Université
franco-allemande
Deutsch-Französische
Hochschule

Characterization of the Fluid-Structure Interaction on a Vertical Axis Turbine with Deformable Blades

Abstract

In this thesis, the fluid-structure interaction (FSI) on a vertical-axis water turbine (VAWT) with flexible blades is investigated using both numerical and experimental investigations.

A numerical study is presented, after a short overview of the peculiarities of VAWT and the current state of the investigations in FSI on VAWT is given. This numerical approach is based on the open source toolbox foam-extend. The code is evaluated and its functionality is extended. The simulation of an oscillating profile with strong deformations, including two-way coupling, is carried out by way of example with simplified fluid properties and without consideration of the composite materials. Although the complexity of the setup could not be fully modeled, the investigations provide an outlook for the potential and the limitations of a numerical approach.

In the experimental investigations, the complex multi-physical interactions in the rotor of a VAWT are partly reproduced in a surrogate model consisting of a single oscillating blade in a water channel. It is shown that, through the variation of oscillation trajectory and frequency, multiple turbine designs can be investigated without changing the hardware configuration. An experimental setup based on existing hardware is developed. A highly-accurate position control is obtained for the forced rotational oscillations, and a data acquisition framework is set up. Force and torque measurements show that flexible blades bring significant benefits for a tip-speed ratio $\lambda = 2$ over a wide range of turbine designs. In order to get deeper insight over the FSI at the blade level, the instantaneous flow field was captured in a time-resolved manner with high-speed, two-dimensional, two-component (2D2C) particle image velocimetry (PIV). An adaptive masking algorithm was developed in order to mask dynamic deformations of the structure. Periodic flow separation with strong, chaotic components is visualized; and the influence of the structural deformations is shown.

The structural deformations of the flexible blades were measured synchronized with the hydrodynamic forces and the position feedback of the drive. The interdependency between, on the one hand, turbine design and operating point, and on the other hand, blade deformation and the associated forces, is characterized. Two independent methods for the deformation measurement were developed and applied. The first measures the deformation of a single cross-section, with usage of the masking technique in raw images of the PIV measurements and a surface-tracking method. The latter is based on a structured light pattern projection on the surface which allows to achieve a measurement of the surface deformation with highly temporal and spatial resolution.