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Fluid-structure interaction of a wind turbine blade employing a refined finite element model coupled with a blade-element momentum method

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Typically the aero-elastic simulation tools that are used in industry employ simple beam models to represent the blades of a wind turbine. The aerodynamic loads are usually calculated using a fast blade-element momentum (BEM) method. These models allow relatively fast calculation of the aero-elastic behavior of the blade which is required in order to allow the simulation of a large number of load cases as required by the IEC 61400 [1] and GL [2] standards in a feasible amount of time. Such beam models do however not incorporate the level of detail required to provide the complete stress and strain distribution in the blade, nor are they able to take into account nonlinear effects such as the change in cross-section of the blade due to the brazier effect [3]. Alternatively, highly detailed 3d computational fluid dynamics (CFD) simulations can be coupled with refined finite element (FE) models to obtain highly accurate results both regarding the flow around the blade as regarding the stress and strain distribution within the structure. However, the computational cost of such a simulation is enormous.

In this work a coupling has been developed between the BEM code HAWC2-aero, which was developed by DTU [4] and the Abaqus FE solver. This allows a fluid-structure interaction (FSI) simulation by means of a so-called “weak” coupling, meaning that the two different solvers are run sequentially in iterations until convergence is achieved. In this way, a refined structural model is coupled with a fast aerodynamics tool, allowing steady-state fluid-structure interaction (FSI) simulations at an acceptable computational cost.

The more advanced structural model allows the investigation of the influence of structural properties such as individual composite plies as well as their positioning, orientation and materials on the aero-elastic behavior of the blade. The influence of non-linear effects on the blade’s aero-elastic behavior can also be analyzed.
The finite element model is used to locate stress hot-spots or buckling effects. Loads were applied using two different methods. One method uses distributing couplings to spread the load of a spanwise cross-section over all the nodes on that section. The other method uses concentrated forces at specific nodes to introduce the loads.

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