A Detailed Study of the Rotational Augmentation and Dynamic Stall Phenomena for Wind Turbines - DTU Orbit (25/12/2018)

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This thesis presents investigations into the aerodynamics of wind turbine rotors, with a focus on the in-board sections of the rotor. Two important aerodynamic phenomena that have challenged scientists over nearly the last half a century are the so-called rotational augmentation and dynamic stall. This thesis presents an investigation into these two phenomena, using data from the MEXICO and the NREL UAE Phase VI experiments, as well as data obtained from full rotor CFD computations carried out using the in-house flow solver Ellipsys3D. The experimental data, CFD data and that from some of the existing reduced order engineering models were analysed to understand rotational augmentation and dynamic stall from a modelling perspective. The first part of the analysis is concerned with steady state aerodynamics. Data from experiments and CFD were analysed in comparison with some of the existing rotational augmentation models, and the relative advantages of these models have been highlighted. The differences between separation characteristics on an airfoil in stationary vs. rotating conditions have not been clarified in the existing literature on this subject. Detailed flow field data obtained using full rotor CFD data was analysed to identify these differences. Comments are made on the mechanism of stall delay, and the main differences between the skin friction and pressure distribution behaviours in 2D and 3D rotating flows are highlighted.

In a second part of this analysis, dynamic stall has been studied on wind turbine blades using the N-sequence data of the NREL UAE Phase VI experiment. The experimental data is compared with the results from unsteady Delayed Detached Eddy Simulations (DDES). The same conditions are also modelled using a Beddoes-Leishman type dynamic stall model by Hansen et al. (2004), using rotationally augmented steady state polars as the input instead of the typically used 2D (stationary) data. The aim of this part of the work has been to investigate the differences between the stall phenomenon on harmonically pitching blades on a rotating wind turbine and the classic dynamic stall representation in 2D flow, as adopted by the reduced order models used for Blade Element Momentum (BEM) based aeroelastic simulations. It has been found that by modelling rotational augmentation and dynamic stall, a more accurate representation of rotor aerodynamics is possible. However higher quantitative accuracy of reduced order modelling maybe limited due to the fact that modelling separated flow is a challenge, even using more rigorous methods such as CFD. It has also been identified that a span-wise variation in the blade loading has an influence on the aerodynamics of the sections nearby. This influence, which has to do with trailing of vorticity, is similar to the tip effect and has been found to be important to be corrected for when using BEM based simulation codes. Additionally, comments are made on the use of the inverse BEM method as a means of determining the angle of attack on wind turbine blades in steady as well as in unsteady conditions.

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