AePW Meeting
22 April 2012,Honolulu,HI

WP : HIRENASD

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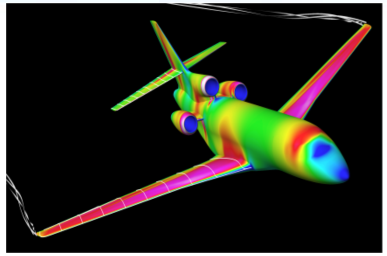
ONERA
THE FRENCH AEROSPACE LAB

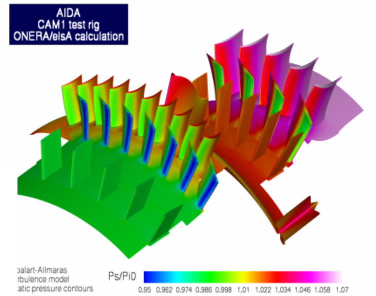
r e t o u r   s u r   i n n o v a t i o n

CFD elsA software

elsA platform:

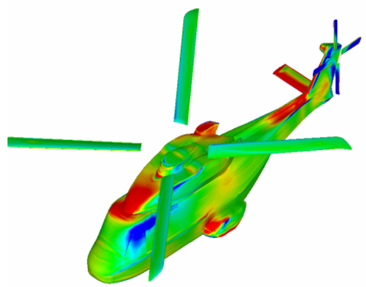
- **Multi-application software : external and internal flows**
- **Aerodynamic simulation, and multi-disciplinary applications including aerodynamics**
- **Object-Oriented (OO) design and implementation (C++, Fortran)**
- **Massively parallel computations**





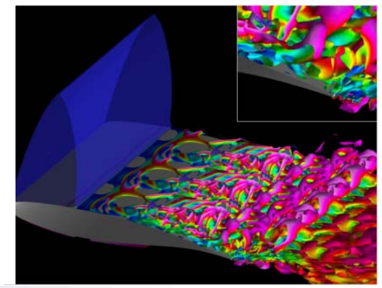
Flow modeling

- **RANS / URANS / DES / LES**
- **Large number of turbulence models, transition criteria**



Mesh strategy

- **Multiblock structured approach with high flexibility (match, no-match, Chimera)**
- **Deformable grids (ALE formulation)**

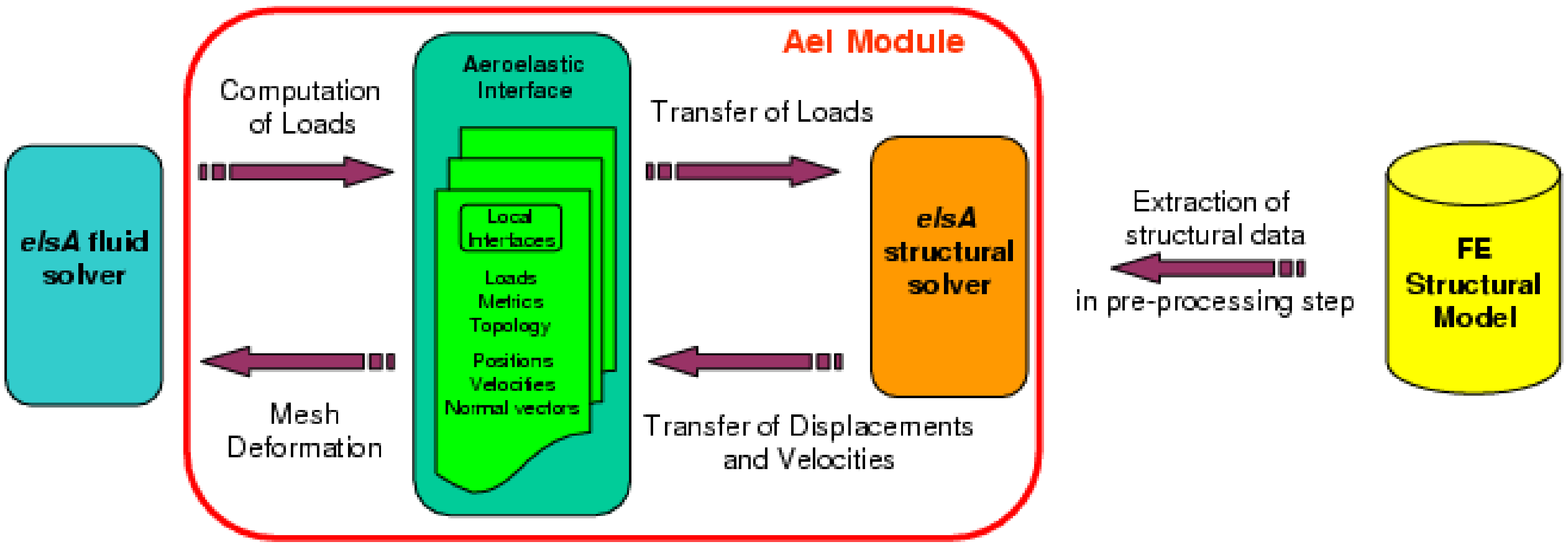


Numerics

- **Cell center Finite volume approach, centered or upwind schemes**
- **Convergence acceleration : multigrid, implicit techniques**
- **Unsteady flows: Dual Time-Stepping, or Gear scheme**

Extension of *elsA* for Aeroelasticity

- **Strategy adopted for aeroelastic developments (linear structure)**
  - **Extract structural information from FE model or experimental data base (pre-processing step)**
  - **Solve flow and structural equations in the same software**
  - **=> Development of a specific optional “aeroelastic” module on elsA**
- **Ael module: general framework for aeroelastic applications**
  - **Aeroelastic interface: stores the common fluid-structure data**
  - **Aeroelastic driver: manages the interaction and transfer of information between the flow and structure computations**



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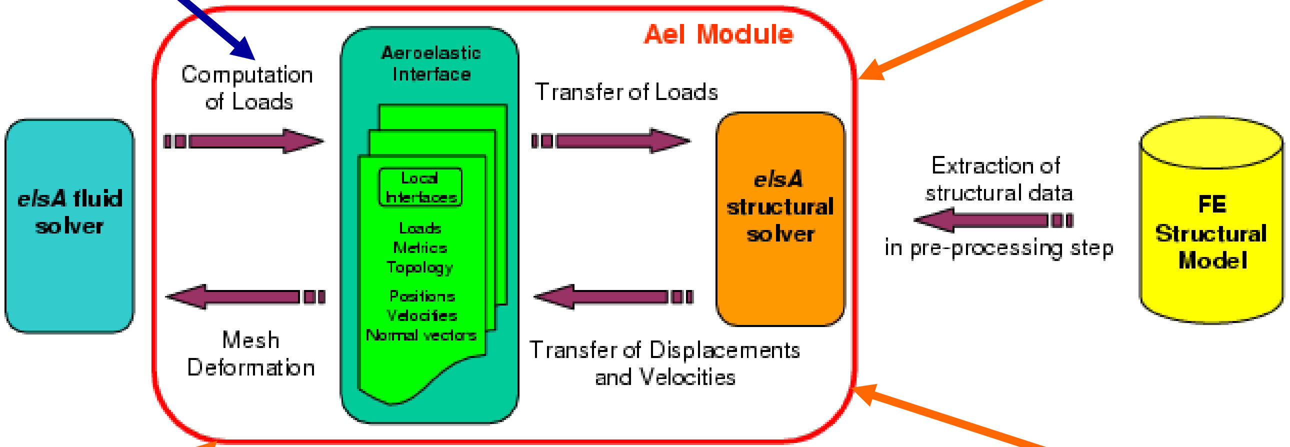
Extension of *elsA* for Aeroelasticity

Chimera grids : use of USURP to correct Loads

- Nonlinear and Linearized harmonic forced motion simulations :
  - GAF for flutter prediction in frequency domain



- Static coupling :
  - Flight shape prediction
  - Static Control Surface efficiency

- Dynamic coupling :
  - Dynamic response induced :
    - Initial perturbation (flutter, LCO)
    - Control surface motion (dynamic efficiency)

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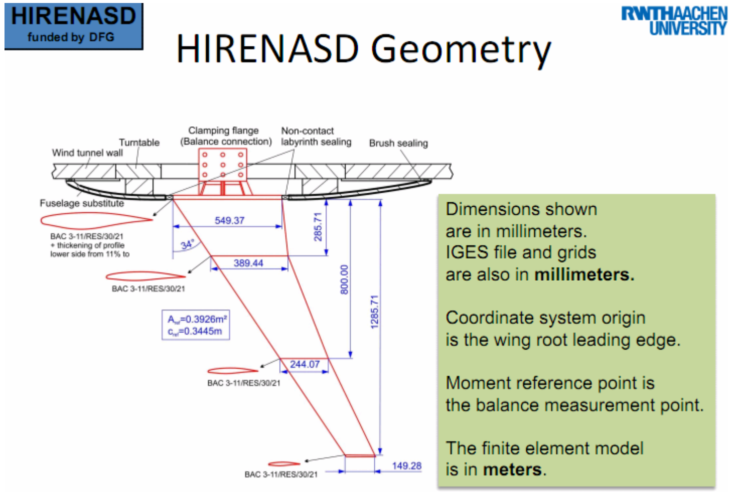


M = 0.80, test medium: Nitrogen

- a) Steady (Static Aeroelastic) Cases
  - i. Re_c = 7.0 million, α = 1.5°, q/E = 0.22 (ETW132)
  - ii. Re_c = 23.5 million, α = -1.34°, q/E = 0.48 (ETW250)
- b) Dynamic Cases: forced oscillation at 2nd Bending mode frequency
  - i. Re_c = 7.0 million, α = 1.5°, q/E = 0.22 (ETW159)
  - ii. Re_c = 23.5 million, α = -1.34°, q/E = 0.48 (ETW271)

M = 0.70, test medium: Nitrogen

- a) Steady (Static Aeroelastic) Cases
  - i. Re_c = 7.0 million, α = 1.5°, q/E = 0.22 (ETW129)
- b) Dynamic Cases: forced oscillation at 2nd Bending mode frequency
  - i. Re_c = 7.0 million, α = 1.5°, q/E = 0.22 (ETW155)

•Static aeroelastic cases with elsA software are available on two grids

Reduced Flexibility matrix,

•Dynamic cases (forced motion) are available on the coarsed grid,
One case (M=0.8,bii) are performed on the fine grid

Nper=64, Niterdual=50, 4 periods computed

Cell-centered scheme with Spalart-Allmaras model

AePW : ANSYS Germany Grid

Hirenasd coarse structured grid :

ANSYS grid , 6.5M nodes,

25 domains

Y^{+}~1,

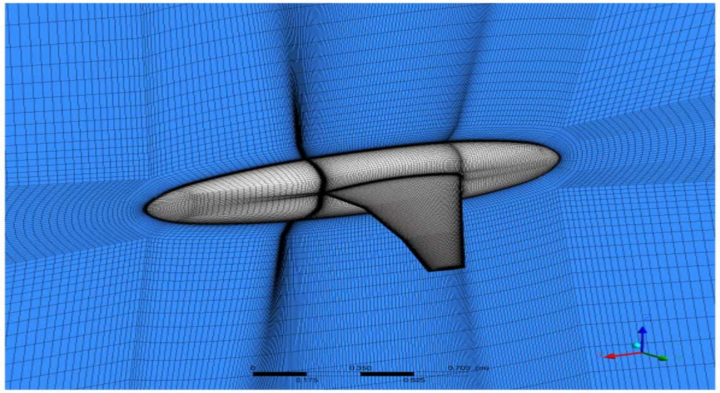
.cgns files on AePW website

15 nodes in aftbody

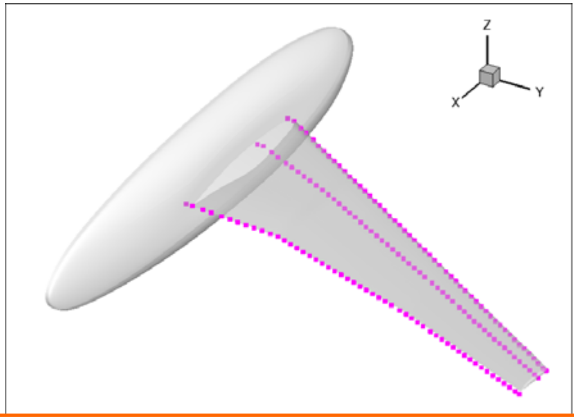
215 nodes on each profil

135 nodes on wing spanwise

ANSYS Germany grid



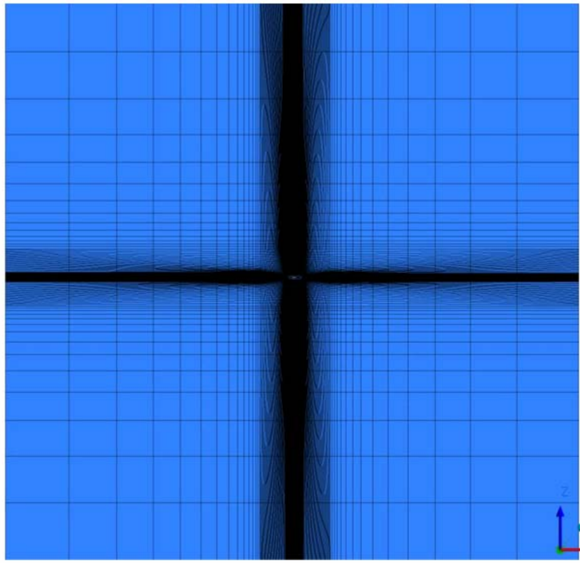
Thorsten Hansen, Ansys Germany, generated structured hexahedral grid (coarse grid)



Skin model structural nodes used to define the « reduced flexibility matrix »

Farfield located

at ~100 cref



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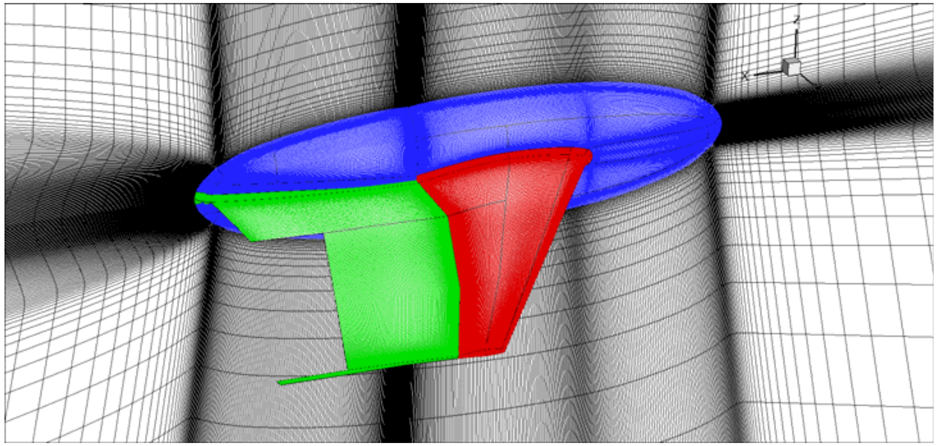
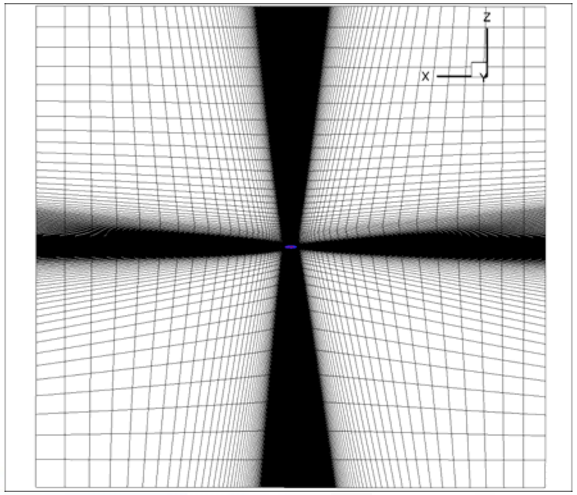
AePW : Airbus Grid

Hirenasd fine structured grid :

- Airbus grid, 30 M nodes,
- 138 domains,
- Multigrid with 3 grids (1 fine and 2 coarsed
  - 33 nodes in aftbody
  - 344 nodes on each profil
  - 130 nodes on wing spanwise

Airbus France grid





Farfield located at ~100 cref

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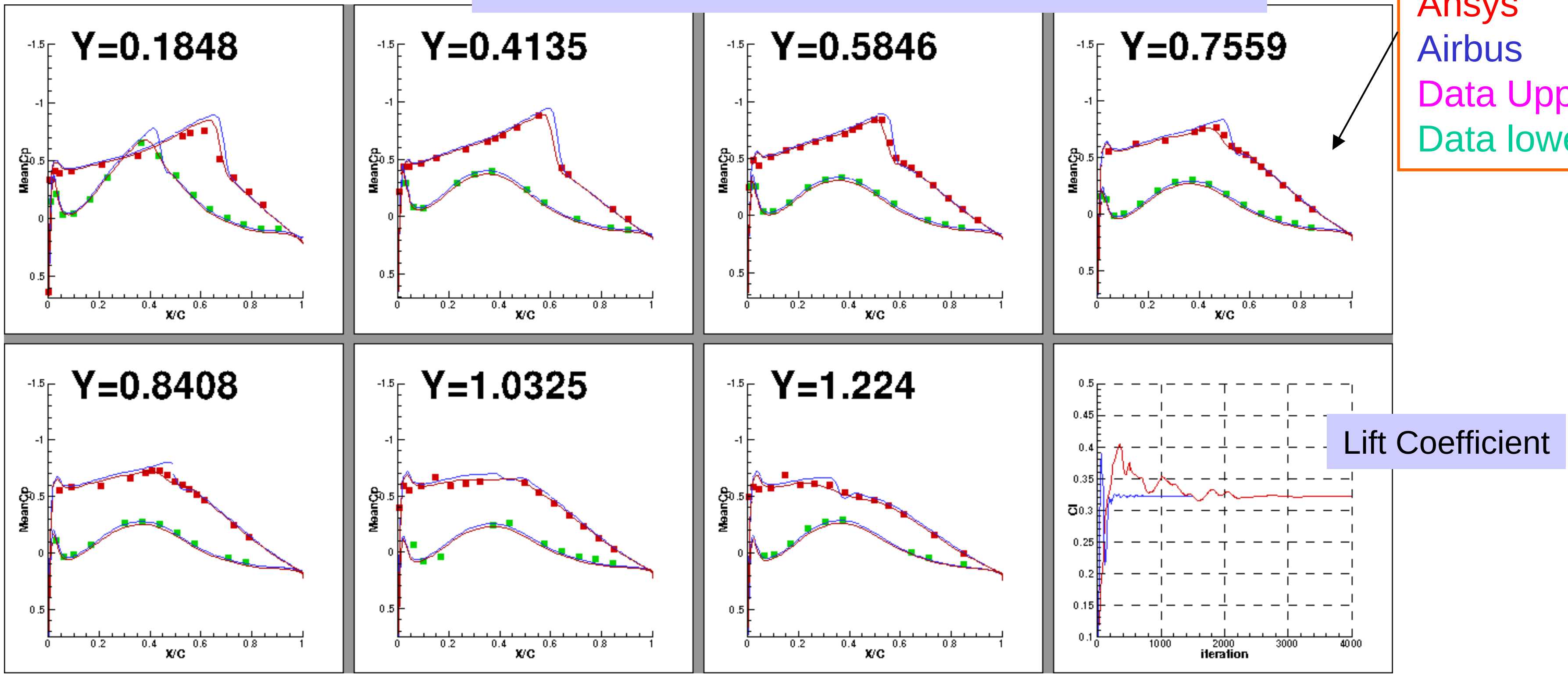
AePW : HIRENASD Static case M=0.8 Re~7M

Investigated flow conditions *: M=0.8005, α= 1.5° Data Pt 159*

Steady Cp cuts: Static coupling simulation with elsA



Ansys
Airbus
Data Upper
Data lower

Good correlation with Experimental data, the shock intensity increase with the fine grid, the lift coefficient levels are similar. For the fine grid the multigrid technique is available.

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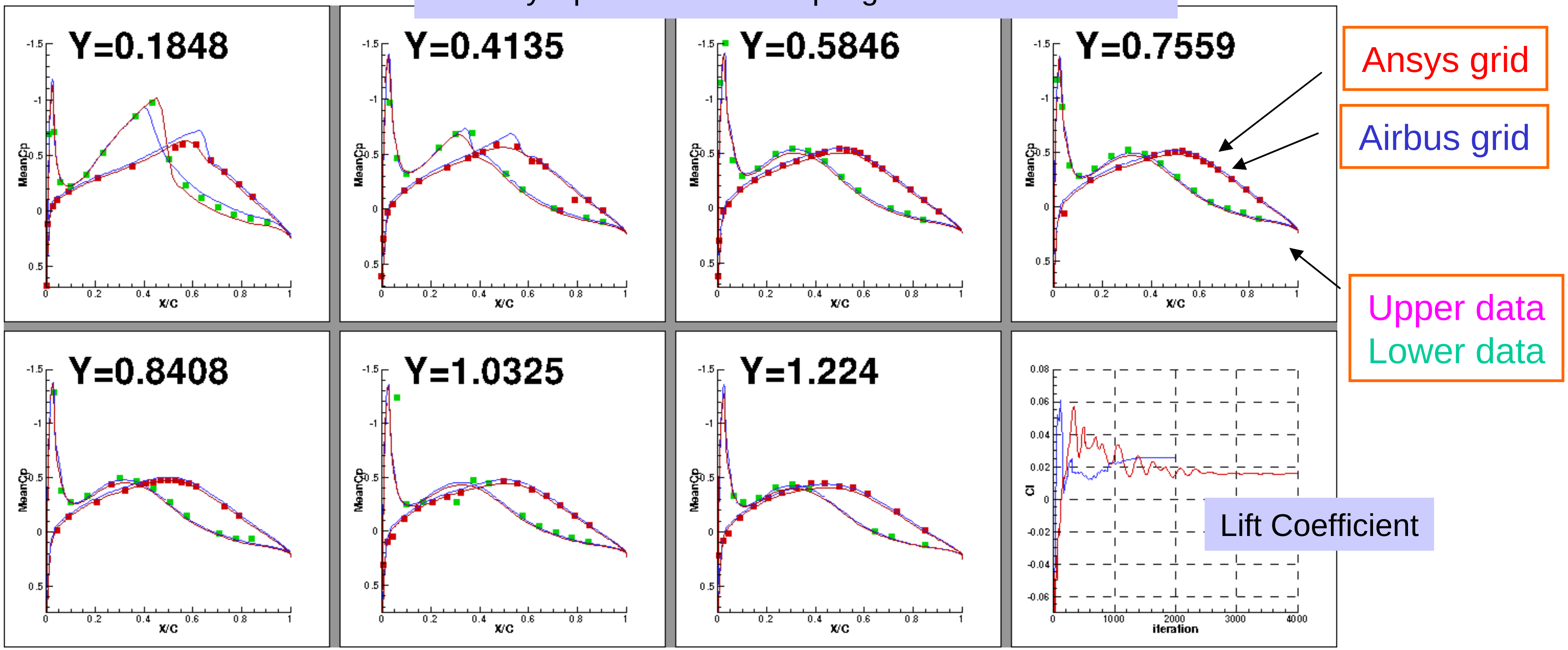
AePW : HIRENASD Static case M=0.8 Re~23.5 M

Investigated flow conditions *:M=0.800, α= -1.34˚ , Data Pt 271*

Steady Cp cuts: Static coupling simulation with elsA

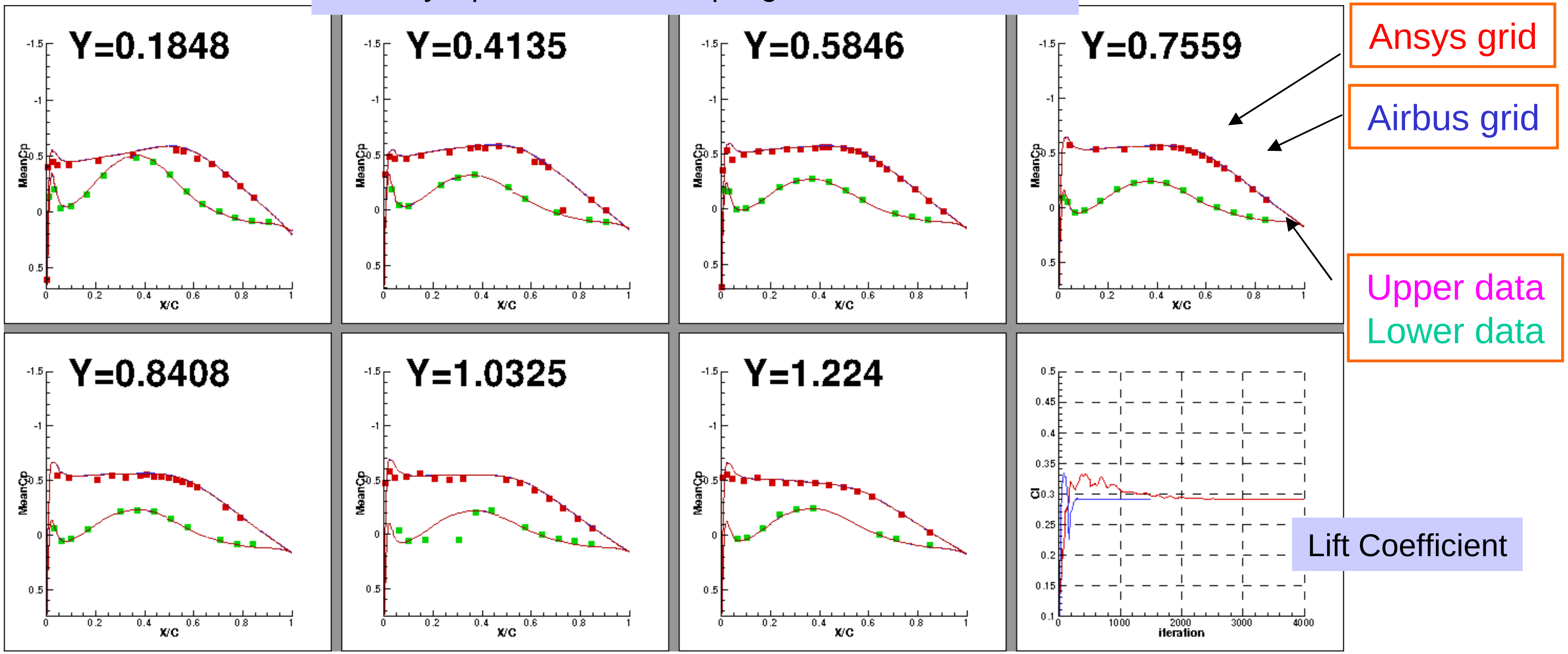


The shock intensity increase on the Upper surface with the fine grid.
We can observe a non negligible deviation on the lift coefficient.

AePW : HIRENASD Static case M=0.7 Re~7M

Investigated flow conditions *: M=0.7, α= 1.5°, Data Pt 155*

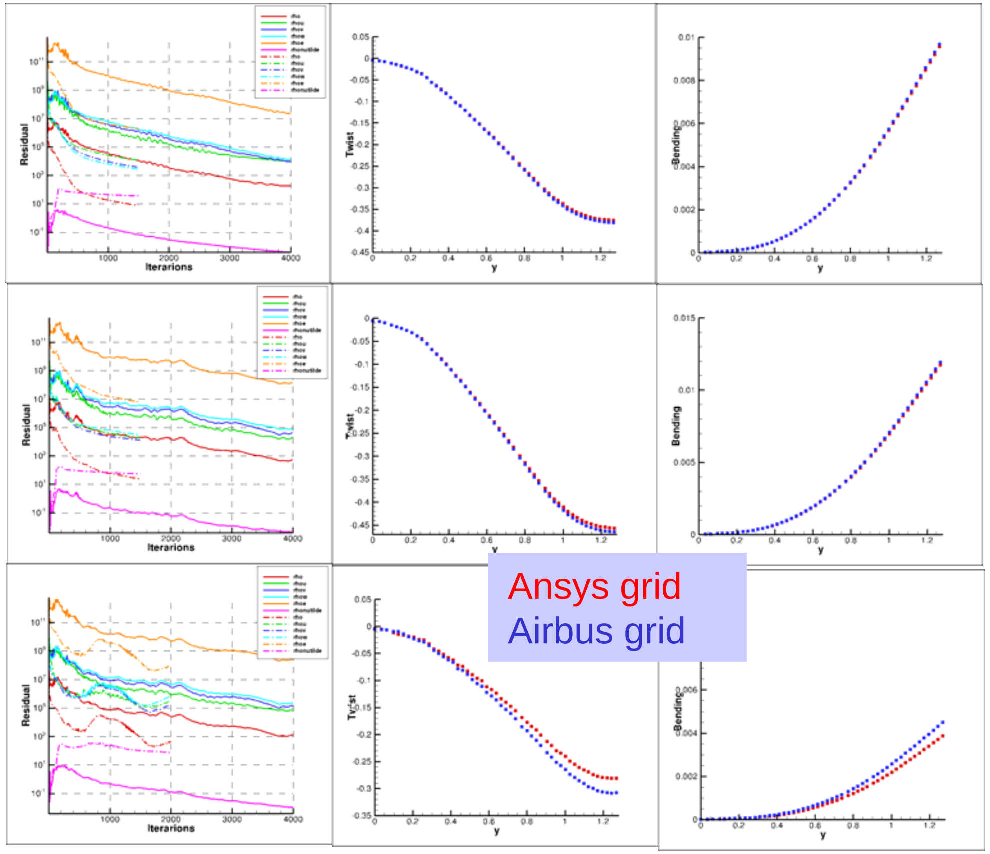
Steady Cp cuts: Static coupling simulation with elsA



Very Good correlation with Experimental data, the lift coefficient levels are identical.
The convergence is very quick.

AePW : HIRENASD Static case

Convergence history, twist and Bending for the 2 grids



M=0.7 Re=7M

M=0.8 Re=7M

M=0.8 Re=23.5M

Significant difference between the 2 grids on the twist and bending at Re~23.5M.

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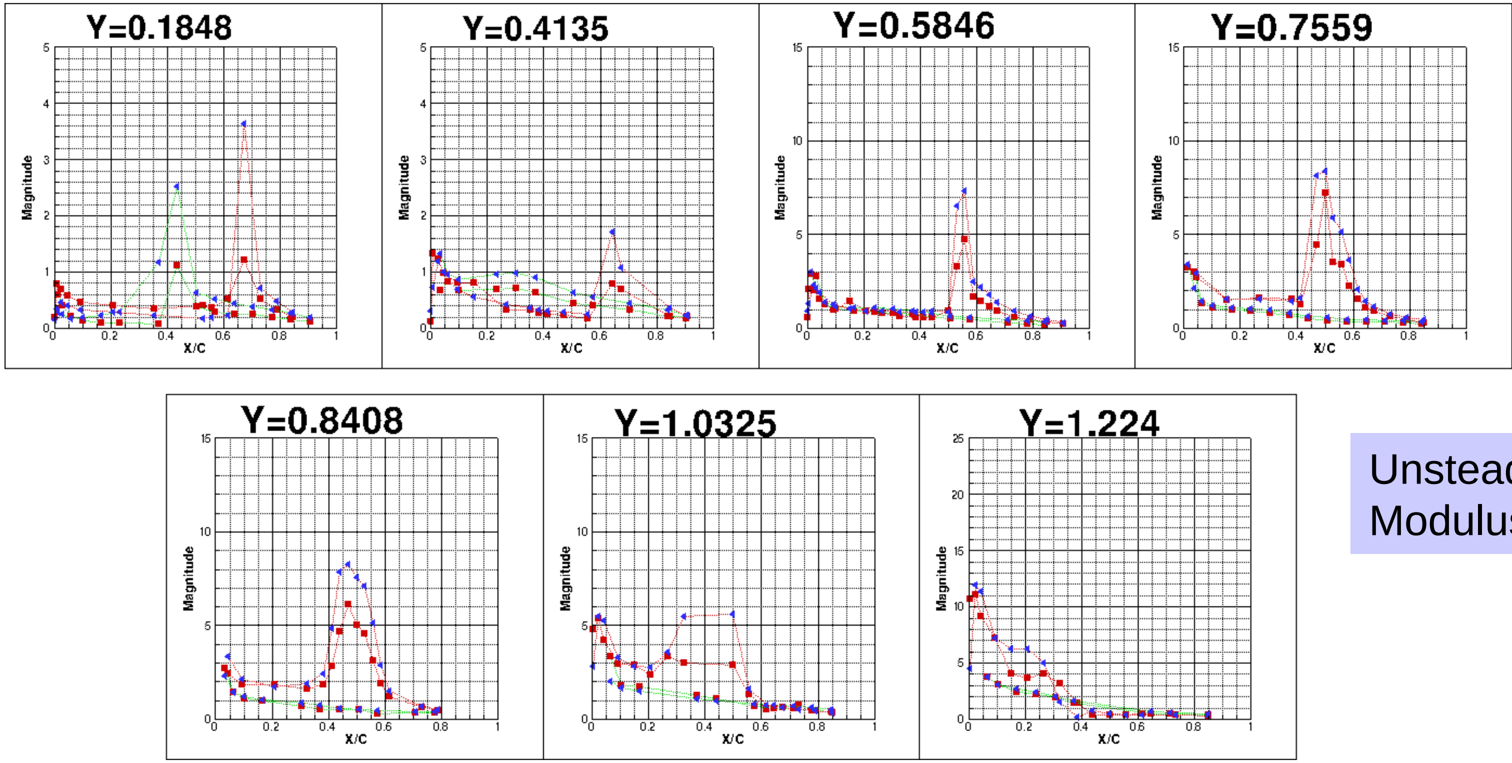
AePW : HIRENASD Dynamic case M=0.8 Re~7M

Investigated flow conditions :

M=0.8003, α= 1.5°, Data Pt 159,   a=2.4mm



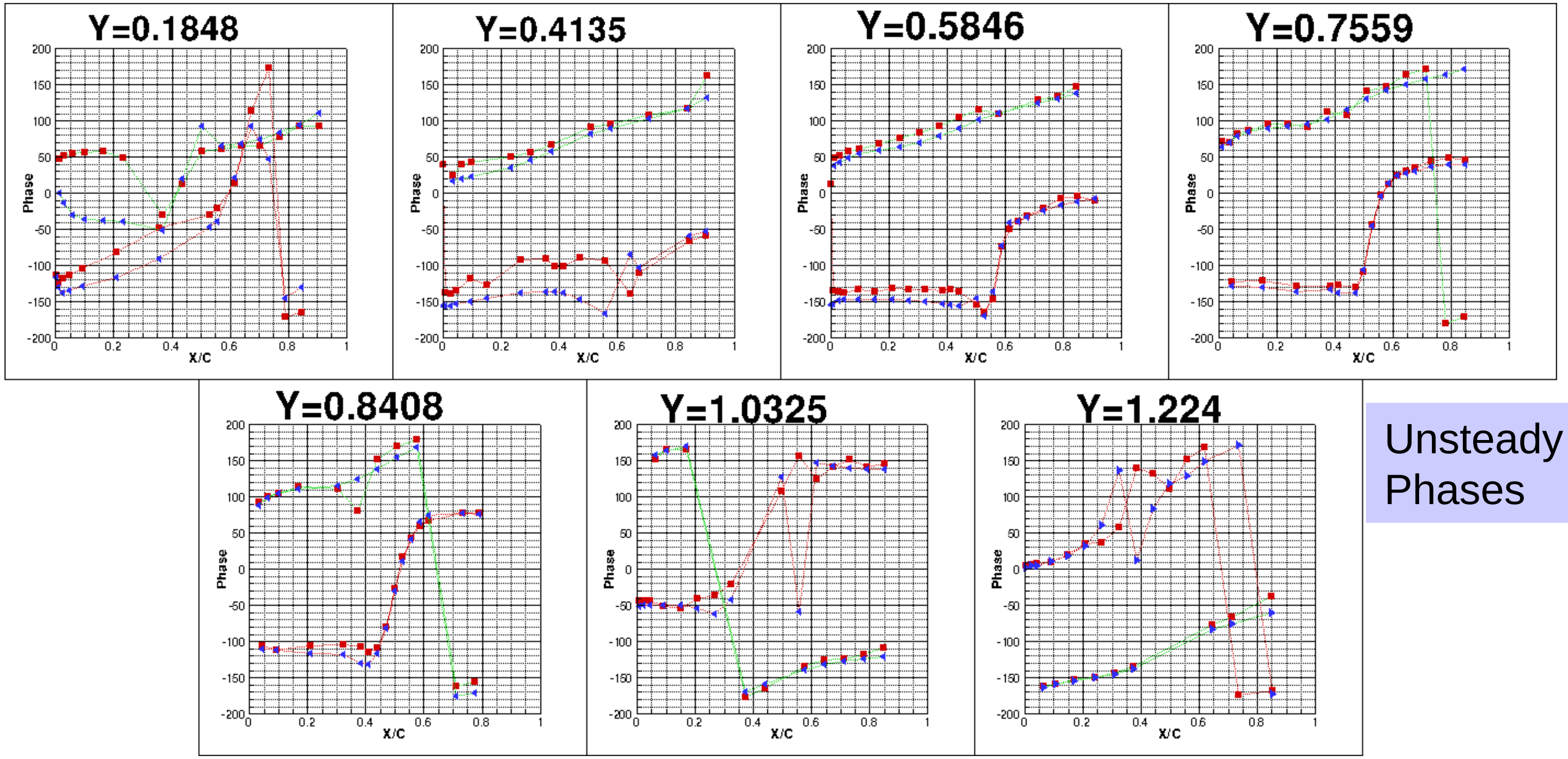
Unsteady Pressure: Modulus

Small difference between elsA (blue scatter) and Experimental data (red scatter) in section s1,s2 and s6.

AePW : HIRENASD Dynamic case M=0.8 Re~7M

Investigated flow conditions :

M=0.8003, α= 1.5°, Data Pt 159 ,   a=2.4mm



Unsteady Pressure: Phases

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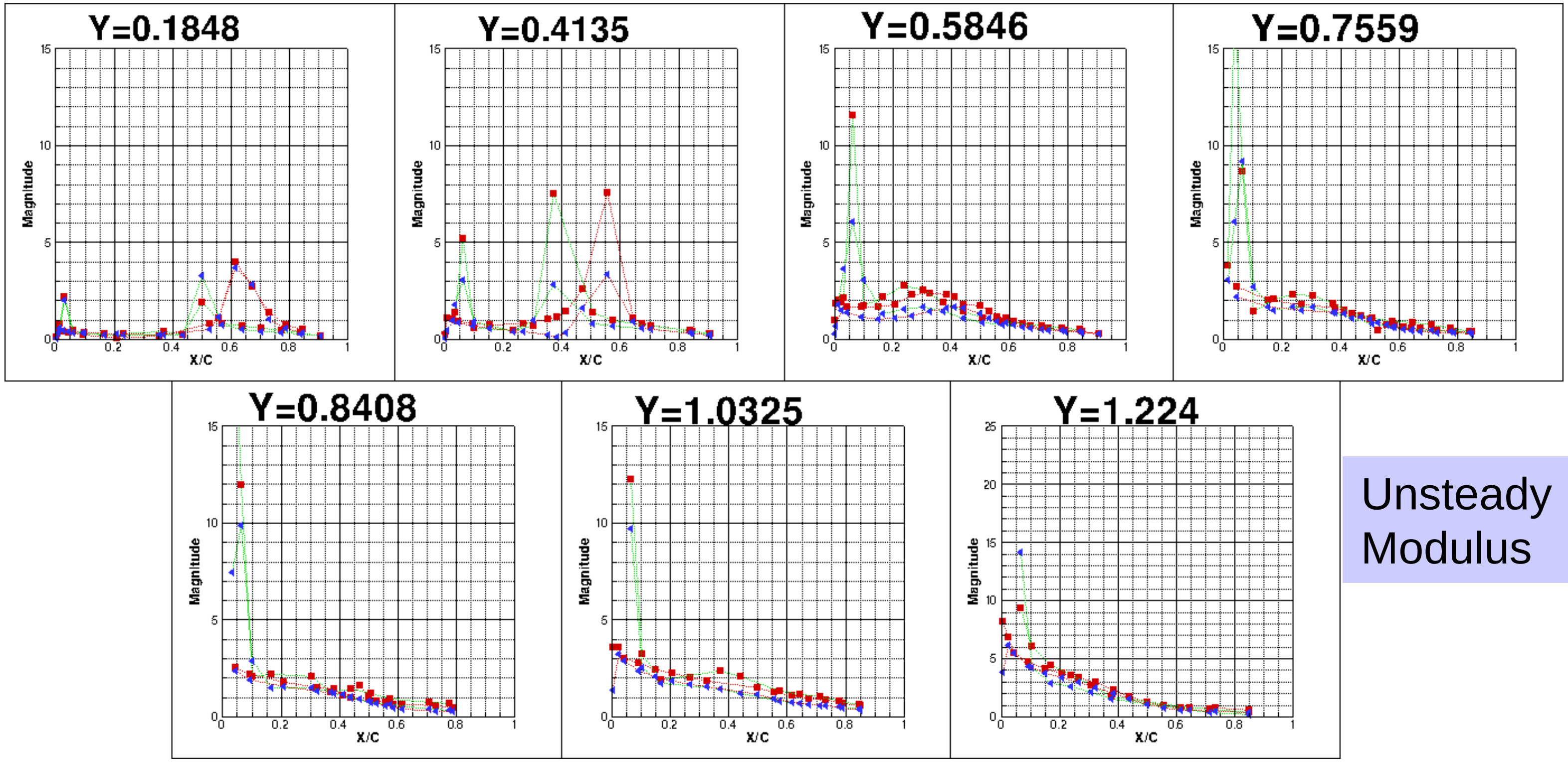
AePW : HIRENASD Dynamic case M=0.8 Re~23M

Investigated flow conditions :

M=0.800, α= -1.34°, Data Pt 271 ,   a=0.9 mm



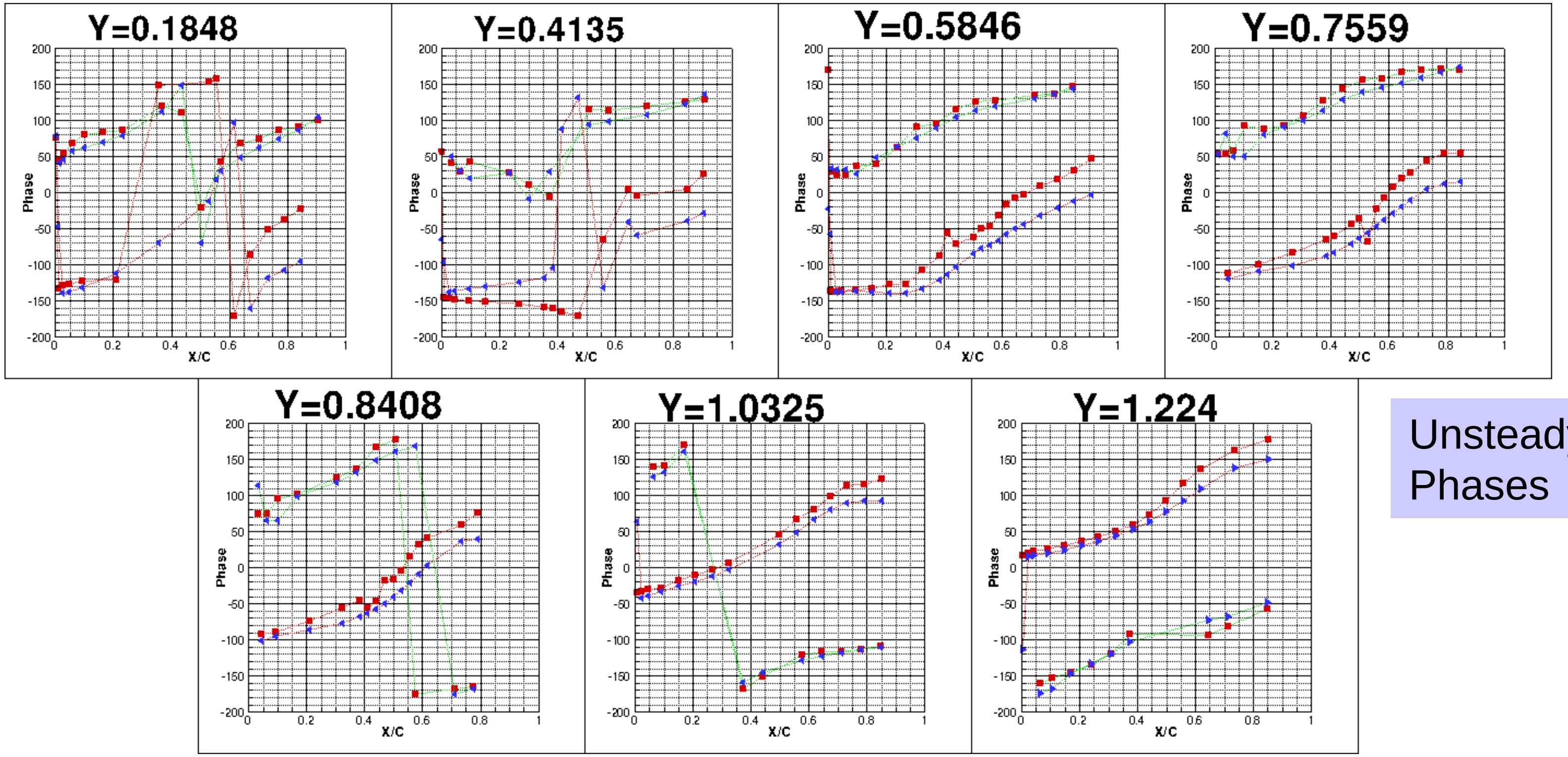
Unsteady Pressure: Modulus

Very Good correlation between elsA (blue scatter) and Experimental data (red scatter)

AePW : HIRENASD Dynamic case M=0.8 Re~23M

Investigated flow conditions :

M=0.800, α= -1.34° , Data Pt 271 ,   a=0.9 mm



Unsteady Pressure: Phases

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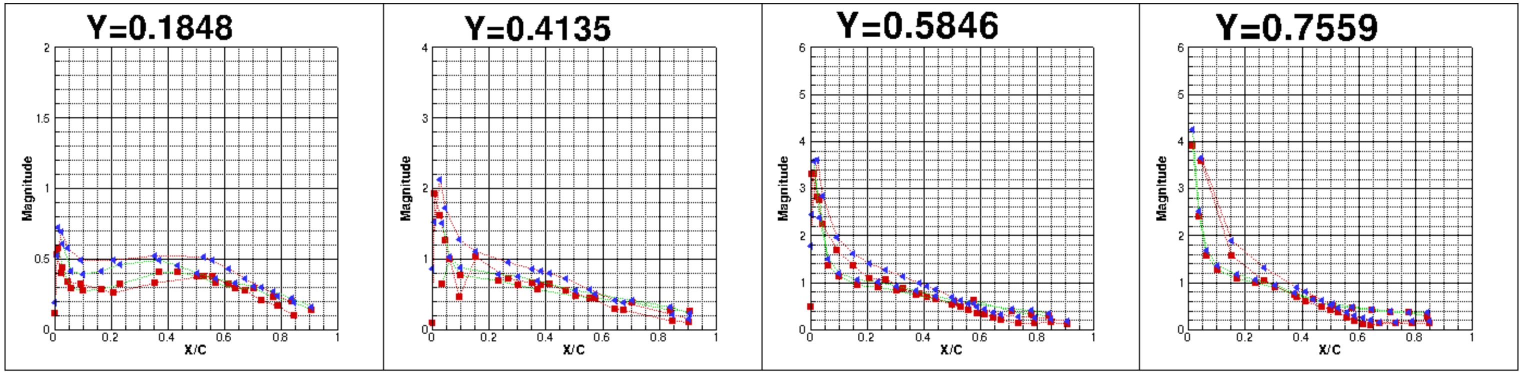
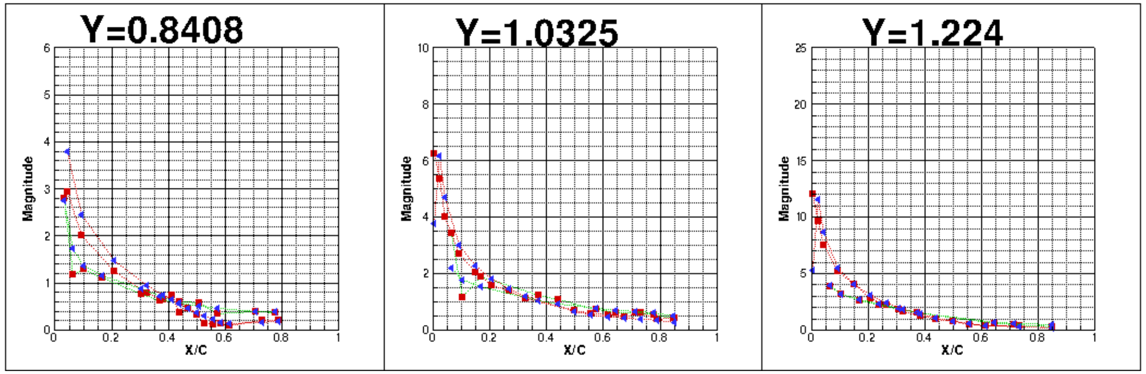
AePW : HIRENASD Dynamic case M=0.7 Re~7M

Investigated flow conditions :

M=0.7, α= 1.5°, Data Pt 155 ,   a=2. mm





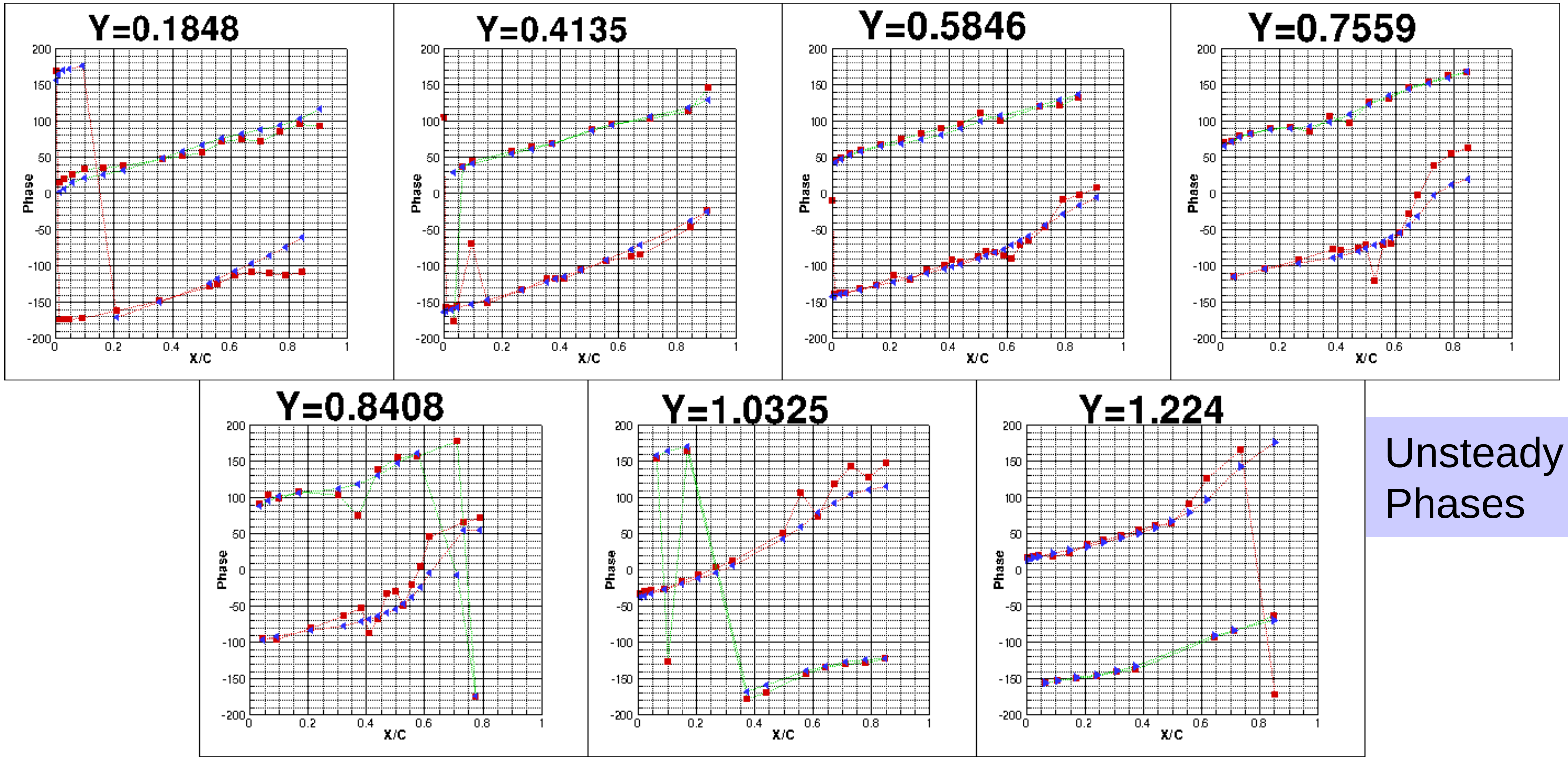
Unsteady Pressure: Modulus

Very good correlation between elsA (blue scatter) and Experimental data (red scatter).

AePW : HIRENASD Dynamic case M=0.7 Re~7M

Investigated flow conditions :

M=0.7, α= 1.5°, Data Pt 155 , a=2. mm



Unsteady Pressure: Phases

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AePW : HIRENASD Dynamic case M=0.8 Re~23M

Investigated flow conditions :

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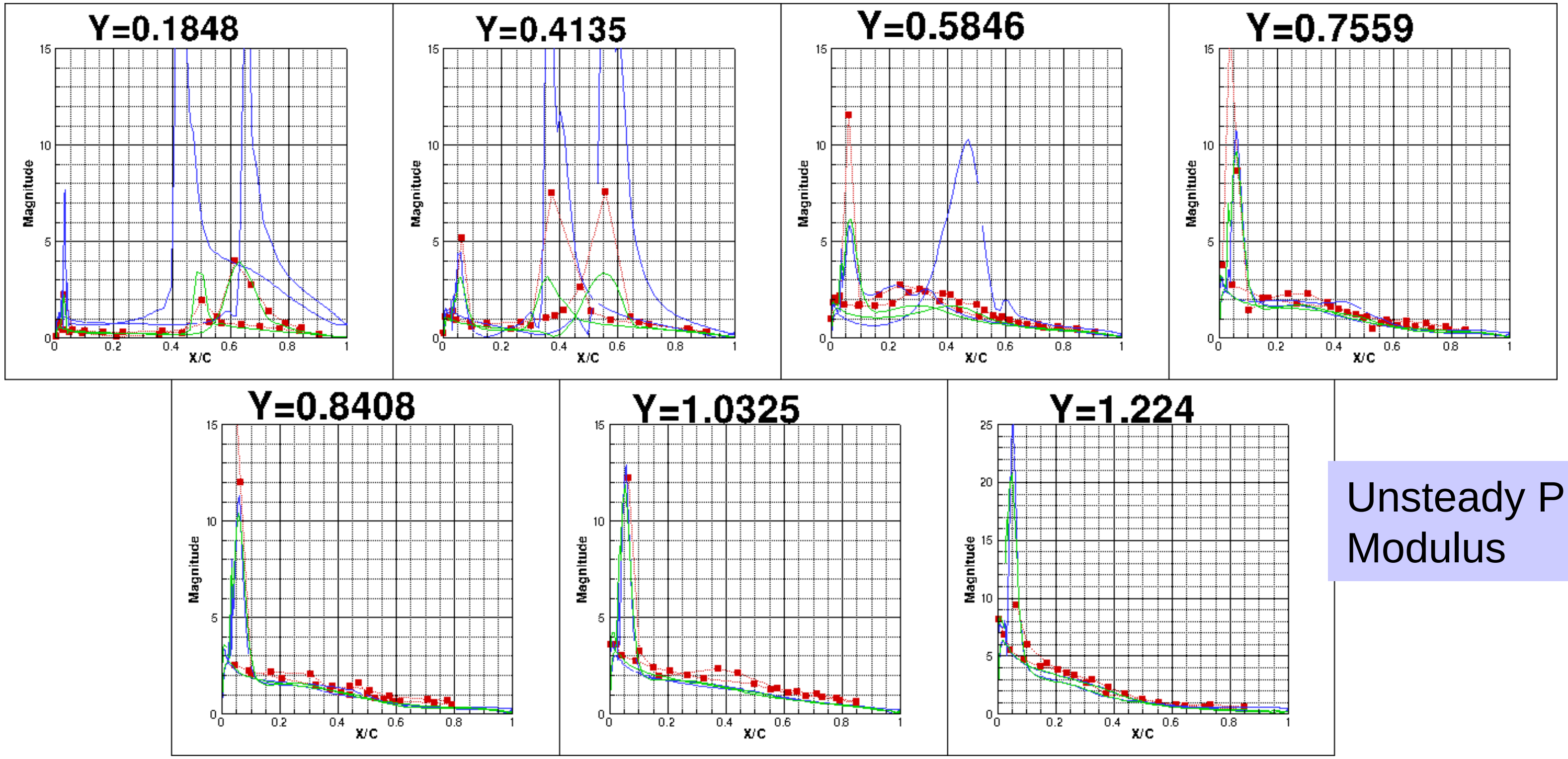


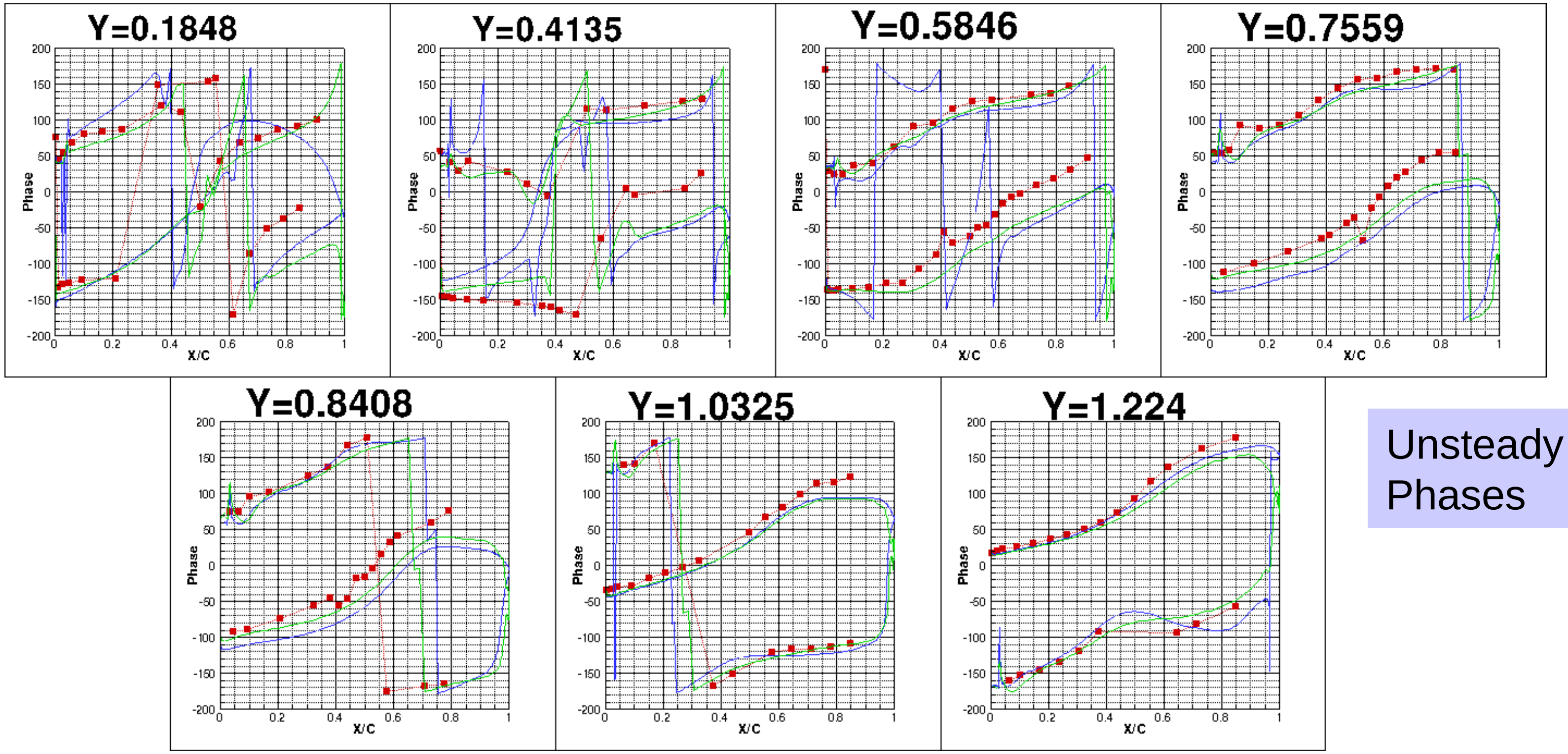
Unsteady Pressure: Modulus

elsA on Ansys grid (green line), on Airbus grid (blue line) and Experimental data (red scatter)
Similar numerical results on the 4 last sections, good agreement with experimental data in the Ansys grid.

AePW : HIRENASD Dynamic case M=0.8 Re~23M

Investigated flow conditions :

M=0.800, α= -1.34° , Data Pt 271 ,   a=0.9 mm



Unsteady Pressure: Phases

elsA on Ansys grid (green line), on Airbus grid (blue line) and Experimental data (red scatter).

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Conclusion and Future Work on HIRENASD

Conclusion:

- ***Global good Simulation/ Experimental Correlations for steady and unsteady Aerodynamic***
- ***Grid sensitivity: effect on the shock intensity with fine grid***

Future Work:

- ***Investigate wall boundary layer effects***
- ***Investigate turbulence models effects***
- ***Application with linearized URANS and Harmonic Balance Method***
- ***Fluid structure coupling***