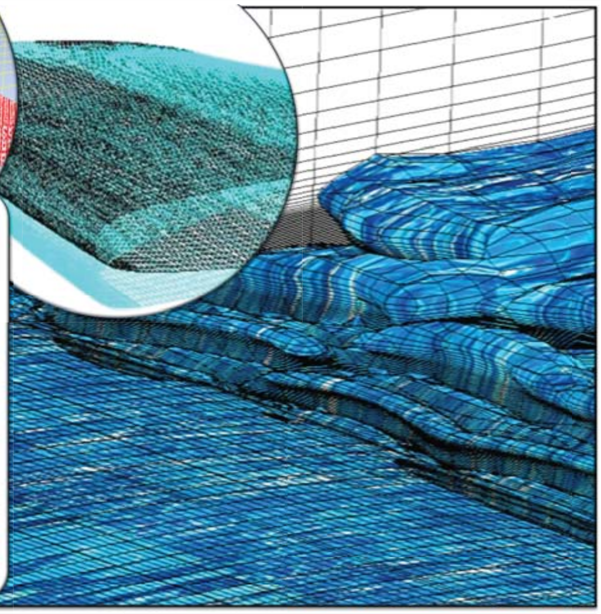
Fluid Structure Interaction Analysis:
Vortex Shedding Induced Vibrations.

Università di Roma Tor Vergata

Authors:
N. Di Domenico[1], C. Groth[1]
[1] *University of Rome «Tor Vergata» Department of Enterprise Engineering «Mario Lucertini»*

INTERNATIONAL CAE CONFERENCE

1. FSI Analysis
2. RBF Functions



1. FSI represents a serious modelling challenge, but most of the times is the key aspect of a structural component behaviour. Modelling such an interaction is useful to finely tune the design parameters, but can be unfeasible using high fidelity methods. The different requirements in terms of grid refinement between fluid and structure due to the different physics involved among with complex mapping algorithm that follows are the most critical point in FSI simulations. In the 2-way partitioned coupling data transfers can be a bottleneck, since mapping and mesh deformation are required at each iteration. At the moment there is a lack of monolithic solvers capable to tackle industrial applications involving high fidelity models made up of hundred millions of cells.

2. RBF are functions able to interpolate, on a distance basis, scalar information known only at discrete points. Quality and behaviour of the interpolation depends from the function and the kind of the basis function. In the case of RBFs which are function of distance, it is possible to define at known points the displacement in the space and to retrieve the value at mesh nodes, obtaining a mesh deformation that leaves unaltered grid topology.

$$s(\boldsymbol{X}) = \sum_{i=1}^{N} \gamma_i \phi(\|\boldsymbol{X} - \boldsymbol{X}_{k_i}\|) + h(\boldsymbol{X})$$

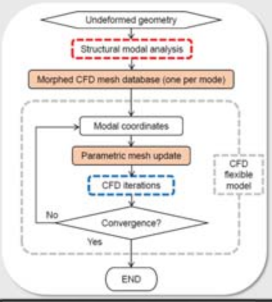
3. Modal FSI Workflow

$$X(t)_{CFD} = X_{CFD_0} + \sum_{i=0}^{k} \xi(t)_i \Delta X_i$$

3. Modal shapes are extracted from the FEM solver and employed by the RBF morpher to properly generate an RBF solution for each shape influencing just the domain close to the FSI interface. The shape variations calculated using FEM displacements can be directly used to deform the CFD numerical grid, due to RBF's meshless nature, avoiding complex mappings between FEM and CFD displacements. RBF shapes are imported directly inside the CFD solver, ANSYS Fluent, ready to be used to move the mesh and making the grid deformable. Deformations associated with each modal shape are stored in memory in order to speed up the mesh update process, being structural response, and then the variation of nodal positions, a matter of a multiplication.

Steady FSI to account for structure elasticity;
Transient simulations with prescribed motions:
- flapping devices;
- structural modes acceleration for Reduced Order Models in flutter analysis;

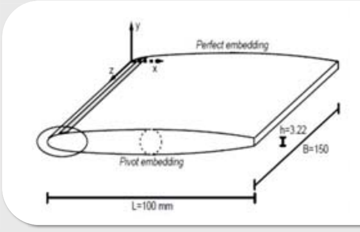
Transient simulation with vibrations excited by the flow:
- forced response;
- computation of damped frequencies.

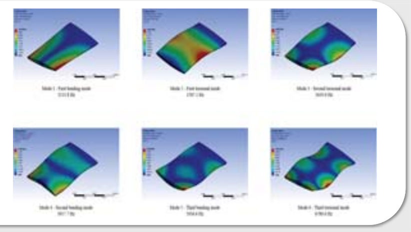


NACA 0009 Hydrofoil

4. Targets and Application

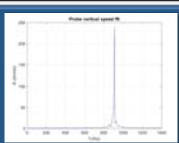
4. With the modal superimposition method, limiting the analysis to the linear structures, the FEM solver can be used just once at initialization, avoiding the resource consuming task of data exchange. Indeed, for large models pressure mapping and mesh update can be very time consuming, making the modal superposition method 10-12 times faster than two-way in transient analysis.

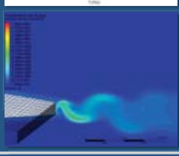




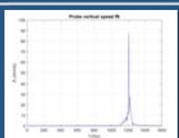
ANSYS
(rbf-morph)™

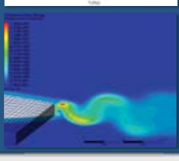
5. Results and Conclusions





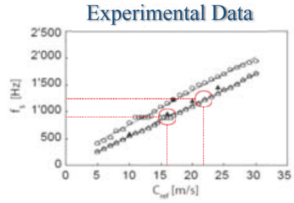
Lock In:
- Probe at a fixed point;
- Observed frequency 909.91 Hz;
- Imposed speed 16 m/s.



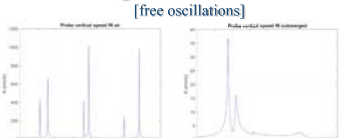


Lock Off:
- Probe at a fixed point;
- Observed frequency 1209.9 Hz
- Imposed speed 22 m/s

Experimental Data



Submerged Modes Calculation
[free oscillations]



Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
1133.8 Hz	1587.1 Hz	3660.9 Hz	3917.7 Hz	5936.6 Hz	6789.6 Hz

Mode 1	Mode 2	Mode 3	Mode 4
891.9 Hz	1118.8 Hz	1619.6 Hz	2902.7 Hz

- FSI approach based on modal superposition based on **mesh morphing** techniques is presented;
- Transient analysis is conducted computing modes by ANSYS Mechanical and then embedding modes within ANSYS® Fluent with RBF Morph™;
- Excellent **HPC performances** are observed 12x vs. full two-way FSI;
- A very **good agreement** is noticed in the ability of capturing resonances in the lock-in lock-off speed range;
- The transient solver can be used for the computation of natural **modes in water;**

References and Contacts

Ausoni, P., Zobeiri, A., Avellan, F., Farhat, M., 2012. The Eects of a Tripped Turbulent Boundary Layer on Vortex Shedding from a Blunt Trailing Edge Hydrofoil. Journal of Fluids Engineering 134, 051207.

Di Domenico, N., Groth, C., Biancolini, M.E., Wade, A., Berg, T., 2017. Fluid structure interaction analysis: vortex shedding induced vibrations. AIAS 2017 International Conference on Stress Analysis, 6-9 September 2017, Pisa, Italy.

Biancolini, M.E.., Cella, U., Groth, C., Genta, M., 2016. Static Aeroelastic Analysis of an Aircraft Wind-Tunnel Model by Means of Modal RBF Mesh Updating. Journal of Aerospace Engineering 29. doi:10.1061/(ASCE)AS.1943-5525.0000627.

nicolodidomenico@gmail.com; corrado.groth@uniroma2.it.