AePW-1 HIRENASD 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

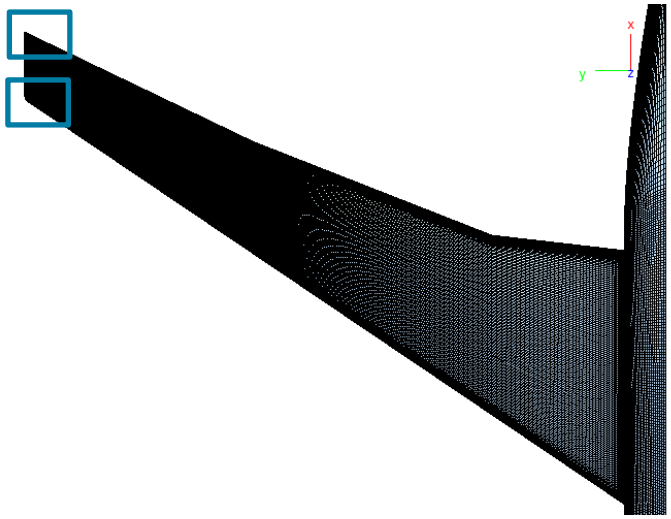
NSMB flow solver and settings

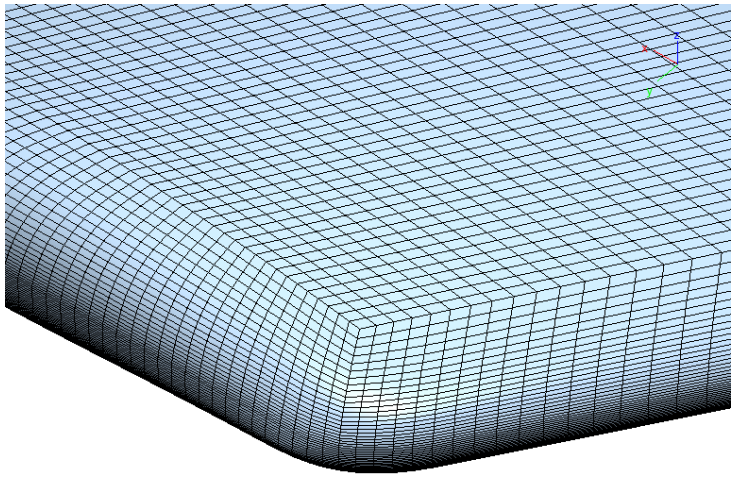
- Multiblock Navier-Stokes solver, hence the name “NSMB”
- Developed at the EPFL in Lausanne since 1991, together with other universities and industrial partners
- Settings used for the HIRENASD test cases:
  - Space discretization: 4th-order central scheme (Jameson)
  - Time integration: implicit LU-SGS scheme
  - Unsteady calculations: dual time stepping, w/ time correction procedure
  - Turbulence model: k-ω Menter Shear Stress (DES, 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, and one case recalculated (not part of data submittal, but shown in this presentation)

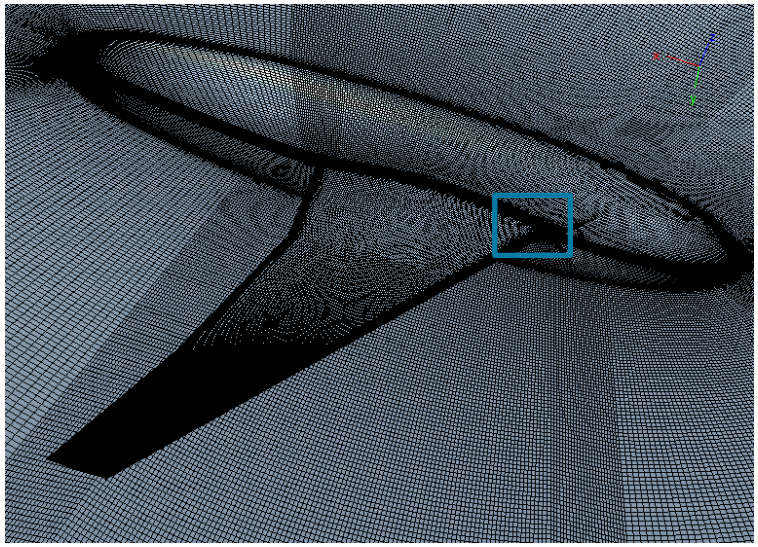
Test case specific settings and assumptions

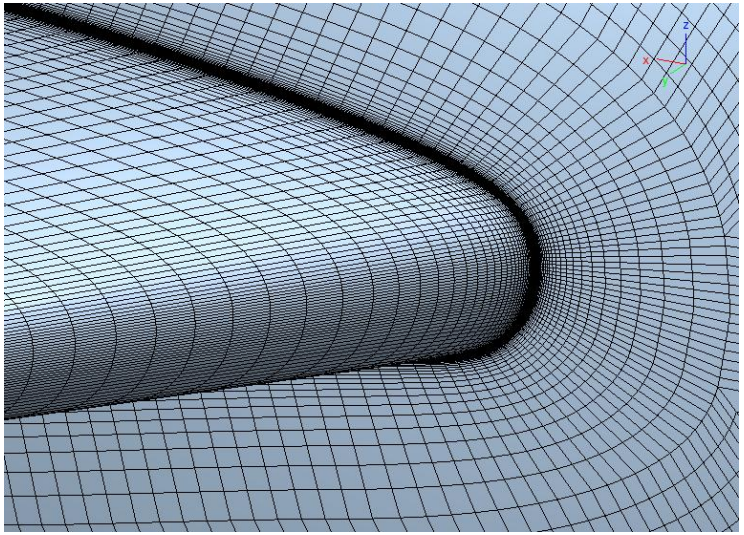
- Cases calculated
  - ct311-4, ETW 159: static steady (c/m/f) -> static aeroelastic (m) -> dynamic (m), each with forced transition (12% U, 5%L)
  - ct311-5, ETW 271: static steady (c/m/f) -> static aeroelastic (m) -> dynamic (m), each fully turbulent
- Dynamic calculations with forced oscillation of the second bending mode
- Modal amplitude of 0.01 reference chord used (wing tip), translates to an amplitude of 2.04mm at position of accelerometer 15
- Six periods have been simulated, with the last two periods used to determine the FRF, 64 time steps per period
- $FRF = \frac{fft(exitation) \cdot fft(response)}{fft(extation) \cdot \overline{fft(extation)}}$

Grid overview









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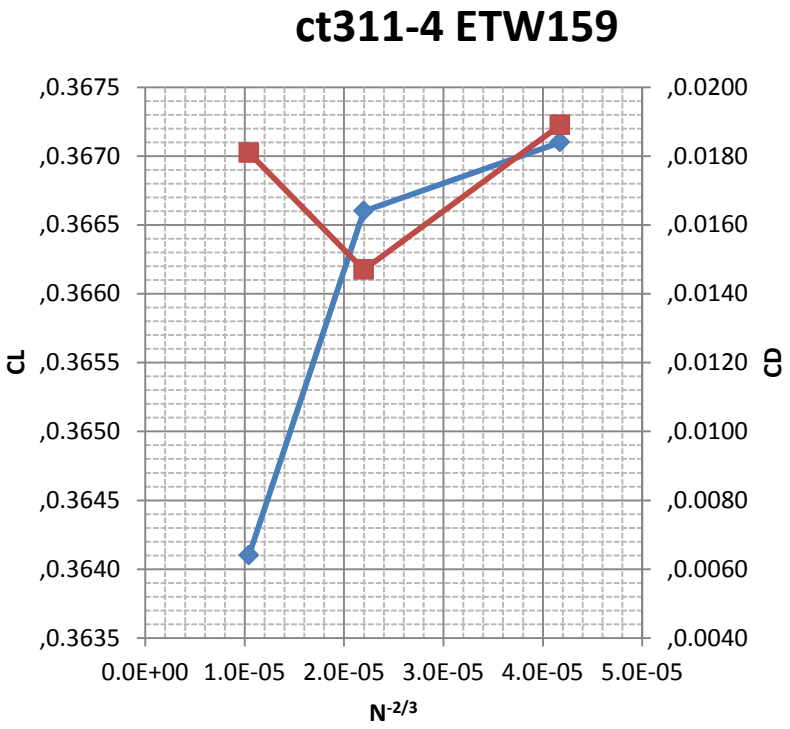
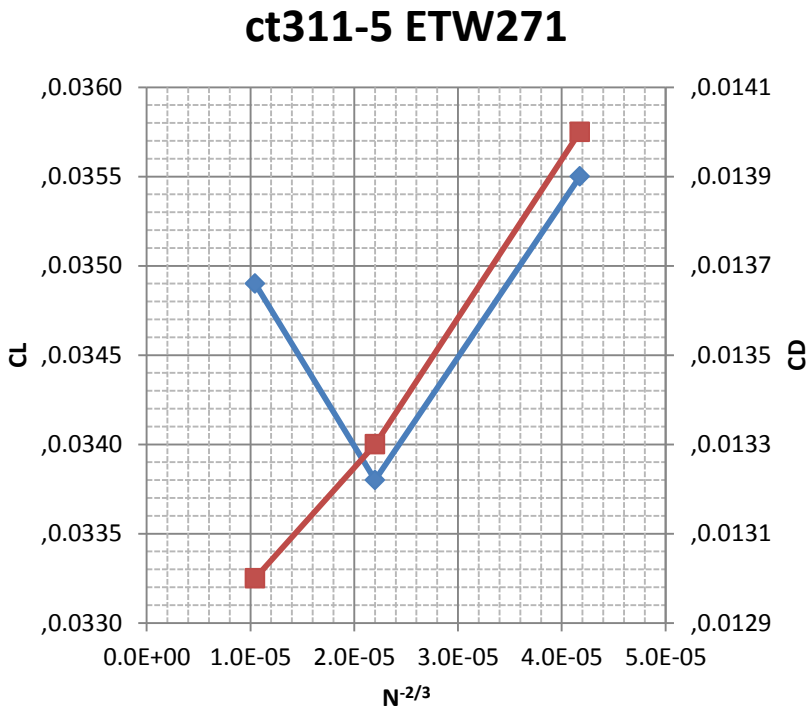
Grid convergence static steady





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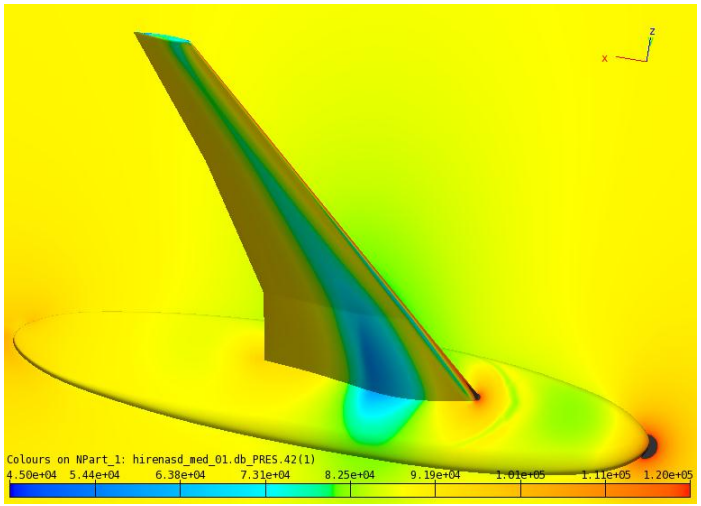
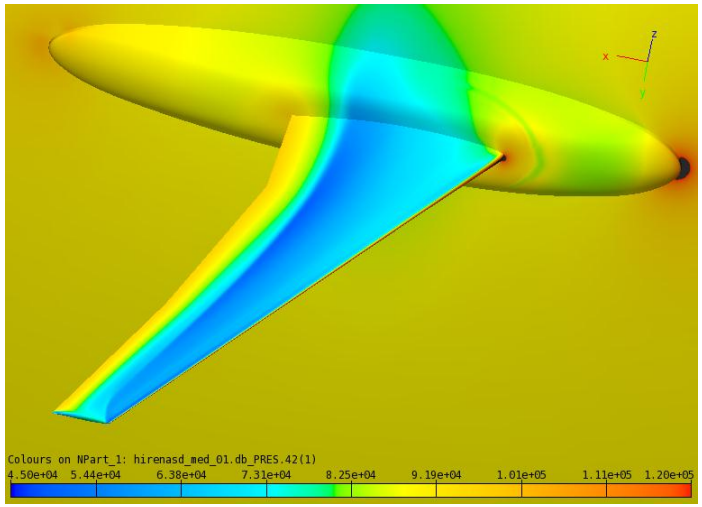
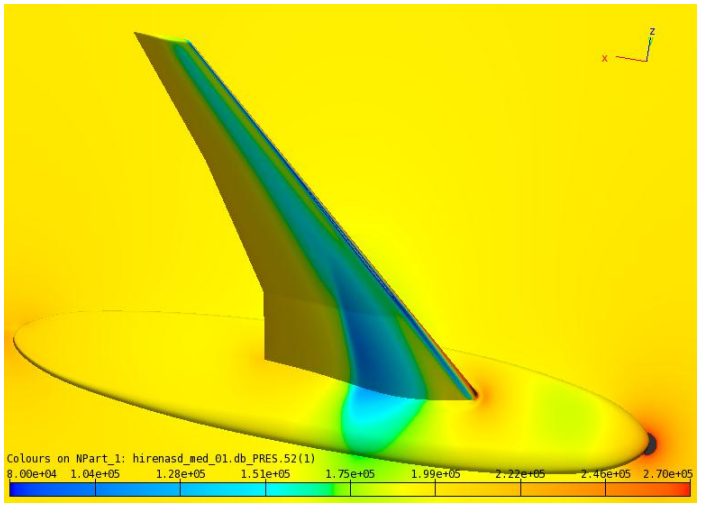
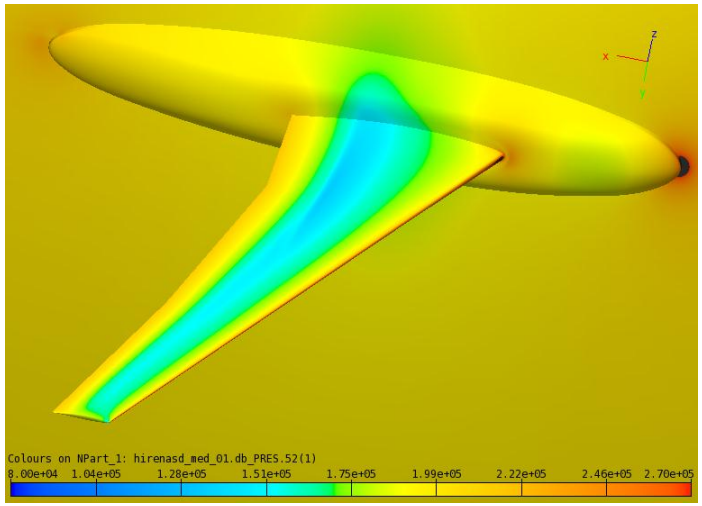
Global picture





ct311-4
ETW159





ct311-5
ETW271

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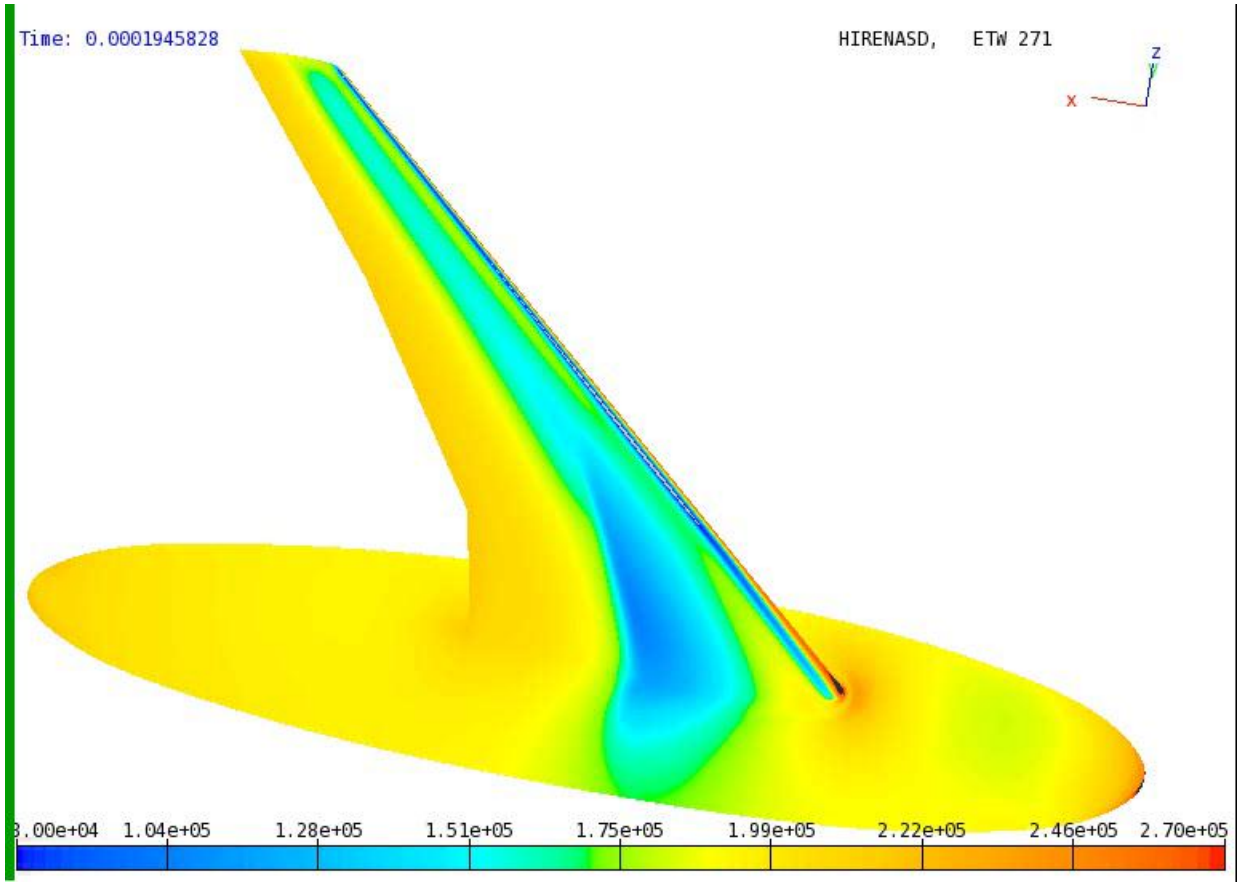
Global picture (video)
ct311-5 ETW271



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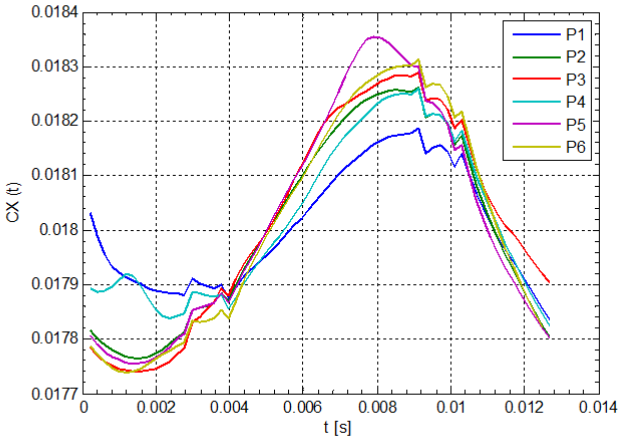
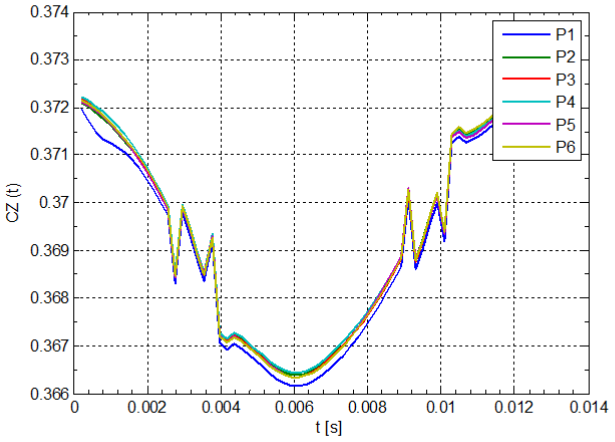
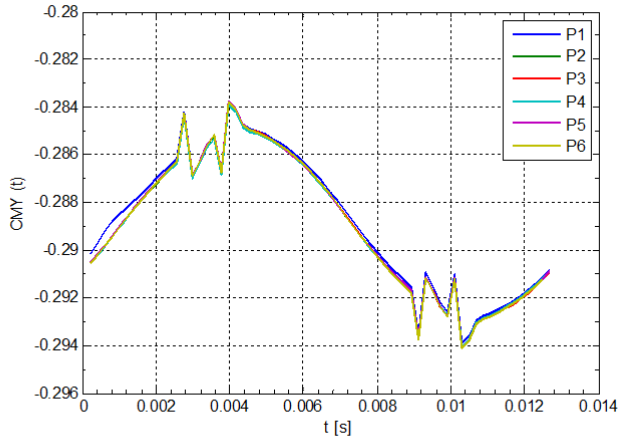
Global coefficients ct311-4 ETW159







ct311-4 (78.9Hz)

CX_{avg} = 0.018012	CZ_{avg} = 0.36932	CMY_{avg} = -0.28897
CX_{re}/dz_{acc} = -0.032406	CZ_{re}/dz_{acc} = -0.60397	CMY_{re}/dz_{acc} = 1.3445
CX_{im}/dz_{acc} = 0.088659	CZ_{im}/dz_{acc} = -0.77609	CMY_{im}/dz_{acc} = -0.0331
CX_{mag}/dz_{acc} = 0.094396	CZ_{mag}/dz_{acc} = 0.9834	CMY_{mag}/dz_{acc} = 1.3449
CX_{phase} = 110.0782	CX_{phase} = -127.8908	CMY_{phase} = -1.4103

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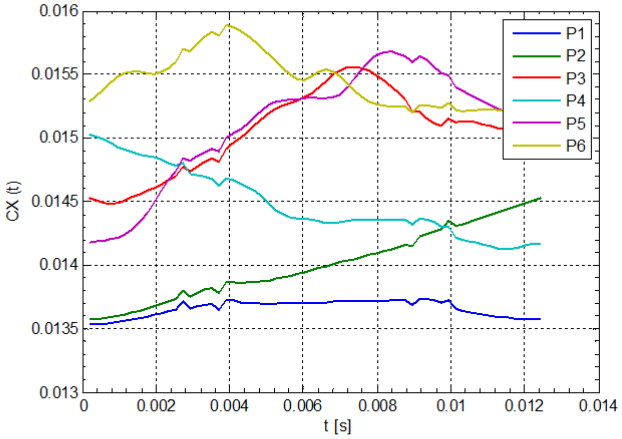
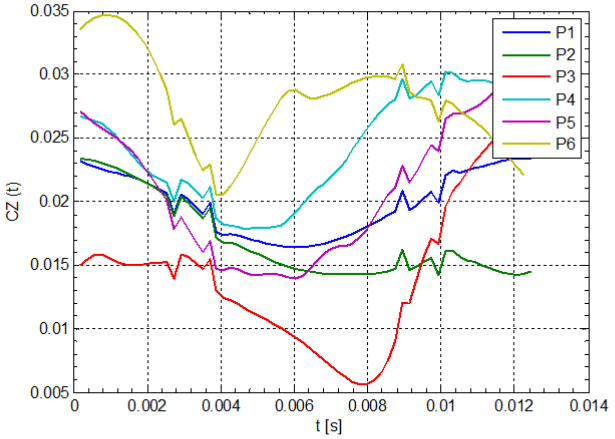
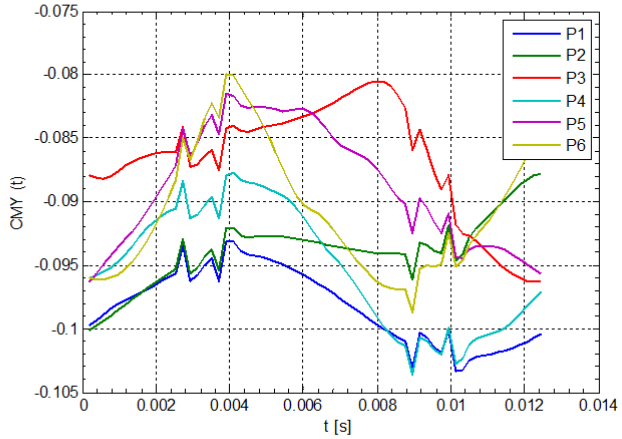
Global coefficients ct311-5 ETW271





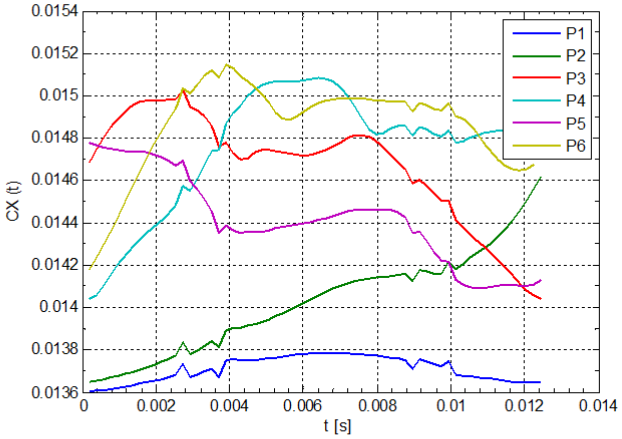


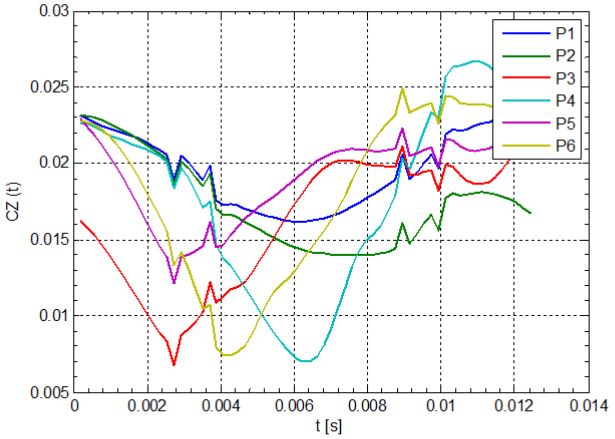
ct311-5 (80.3Hz)

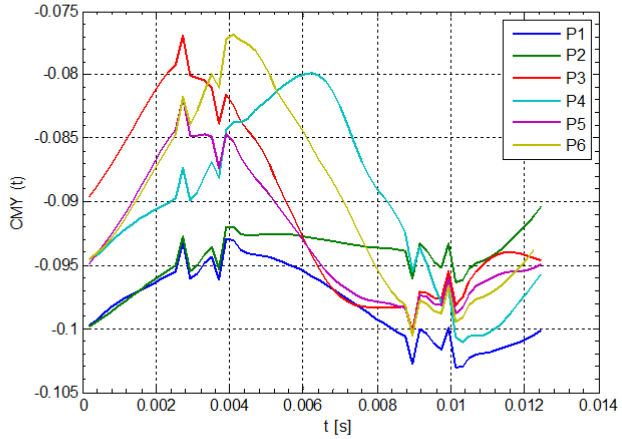
CX_{avg} = 0.015271	CZ_{avg} = 0.024429	CMY_{avg} = -0.089801
CX_{re}/dz_{acc} = -0.030478	CZ_{re}/dz_{acc} = -0.55478	CMY_{re}/dz_{acc} = 1.271
CX_{im}/dz_{acc} = 0.080589	CZ_{im}/dz_{acc} = -1.4163	CMY_{im}/dz_{acc} = 1.2484
CX_{mag}/dz_{acc} = 0.08616	CZ_{mag}/dz_{acc} = 1.5211	CMY_{mag}/dz_{acc} = 1.7815
CX_{phase} = 110.7163	CX_{phase} = -111.3905	CMY_{phase} = 44.4856

Together ahead. RUAG

Global coefficients ct311-5 ETW271 ALE fixed







ct311-5-alefix (80.3Hz)

CX_{avg} = 0.014636	CZ_{avg} = 0.01863	CMY_{avg} = -0.091412
CX_{re}/dz_{acc} = 0.028089	CZ_{re}/dz_{acc} = -1.473	CMY_{re}/dz_{acc} = 2.5366
CX_{im}/dz_{acc} = 0.037335	CZ_{im}/dz_{acc} = -1.0316	CMY_{im}/dz_{acc} = 0.82931
CX_{mag}/dz_{acc} = 0.046721	CZ_{mag}/dz_{acc} = 1.7983	CMY_{mag}/dz_{acc} = 2.6688
CX_{phase} = 53.0435	CX_{phase} = -144.994	CMY_{phase} = 18.1043

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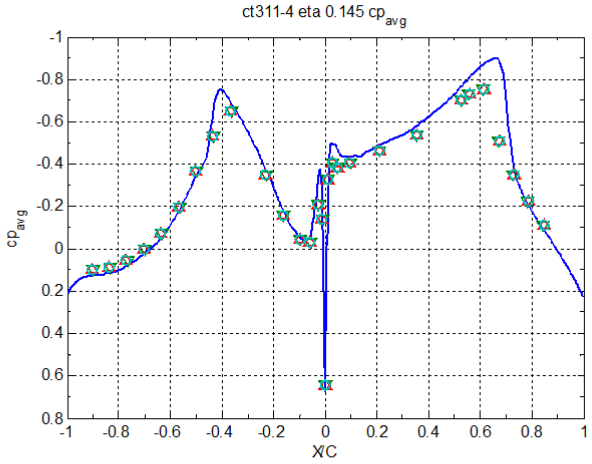
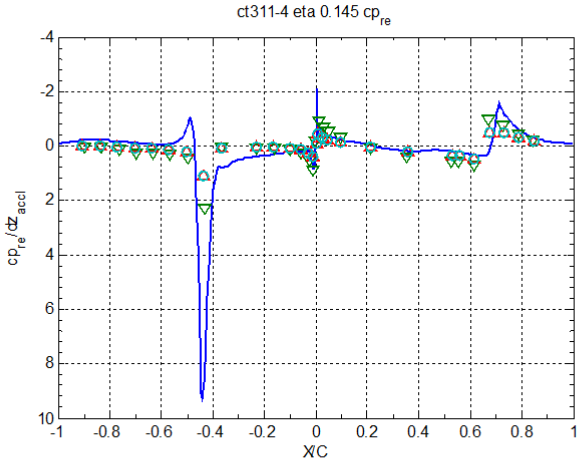
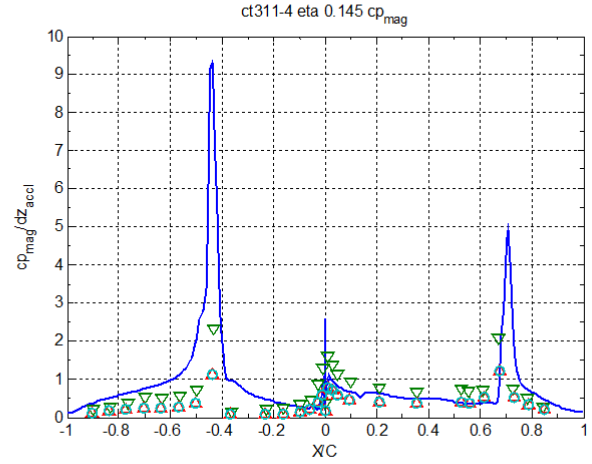
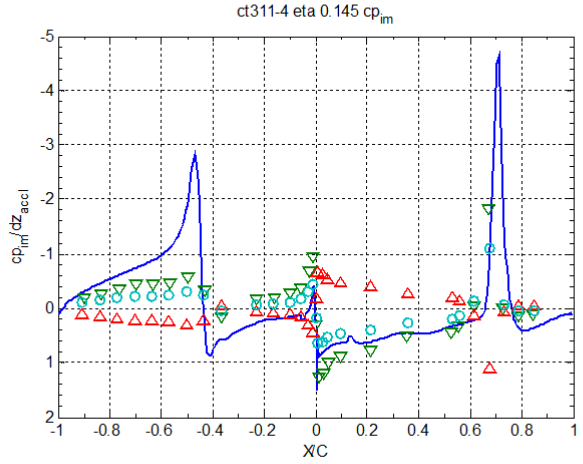
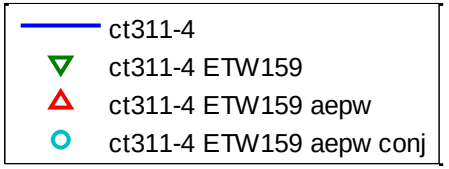
Cp at wing root
ct311-4 ETW159 section 1











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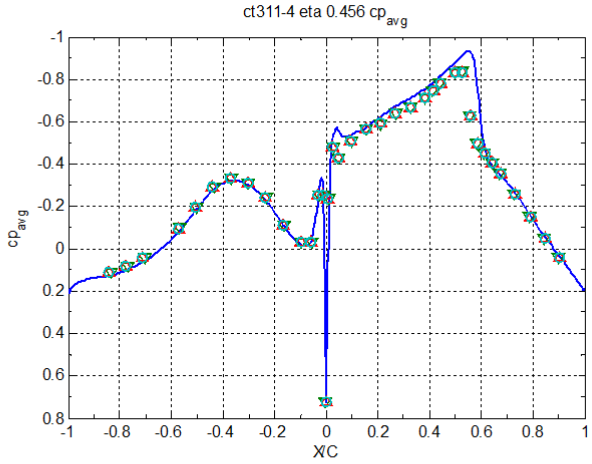
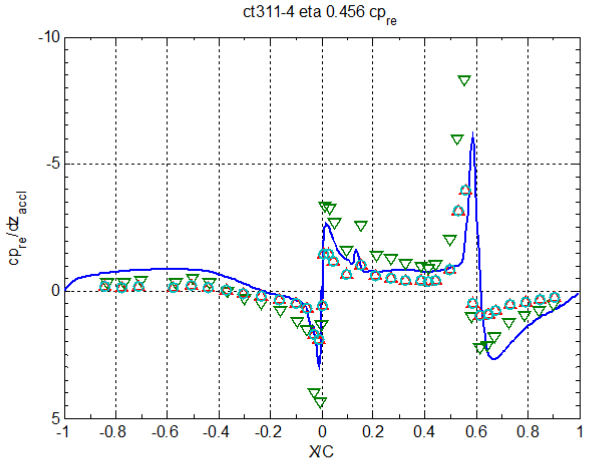
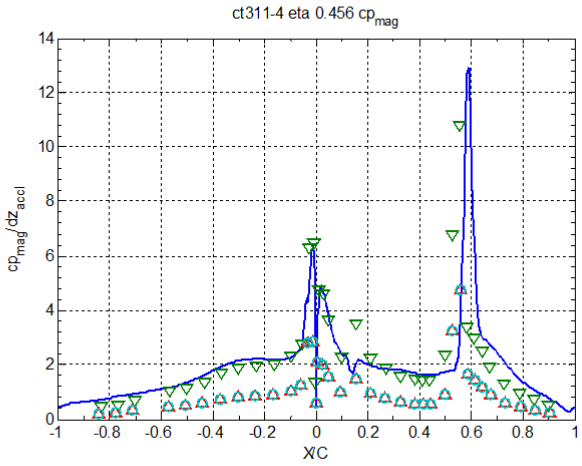
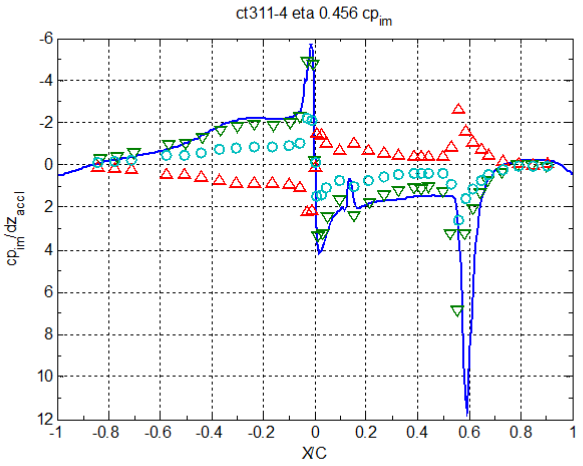
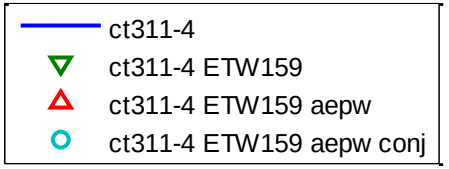
Cp mid wing
ct311-4 ETW159 section 3











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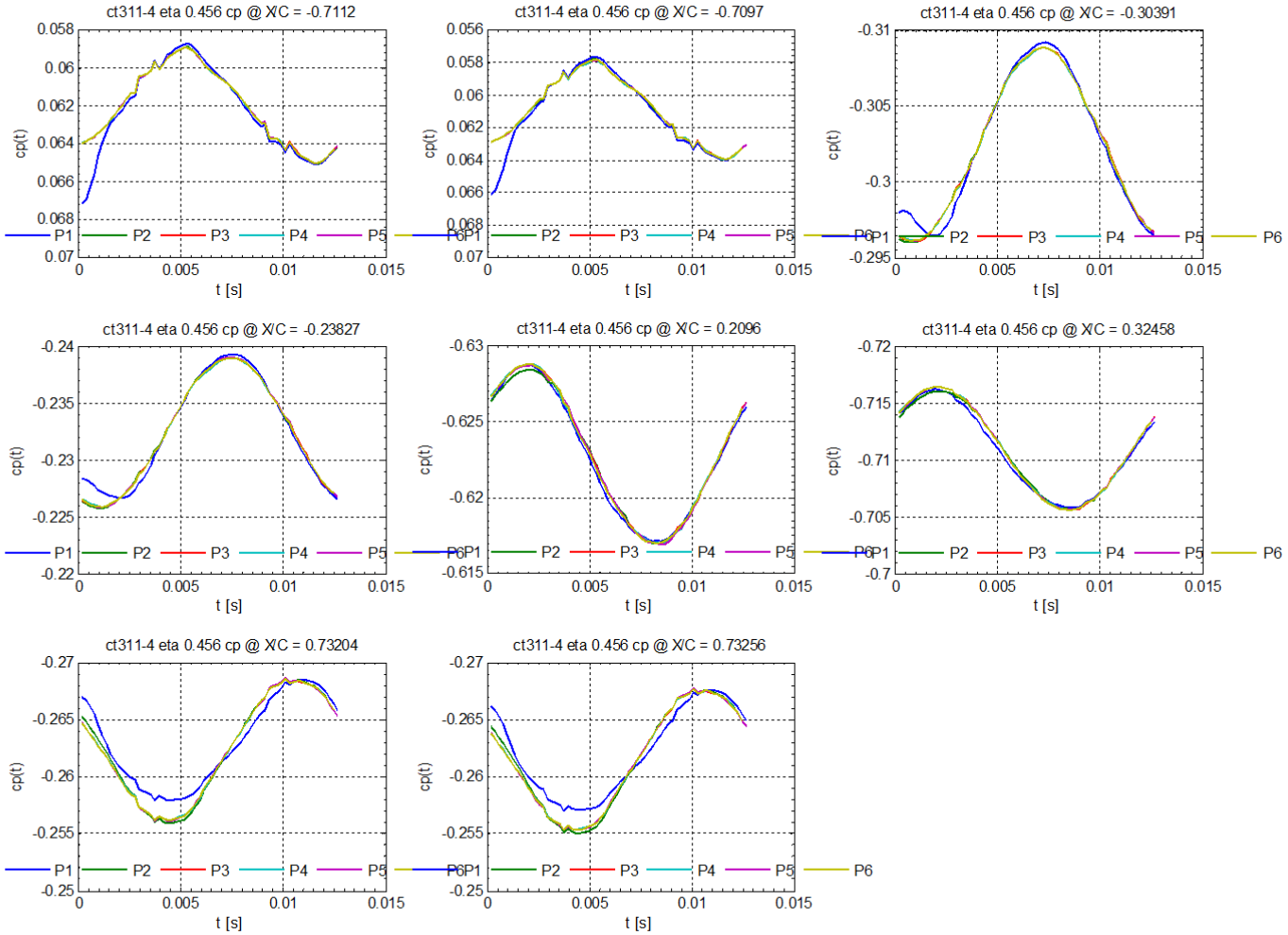
Cp time resolved
ct311-4 ETW159 section 3



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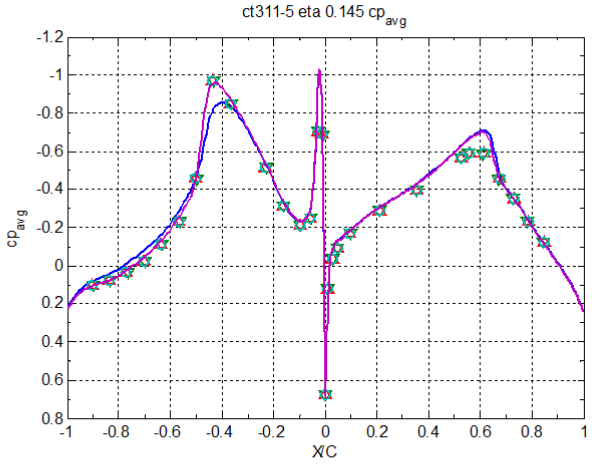
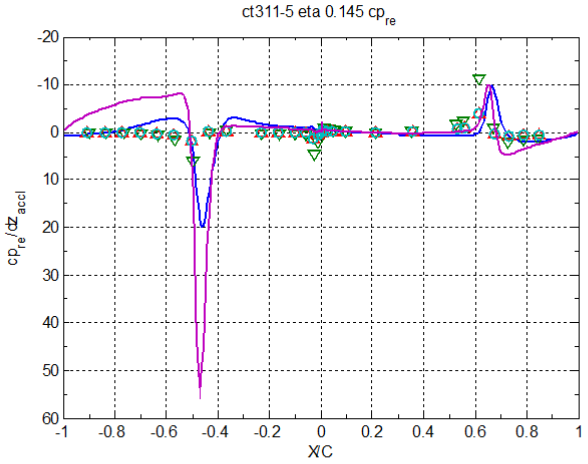
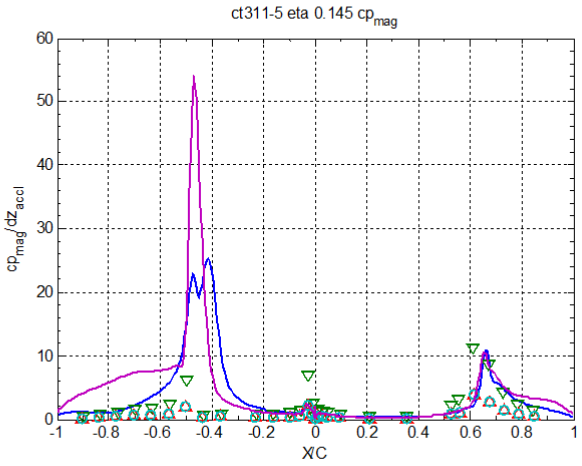
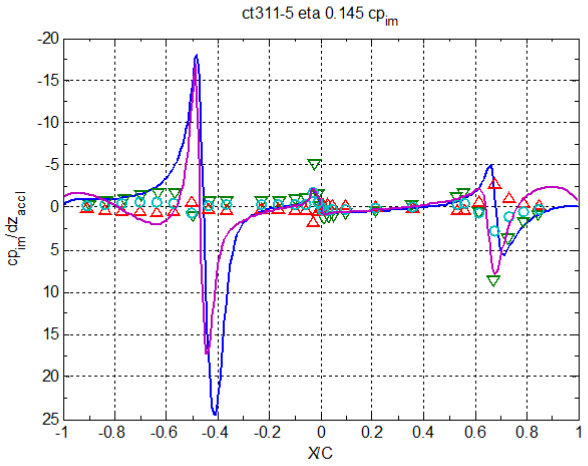
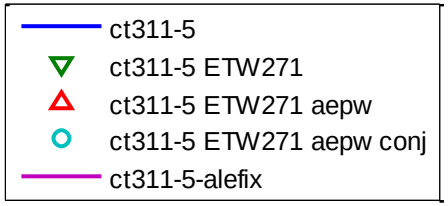
Cp wing root
ct311-5 ETW271 section 1











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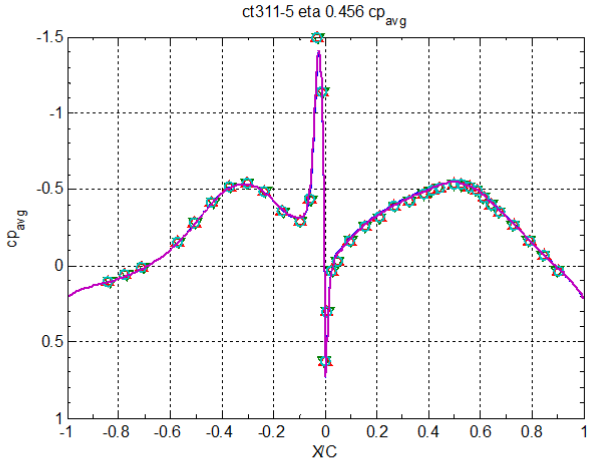
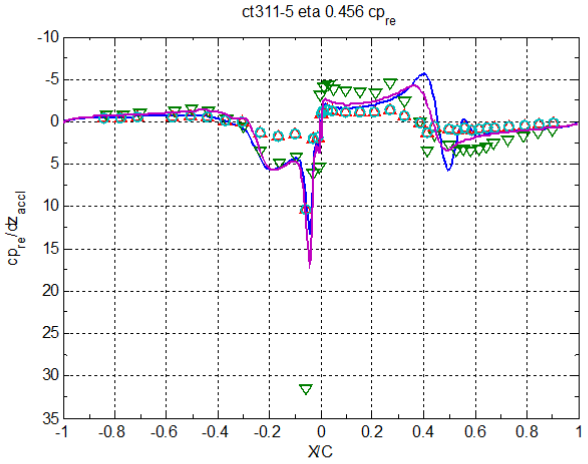
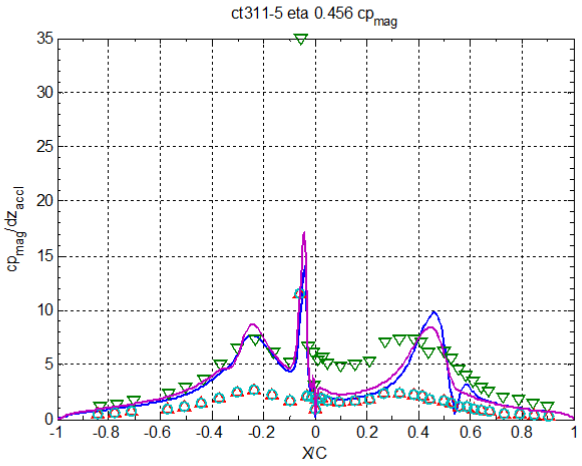
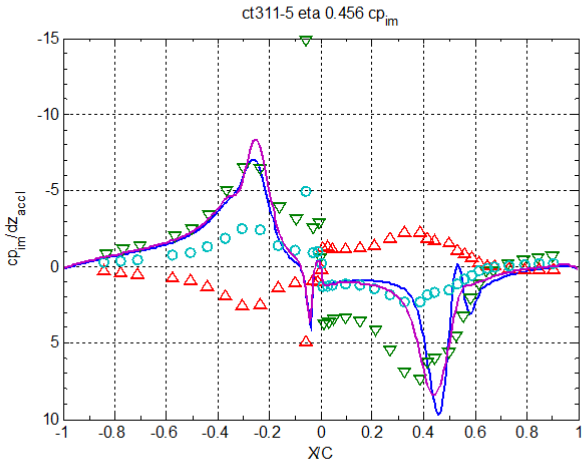
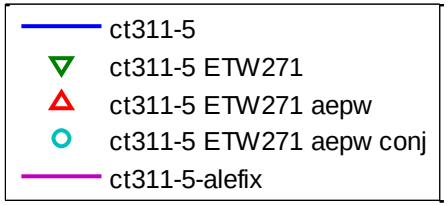
Cp mid wing
ct311-5 ETW271 section 3











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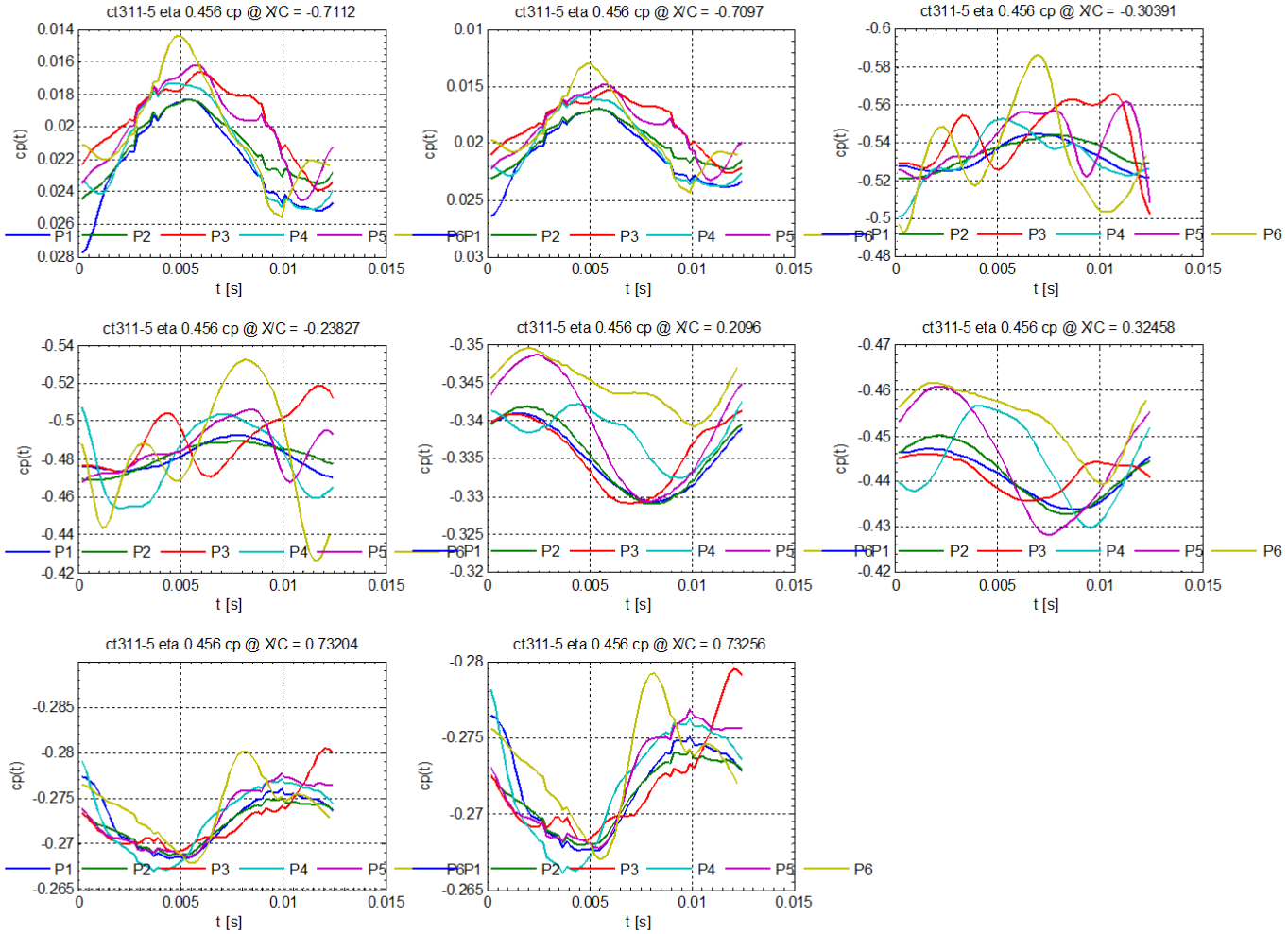
Cp time resolved
ct311-5 ETW271 section 3



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Issues encountered & challenges

- Flow at wing root, effect of fuselage dummy
- Periodicity of unsteady flow for ETW271 in some areas questionable after only six periods of excitation
- Scaling/normalizing of results, plus complex conjugate issue
- ALE bug encountered

Thank you for your attention!

Questions?

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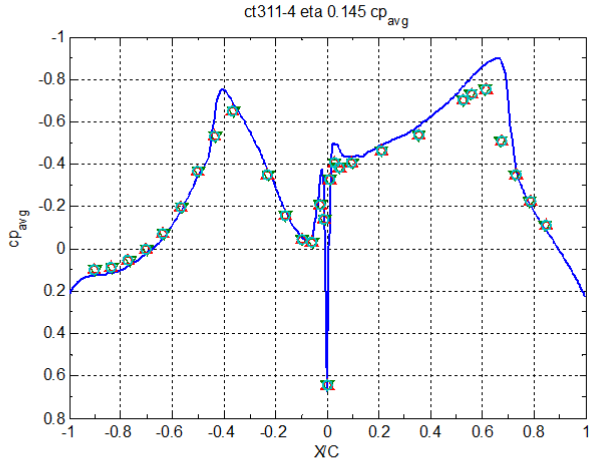
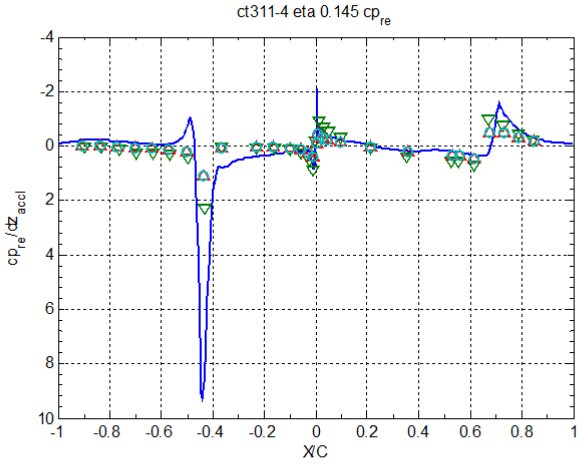
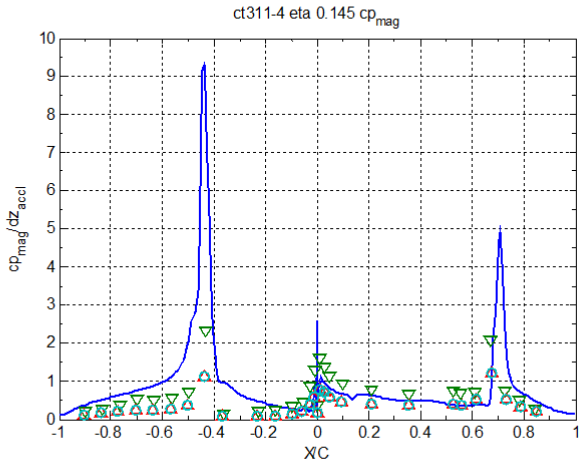
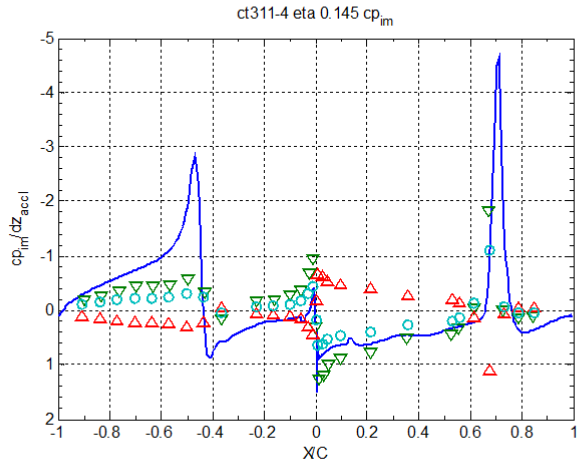
Backup

Unsteady pressure coefficients ct311-4 ETW159 section 1









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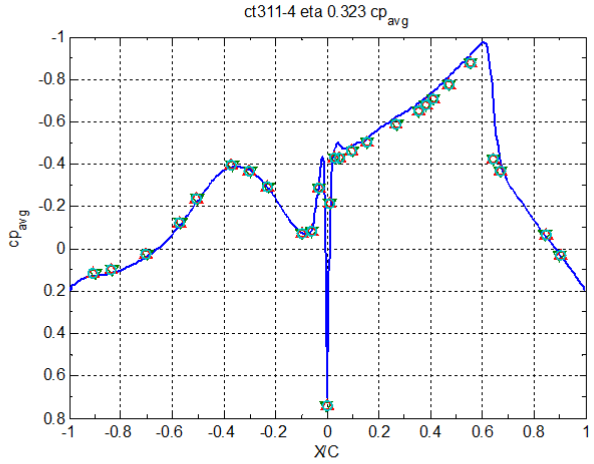
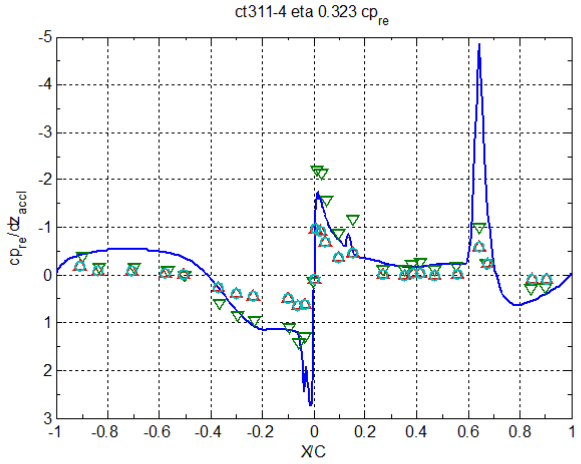
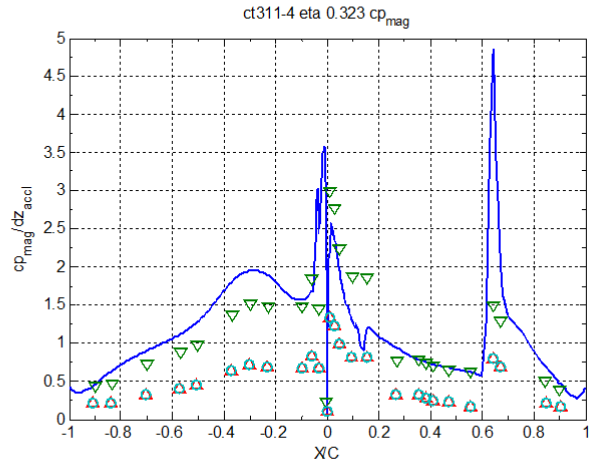
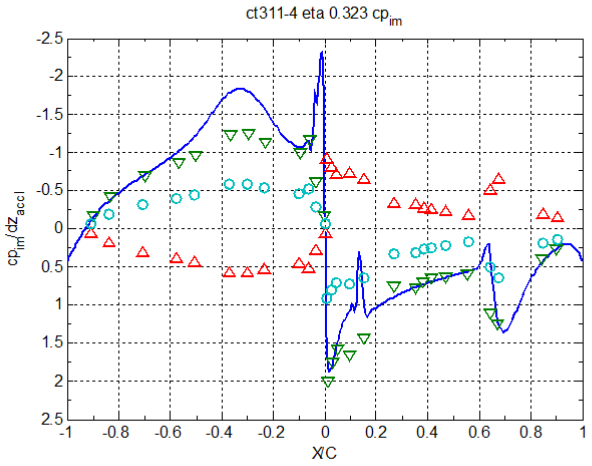
Unsteady pressure coefficients ct311-4 ETW159 section 2



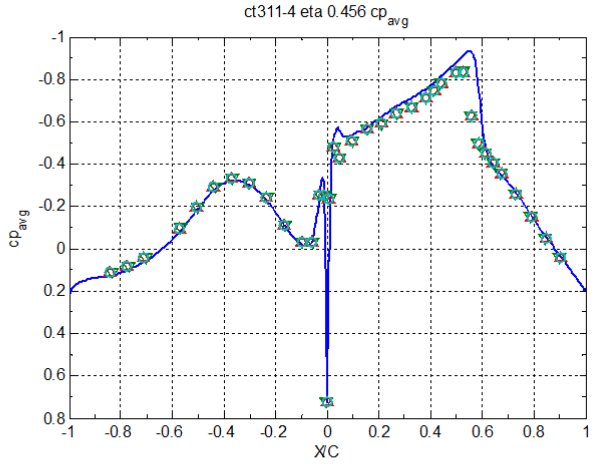


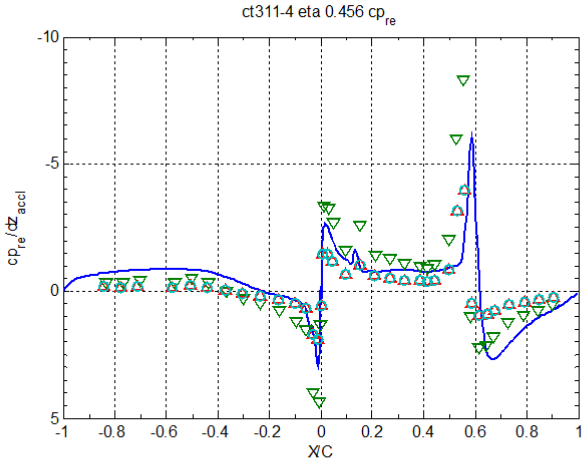


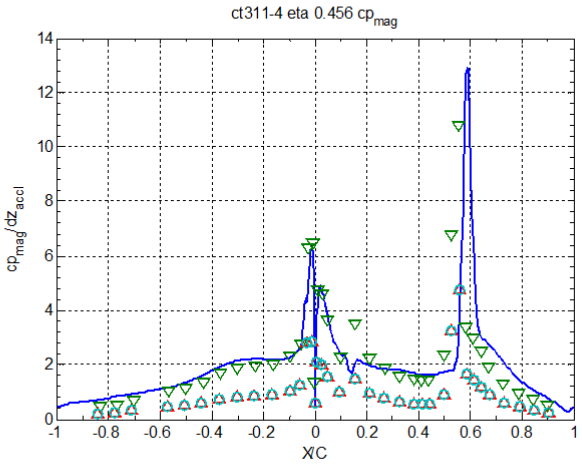


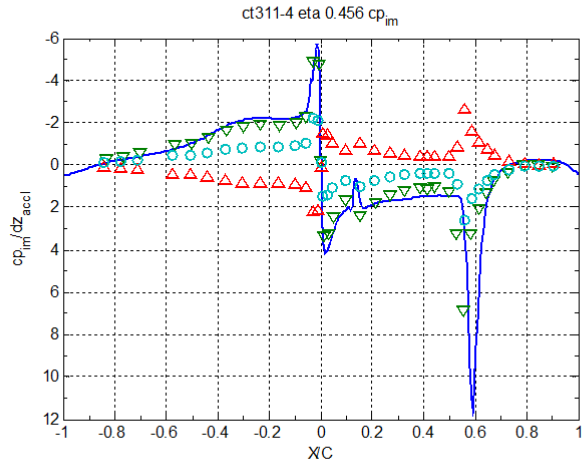
Together ahead. RUAG

Unsteady pressure coefficients ct311-4 ETW159 section 3



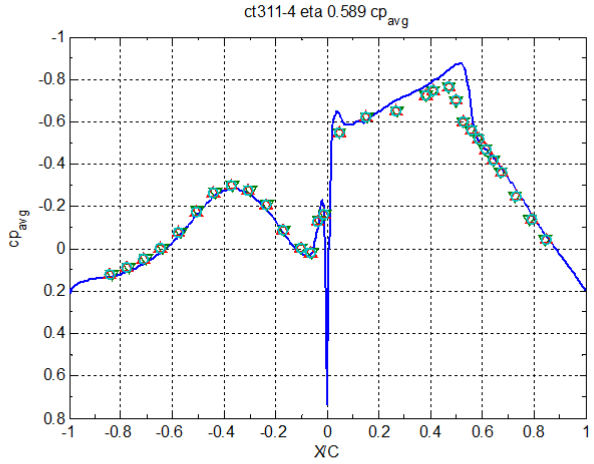


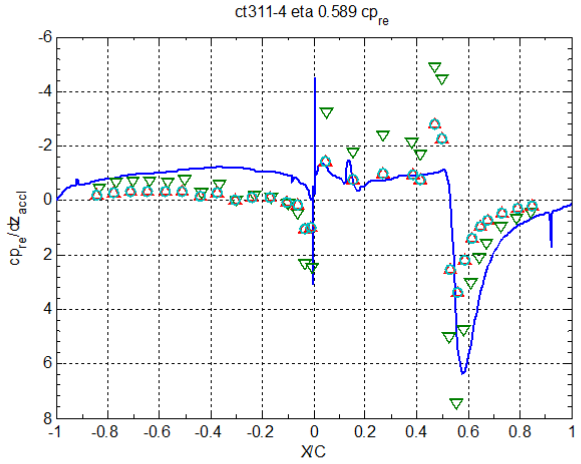


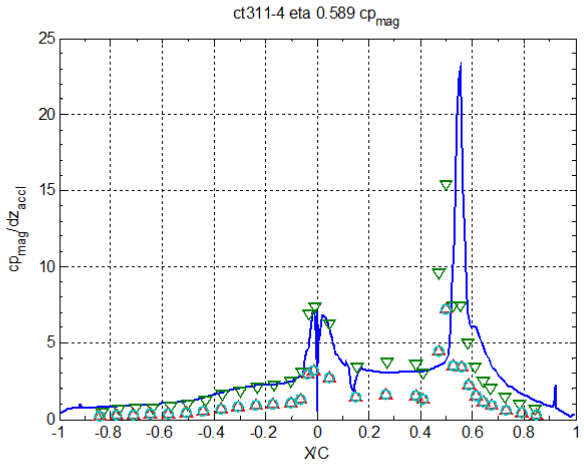


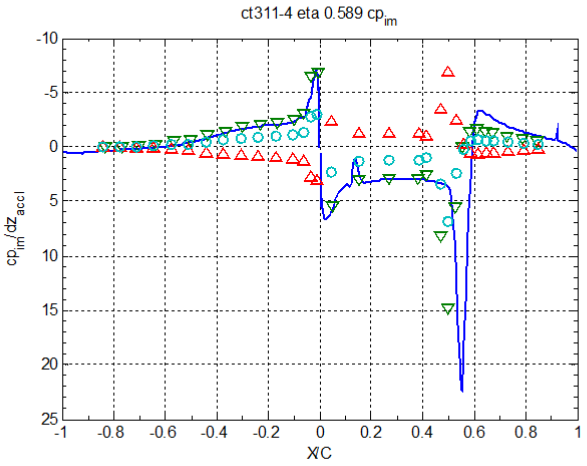
Together ahead. RUAG

Unsteady pressure coefficients ct311-4 ETW159 section 4









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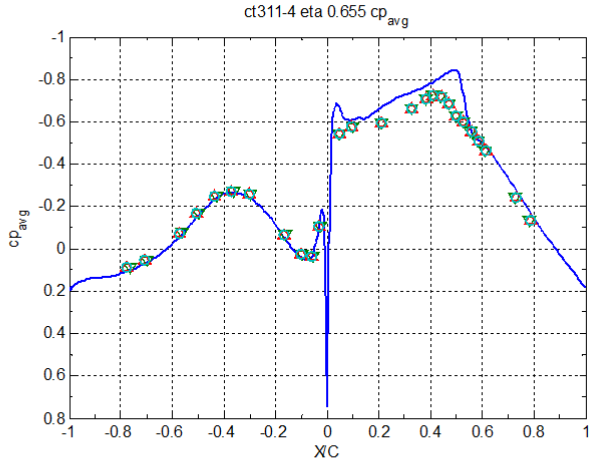
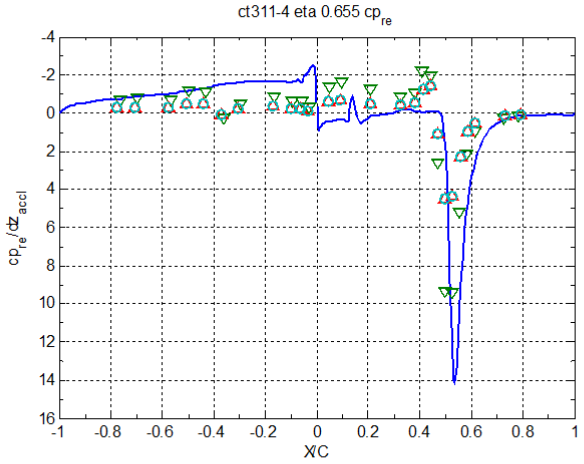
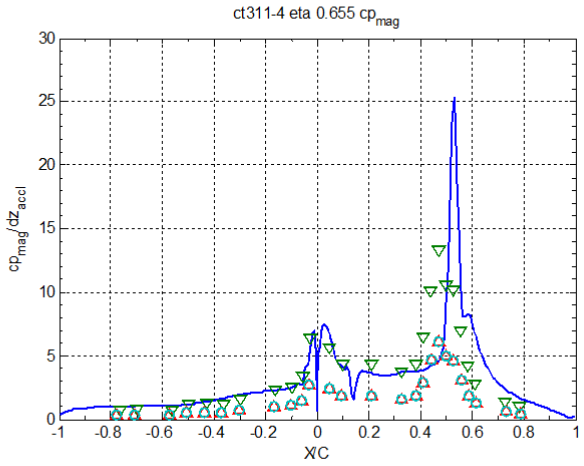
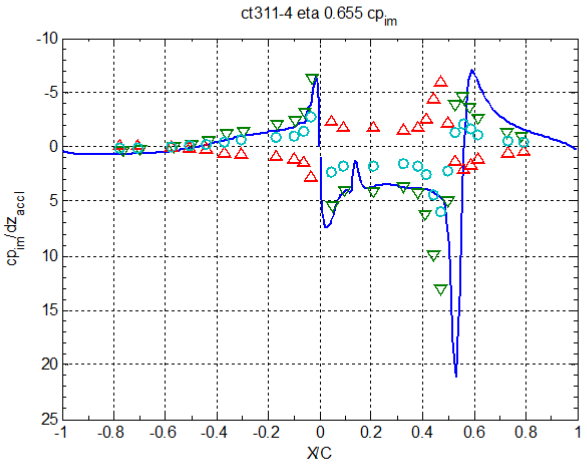
Unsteady pressure coefficients ct311-4 ETW159 section 5









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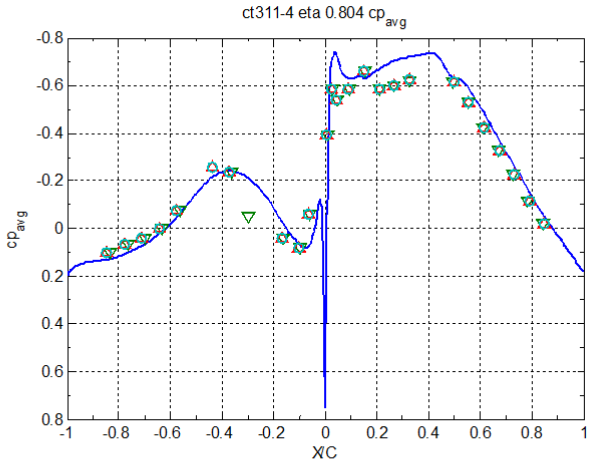
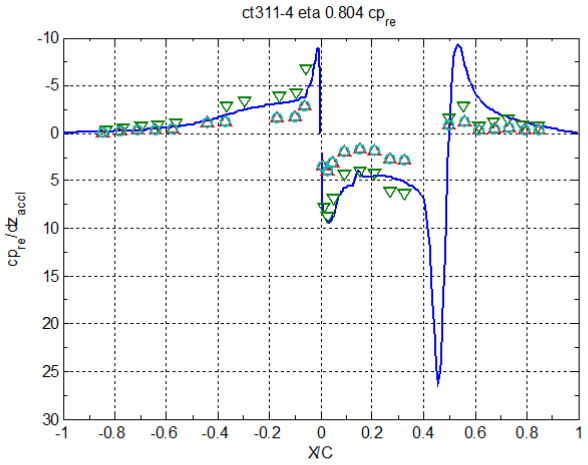
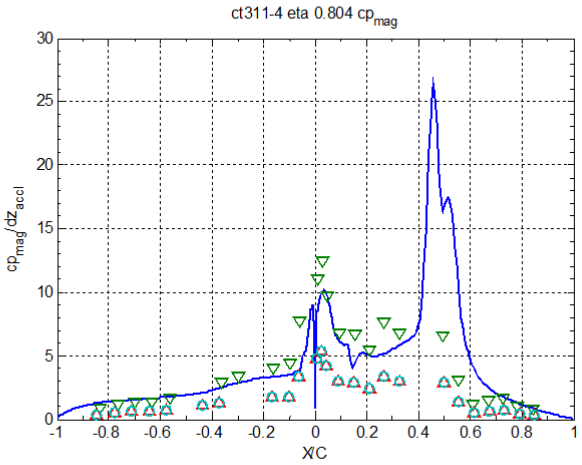
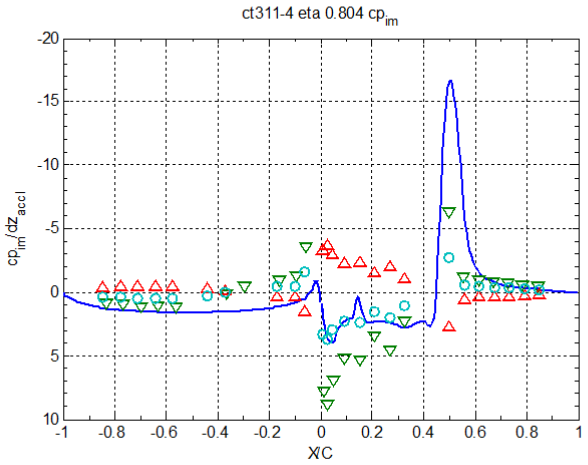
Unsteady pressure coefficients ct311-4 ETW159 section 6









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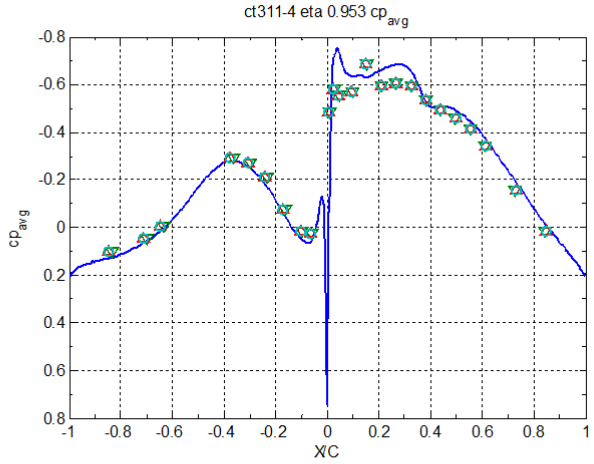
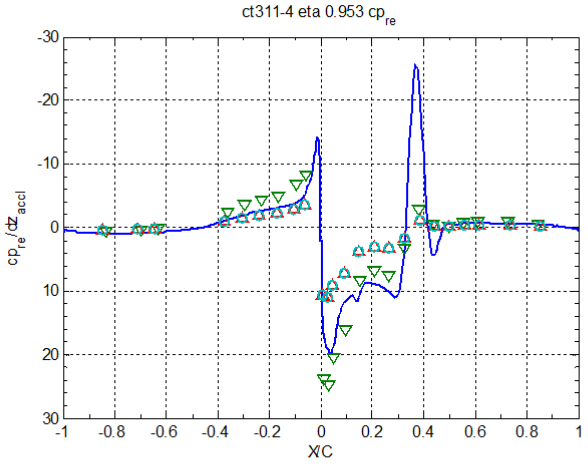
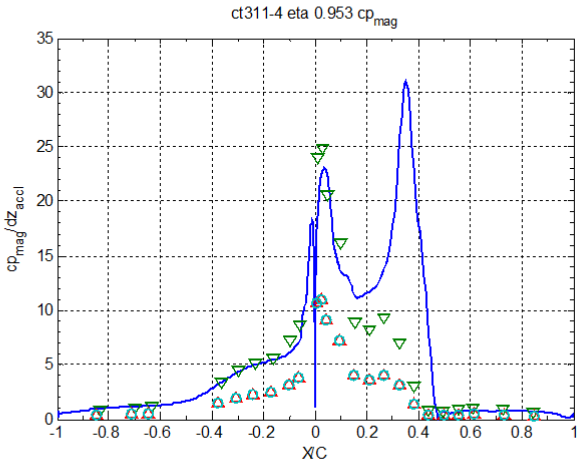
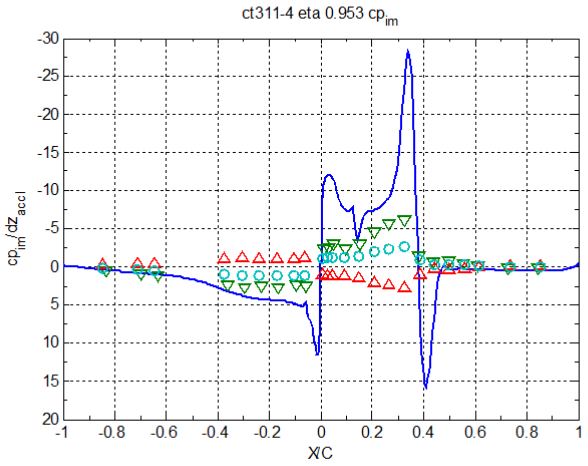
Unsteady pressure coefficients ct311-4 ETW159 section 7



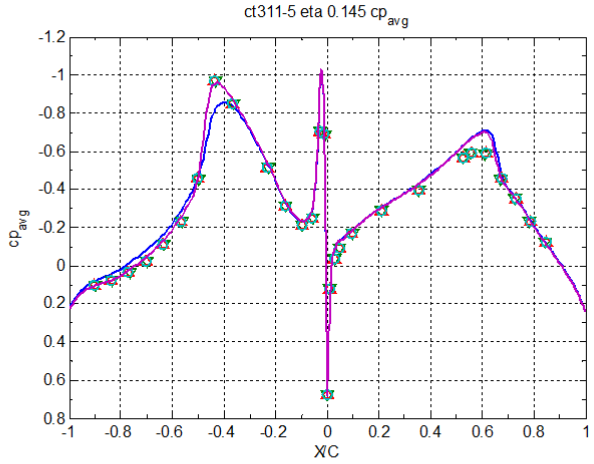


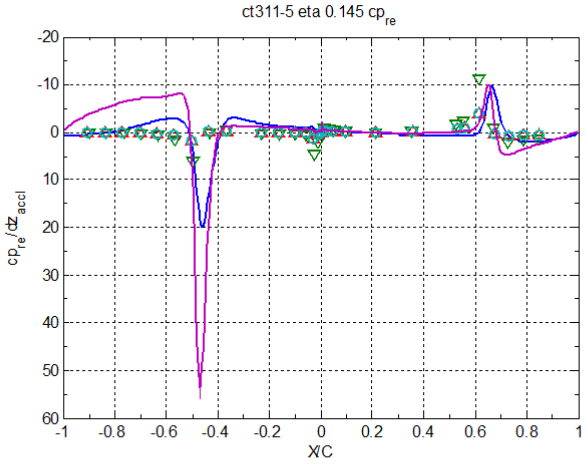


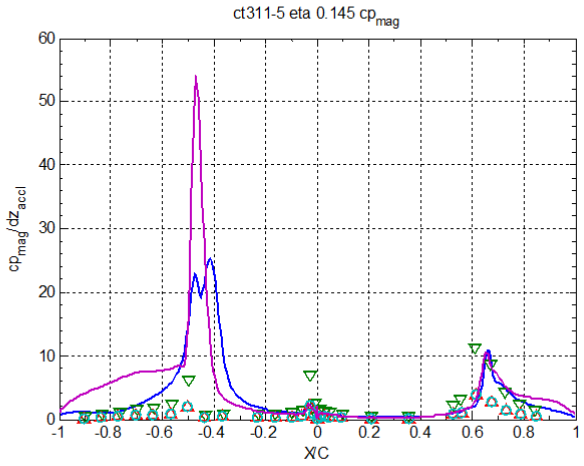


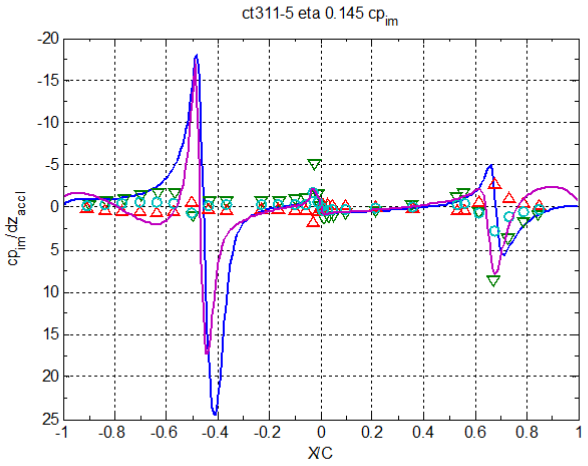
Together ahead. RUAG

Unsteady pressure coefficients ct311-5 ETW271 section 1



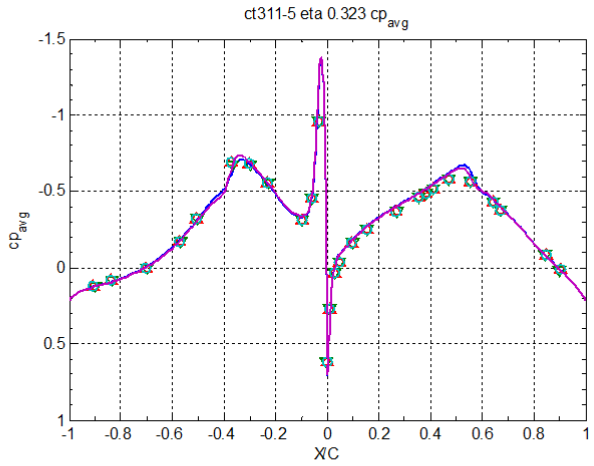


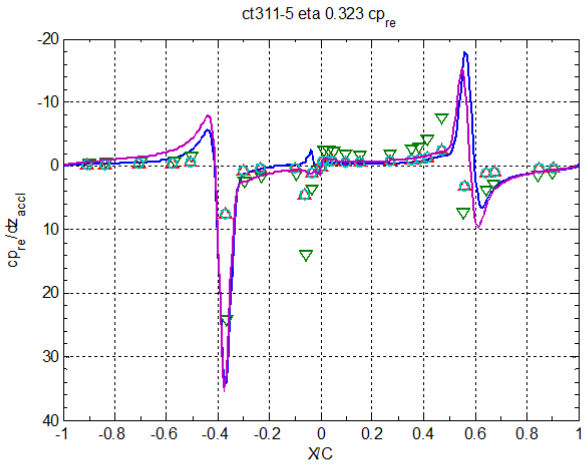


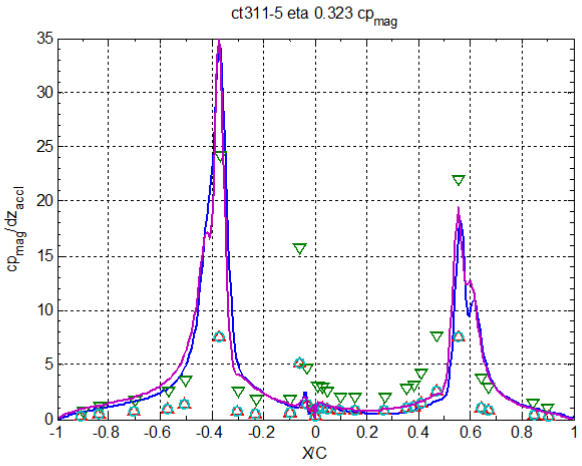


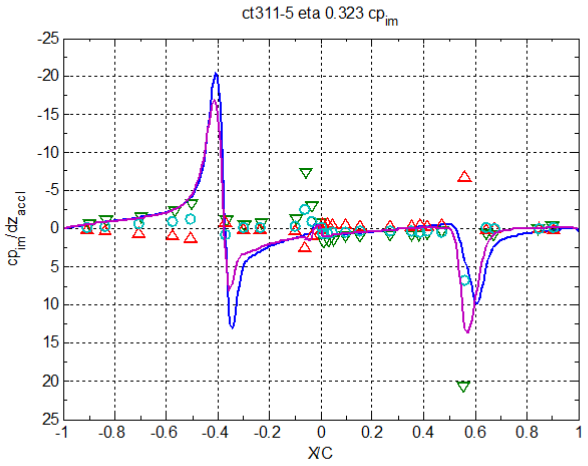
Together ahead. RUAG

Unsteady pressure coefficients ct311-5 ETW271 section 2



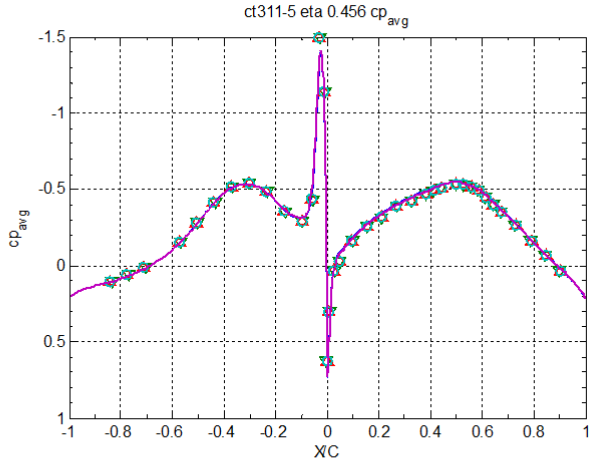


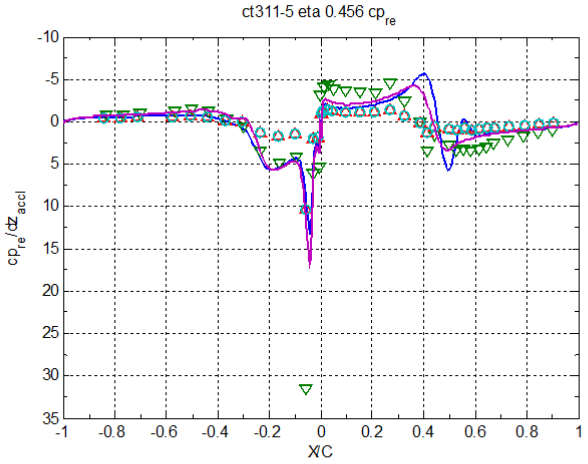


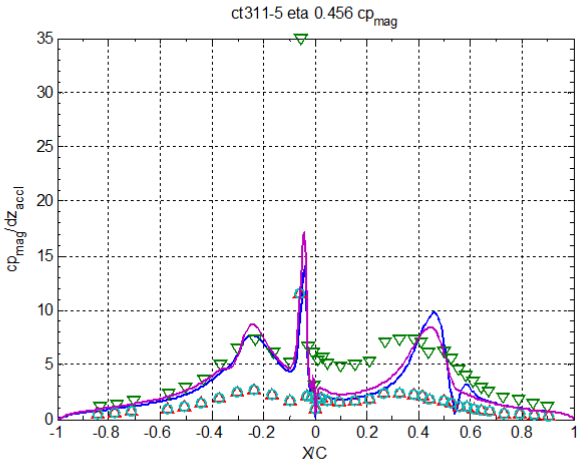


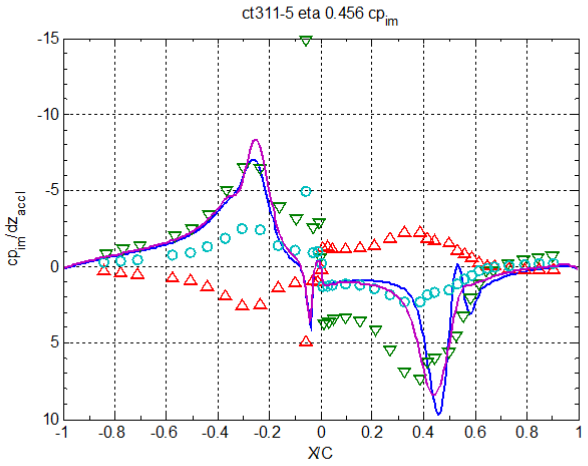
Together ahead. RUAG

Unsteady pressure coefficients ct311-5 ETW271 section 3









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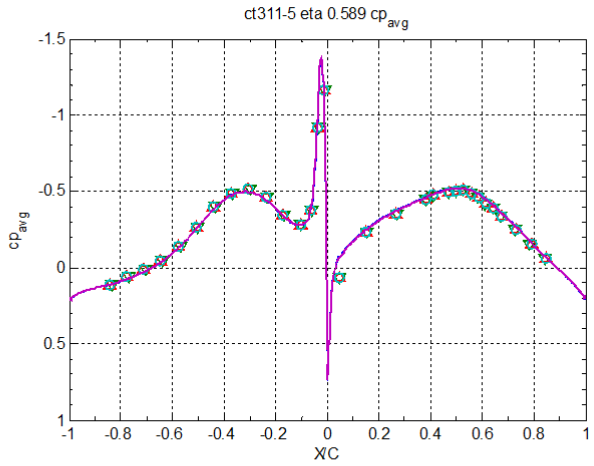
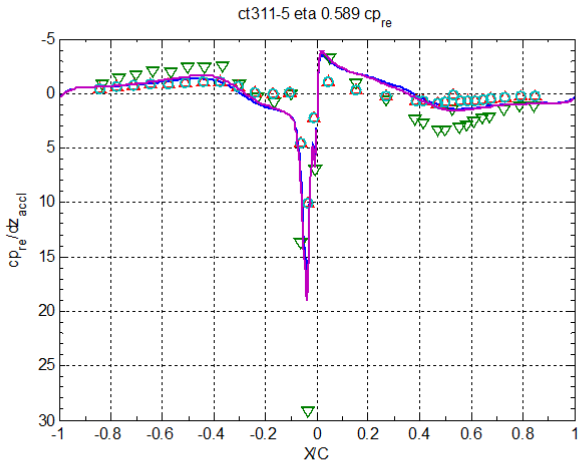
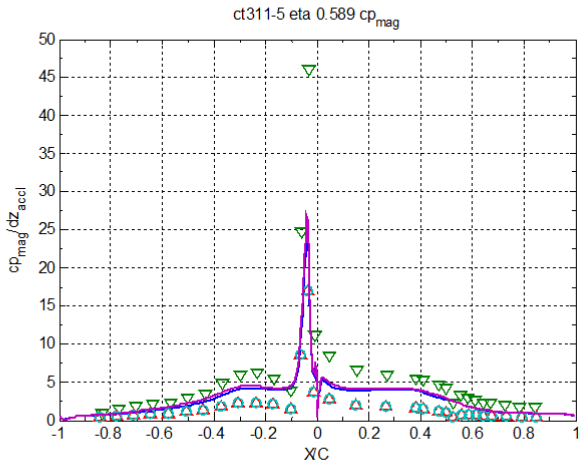
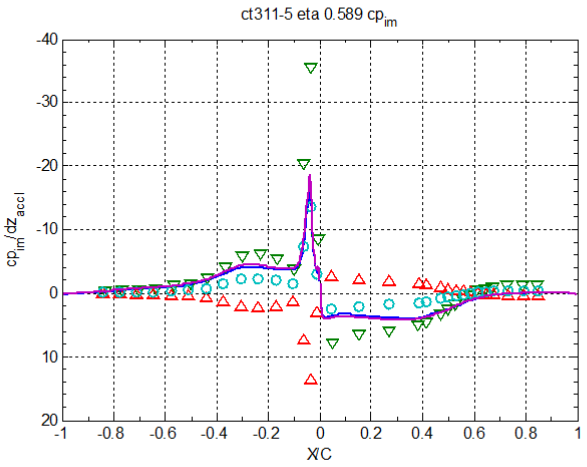
Unsteady pressure coefficients ct311-5 ETW271 section 4









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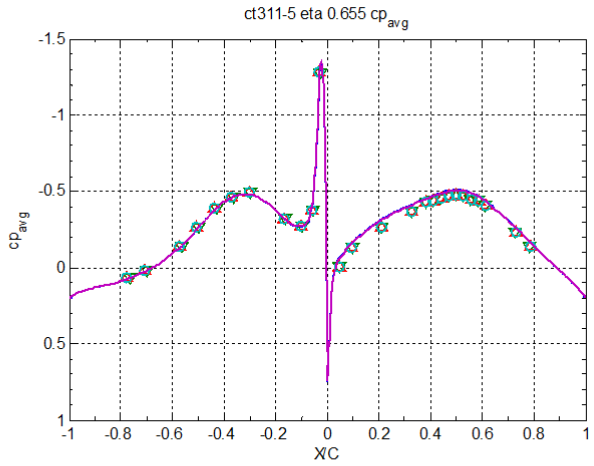
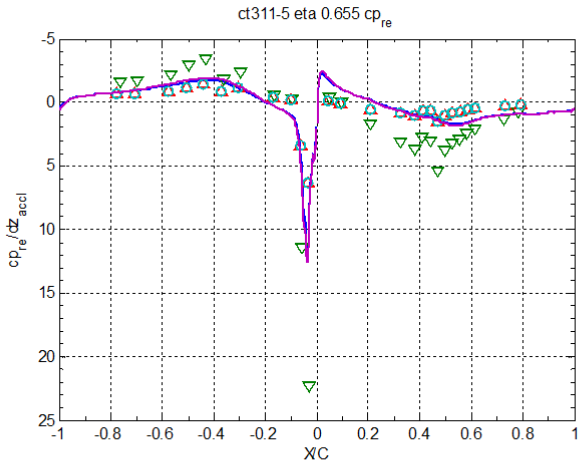
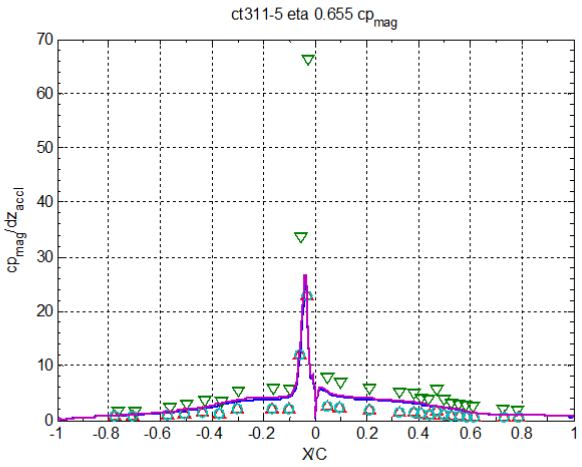
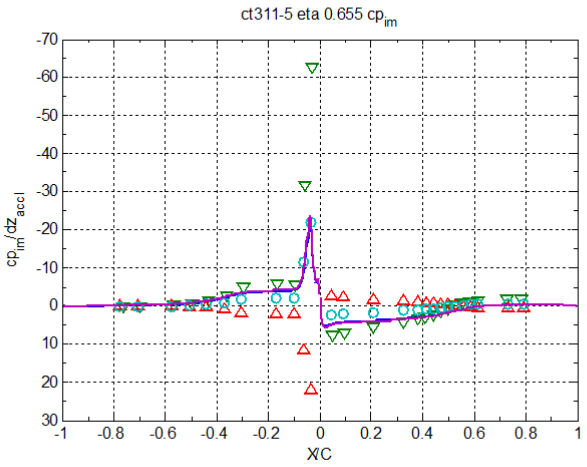
Unsteady pressure coefficients ct311-5 ETW271 section 5



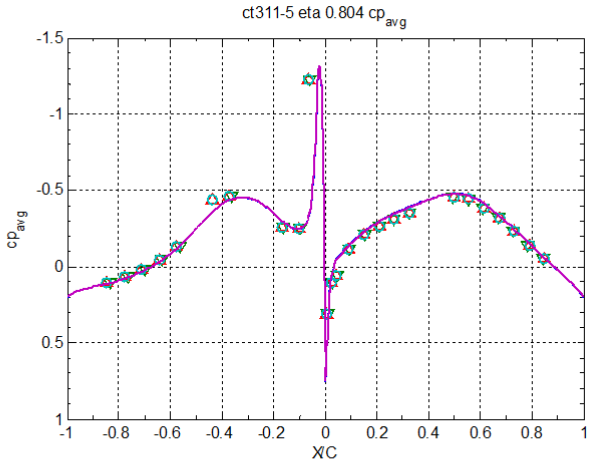


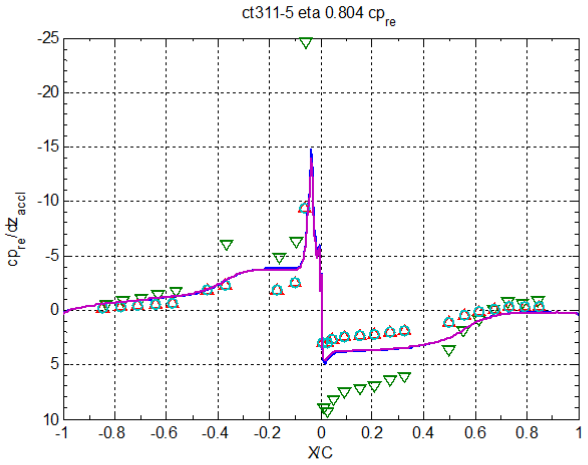


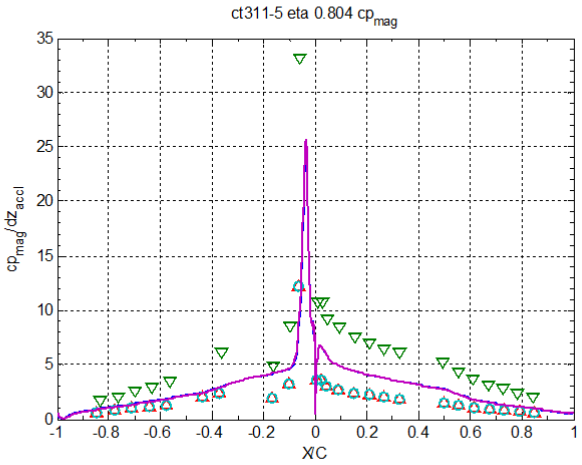


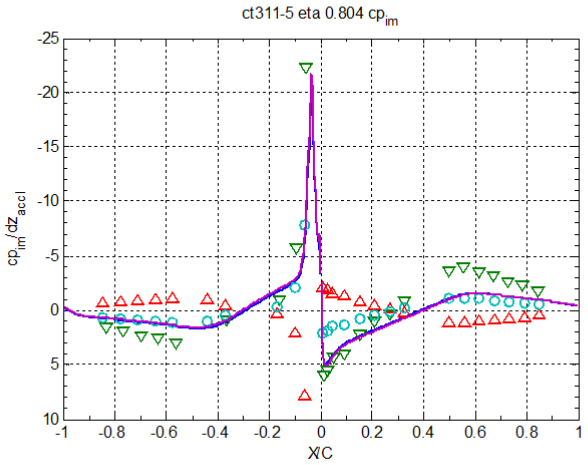
Together ahead. RUAG

Unsteady pressure coefficients ct311-5 ETW271 section 6



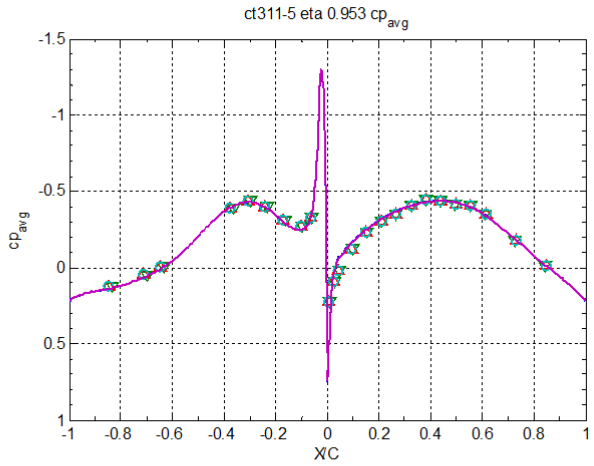


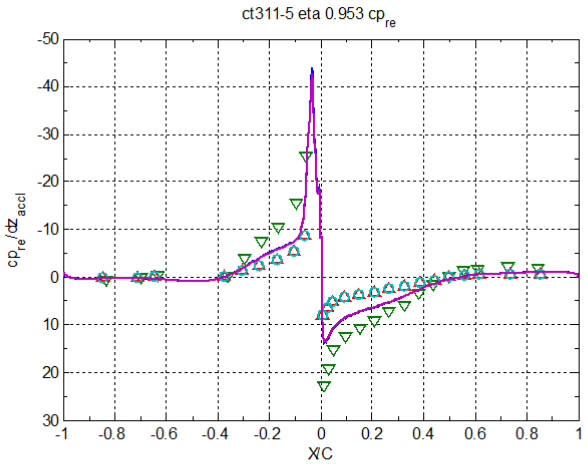


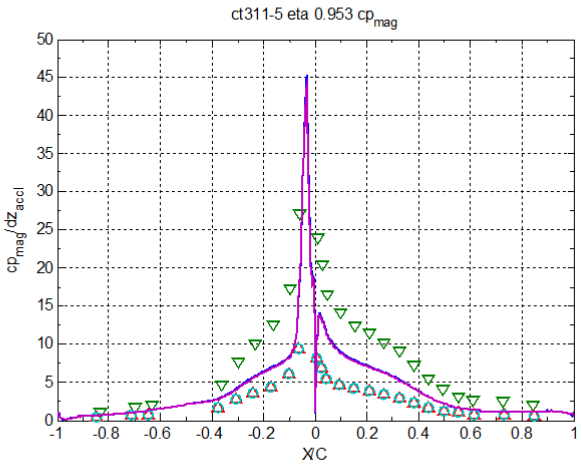


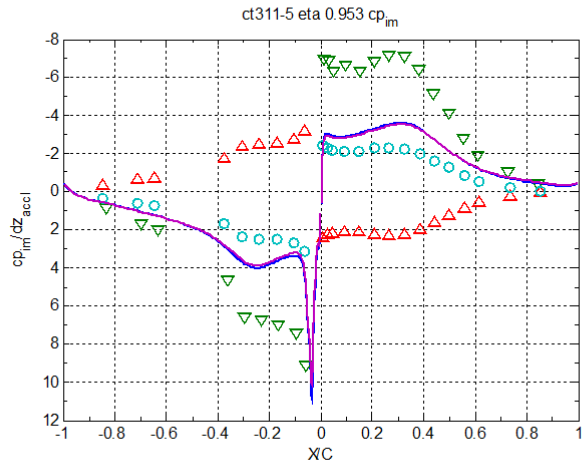
Together ahead. RUAG

Unsteady pressure coefficients ct311-5 ETW271 section 7









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