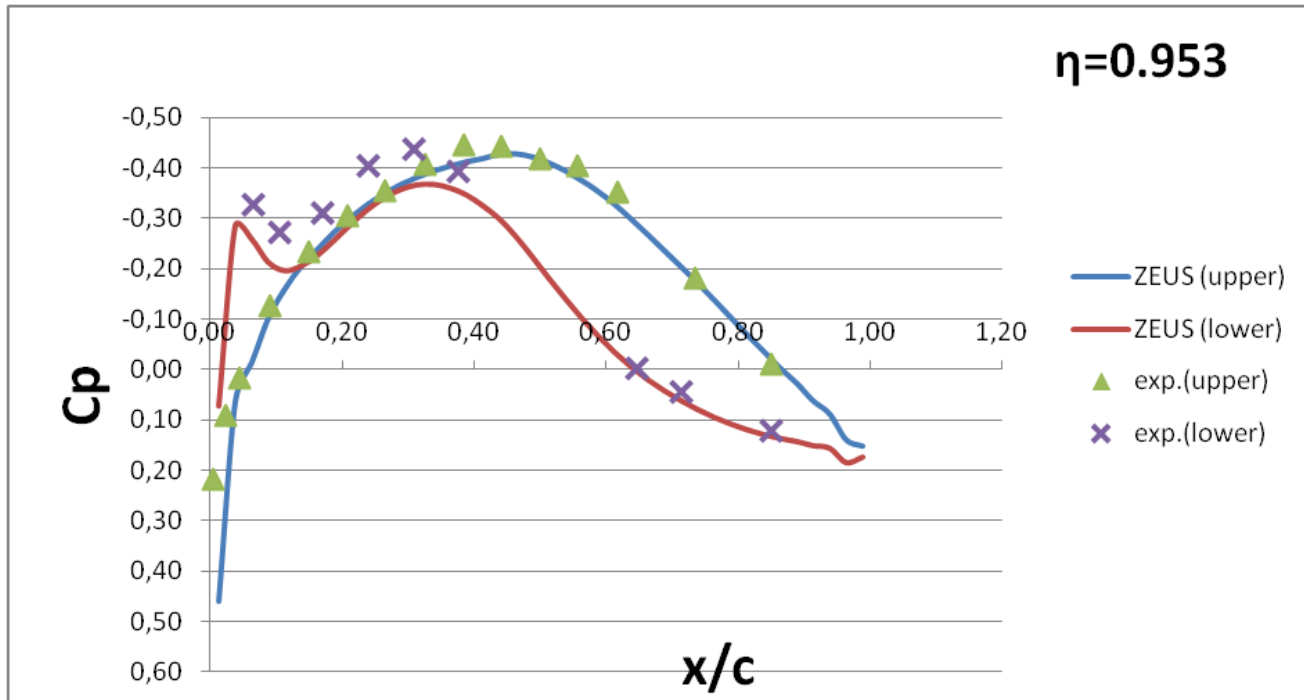


$\eta=0.589$



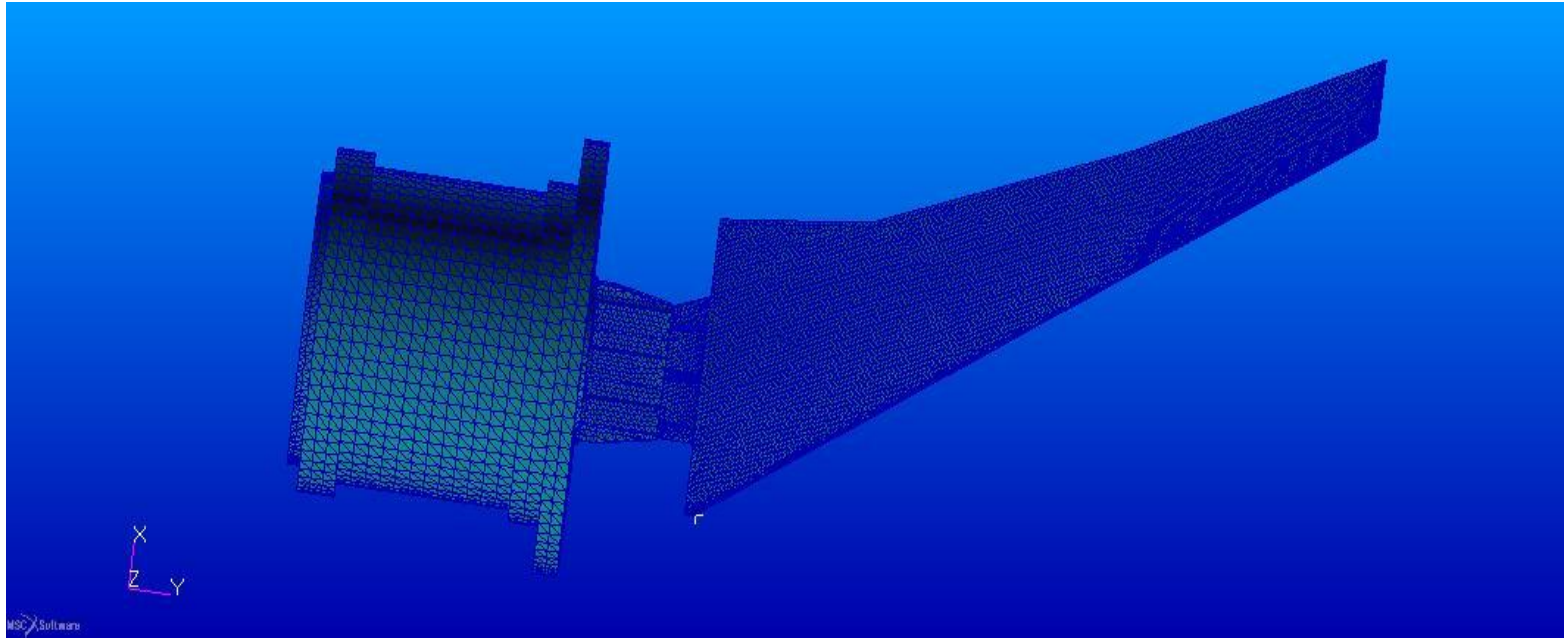


Results for exp.250 Set-1



Analysis Set-(2)

- ▶ **FEM Model**: HIRENASD Nov2011 FEM Model
- ▶ Set-2 is analyzed by ZONA.



Aerodynamic Model Information

Set-2

- ▶ **Aerodynamic Model is generated in ZEUS.**
- ▶ **Grid Type:** Structured
- ▶ **Element Type:** Quadrilateral
- ▶ **Computational Mesh:** (164 x 62 x 55)
- ▶ **Solver:** Cell Based
- ▶ **Platform:** Intel Xeon 8 CPU Cores ~ 10 minutes (for steady analysis), 35 minutes (for unsteady analysis)
- ▶ **Fluid-Structure Interaction (FSI) is provided by ZEUS.**

Results of Steady Analyses Set-2

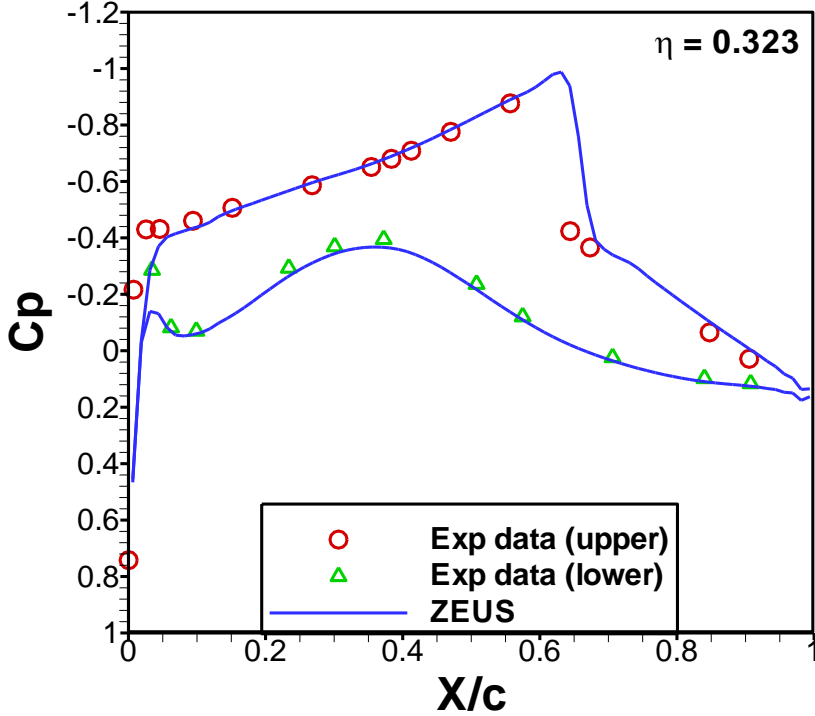
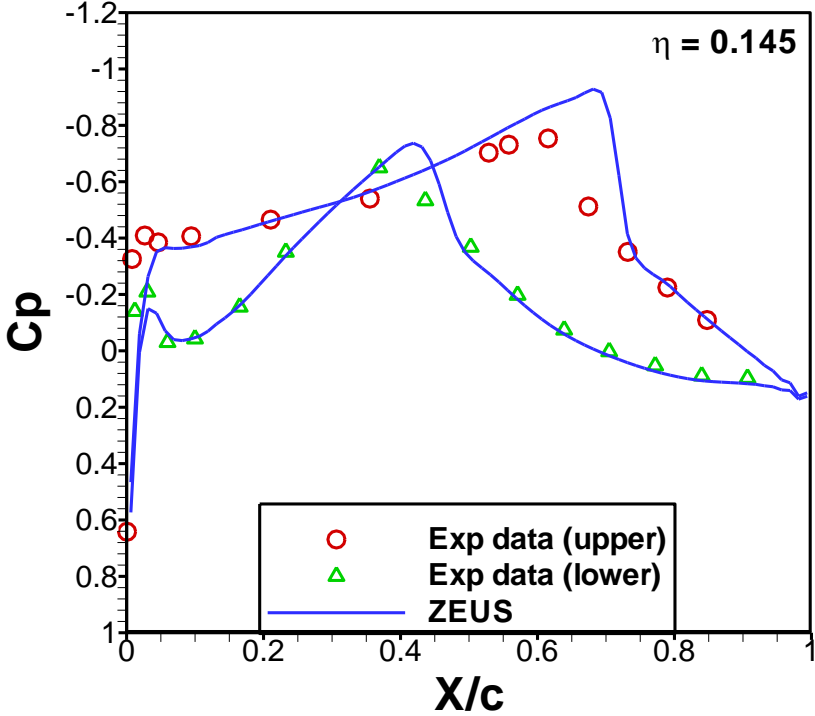
Low Re Case (for exp.132)

Quantity	Calculated
C_L	0.3533
C_M	-0.3076
C_D	0.026

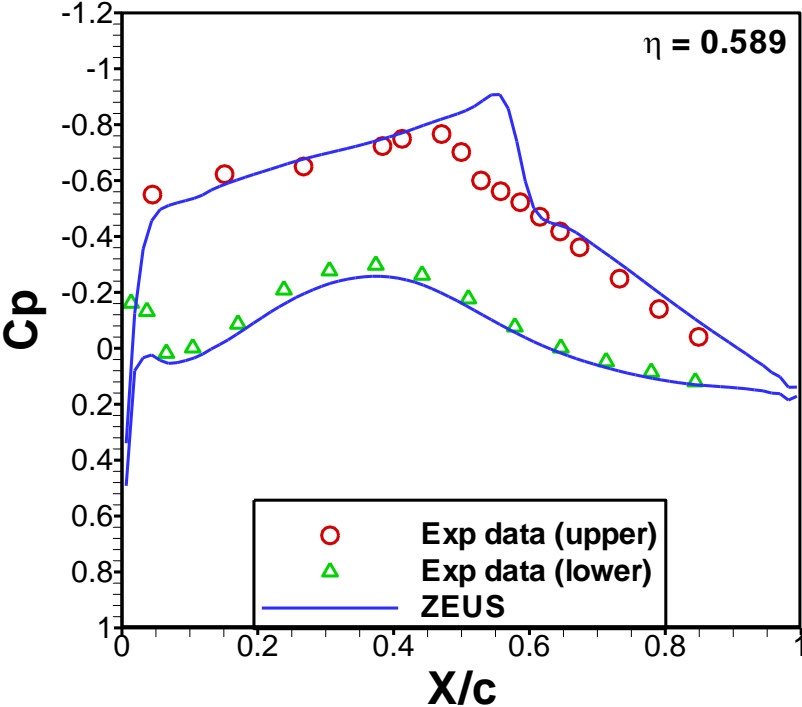
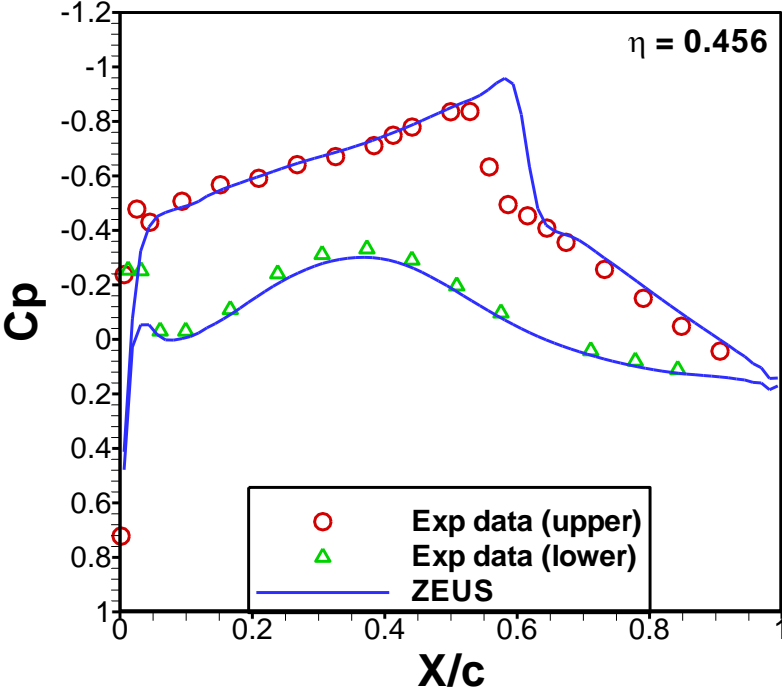
High Re Case (for exp.250)

Quantity	Calculated
C_L	0.0355
C_M	-0.09585
C_D	0.02268

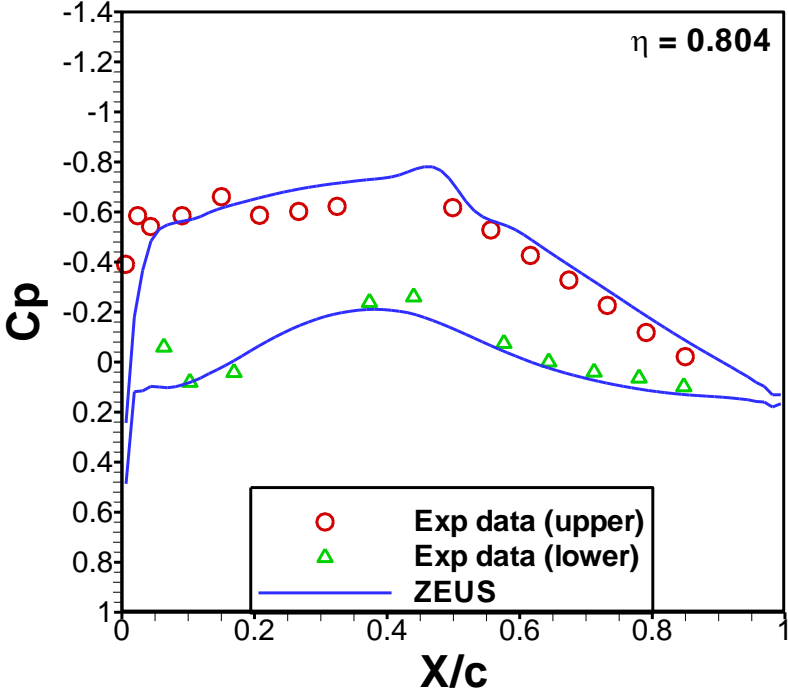
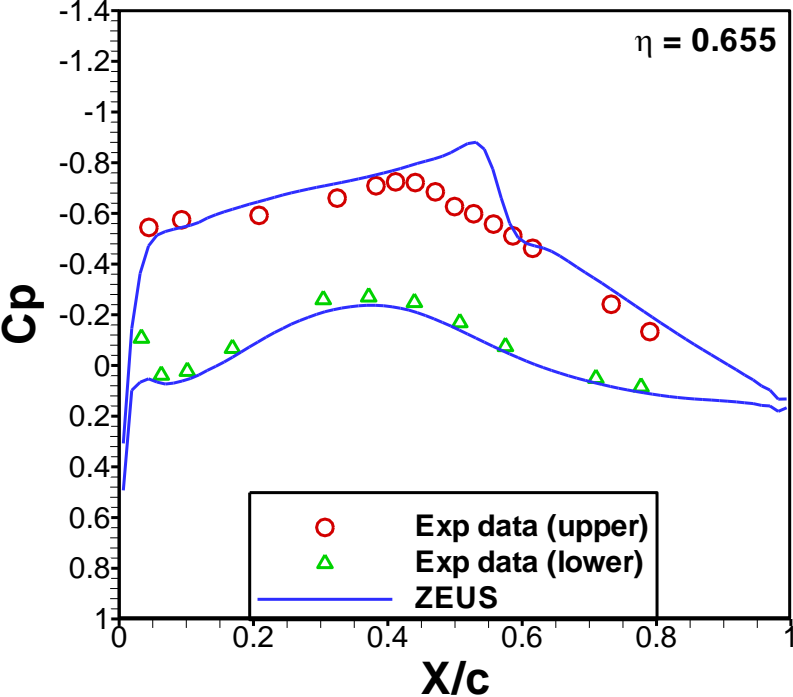
Steady Results for exp.132 Set-2



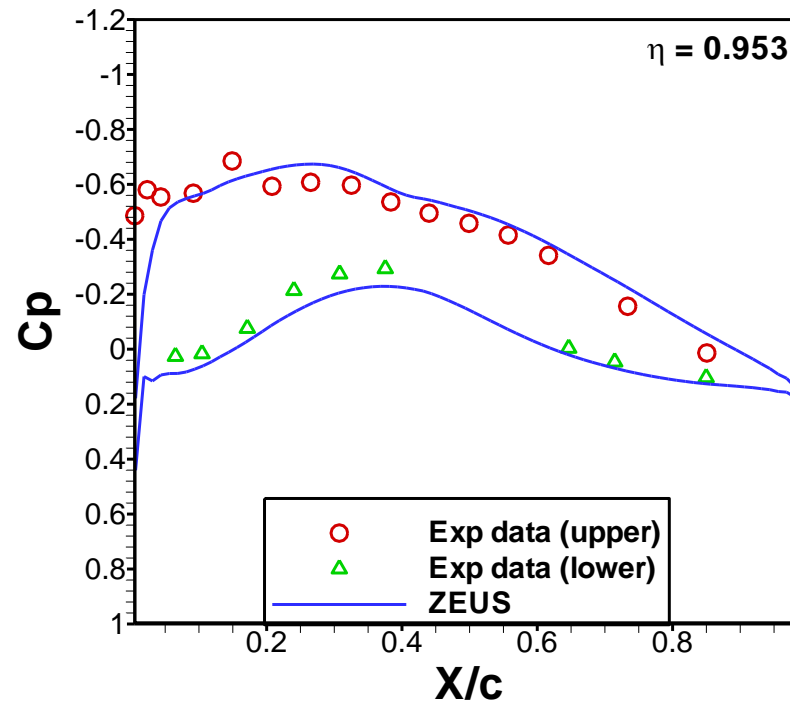
Steady Results for exp.132 Set-2



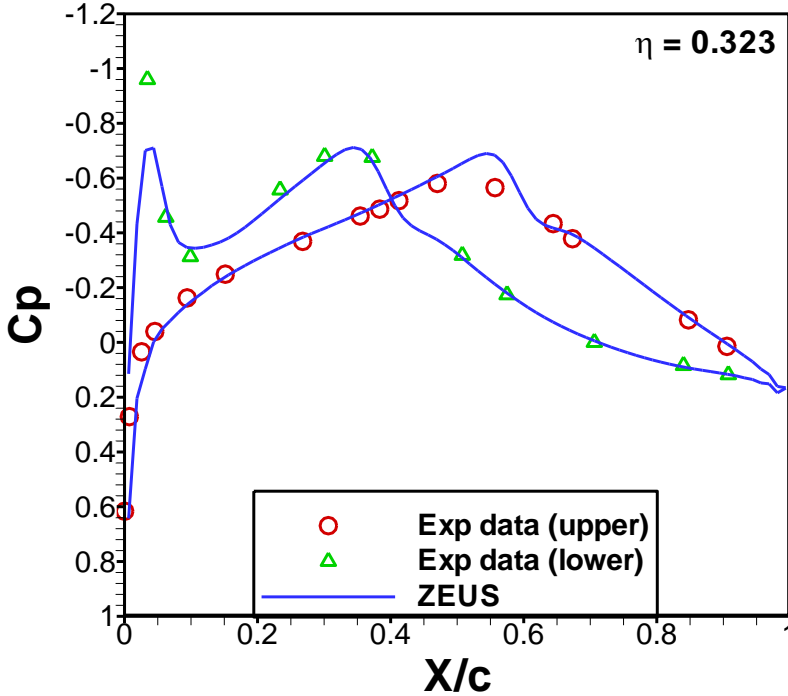
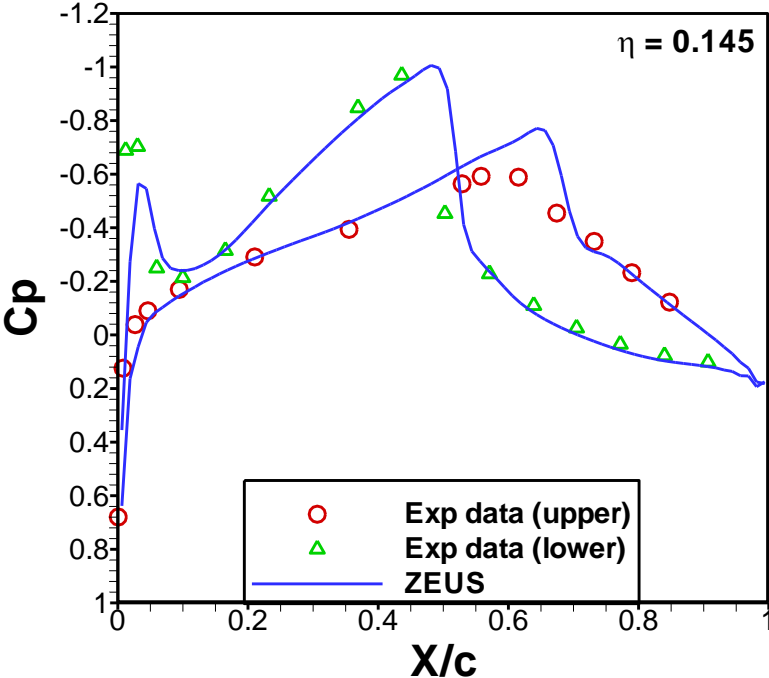
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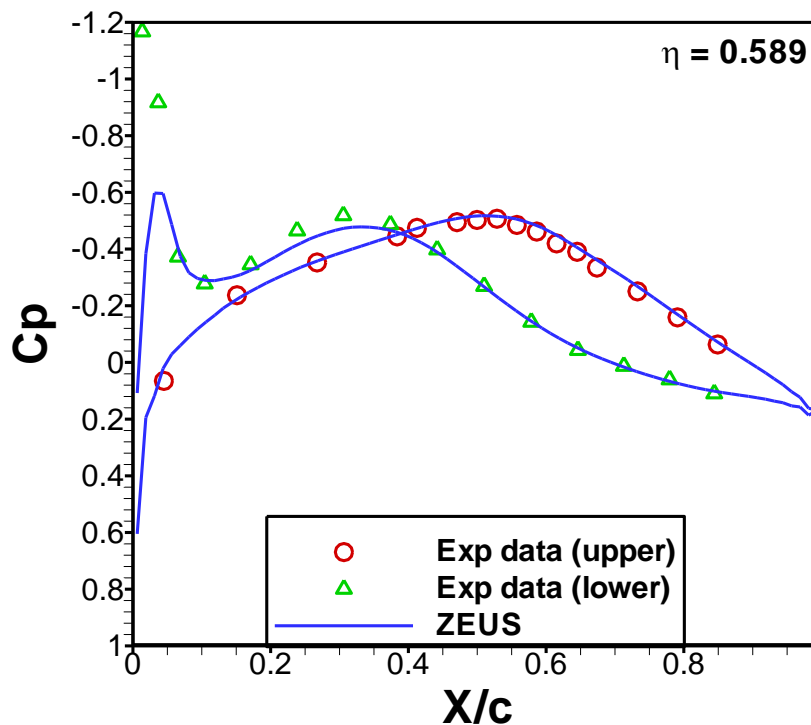
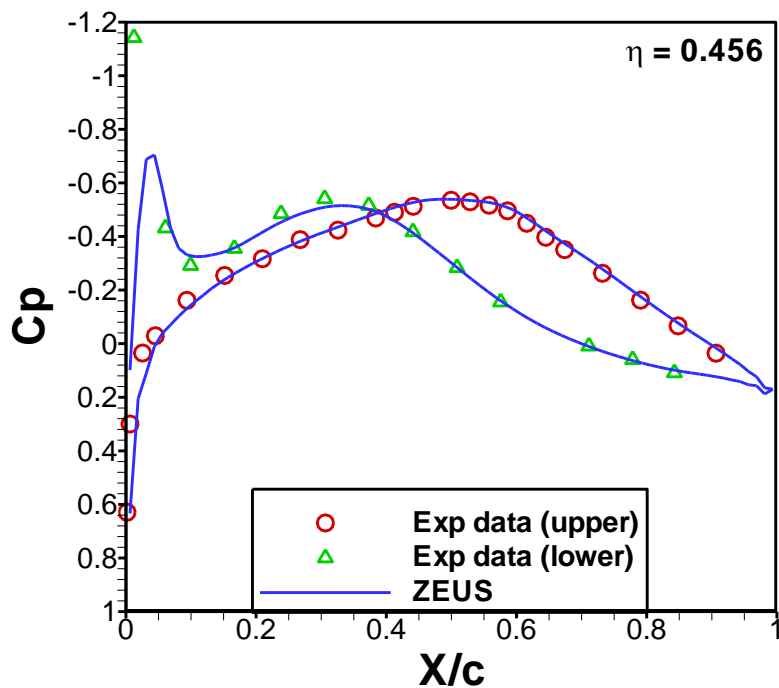
Steady Results for exp.132 Set-2



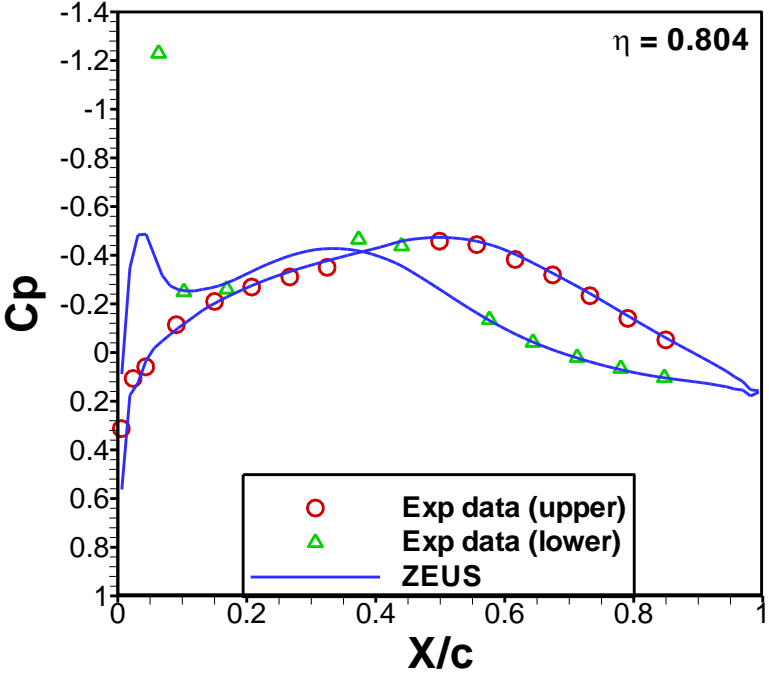
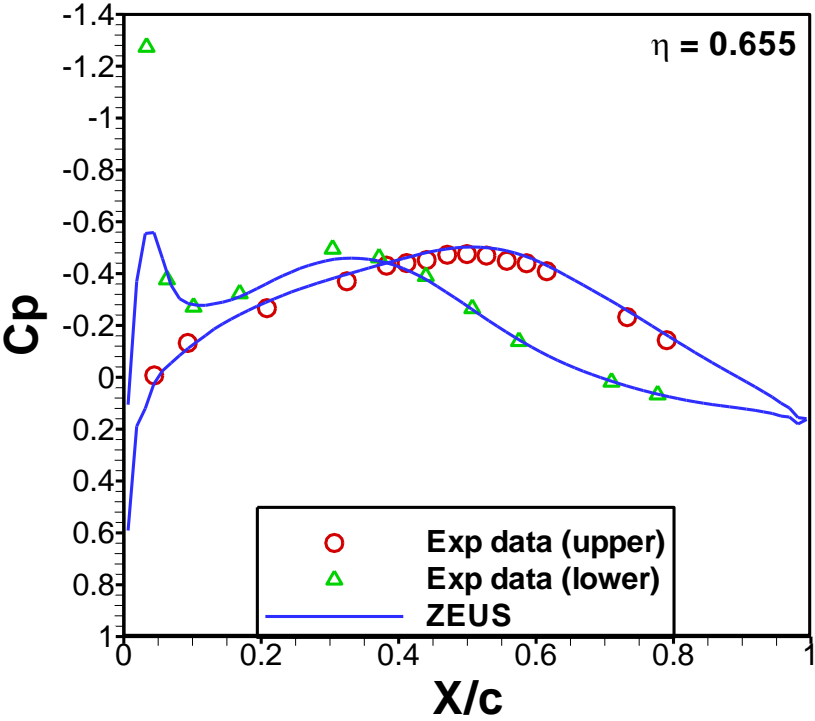
Steady Results for exp.250 Set-2



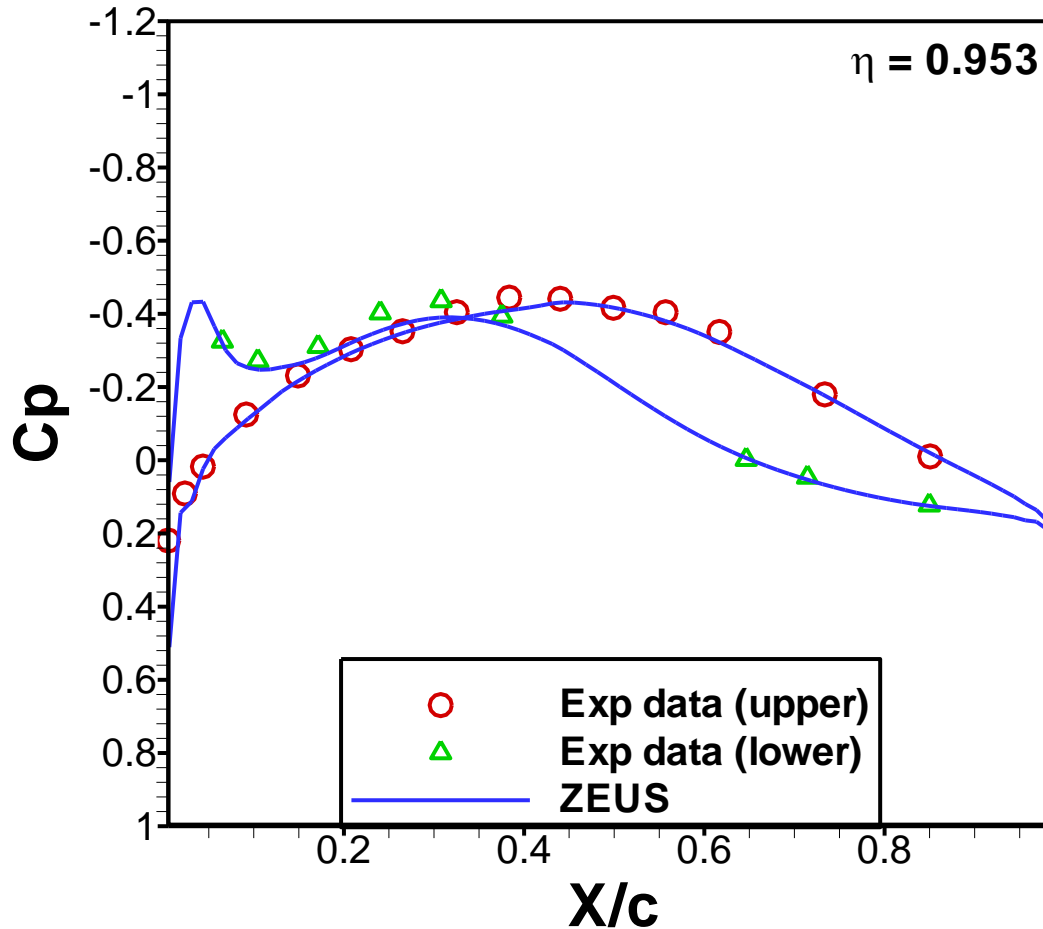
Steady Results for exp.250 Set-2



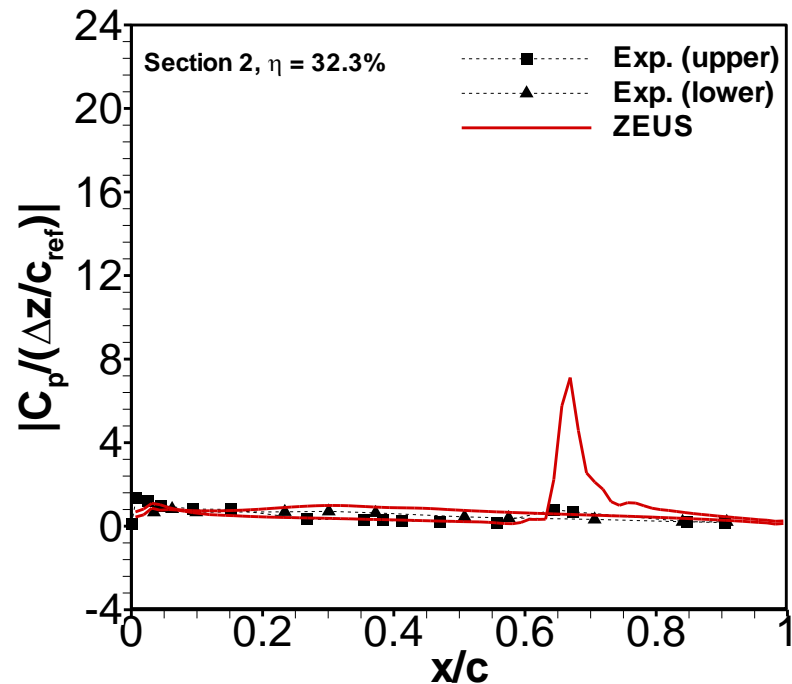
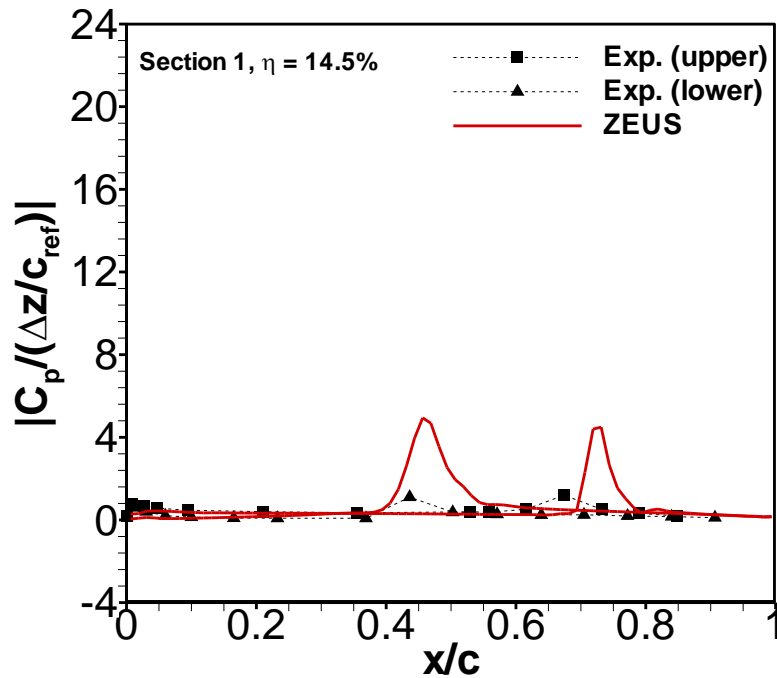
Steady Results for exp.250 Set-2



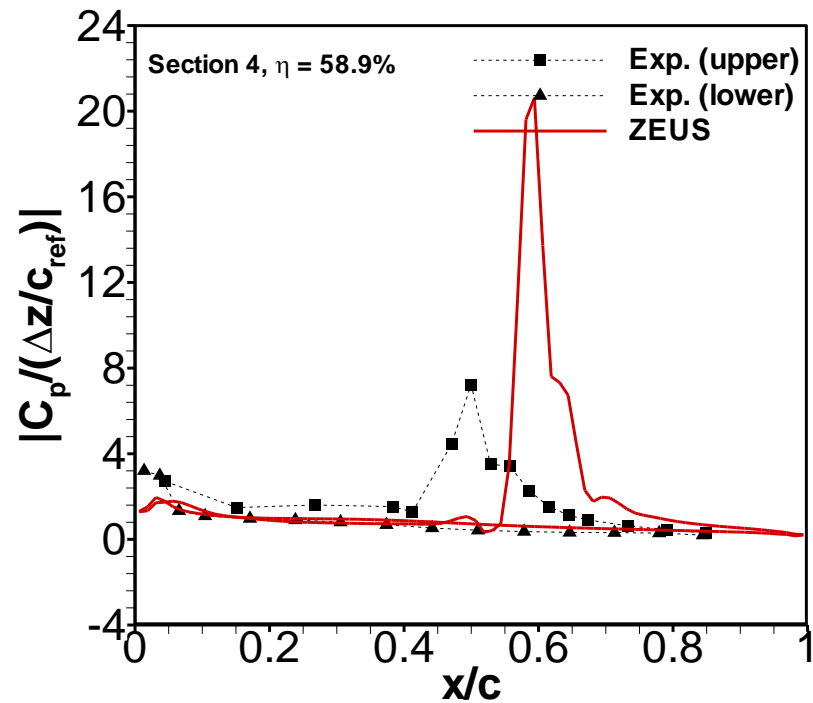
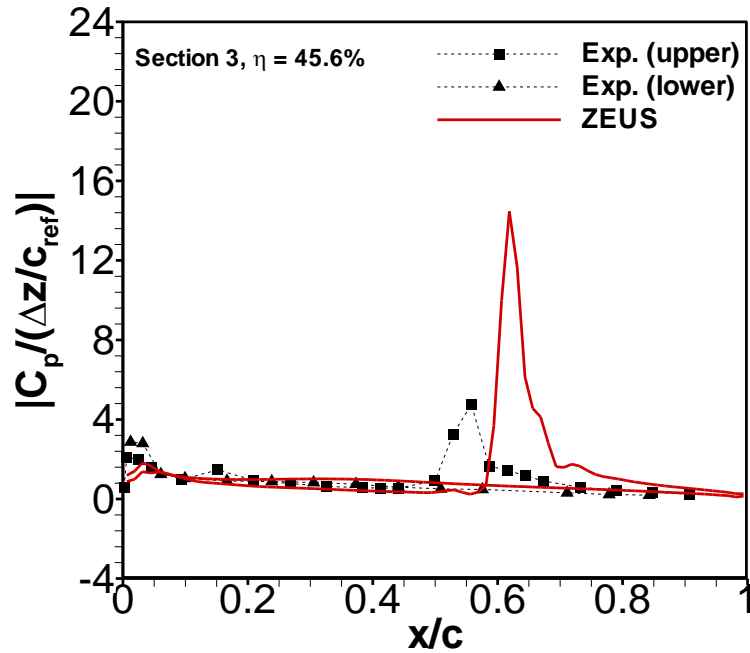
Steady Results for exp.250 Set-2



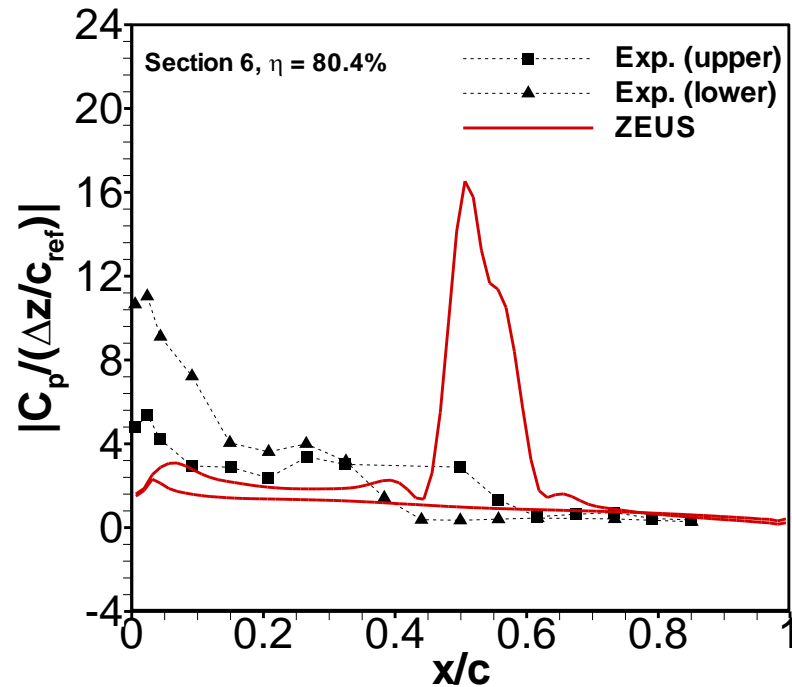
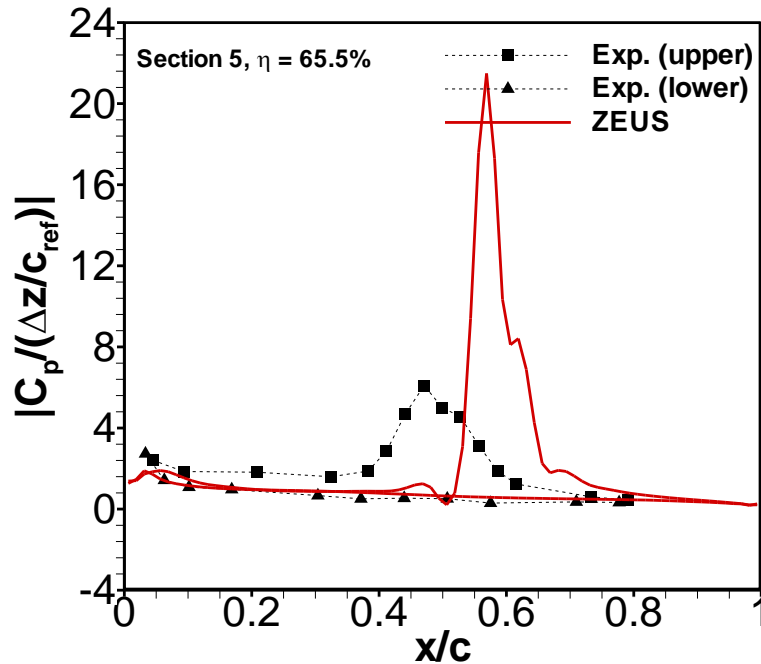
Unsteady Results for exp.159 (C_p Magnitude) Set-2



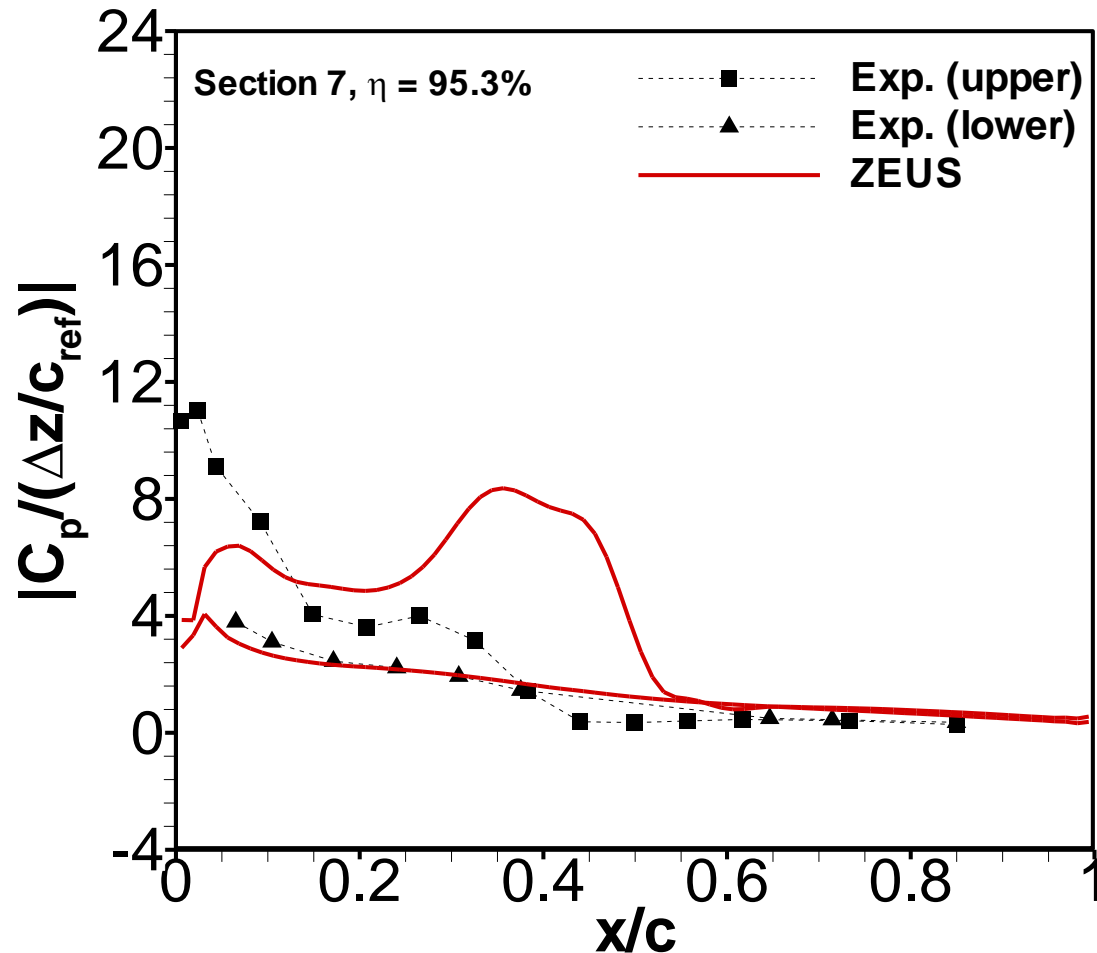
Unsteady Results for exp.159 (C_p Magnitude) Set-2



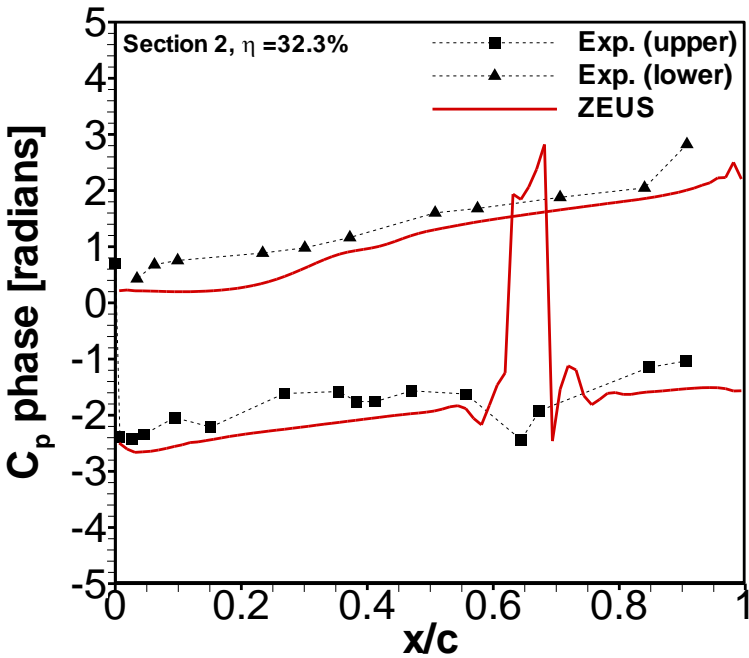
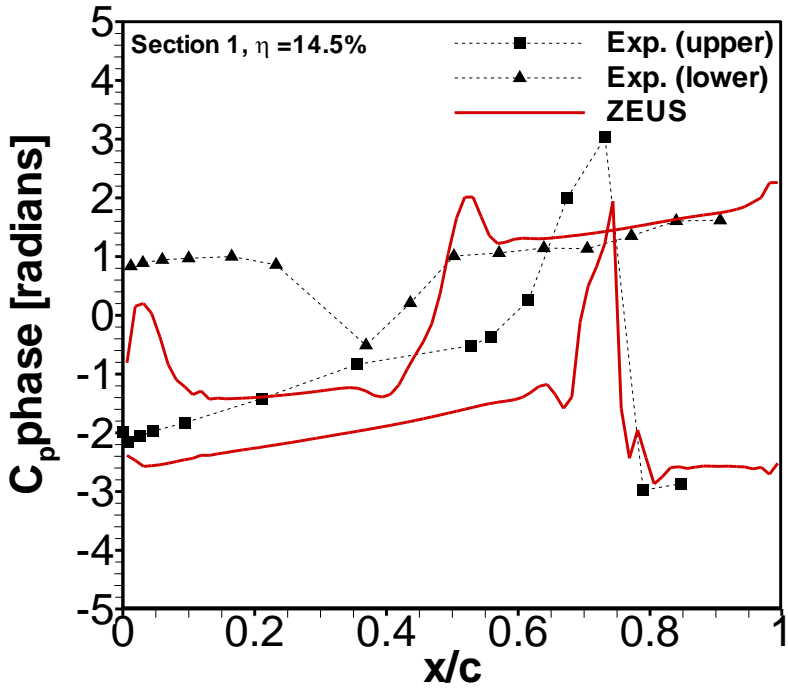
Unsteady Results for exp.159 (C_p Magnitude) Set-2



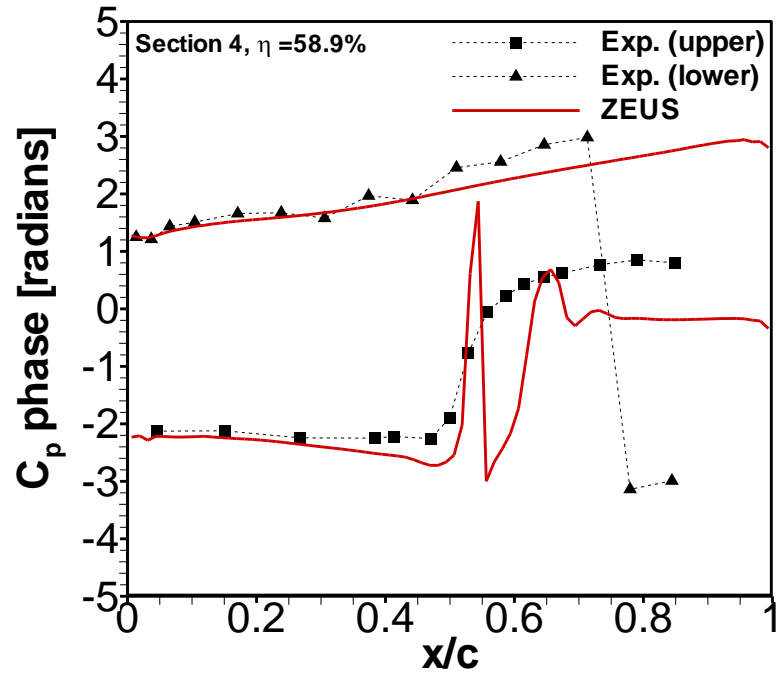
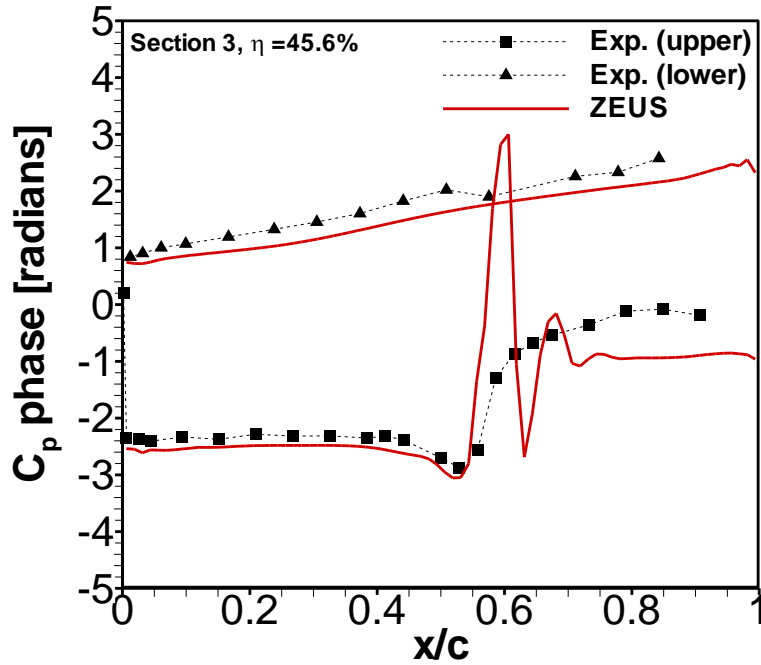
Unsteady Results for exp.159 (C_p Magnitude) Set-2



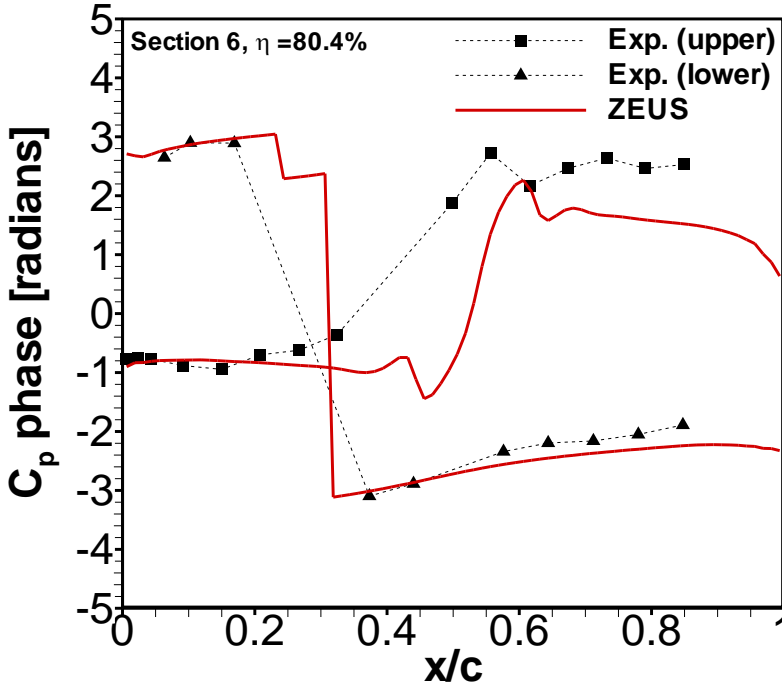
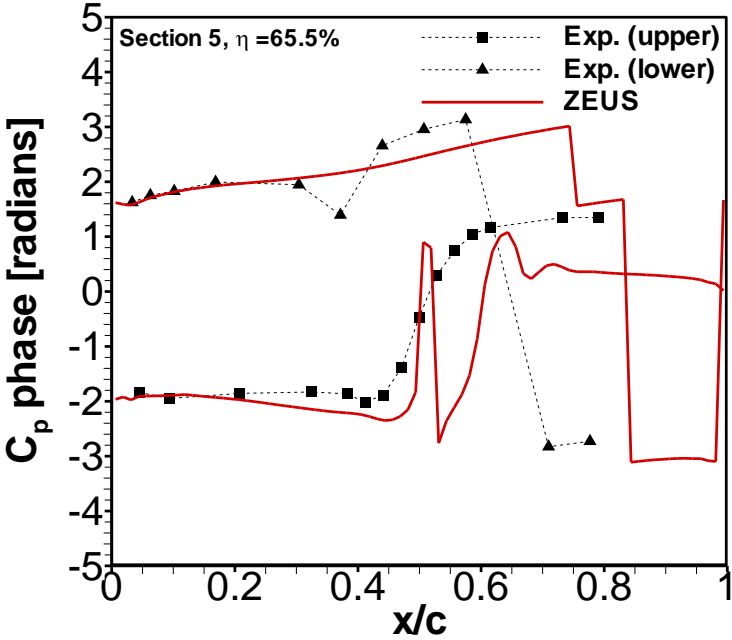
Unsteady Results for exp.159 (C_p Phase) Set-2



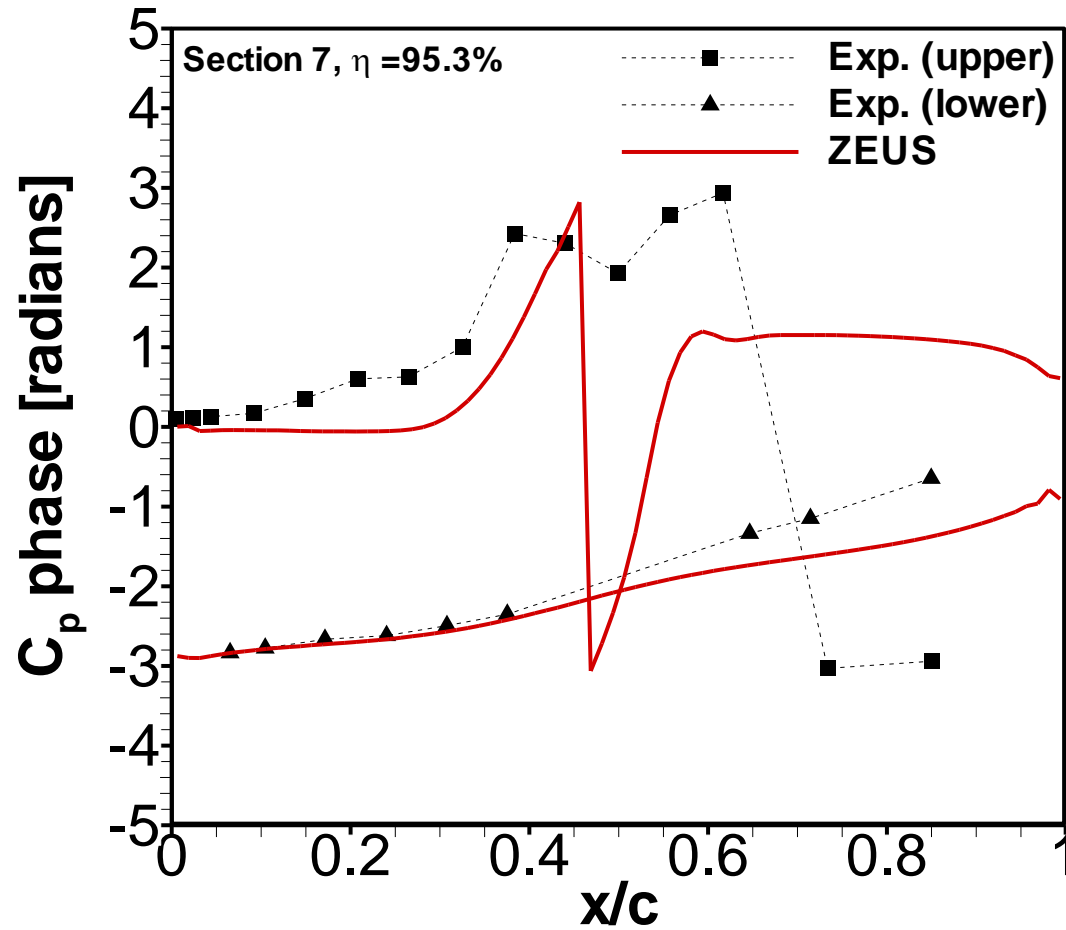
Unsteady Results for exp.159 (C_p Phase) Set-2



Unsteady Results for exp.159 (C_p Phase) Set-2

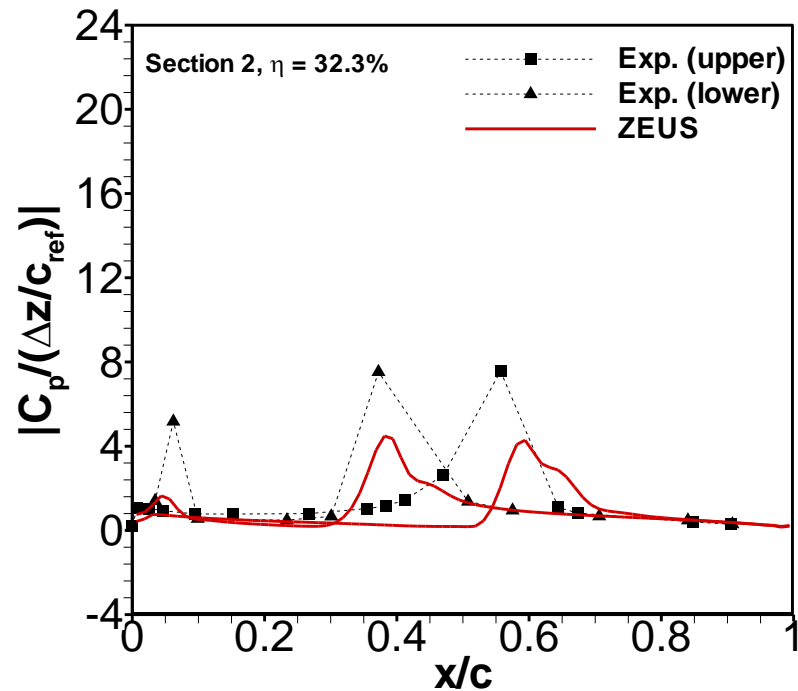
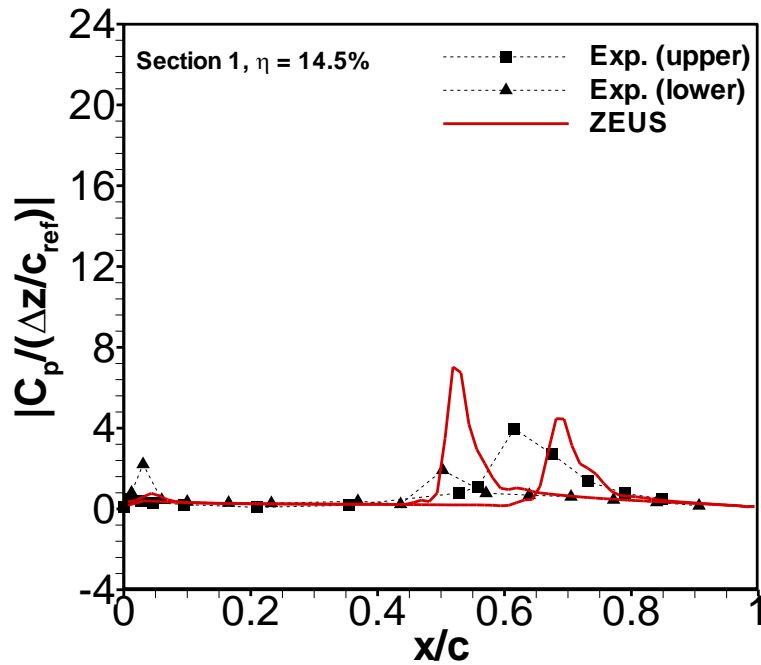


Unsteady Results for exp.159 (C_p Phase) Set-2

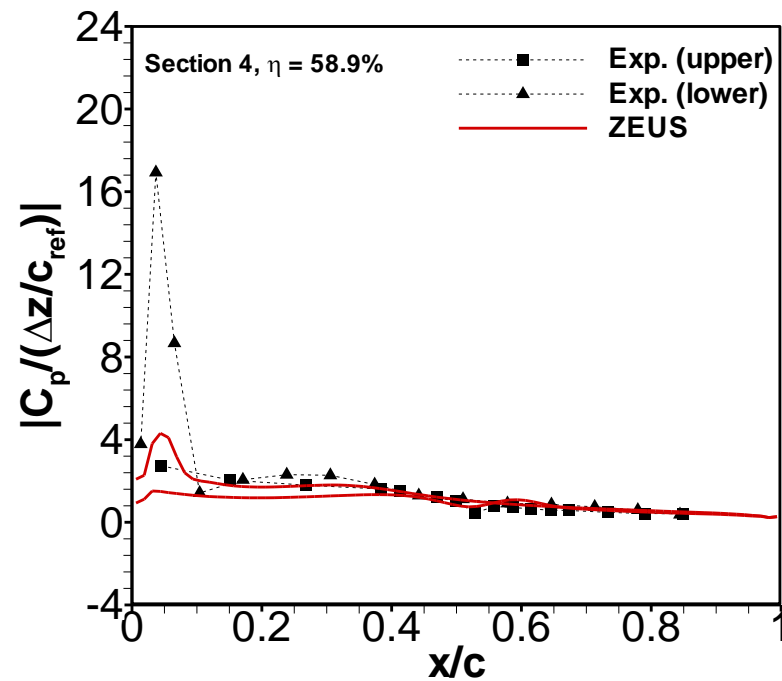
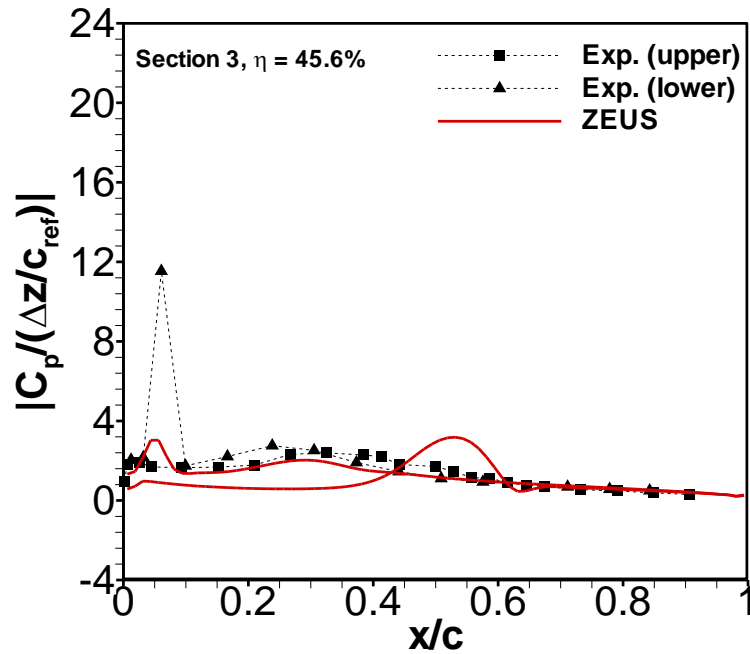


Unsteady Results for exp.271 (C_p Magnitude)

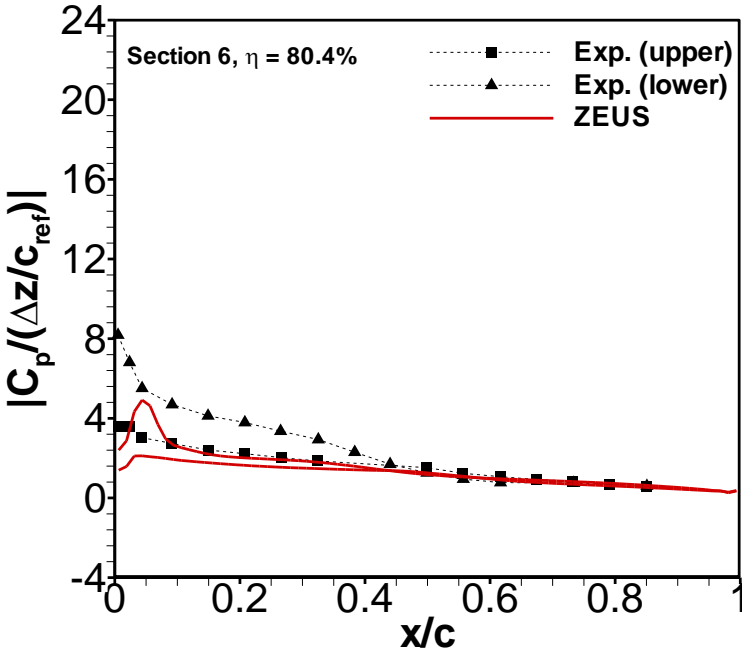
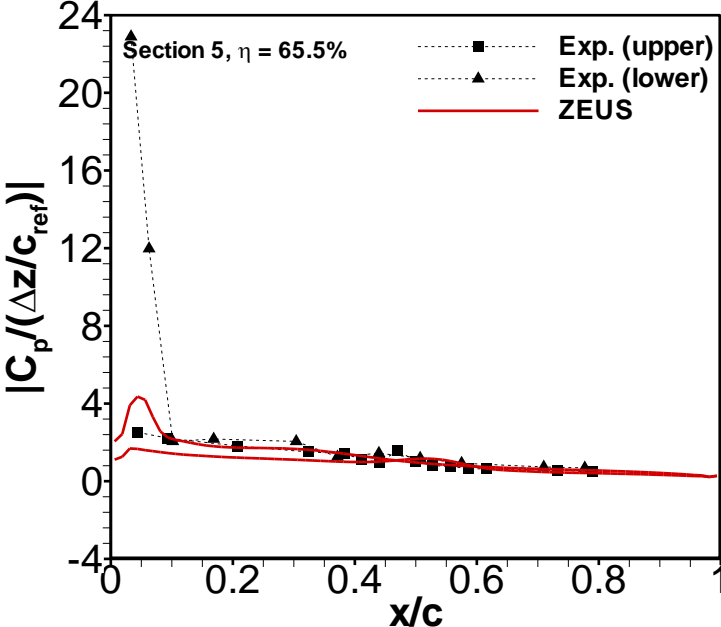
Set-2



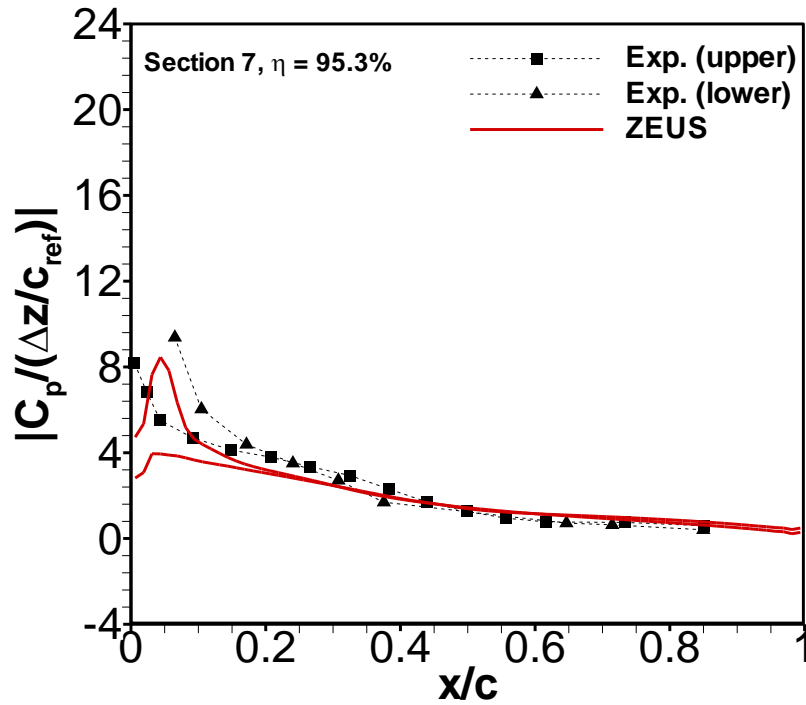
Unsteady Results for exp.271 (C_p Magnitude) Set-2



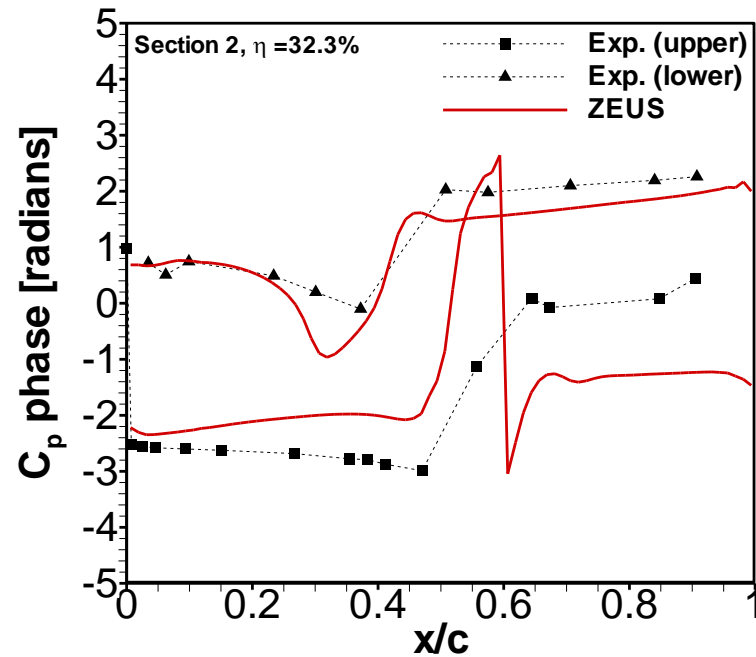
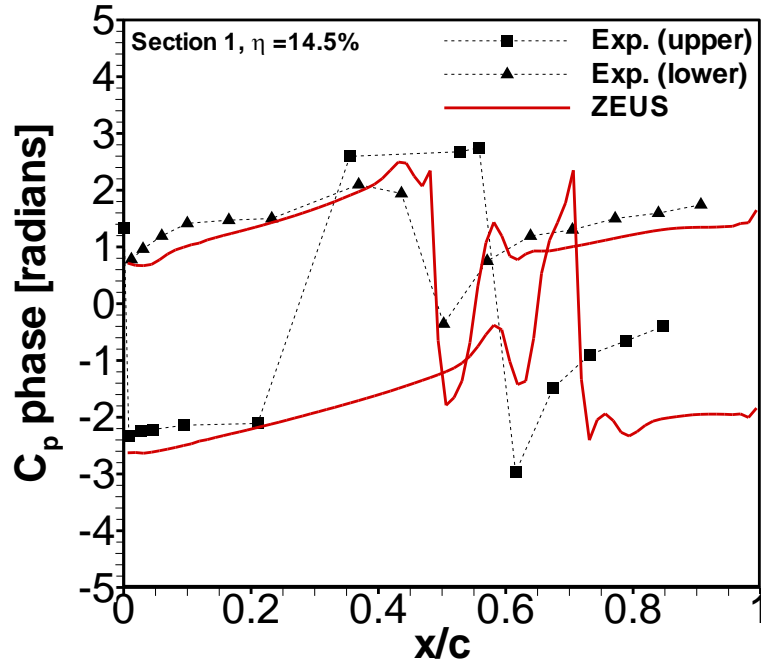
Unsteady Results for exp.271 (C_p Magnitude) Set-2



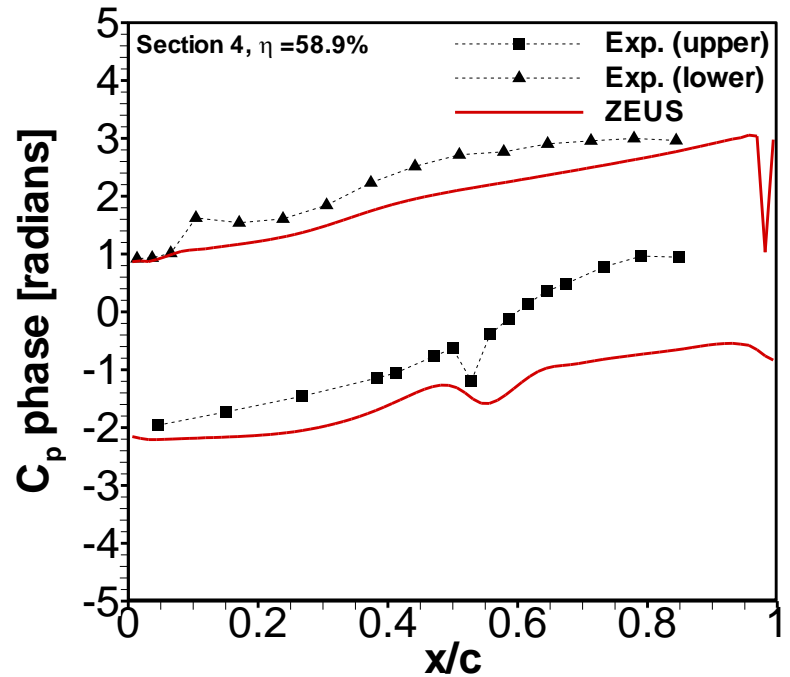
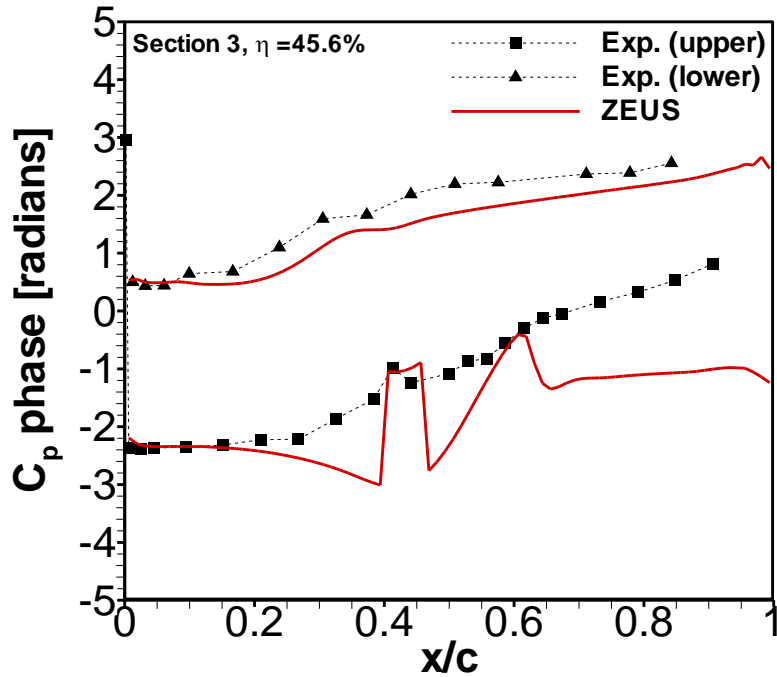
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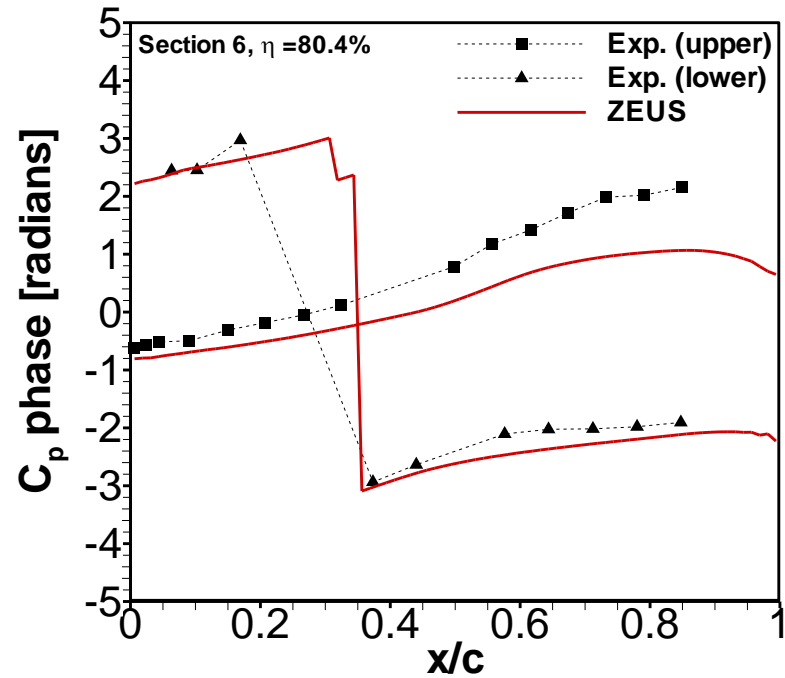
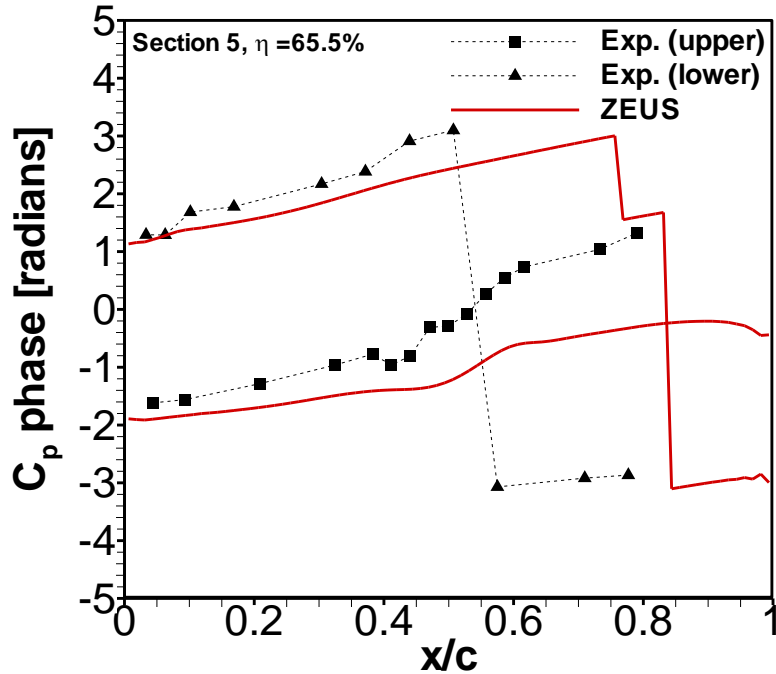
Unsteady Results for exp.271 (C_p Phase) Set-2



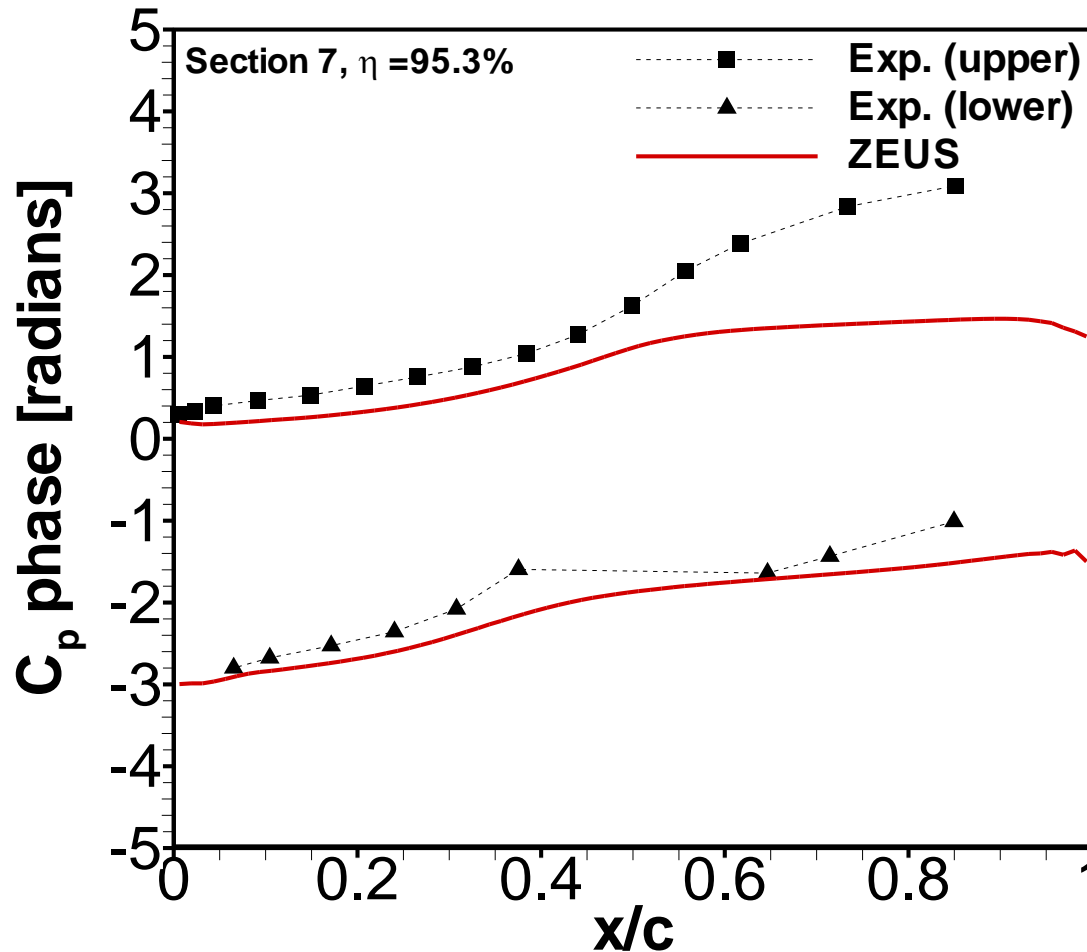
Unsteady Results for exp.271 (C_p Phase) Set-2



Unsteady Results for exp.271 (C_p Phase) Set-2



Unsteady Results for exp.271 (C_p Phase) Set-2



Conclusions and Future Work

- ▶ Steady and unsteady aeroelastic analyses of HIRENASD wing are performed by using ZEUS software.
- ▶ Analyses are performed by utilizing two different FEM models (both were coarse).
- ▶ Steady results of old model (structured wing with hollow wing body) are comparable.
- ▶ The results for new model (Nov2011) give comparable data in both steady and unsteady analyses.

As future work:

- ▶ Time histories of C_p values (missing data) should be provided.
- ▶ Mesh quality will be improved to reach more accurate results.

Thank You!

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