Analysis of wind turbine aerodynamics and aeroelasticity using vortex-based methods - DTU Orbit (11/08/2019)

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Momentum analysis through Blade Element Momentum (BEM) and Computational Fluid Dynamics (CFD) are the two major paths commonly followed for wind turbine aerodynamic and aeroelastic research. Instead, the current PhD thesis focuses on the application of vortex-based methods. Vortex-based methods are understood as both simple vortex models and advanced numerical vortex methods. Prandtl’s tip-loss factor and Coleman’s yaw model are examples of features that were obtained using simple vortex models and implemented in BEM-based codes. Low-order vortex lattice codes and high-order vortex particle methods have regained interest in wind energy applications over the last two decades. The current work derives and illustrates some of the potential benefits of vortex-based analyses. The two key wake geometries used in this study to derive simple vortex models are the cylindrical and helical wake models. Both models can be attributed to the work of Joukowski. They are further studied in this thesis. The cylindrical wake model is detailed for the finite-tip speed ratio case. A superposition of such models is used to investigate the effect of wake rotation. A proper implementation of this effect in BEM codes is suggested. The application to yawed conditions leads to the derivation of a new yaw model applicable in BEM codes. Further applications of the cylindrical wake model considered include the study of unsteady inflow and sheared inflow. The helical wake model is used to derive a new tip-loss factor intended to be used in BEM implementations. The current thesis also presents the implementation of a vortex code to further investigate wind turbine aerodynamics. The code consists of both low-order and high-order formulations. The implementation features are described and illustrated through different validation cases. Analytical results, measurements and CFD simulations are used for comparison and validation. Low-order methods are used to validate the simple vortex models. The vortex particle method is applied to model a turbulent field and investigate the impact of a wind turbine on the inflow turbulence. The code is coupled to the in-house aero-servo-elastic code in order to obtain a “next generation” aeroelastic simulation tool.

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