Strip theory approach for FSI-simulations of flow around turbine blades

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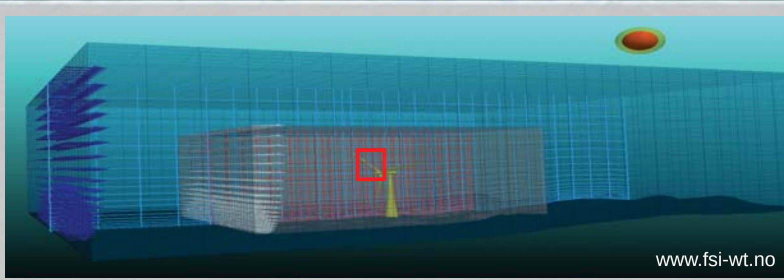
INTRODUCTION

In the present study we investigate the feasibility to do 2D CFD analysis in a number of cross-sections along the turbine blade and couple those to a 3D nonlinear beam model for doing coupled FSI-simulations. This way of handling FSI problems is often called The strip theory approach and has for example been utilized earlier for vortex induced vibration (VIV) of offshore risers.
IFEM Semi3D-FSI can handle two different FSI-cases:
Forced FSI: Prescribed blade deformations
Free FSI: Wind induced blade deformations



SEMI3D FSI GRID

The NREL 5MW blade is defined as a series of cross-section airfoils at various points along the blade axis. Using *IFEM GeoModeler* we may make a Semi3D FSI-model.

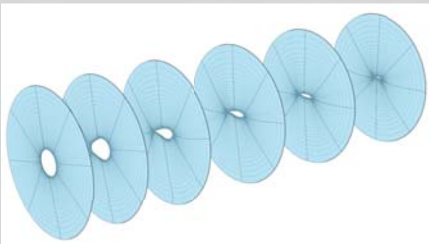


Figure 1: Semi3D FSI :The strip theory approach, i.e. 2D CFD-planes along the NREL 5MW turbine blade generated by *IFEM GeoModeler.*

SEMI3D FSI FORMULATION FOR FLOW AROUND TURBINE BLADES

The strip theory approach is in this case implemented by solving the viscous Navier-Stokes equations on each CFD plane. The CFD solver in the isogeometric finite element module IFEM is based on a Chorin projection method (incremental pressure correction) along with the Spalart-Allmaras turbulence model. The tangential and normal tractions are computed and applied loads on the turbine blade which is modeled as 3D nonlinear beam elements in IFEM that solves the resulting nonlinear structural dynamics problem. Through the motions of the turbine blade, all the CFD planes are coupled. The movement of the structure relative to the CFD-plane is handled in IFEM by the Arbitrary Lagrange Euler (ALE) formulation.

IFEM Semi3D uses: *IFEM GeoModeler* for making the CFD-grids, and couples *IFEM CFD*, *IFEM Beam* and *IFEM ALE* for doing coupled semi3D FSI-simulations.

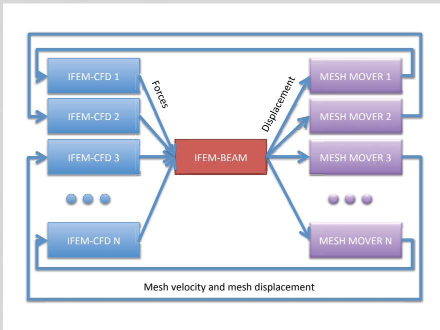


Figure 2: ***Semi3D FSI:*** *The modules of IFEM that are used by Semi3D-FSI.*

EIGENMODE COMPUTATIONS FOR FORCED FSI-SIMULATIONS

In order to determine aerodynamic coefficients we have to determine the relevant eigenmodes of the turbine blade. IFEM Beam includes algorithms for computing eigenmodes, and IFEM Semi3D-FSI can handle forced FSI simulations using the eigenmodes as prescribed deformations.

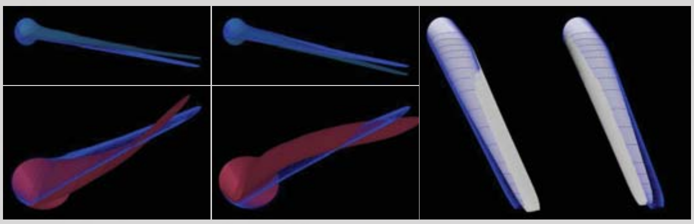


Figure 3: ***Eigenmodes for turbine blade:*** The three lowest modes.

FORCED FSI-SIMULATIONS

Semi3D FSI simulation of the lowest eigenmode for the NREL 5 MW turbine blade.

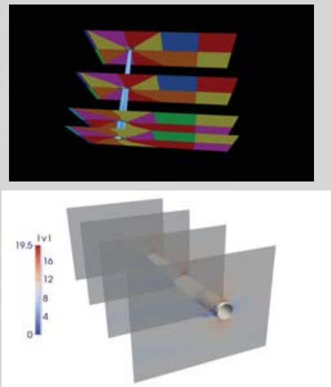


Figure 4: ***Forced FSI:*** Contour plot of a velocity component around the NREL 5 MW turbine blade.

CONCLUSION

IFEM Semi3D-FSI is a versatile tool for simplified ("reduced order") FSI-simulations of airflow around offshore wind turbines.

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