ANSYS
Coventry, UK • May, 2-3, 2018
INNOVATION CONFERENCE

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ANSYS PREFERRED SOLUTION PARTNER

Fast FSI in the Fluent Solver using RBF Morph Modal Superposition Method

Università di Roma Tor Vergata

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Outline

- RBF Morph UTV synergy
- Parametric CAE
- Software line
  - RBF Morph Fluent Add On
  - RBF Morph ACT Extension
- Modal FSI approach
  - Introduction and research path
  - RBF Background and Structural modes embedding
  - Examples
- Conclusions

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Welcome to the World of Fast Morphing!

www.rbf-morph.com

A powerful synergy

Academic | **CAE business**

UTV + ISV RBF Morph

- A variety of applications ranging from **research** to **industrial** exploitation can be tackled
- **Technology transfer** is boosted (including personnel)
- **Funds** access is facilitated
- A **network** of **partners** (Industries, Universities, Research Institutes, CAE Companies)

Clean Sky

R.I.B.E.S.

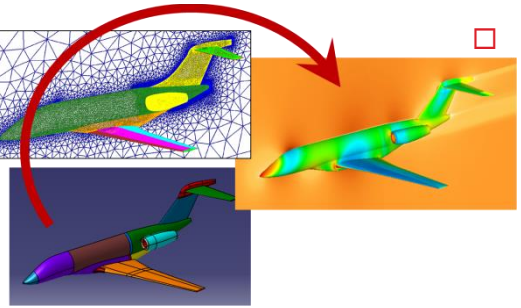
FORTISSIMO

RBF4AERO

Geometry - CAE link

RBF mesh Morphing

- Main advantages
  - No re-meshing
  - Can handle any kind of mesh
  - Can be integrated in the CAE solver
  - Highly parallelizable
  - Robust process
- Main disadvantages
  - Can't handle topology change
  - Back to CAD procedure required



CAD to mesh

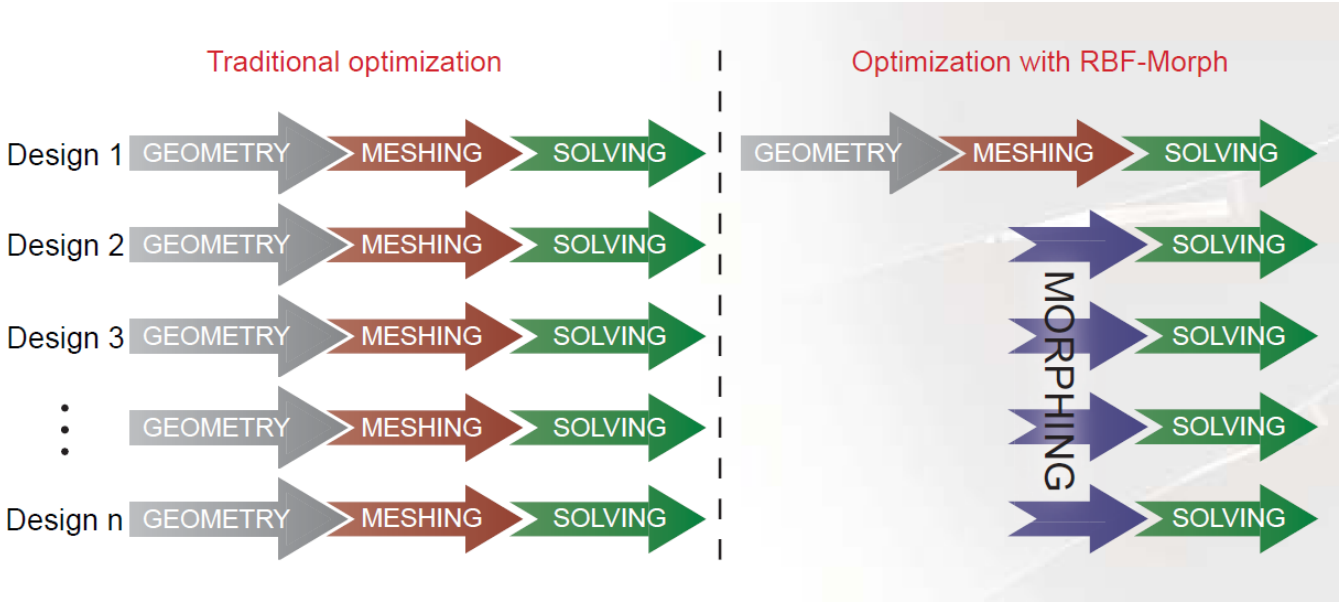
- Main advantages
  - Accurate geometry quality control
  - High constraints setup flexibility
  - No "back to CAD" required
- Main disadvantages
  - Complex setup
  - Highly skilled CAD user required
  - Robustness
  - Remesh required

Parametric CAE models

RBF Morph makes the CAE model **parametric** with respect to the **shape.**

Works for **any size of the mesh.**

Shape parameters can be steered with the **optimizer of choice.**



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RBF Morph software line

Fluent Add On

- Released in **2009**
- Fully integrated within Fluent (GUI, TUI & solving stage), Workbench and **Adjoint Solver**
- Multi physics features (**FSI**)

Stand Alone

- Released in **2012**
- Tcl/Tk GUI accepts **CGNS** and **STL** (Linux only)
- **Cross solver** (OpenFoam, CFD++, SU2, Fluent, Nastran, ANSYS, Abaqus)

ACT Extension

- Released in **2015**

- Fully embedded in ANSYS **Mechanical** (parametric)
- Benefits of **underlying geometry** (or aux geo with dead meshes)
- **…WB** Meshing

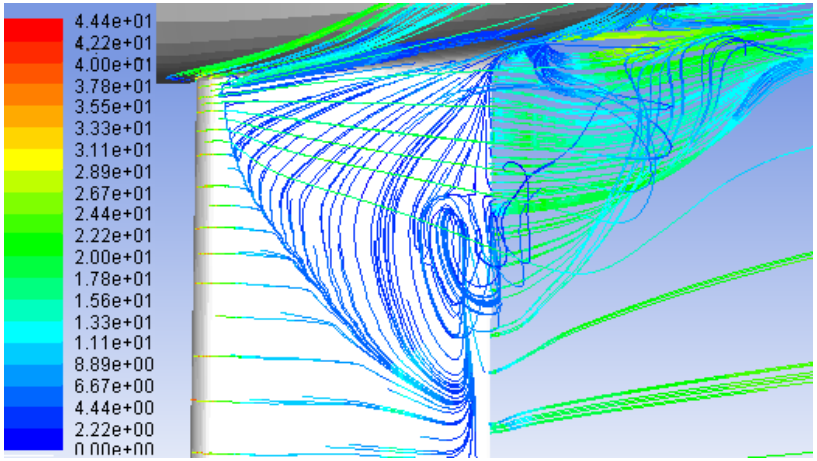
RBF Morph Fluent Add On

Our flagship product. Released in 2009, distributed also by ANSYS since 2012.

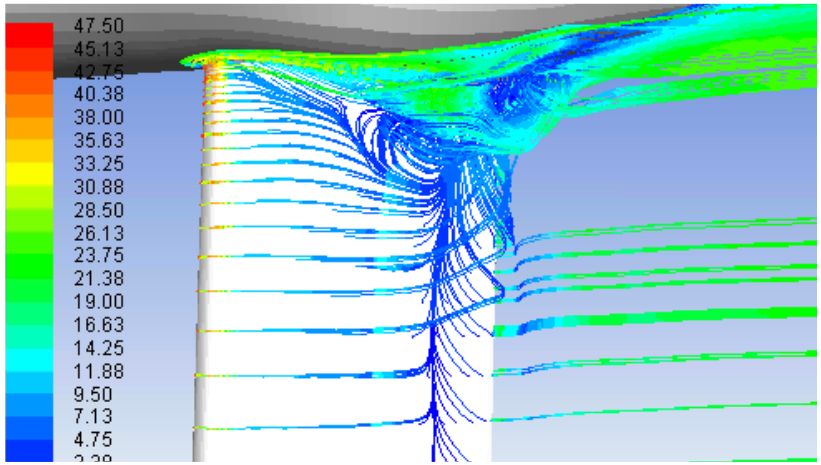
https://youtu.be/_geLbD-Be-k

Taurus glider

Original design E=14.9

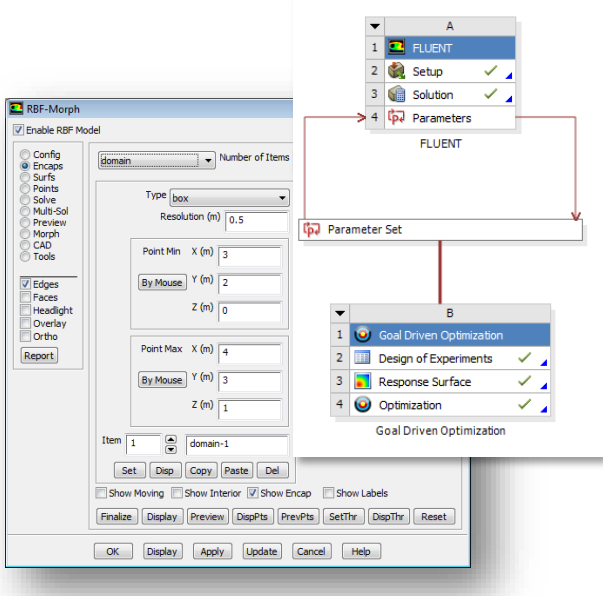


Optimal design E=20.1 (+35%)



Fluent add-on

- Add on fully integrated within Fluent (GUI, TUI & solving stage), **Workbench** and **Adjoint Solver**
- Mesh-independent RBF fit used for **surface** mesh morphing and **volume** mesh smoothing
- **Parallel** calculation allows to morph large size models (many millions of cells) in a short time
- Management of **every kind of mesh** element type (tetrahedral, hexahedral, polyhedral, etc.)
- Support of the **CAD** re-design of the morphed surfaces
- Multi fit makes the Fluent case **truly parametric** (only 1 mesh is stored)
- Precision: exact nodal movement and exact feature preservation (**RBF are better than FFD**)



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MODAL FSI APPROACH

Fluent Add On based workflows

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ANSYS®

12 CYLINDERS
TRANSIENT FSI

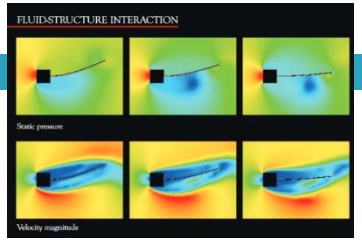
Transient FSI Example (with ANSYS France)

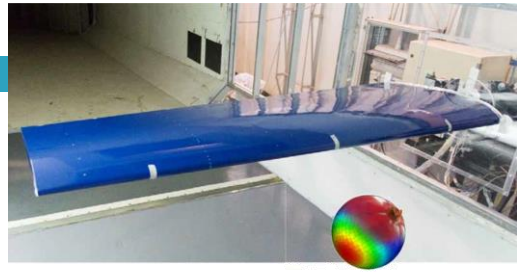
Simulation captures the instability observed at 0.35 m/s

https://youtu.be/A0WPDyhlr8Q

Research path

- The first UDF in 2005 (2D and 3D) for **time marching solutions.**
- RBF for **mesh morphing** and pressure mapping was introduced in 2009 with RBF Morph Fluent Add On.
- RBF Morph Stand alone for FSI with **OpenFoam** released in 2012.
- RBF4AERO (www.rbf4aero.eu) implementation (**cross solvers,** steady, 2-way and modal) 2013-2016
- RIBES (www.ribes-project.eu) implementation
- RBF Morph Fluent Add On **advanced FSI module** (steady and transient, HPC)
- 3 Awards! (2005, 2011, 2013)





RIBES

RBF4AERO

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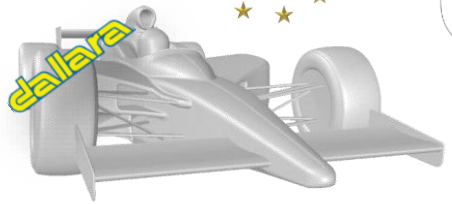

PIAGGIO AEROSPACE

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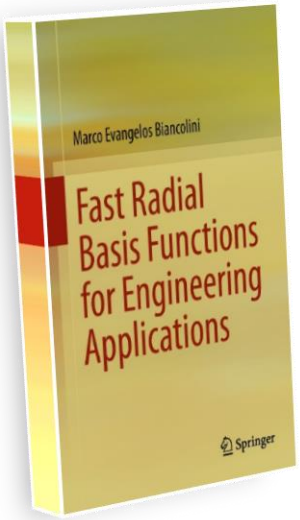
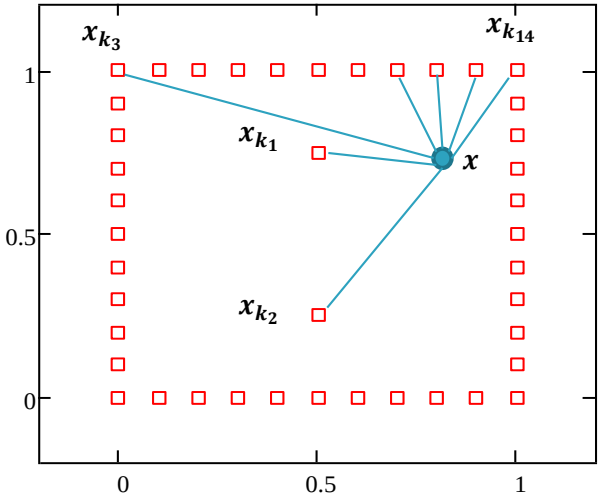
RBF Background



- RBFs are a mathematical tool capable to **interpolate** in a generic point in the space a function **known** in a discrete set of points (**source points**).
- The interpolating function is composed by a **radial basis** and by a **polynomial**.

radial basis polynomial

$$s(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i \varphi\left(\left\|\boldsymbol{x} - \boldsymbol{x}_{\boldsymbol{k}_i}\right\|\right) + h(\boldsymbol{x})$$



Structural modes embedding

- A certain number of **modes** is computed using FEA.
- An **RBF solution** is computed for each mode (constraining far field conditions and rigid surfaces, mapping FEA field on deformable surfaces). Modes on CFD mesh are stored.
- At initialization the CFD solver loads the modes and then:
  - the mesh deformation can be **amplified** prescribing the value of **modal coordinates**
  - **modal forces** are computed on prescribed surfaces by projecting the nodal forces (fluid pressure and shear) onto the modal shape

number of natural modes

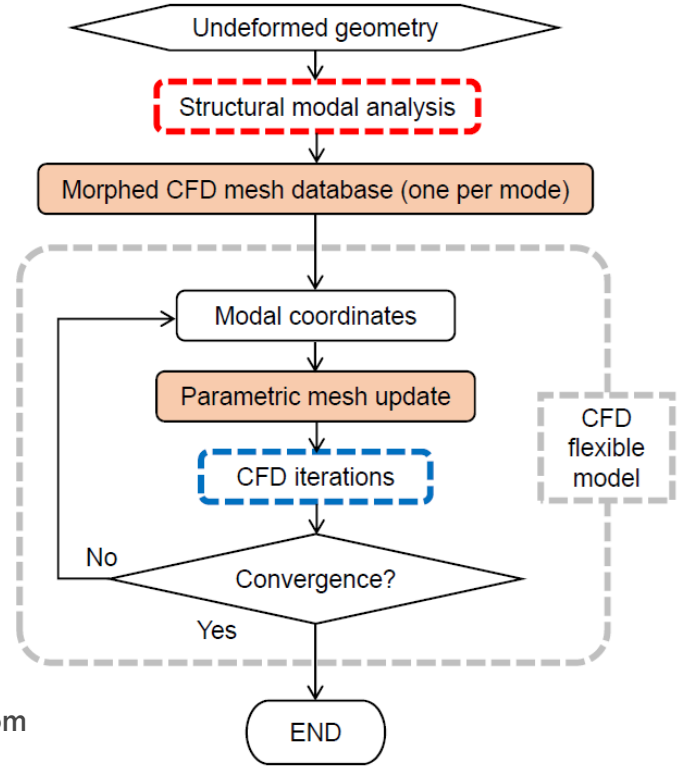
nodal modes displacement

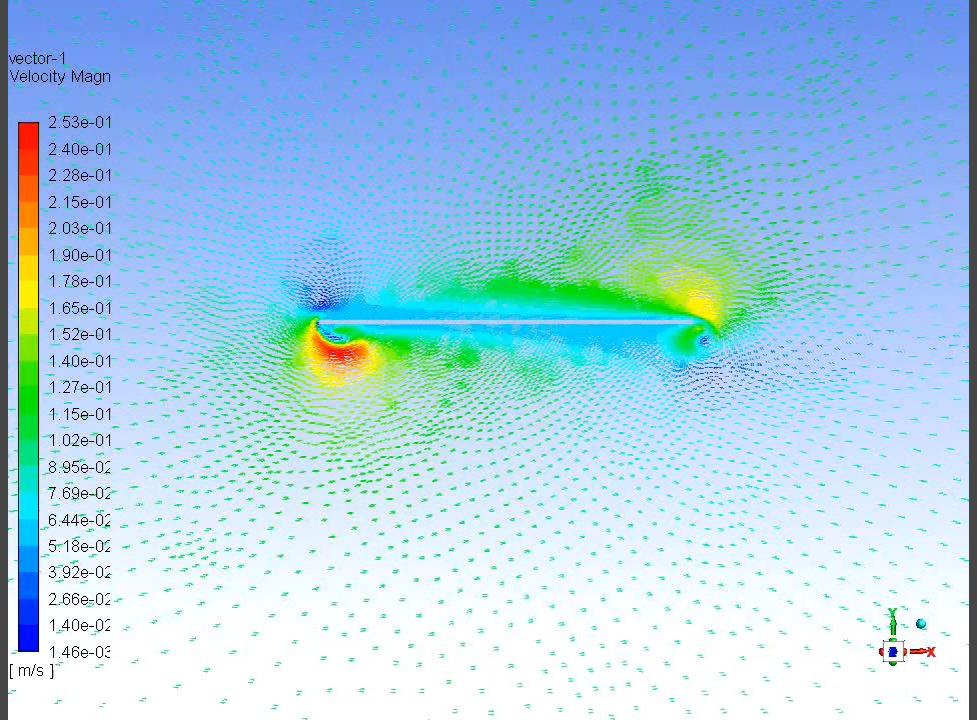
$$X_{CFD} = X_{CFD_0} + \sum_{i=1}^{k} q_i \Delta X_i$$

modal coordinate

Possible Simulation Scenario

- Steady FSI to account for structure elasticity (aircraft wings, propeller blades, racing)
- Transient simulations with prescribed motions
  - flapping devices
  - structural modes acceleration for Reduced Order Models in flutter analysis
- Transient simulation with vibrations excited by the flow
  - forced response
  - computation of damped frequencies
- https://www.ansys-blog.com/rbf-morph-clean-sky/

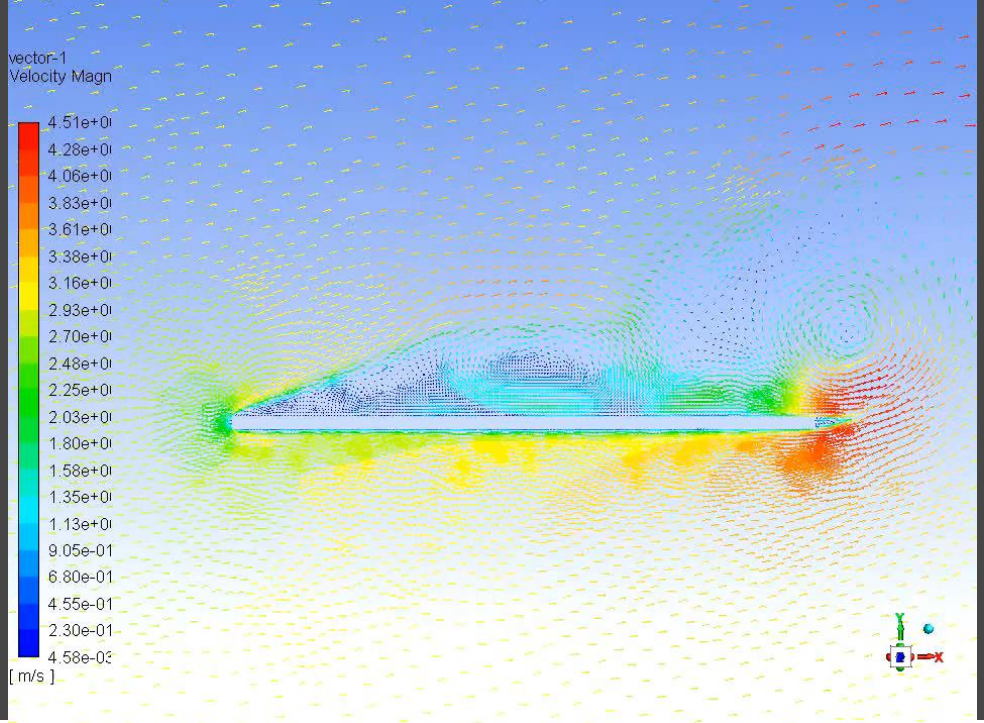




Possible Simulation Scenario - rigid

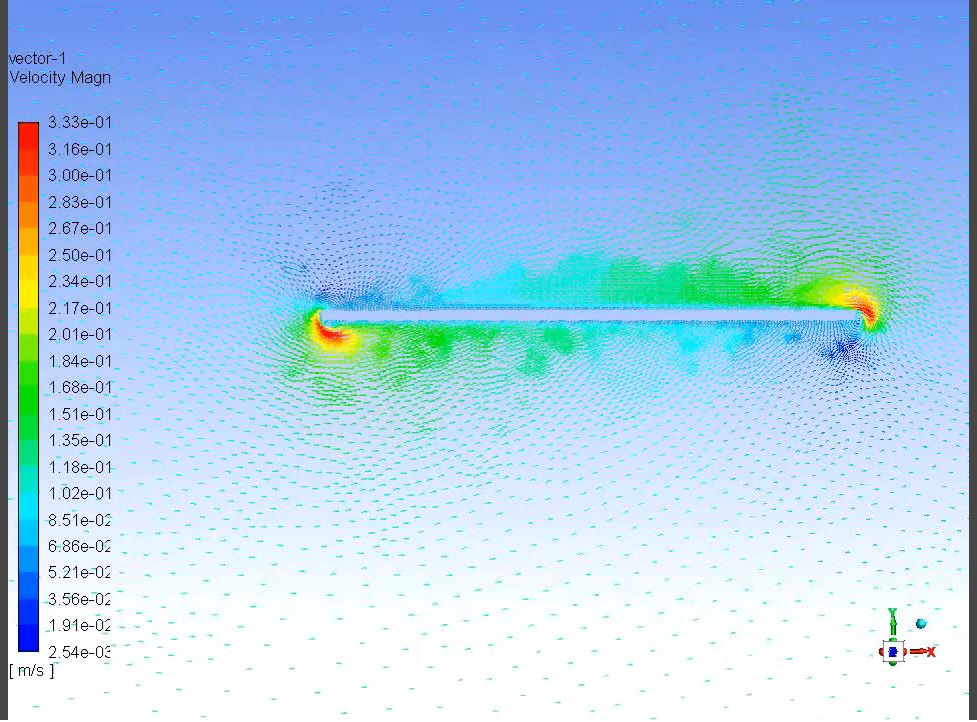
Rigid movement assigned – mesh deformation controlled with RBF

Possible Simulation Scenario - flexible



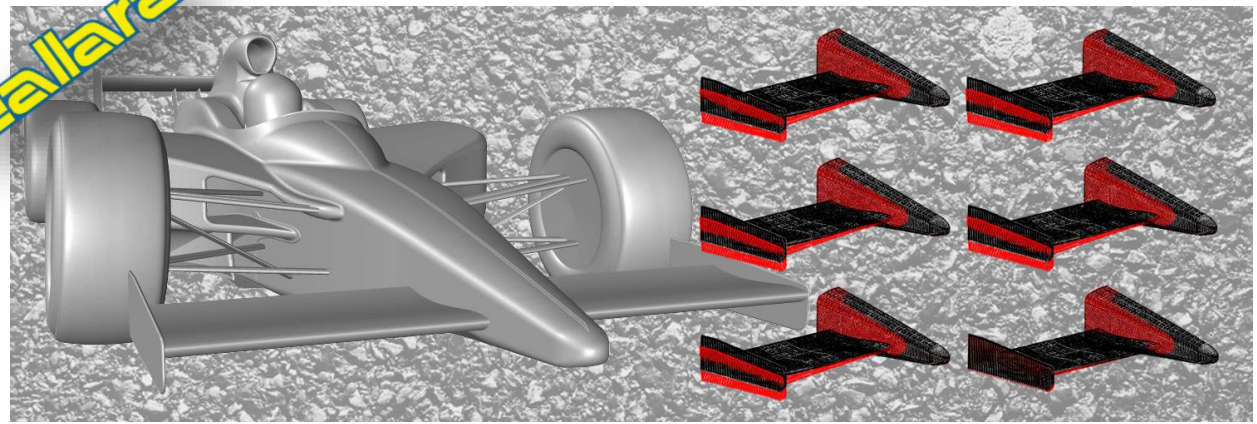
Deflection computed with 4 structural modes – vertical speed component added

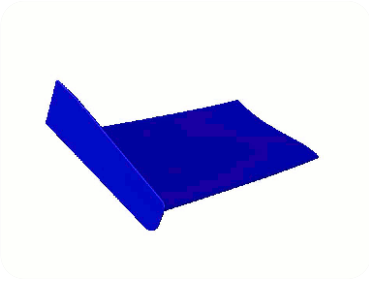
Possible Simulation Scenario - flapping



4 structural modes – ground vibration inertial forces added

Examples: Indy Race Car





Modes used	Maximum displacement (mm)	Maximum error (%)
1	5.941	8.3
2	5.898	6.5
3	5.584	2.7
4	5.56	1.4
5	5.555	0

Examples: P1XX aircraft

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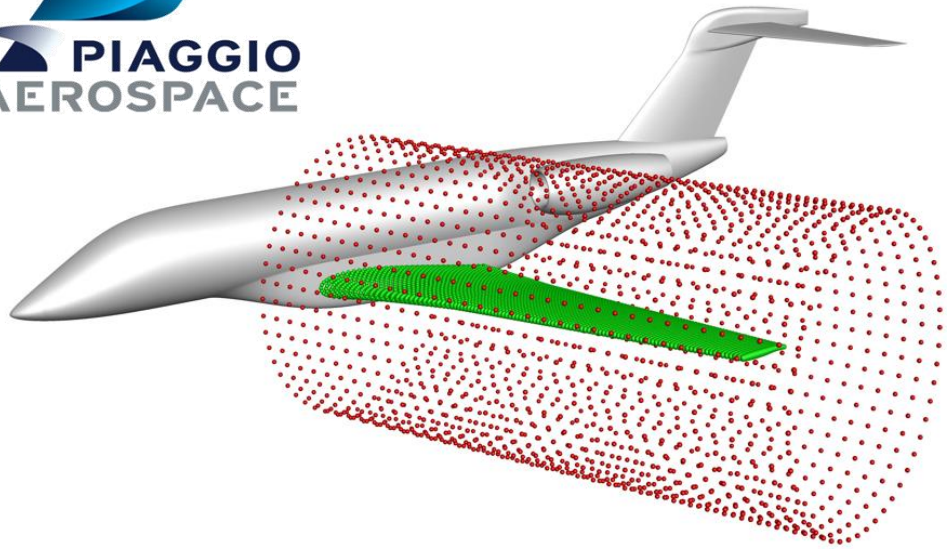
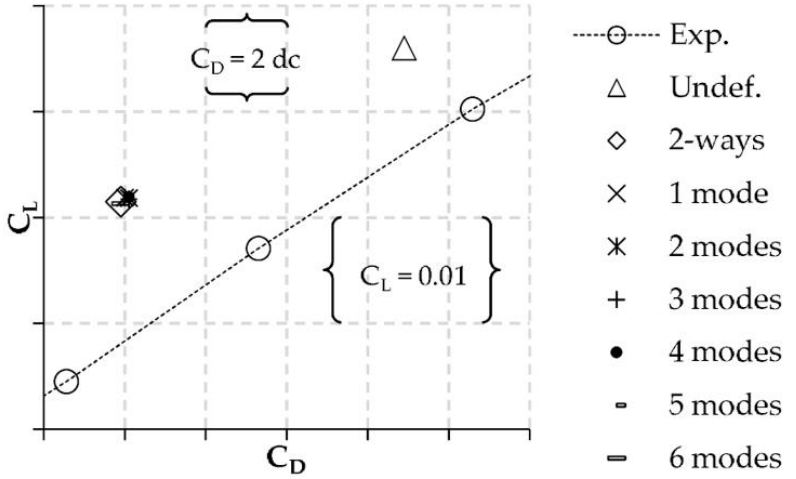
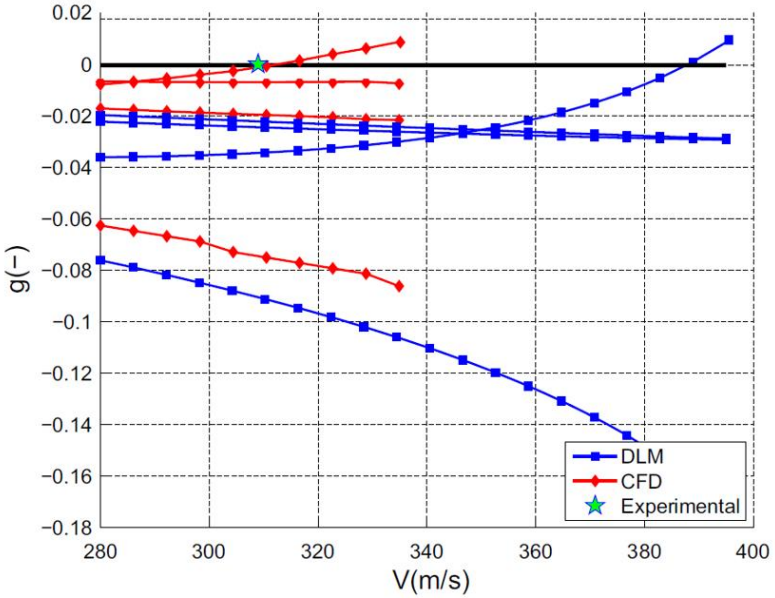
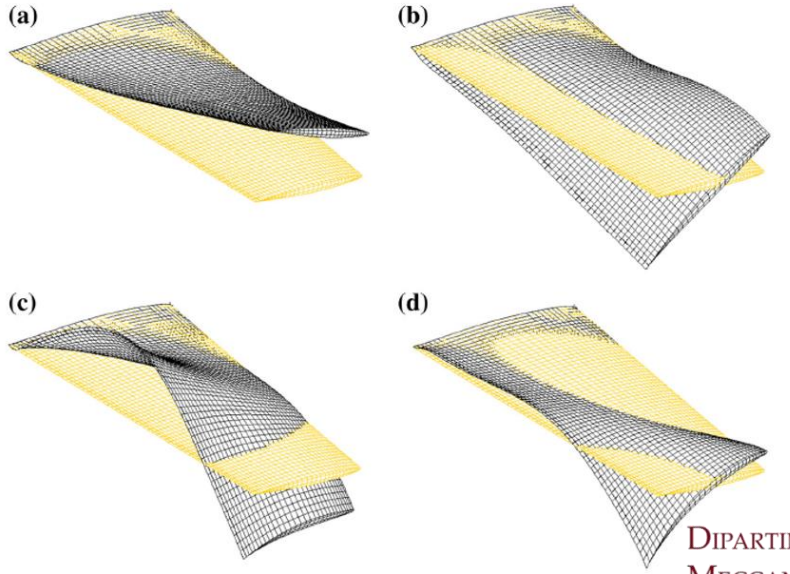


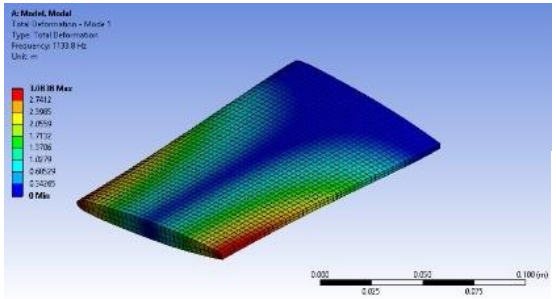


Examples: transonic dip AGARD 445.6

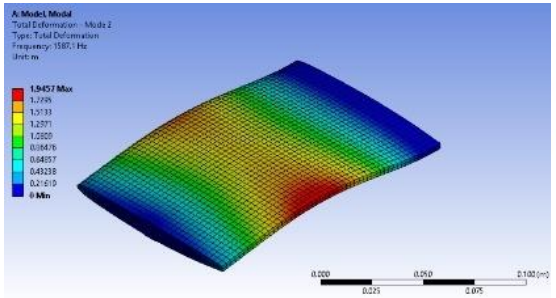




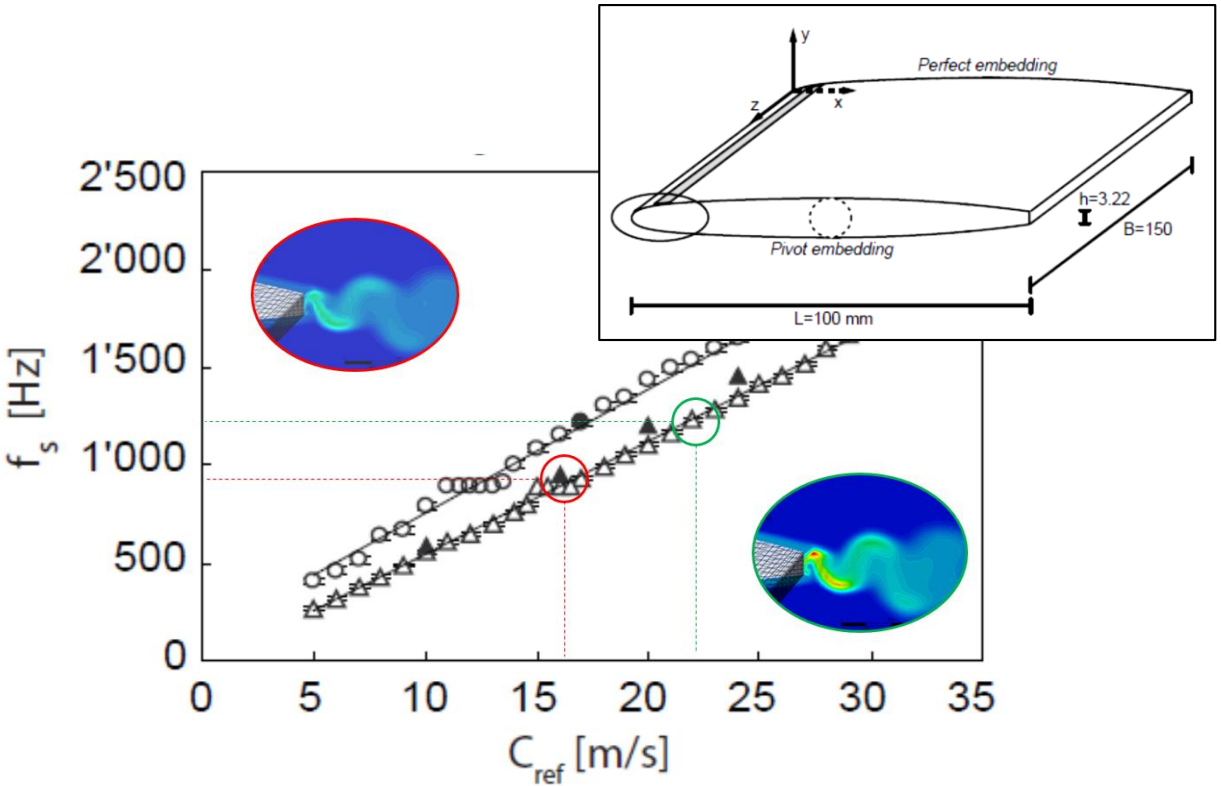
Examples: Hydrofoil in water



Mode 1 - First bending mode - 1133.8 Hz



Mode 2 - First torsional mode - 1587.1 Hz



Conclusions

- RBF Morph is an advanced **mesh morphing** technology based on Radial Basis Functions
- A **shape parametric** mesh is obtained. Parameters can be steered using standard optimization tools. **Modal shapes can be embedded as well!**
- Strong integration in **ANSYS products**: an Add On for Fluent & ACT Extension for Mechanical (and more…)
- FSI capabilities of RBF Morph Fluent Add on are today demonstrated for steady and transient simulations
- Many advanced industrial applications can be faced. Visit our web site www.rbf-morph.com to learn more.

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Many thanks for your kind attention!

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