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FLUID-STRUCTURE INTERACTION ANALYSIS OF WIND TURBINE BLADE PROFILES

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Driven by ecological and political demands, advanced numerical simulations of wind turbine aerodynamics have become an important field of research in recent years. In this regard, optimization of the aerodynamic performance of the turbine and the analysis of special instability phenomena such as flutter of turbine blades due to high-peak wind levels are of high interest to the wind industry.

In the current work, we present a fluid-structure interaction (FSI) analysis of wind turbine blade profiles. A transient 2D wind turbine aerodynamics model based on RANS is employed where the profile of the rotor blade is considered at specific height levels of the turbine. We also include in the analysis the influence of the tower on the aerodynamics of the turbine.

Generally, two approaches can be used in FSI analyses, the monolithic and the partitioned method. While in the monolithic approach the fluid and solid equations are simultaneously solved by generally using a one-matrix approach, the equations in the partitioned coupling scheme are solved in a staggered manner [1], where the most appropriate method for each field is used. Such a partitioned coupling scheme is employed for the FSI computations in this work using a two-way iteratively coupled implicit method. In the present FSI model the fluid flow is computed using a finite-volume method, and the structure field is solved by employing a finite-element method.

In contrast to the work in [2], where a standalone 2D computational fluid dynamics (CFD) analysis has been employed, in the present paper we consider a fully coupled FSI analysis. That allows us to take into account both the structural and the fluid field of the wind turbine, where the fluid forces affect the structure which at the same time has an impact on the fluid field.

While in [3] a full 3D FSI analysis of a wind turbine has been presented not allowing to resolve the details, in our 2D analysis the boundary layers of the blade are fully resolved which allows a detailed analysis of the lift and drag coefficients. Hence, our approach provides detailed research on the flow field in the direct vicinity of the rotor blade and, thus, can be used to increase the aerodynamic performance of a wind turbine.

In extension to our previous work [4], we here consider blade profiles at different height levels of the wind turbine pertaining to changing bending stiffness of the turbine blades and, thus, showing an influence on the aerodynamic parameters of the blade profile. Furthermore, the transition effect in the boundary layers is also taken into account which can be relevant for large pitch angles.

Numerical results of 2D FSI analysis are presented including the analysis of lift and drag coefficients for different pitch angles of rotor blades and different height levels of the turbine. The influence of the turbine tower is considered in any case. The analysis is carried out using standard NACA profiles at operational rotor and wind velocities. The results show an effect of the different pitch angles and height levels on the aerodynamics of the blade. We also observe an impact of the tower on the lift and drag coefficients. Figure 1 exemplarily depicts the lift coefficient of the profile for different pitch angles clearly showing the effect of the tower.

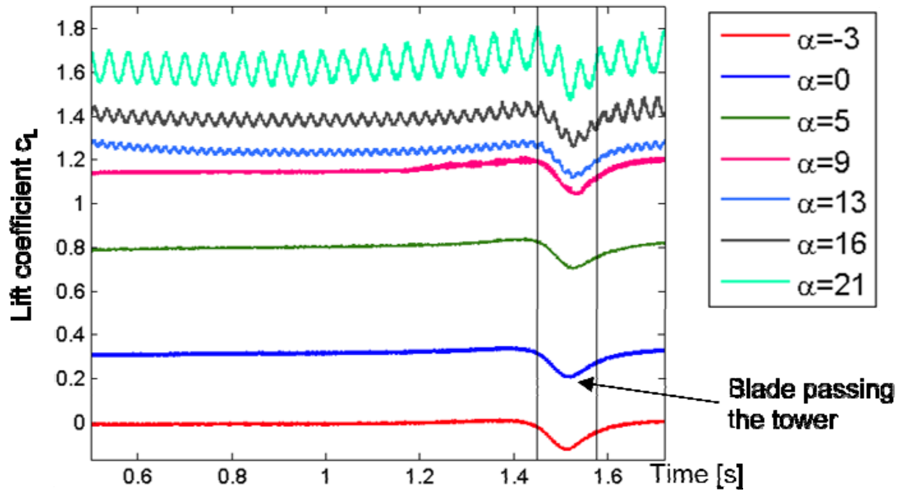

Fig. 1: Lift coefficients of blade profile depending on pitch angle α.

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