AePW-1 RSW test cases

A. Gehri and D.Steiling

RUAG Aviation

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Who we are

- RUAG Aviation, Department Aerodynamics
  - Operates two subsonic wind tunnels
    - Large Wind Tunnel Emmen (LWTE), 7x5m, aerospace (powered/unpowered), full scale automotive rain testing
    - Automotive Wind Tunnel Emmen (AWTE), 2.45x1.55m, with road simulation
  - Manufactures wind tunnel balances for other wind tunnels
  - CFD in collaboration with CFS Engineering at the EPFL (Swiss Federal Institute of Technology) in Lausanne
- Alain Gehri
  - Experienced CFD engineer, within AePW responsible for meshing and setup of calculations
- Daniel Steiling
  - Aerodynamic engineer, within AePW responsible for coordination and post-processing

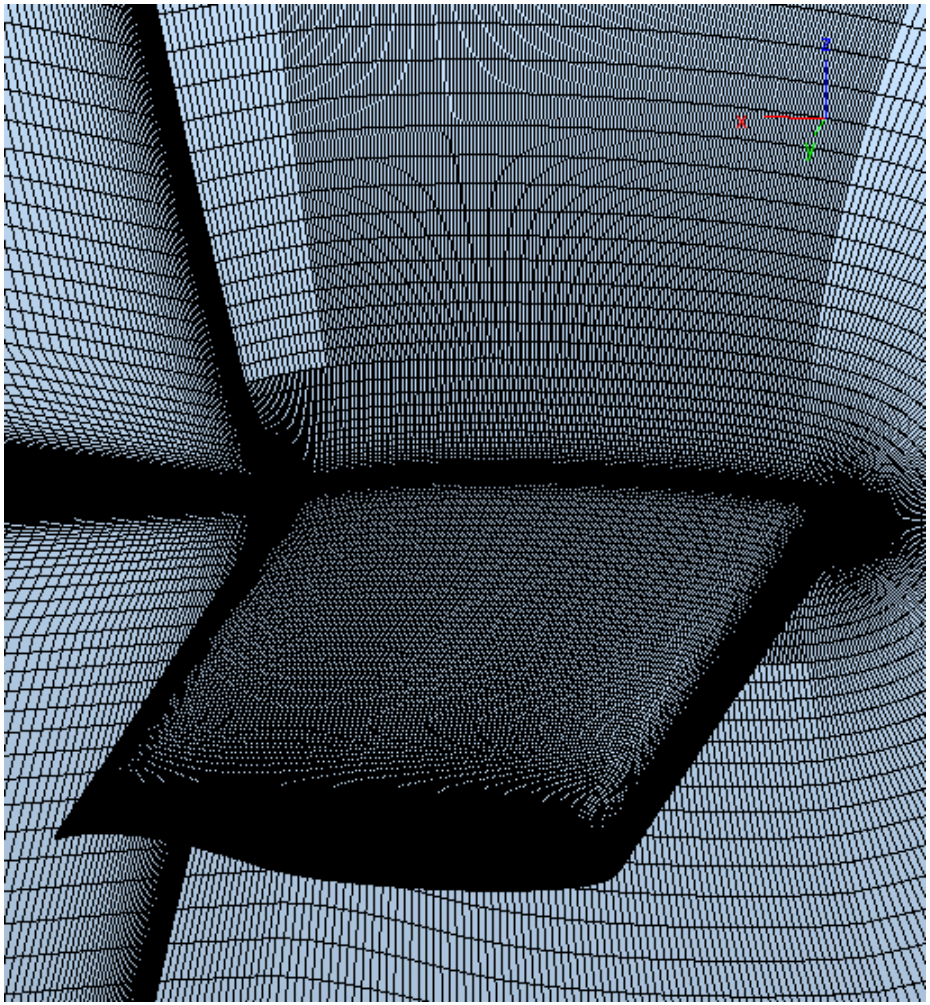
NSMB flow solver and settings

- Multiblock Navier-Stokes solver, hence the name “NSMB”
- Developed at the EPFL in Lausanne since 1991, together with other universities and industrial partners
- Settings used for the BSCW test cases:
  - Space discretization: 4th-order central scheme (Jameson)
  - Time integration: implicit LU-SGS scheme
  - Unsteady calculations: dual time stepping, w/ time correction procedure
  - Turbulence model: SA (URANS, RANS for static)
- Particular version of NSMB had a bug in the ALE formulation
  - Dissipation for the turbulent equations was wrong, grid velocity not included
  - Corrected now, see HIRENASD presentation

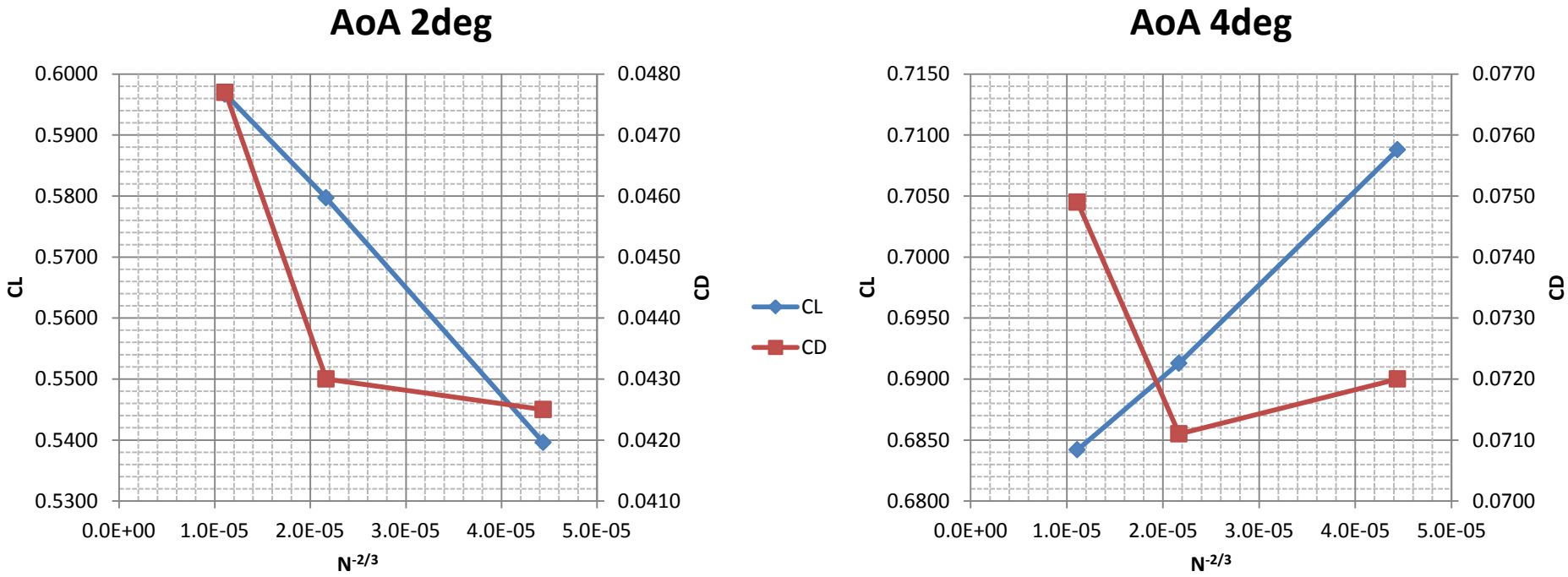
Test case specific settings and assumptions

- Cases calculated: static steady (c/m/f) -> dynamic(m) , each with forced transition (6.0% U/L)
- 64 time steps per period for each case
- Six (10Hz case) / seven (20Hz case) periods have been simulated, with the last four periods used to determine the FRF
- $FRF = \frac{fft(exitation) \cdot fft(response)}{fft(extation) \cdot \overline{fft(extation)}}$
- Model used was 7in+48in wingspan, no splitter plate, viscous wall
- Only the outer 48in where taken into account when integrating for the global coefficients, reference area was taken from the 48in model
- Computational domain starts 40 c_ref ahead from wing

Grid overview



Grid convergence static case



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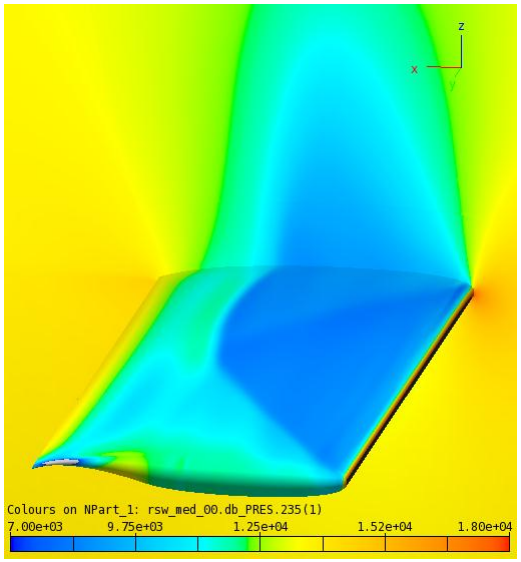
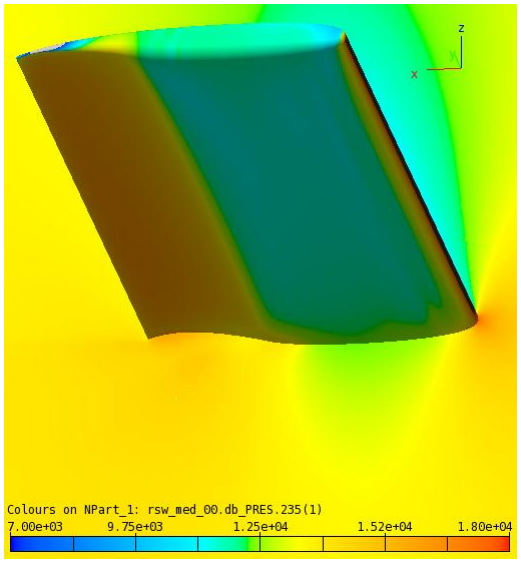
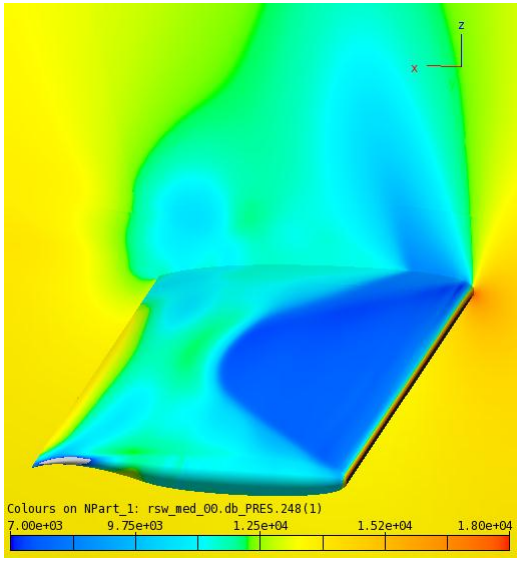
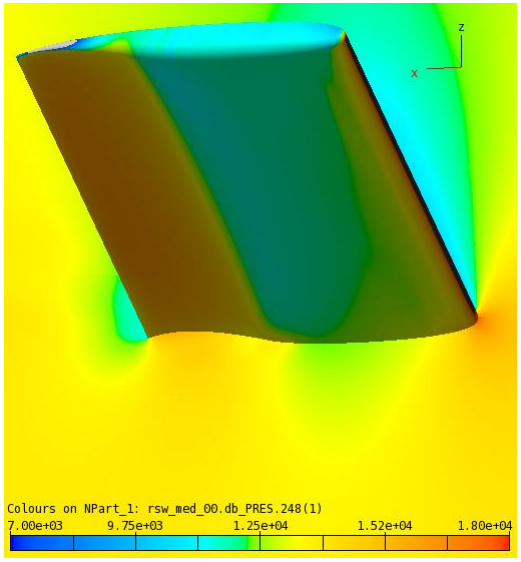
Global picture





AoA 2deg





AoA 4deg

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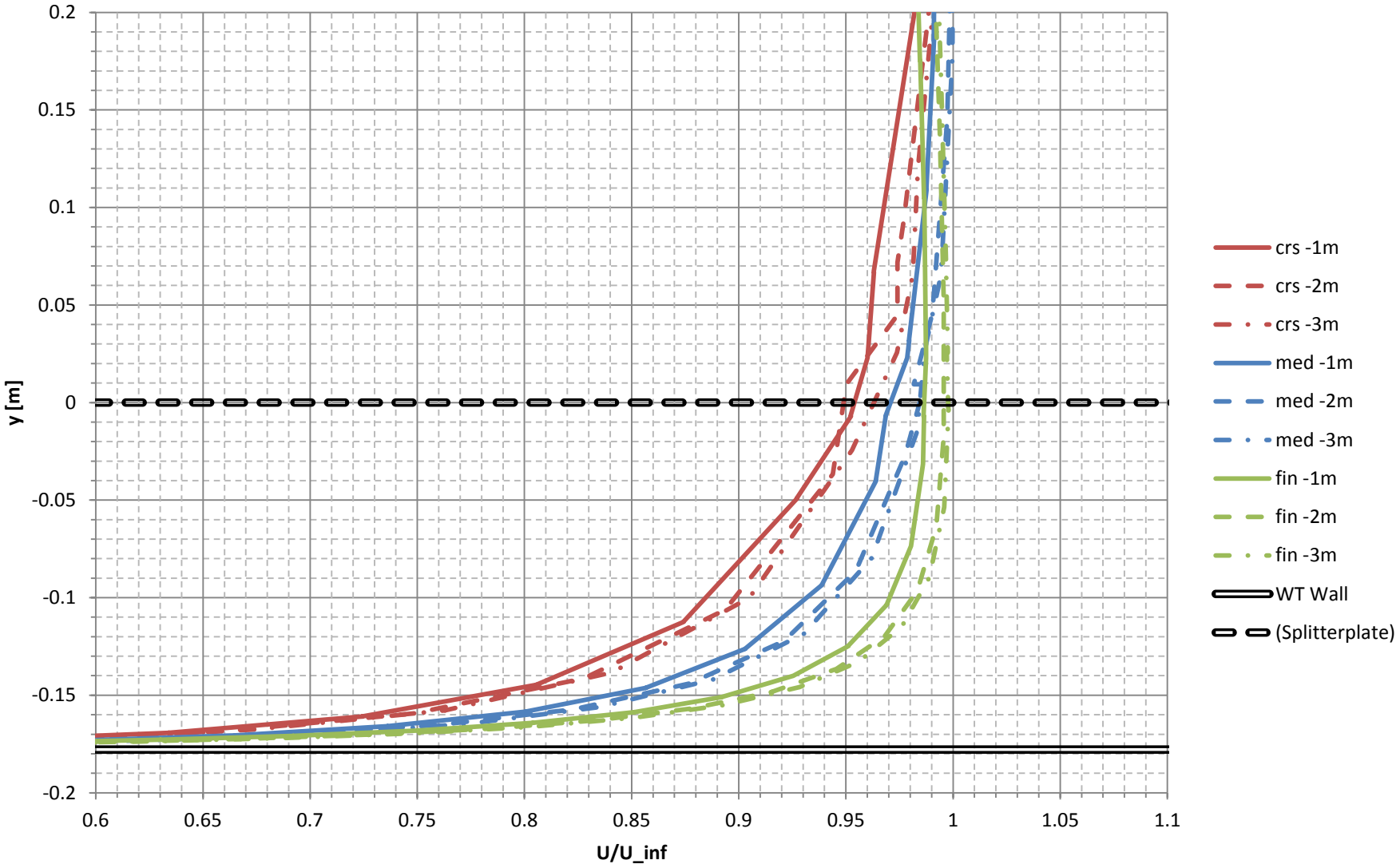
Boundary layer profile



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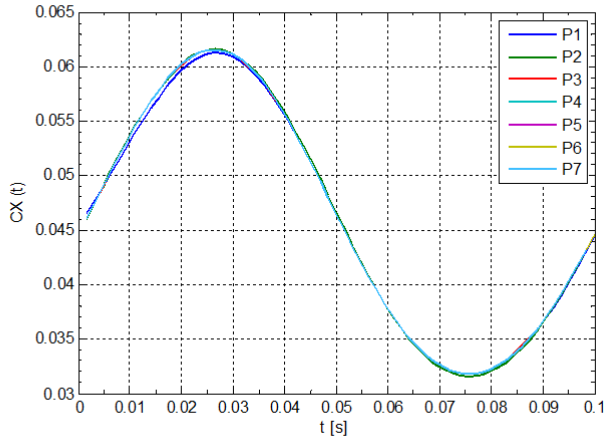
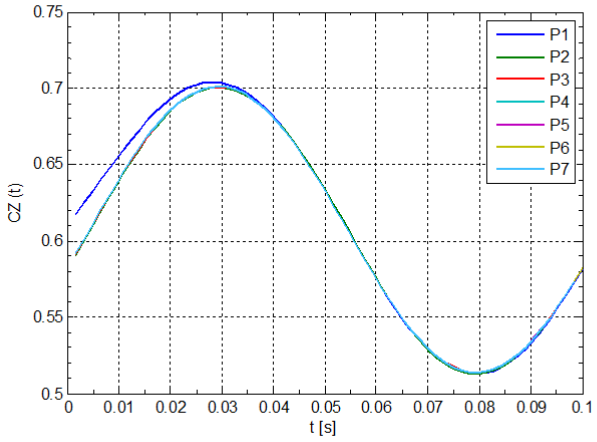
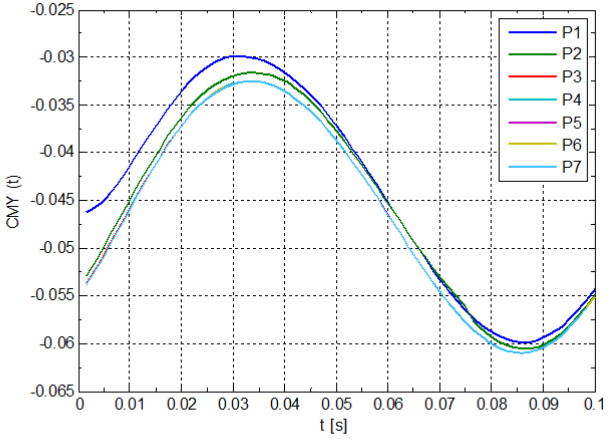
Global coefficients 10Hz case



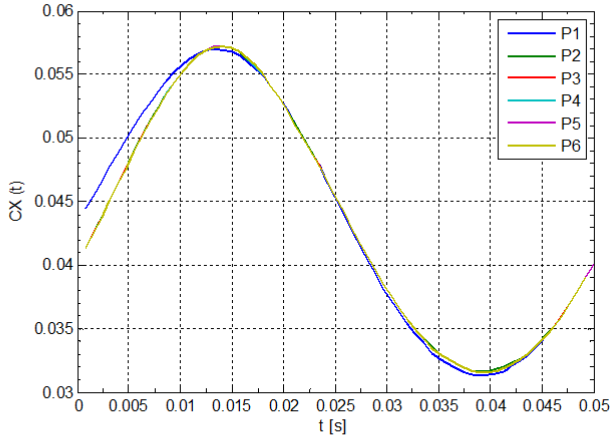


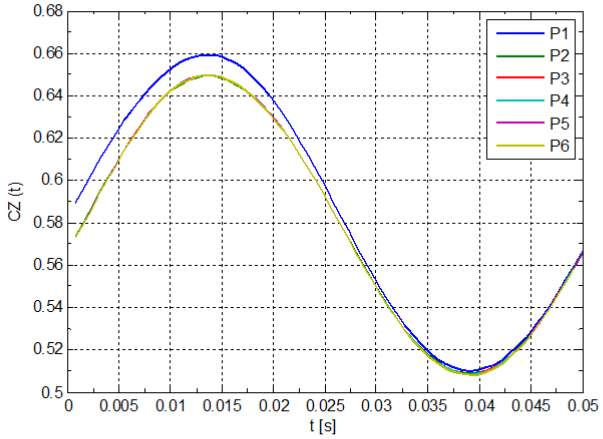


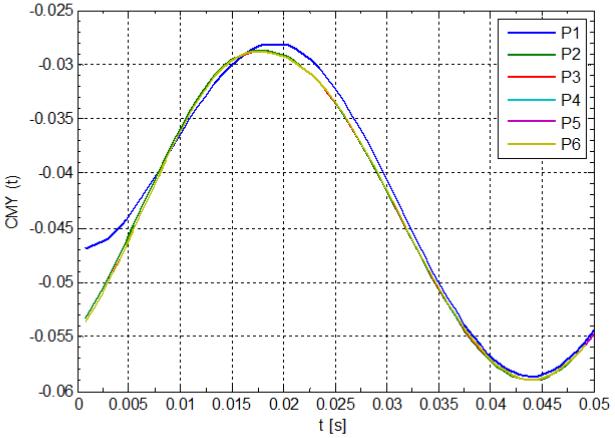
RTO6E54 (10Hz)

CX_{avg} = 0.046097	CZ_{avg} = 0.60762	CMY_{avg} = -0.04646
CX_{re}/θ = 0.8507	CZ_{re}/θ = 5.1753	CMY_{re}/θ = 0.67128
CX_{im}/θ = -0.053548	CZ_{im}/θ = -1.4404	CMY_{im}/θ = -0.46676
CX_{mag}/θ = 0.85238	CZ_{mag}/θ = 5.372	CMY_{mag}/θ = 0.81761
CX_{phase} = -3.6018	CX_{phase} = -15.5533	CMY_{phase} = -34.812

Global coefficients 20Hz Case



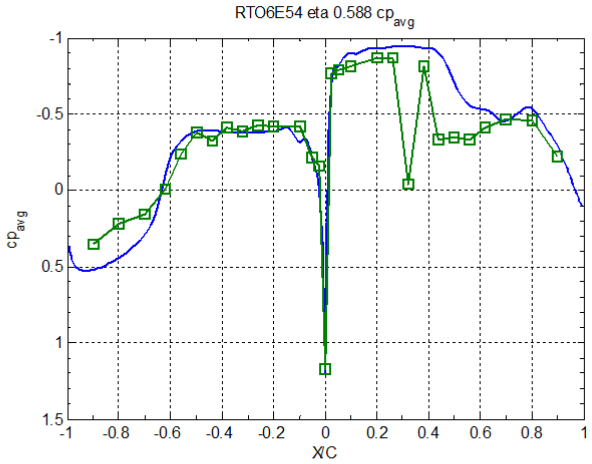


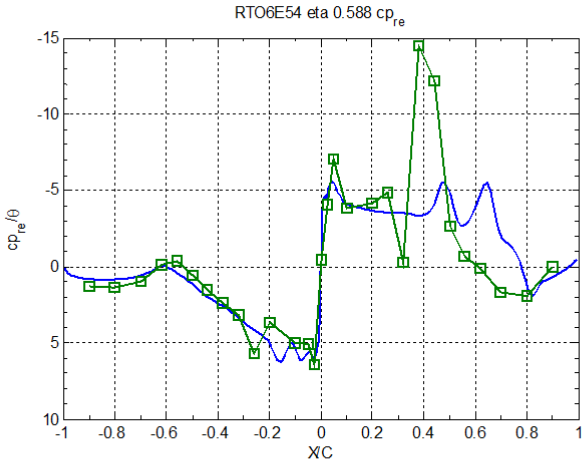


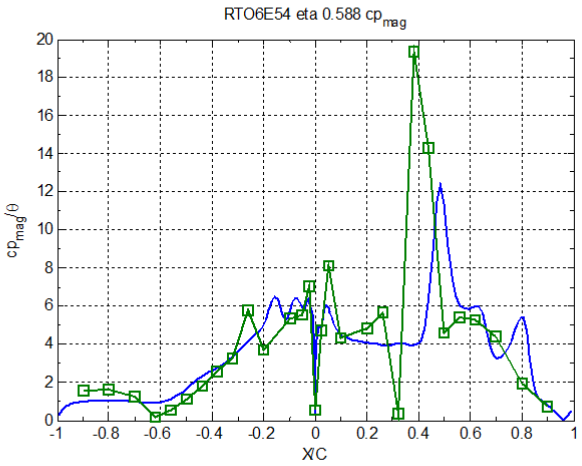
RTO6E56 (20Hz)

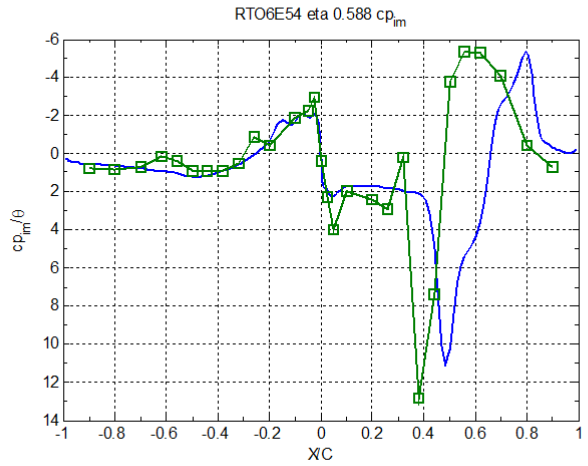
CX_{avg} = 0.043522	CZ_{avg} = 0.57913	CMY_{avg} = -0.043713
CX_{re}/θ = 0.70918	CZ_{re}/θ = 3.9835	CMY_{re}/θ = 0.62516
CX_{im}/θ = -0.15102	CZ_{im}/θ = -0.74857	CMY_{im}/θ = -0.60511
CX_{mag}/θ = 0.72509	CZ_{mag}/θ = 4.0532	CMY_{mag}/θ = 0.87005
CX_{phase} = -12.0213	CX_{phase} = -10.6429	CMY_{phase} = -44.0667

Cp at 58.8% station for 10Hz Case









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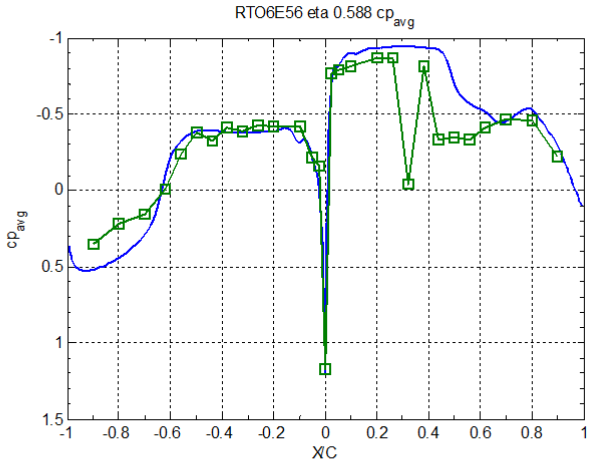
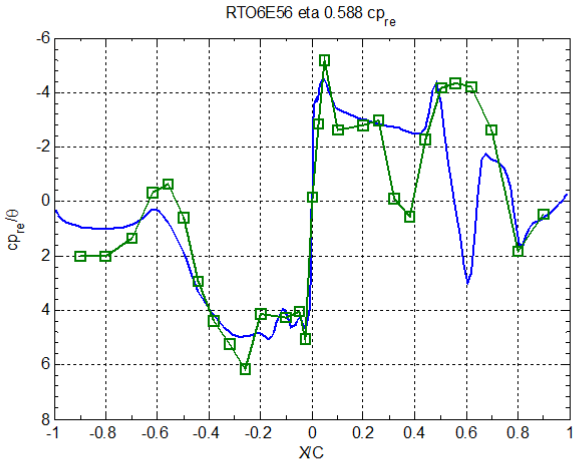
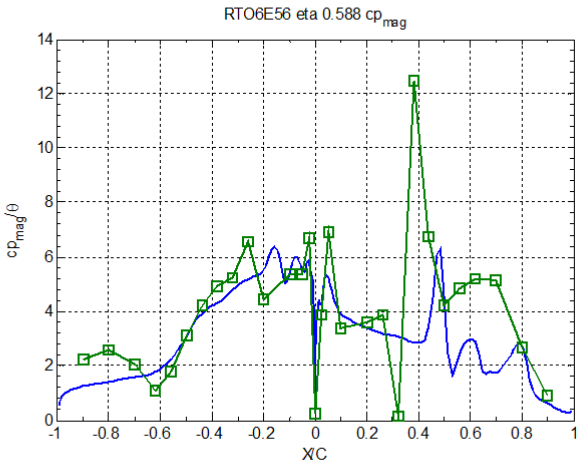
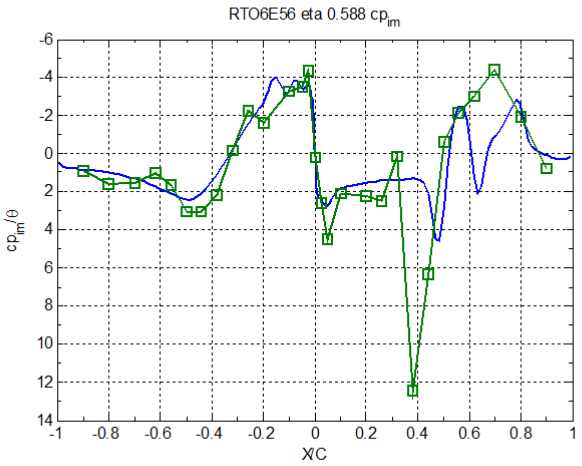
Cp at 58.8% station for 20Hz Case









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Issues encountered & challenges

- Convergence issues with static calculations for the 4deg case, high number of iterations needed, residual oscillation (in Drag Counts) comparatively high
- Number of time steps per period?
- Boundary layer profile
- Shock location, effect of boundary layer on location

Thank you for your attention!

Questions?

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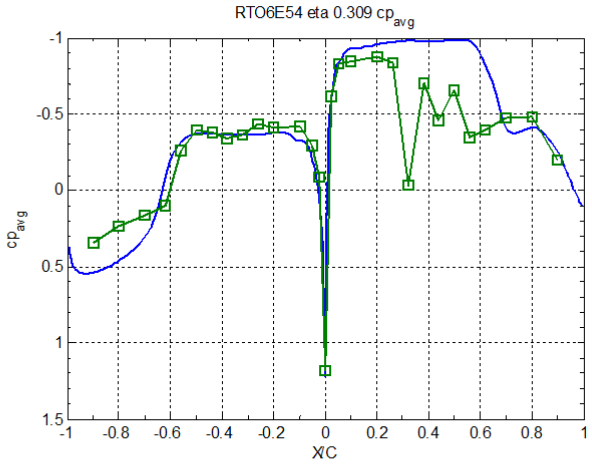
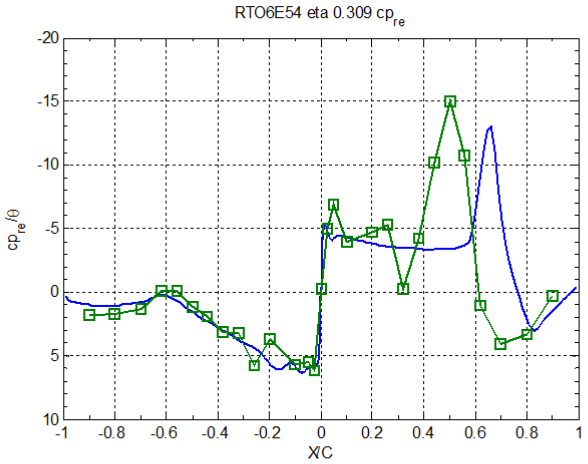
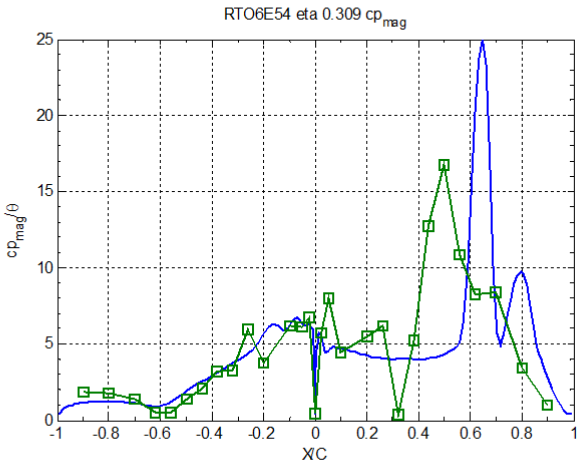
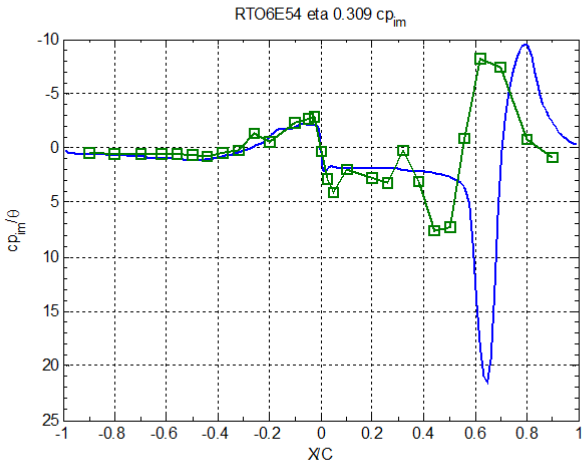
Backup

Cp at 30.9% station for 10Hz Case









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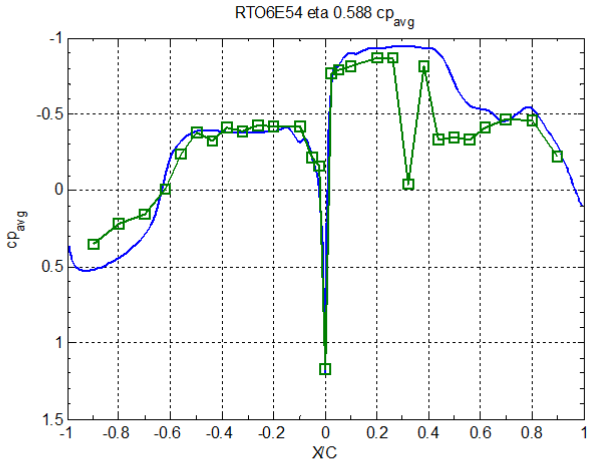

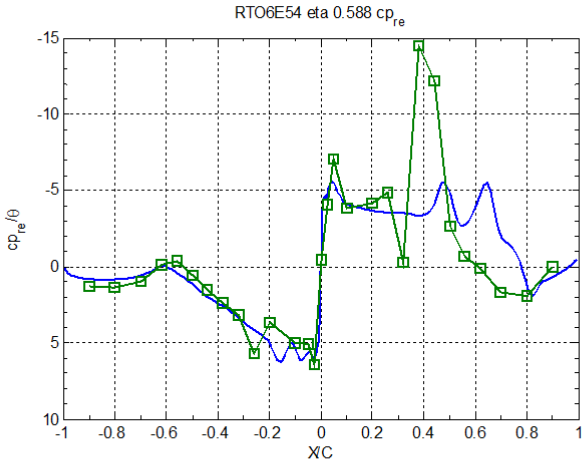

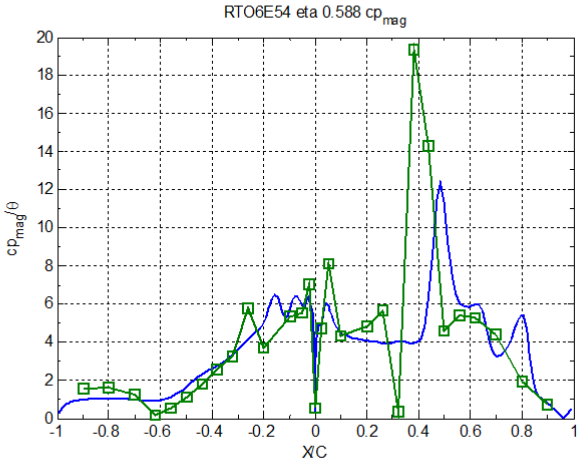

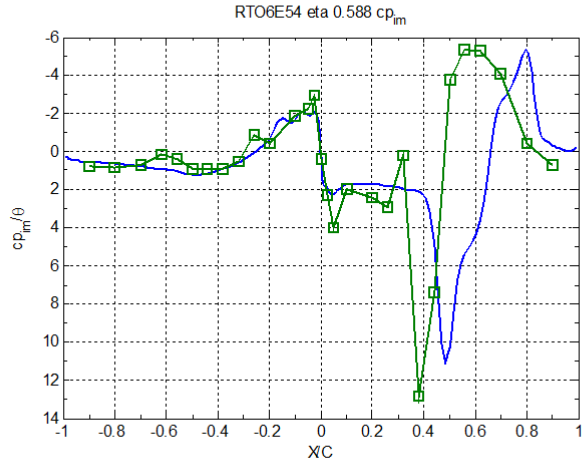

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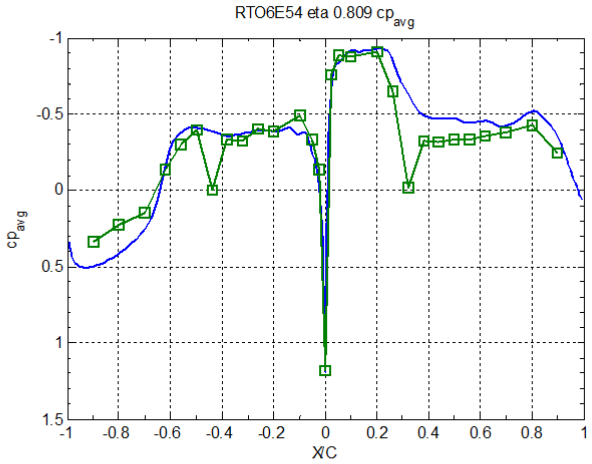
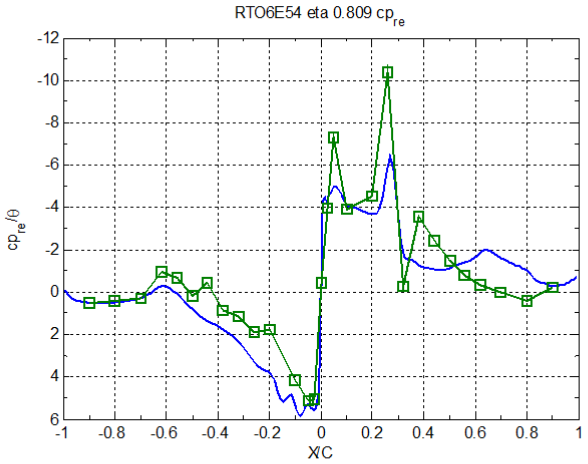
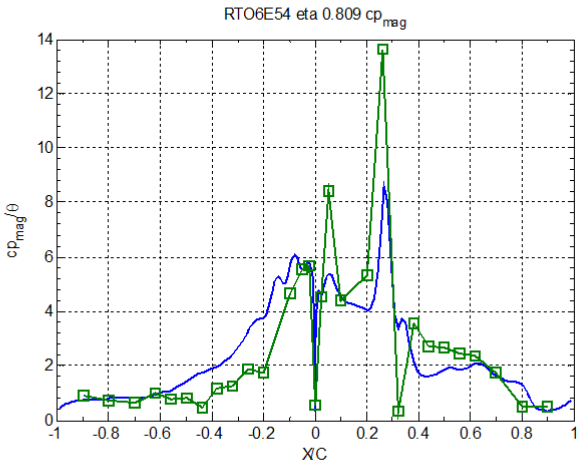
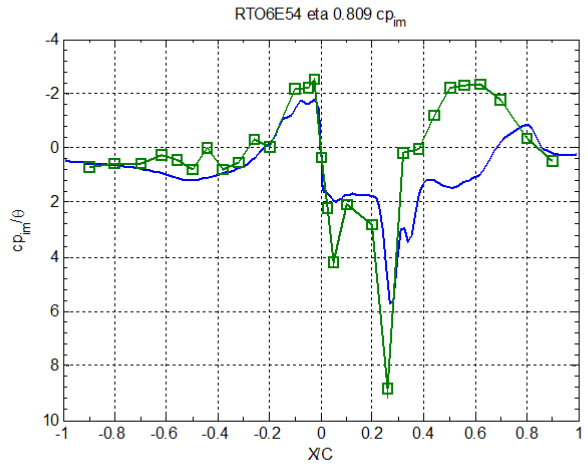
Cp at 80.9% station for 10Hz Case









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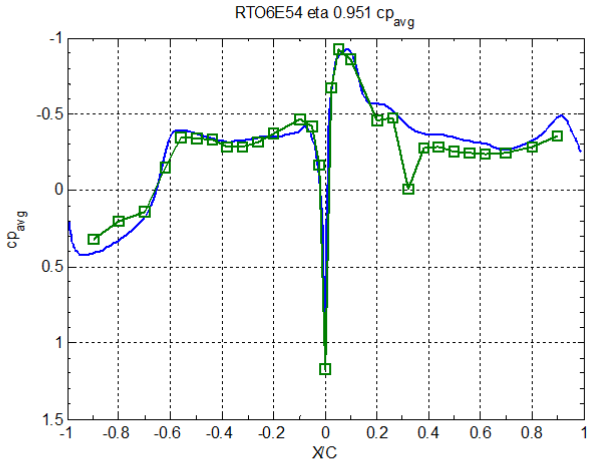
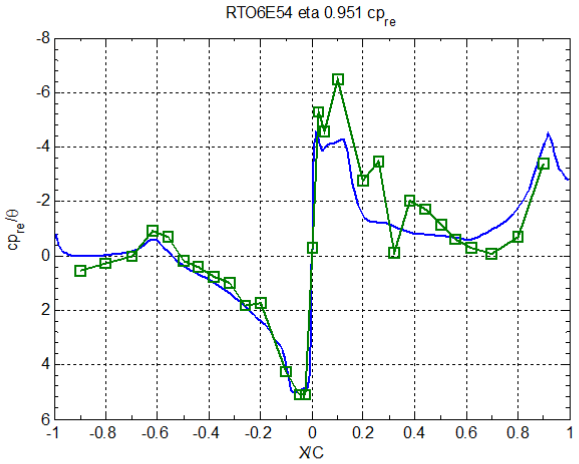
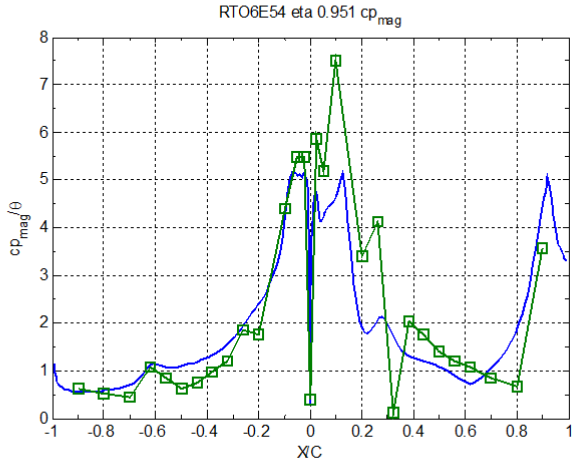
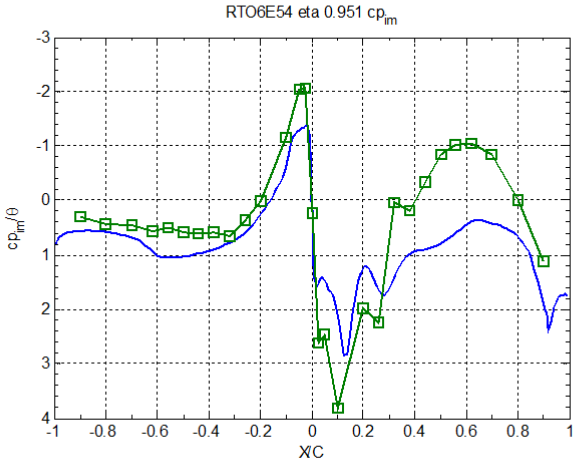
Cp at 95.1% station for 10Hz Case









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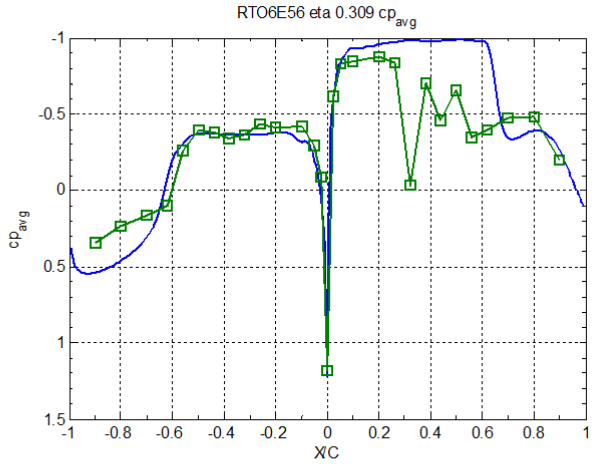
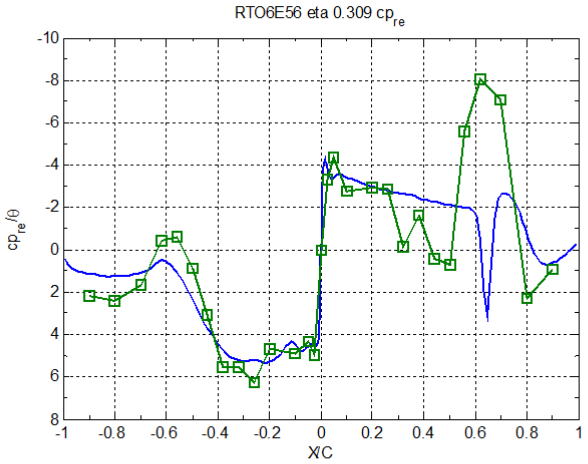
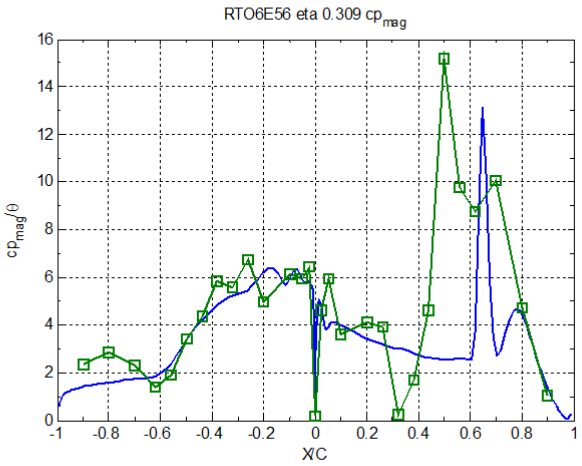
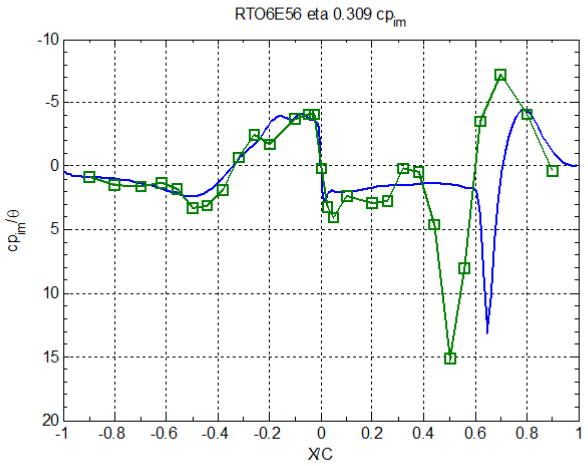
Cp at 30.9% station for 20Hz Case









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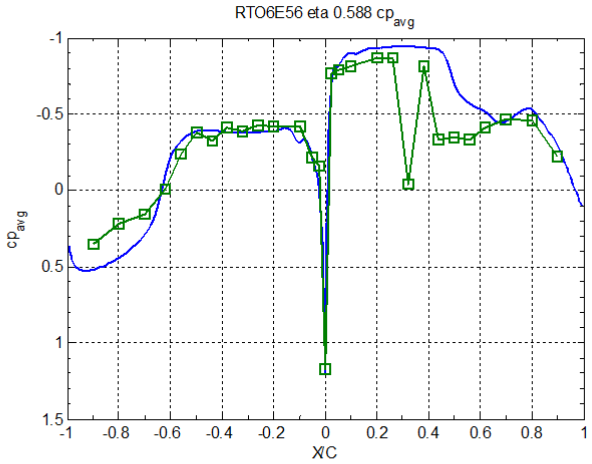
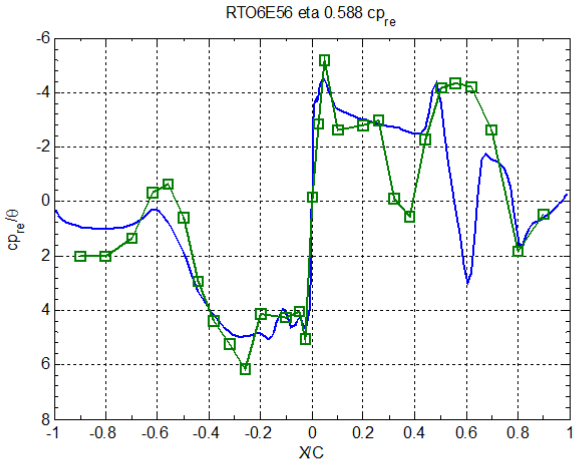
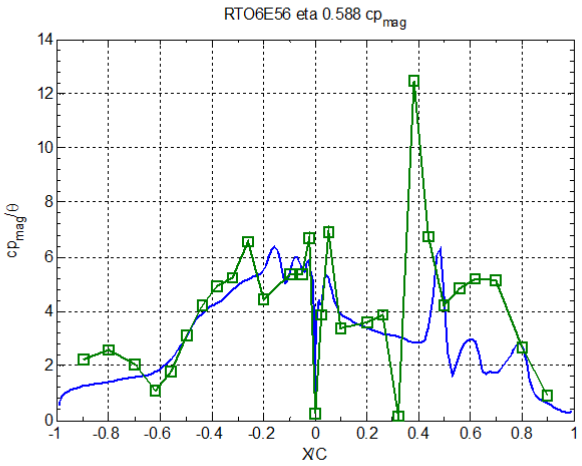
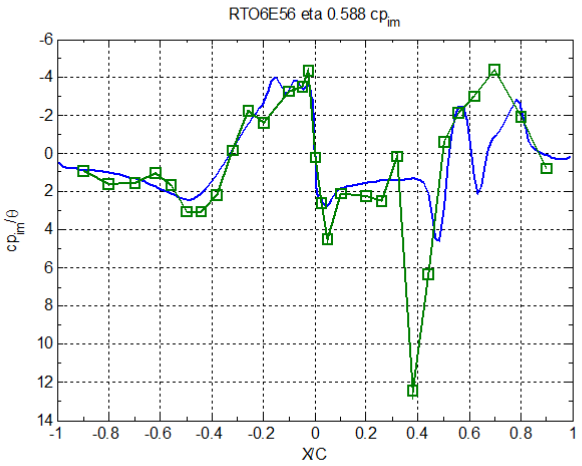
Cp at 58.8% station for 20Hz Case









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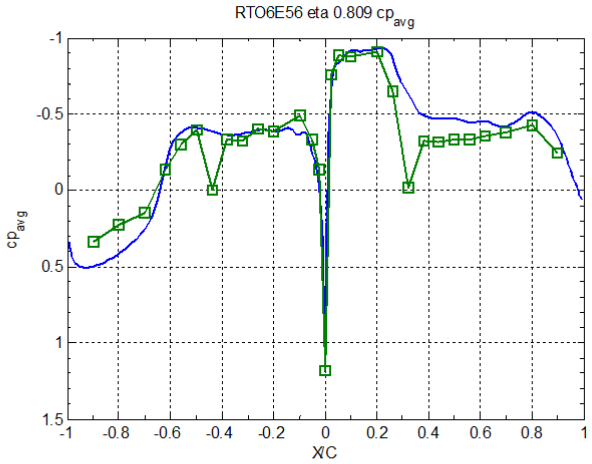
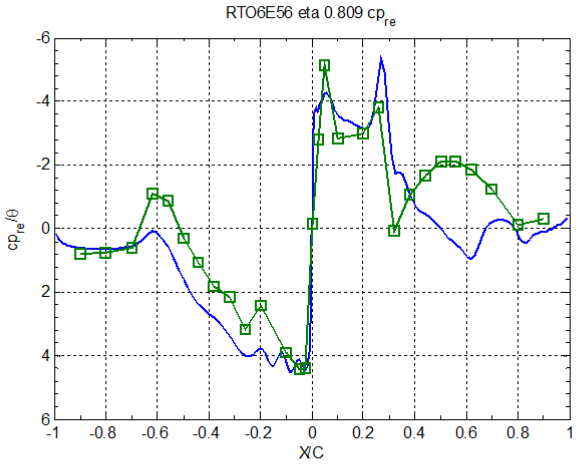
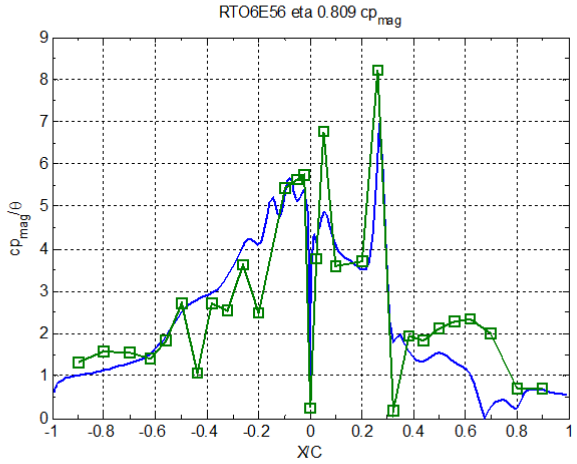
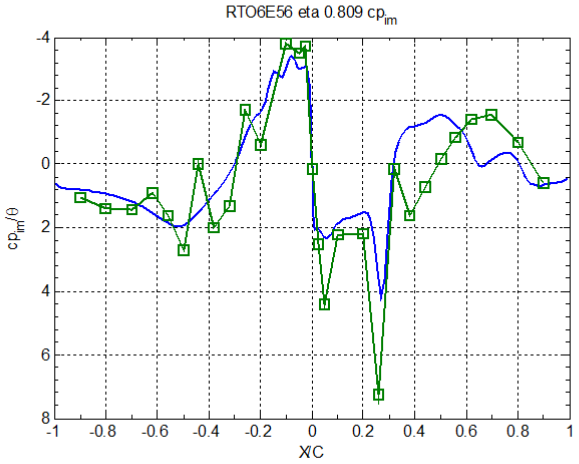
Cp at 80.9% station for 20Hz Case









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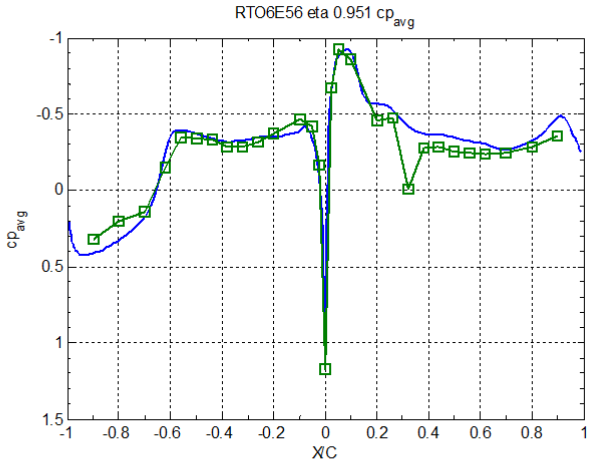
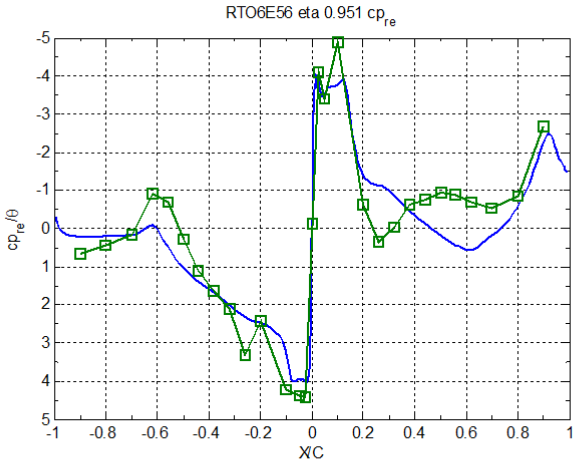
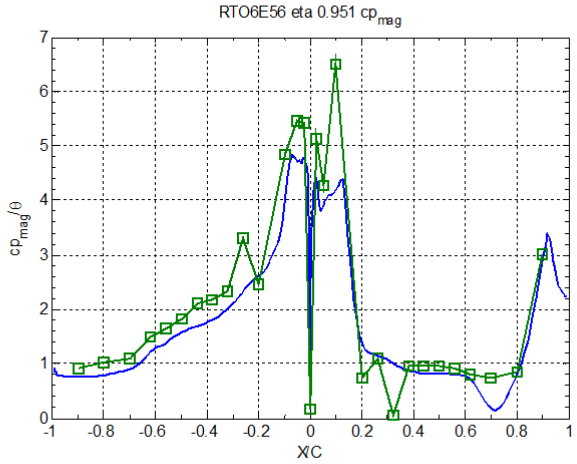
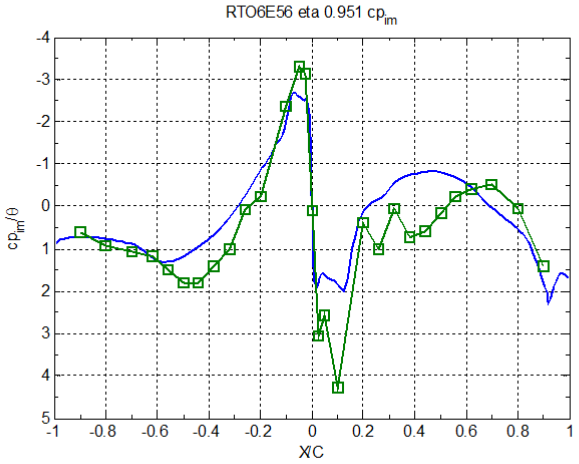
Cp at 95.1% station for 20Hz Case



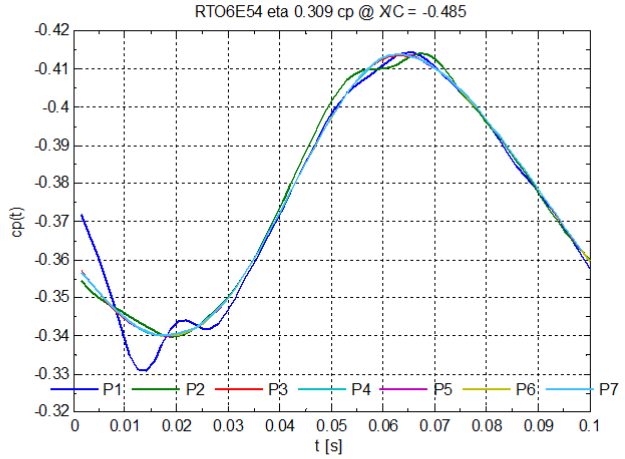


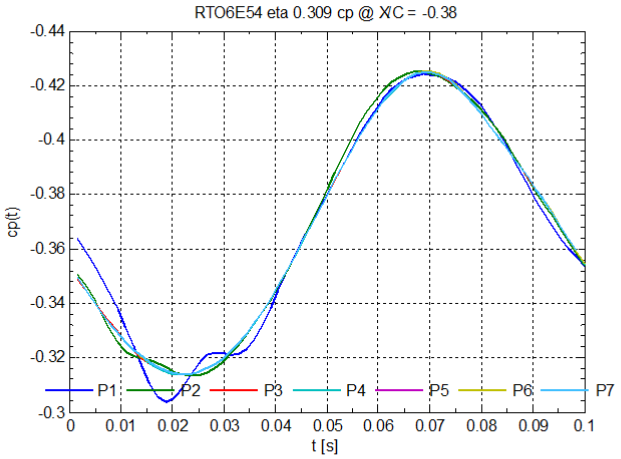


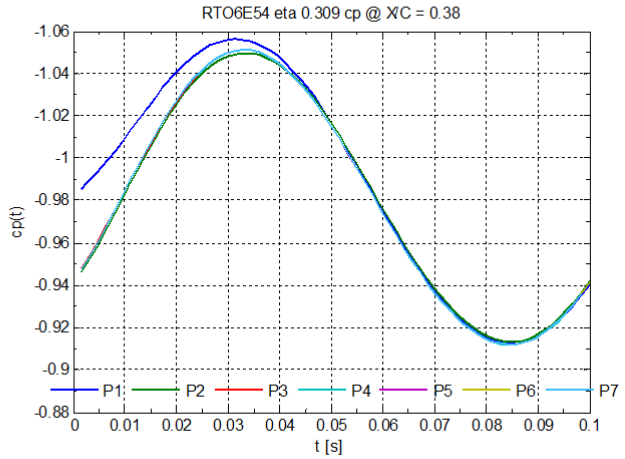


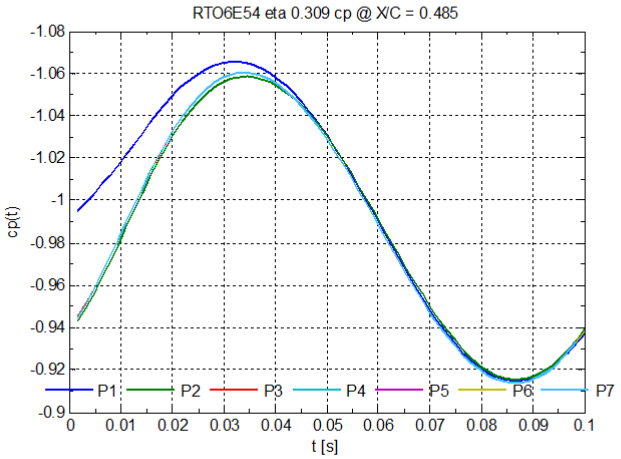
Together ahead. RUAG

Cp time resolved at 30.9% station 10Hz case



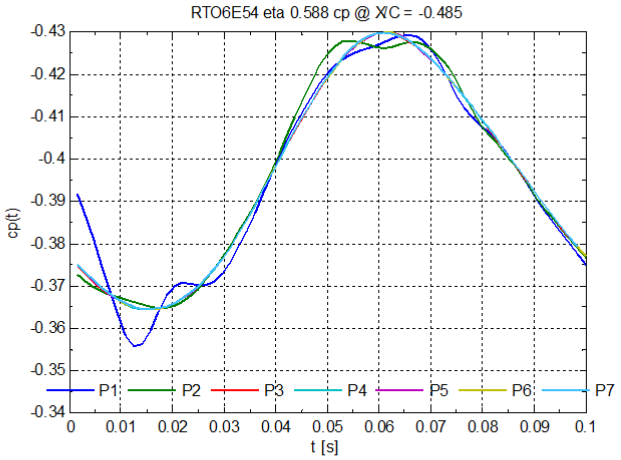


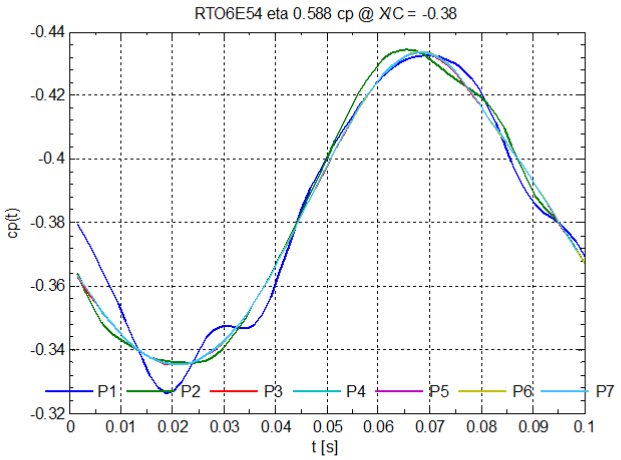


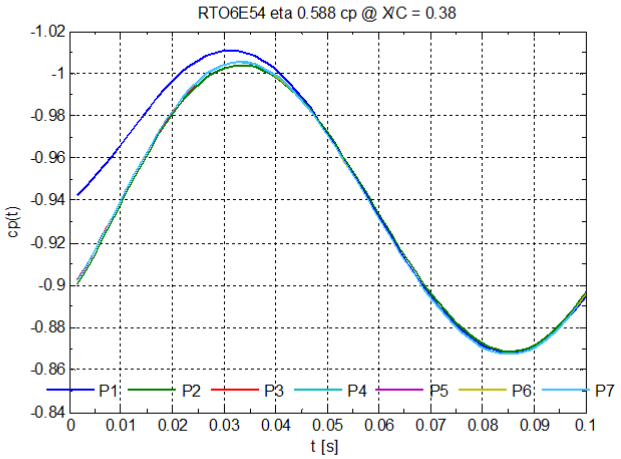


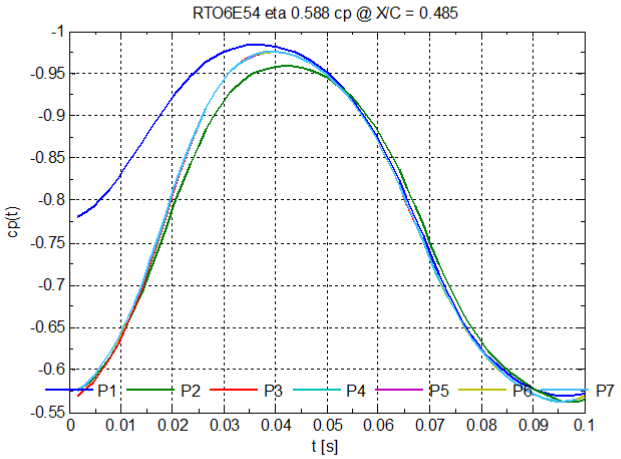
Together ahead. RUAG

Cp time resolved at 58.8% station 10Hz case



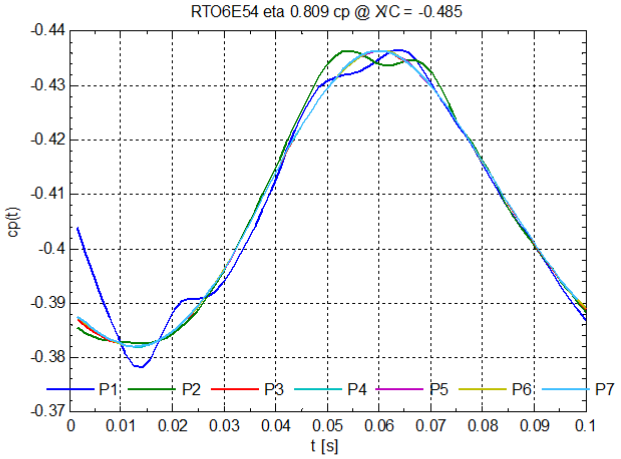


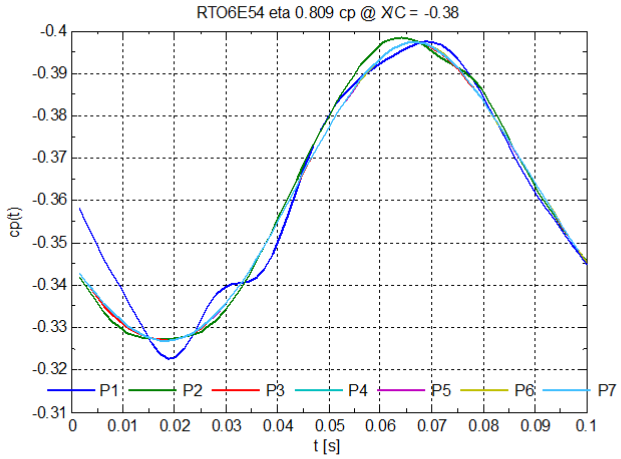


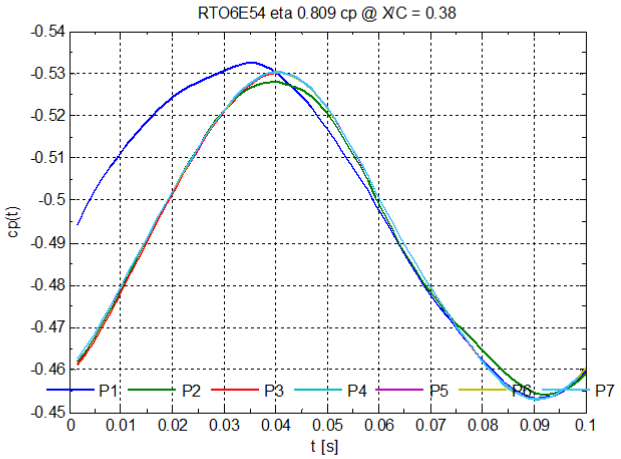


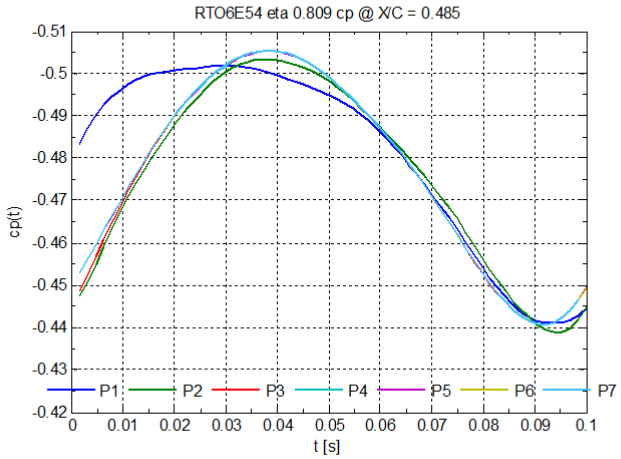
Together ahead. RUAG

Cp time resolved at 80.9% station 10Hz case



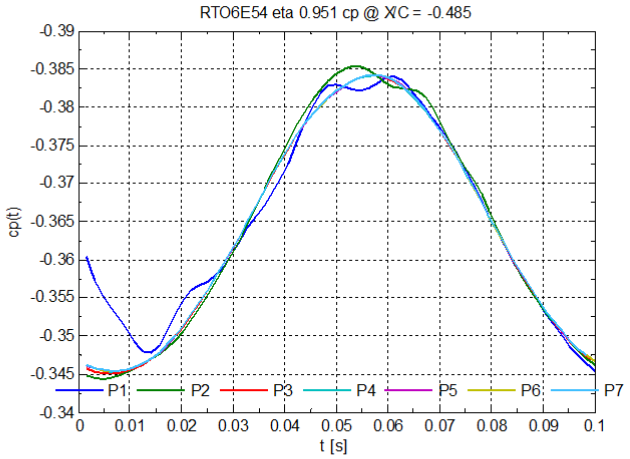


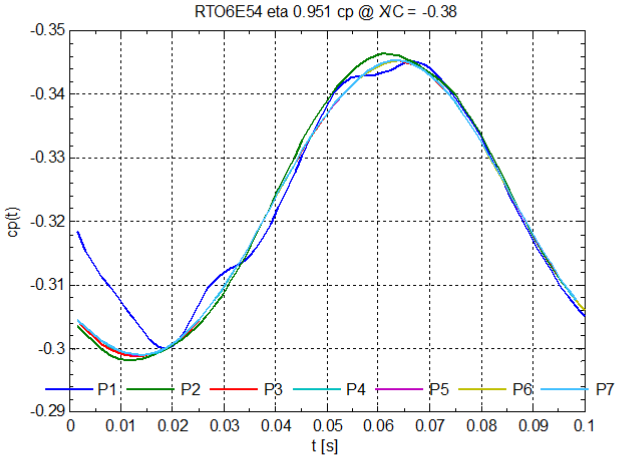


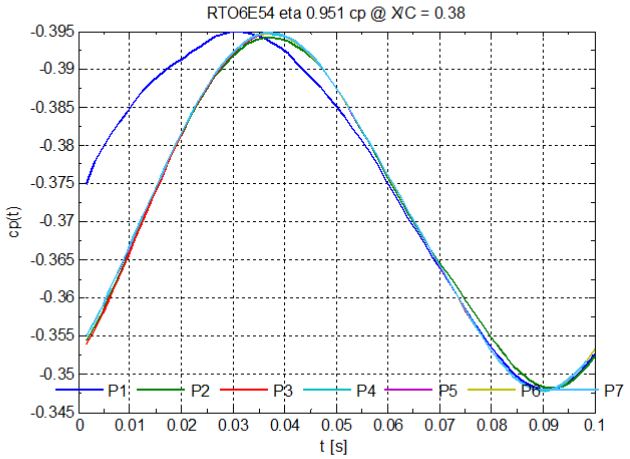


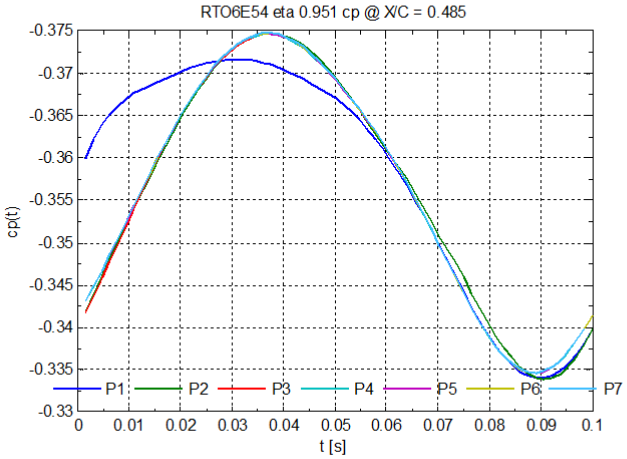
Together ahead. RUAG

Cp time resolved at 95.1% station 10Hz case



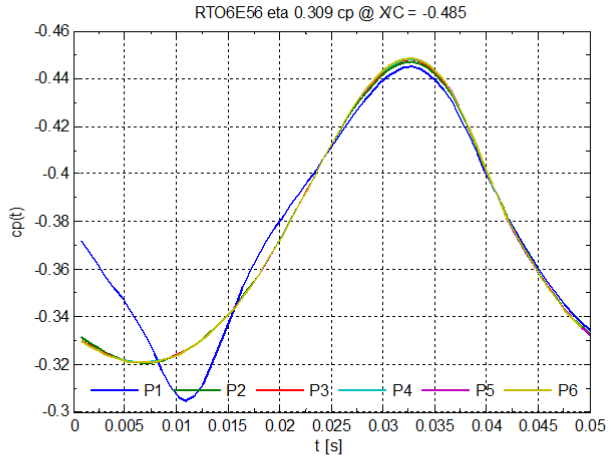


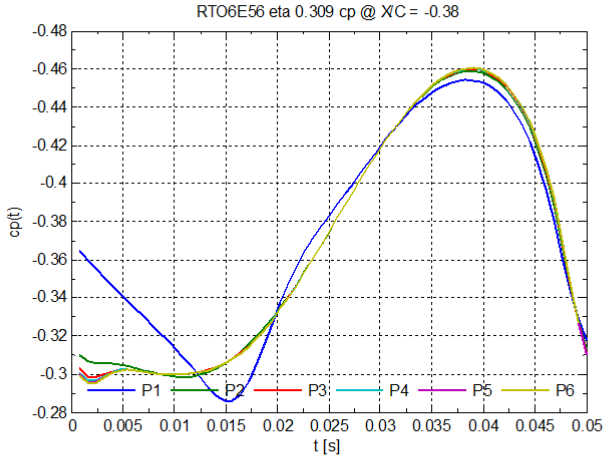


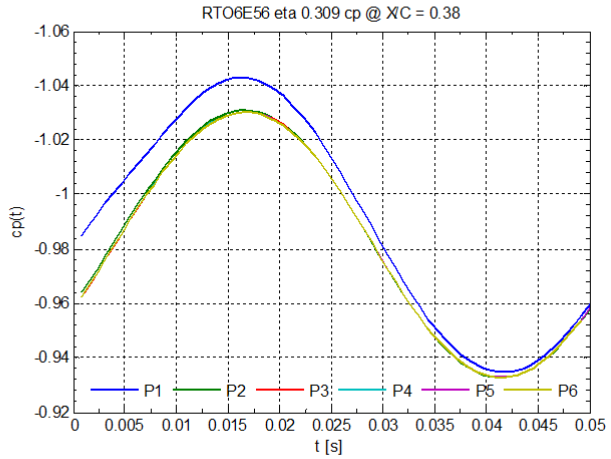


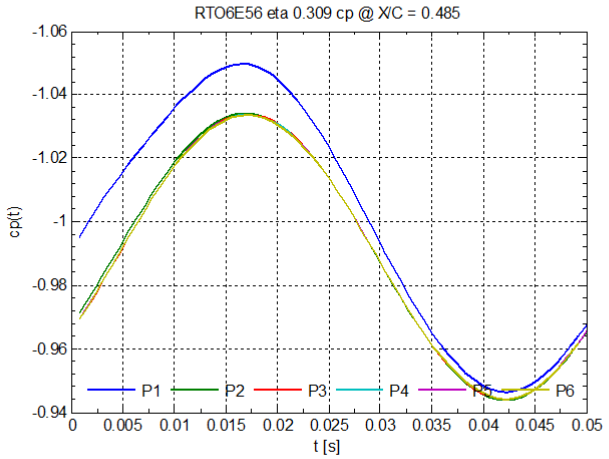
Together ahead. RUAG

Cp time resolved at 30.9% station 20Hz case



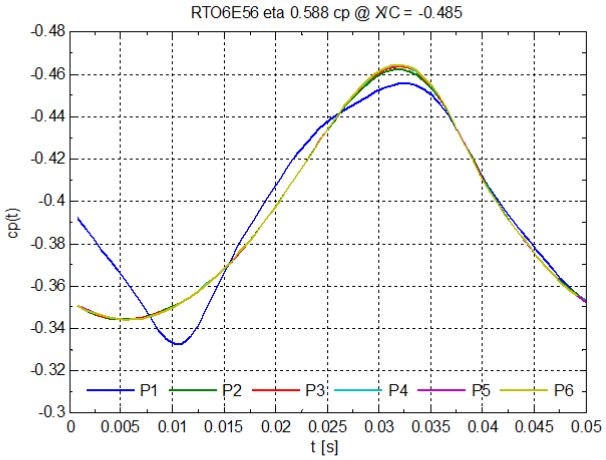


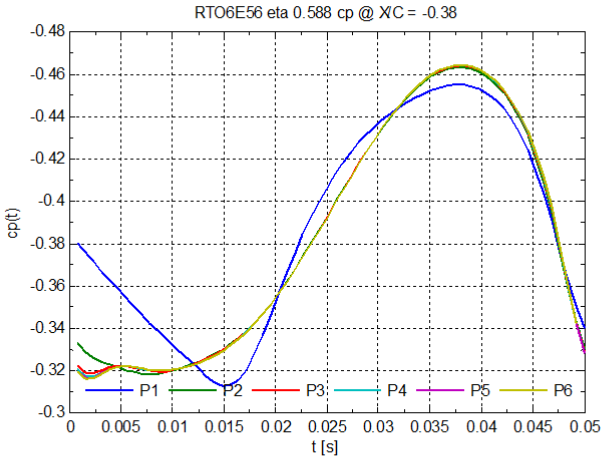


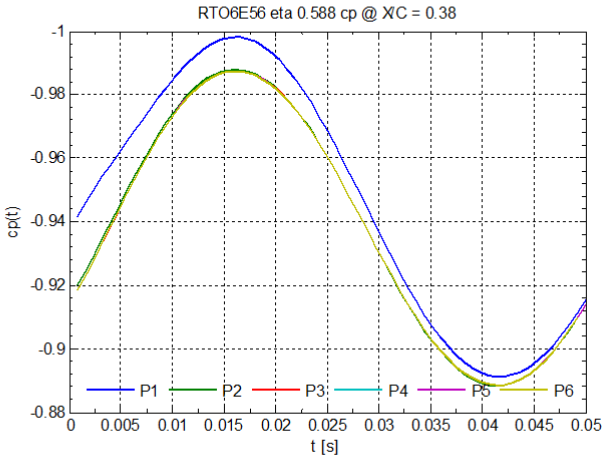


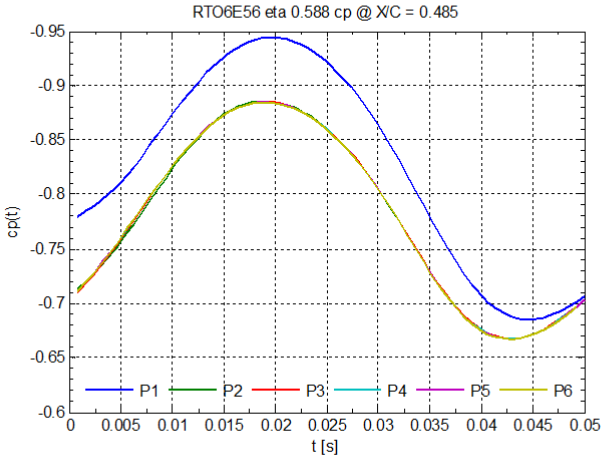
Together ahead. RUAG

Cp time resolved at 58.8% station 20Hz case



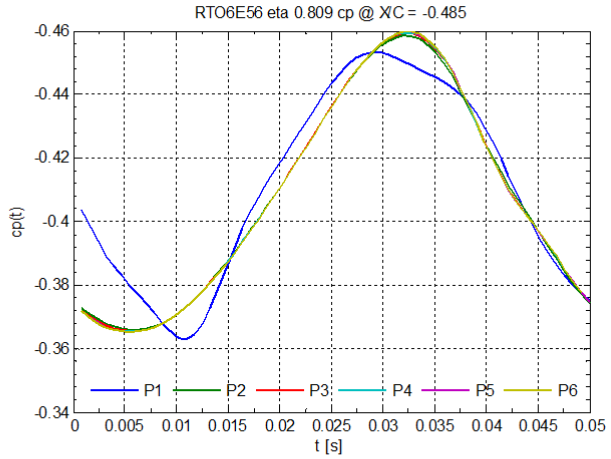


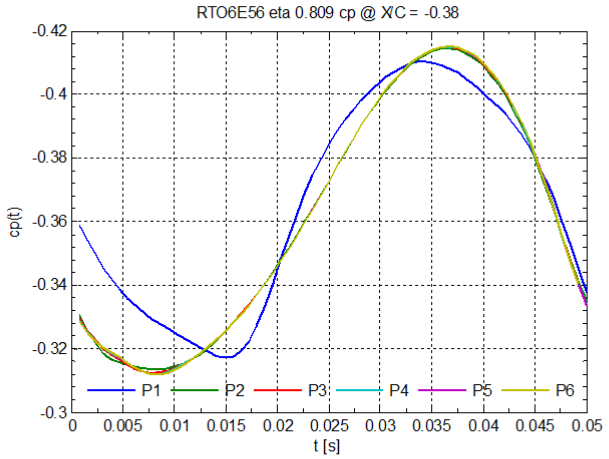


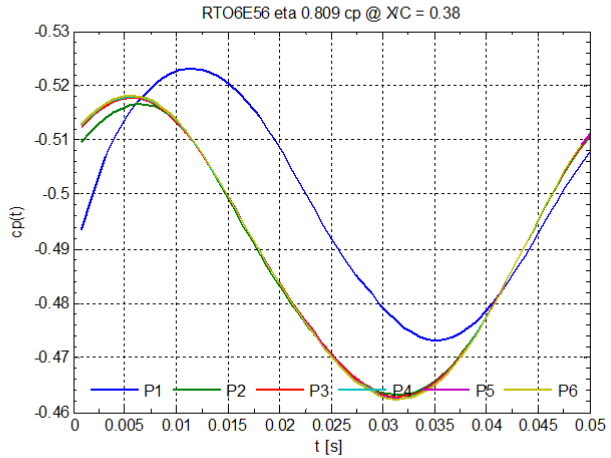


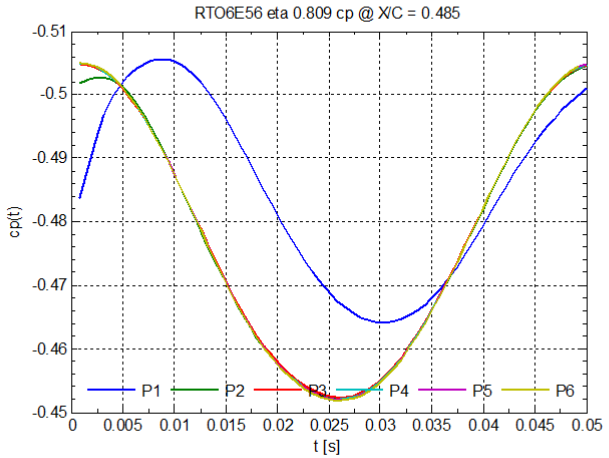
Together ahead. RUAG

Cp time resolved at 80.9% station 20Hz case



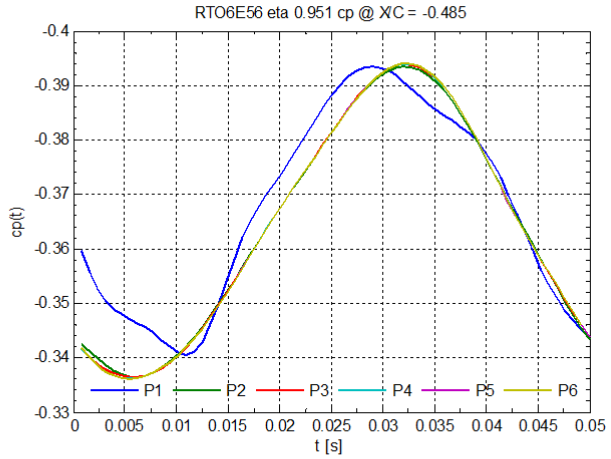


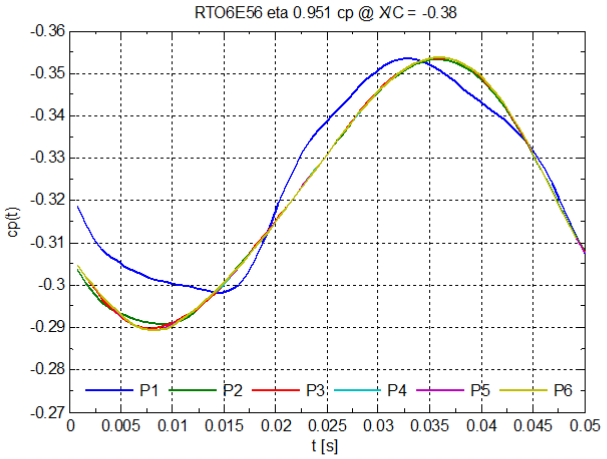


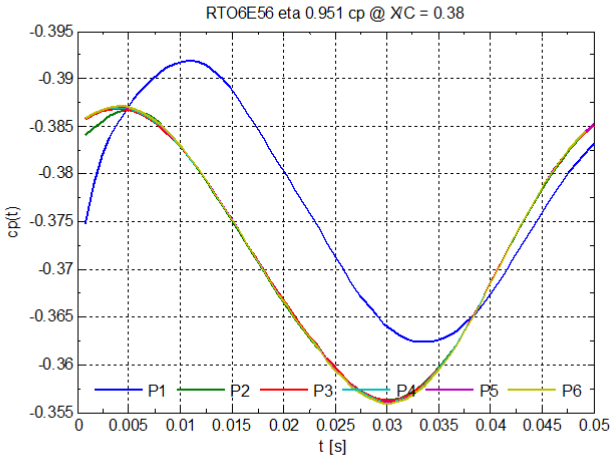


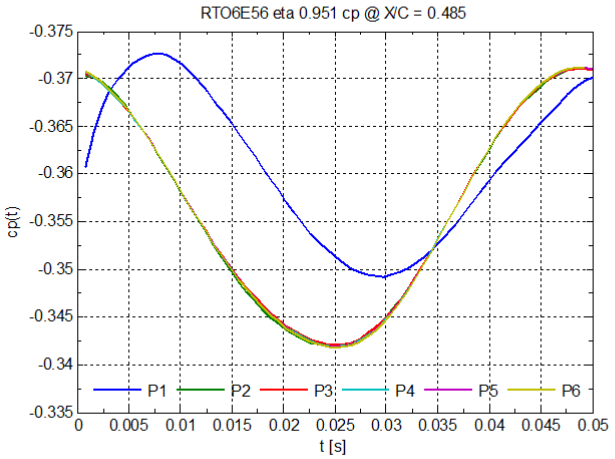
Together ahead. RUAG

Cp time resolved at 95.1% station 20Hz case









Together ahead. RUAG