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A weak coupled model for the Fluid-Structure Interactions on a Cross-Flow Tidal Turbine Model

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Cross flow tidal turbines (CFTT) are very attractive for a use in tidal energy exploitation as they can be operated from various flow directions [1] and feature a high area based power density [2, 3]. During each turning cycle the blades of such a turbine undergo various angles of attack, resulting in high alternating forces [4, 5, 6, 7]. These forces can be reduced by continuously pitching the angle of attack for each turbine blade during the rotation, which also increases the hydrodynamic efficiency [8, 9, 10]. The OPTIDE project develops a vertical axis turbine with such an active pitch adjustment. Beside numerics, a turbine model will be tested in the laboratory flume. The turbine model will operate at a chord Reynolds number of roughly 200 000 with a flume velocity of 0,8 m/s.

The turbine to be developed (see fig. 1) features a diameter and height of 400 mm. Due to the installed measurement and blade actuation technology and with respect to the pulsating and alternating loads, mechanical stability has to be assessed. Beside a pressure sensing concept on one blade, strain gauges will be used to measure the hydrodynamic blade loads in the experiments. With purpose to generate a bidirectional stress distribution at the sensor placement, the support structure is specifically weakened at certain points for a decoupling of the blade bending forces. Therefore, material and fatigue strength as well as vibration prevention are challenging.

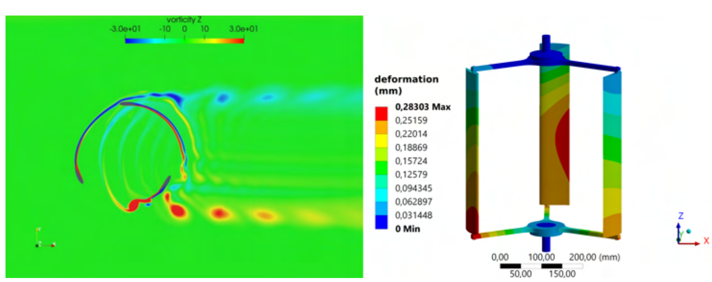

Figure 1: left: Vorticity field around the turbine from 2D CFD simulations (OpenFOAM); right: overall displacement of the rotor from FEA (Ansys Workbench); The CFD results were mapped on the structure for the FEA.

In consequence, a weak coupled fluid-structure interaction simulation is performed for the projected turbine's best operating point. The fluid flow is simulated using the open-source CFD toolkit OpenFOAM (2106) [11]. Subsequently, the pressure distribution is mapped to the turbine model using the Mechanical module of Ansys-Workbench (2020 R2). The material stress for a complete rotation is assessed in 36 load steps. For a validation of the approach, the torque coefficients from CFD and FEM analysis are compared and show good accordance.

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