Review of the State-of-Art in Wind Turbine Aerodynamics

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The modern development of wind power is a remarkable story of the combined effort of enthusiastic entrepreneurs and skilled engineers and scientists. Today, wind power forms the most rapid advancing renewable energy resource with an annual growth rate of about 30%. Within the last 20 years the size of wind turbines have increased from a rotor diameter of about 30 m to 150 m, corresponding to an increase in power by a factor of more than 25. In the same period of time, the knowledge and scientific level of the aerodynamic research tools to develop optimally loaded rotor blades have increased dramatically. Today, wind turbine aerodynamics forms one of the research frontiers in modern aerodynamics.

The aerodynamics of wind turbines concerns modelling and prediction of the aerodynamic forces on the solid structures of a wind turbine, and in particular on the rotor blades of the turbine. Aerodynamics is the most central discipline for predicting performance and loadings on wind turbines, and it is a prerequisite for design, development and optimization of wind turbines. From an outsider's point of view, aerodynamics of wind turbines may seem simple as compared to aerodynamics of e.g. fixed-wing aircraft or helicopters. However, there are several added complexities. Most prominently, aerodynamic stall is always avoided for aircraft, whereas it is an intrinsic part of the wind turbines operational envelope. Furthermore, wind turbines are subjected to atmospheric turbulence, wind shear from the atmospheric boundary layer, wind directions that change both in time and in space, and effects from the wake of neighbouring wind turbines.

In the past year the development in numerical and experimental techniques dealing with rotor and wake aerodynamics of wind turbines has developed dramatically, and with appropriate simplifications it is possible to perform advanced simulations of single wakes of wind turbines as well as simulations and performance predictions of full wind farms. An example of a simulation using the so-called actuator line technique to predict the dynamics of the wake behind a wind turbine is shown in Figure 1.

In the presentation I will give a review of the state-of-the-art of fluid mechanical aspects of wind energy, focusing mainly on wake aerodynamics and the fluid mechanics of wind farms.

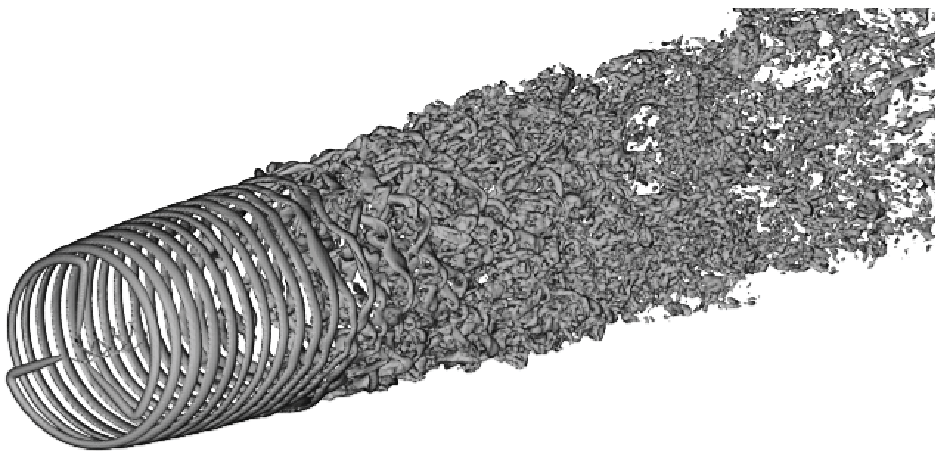

Figure 1. Isolines of vorticity based on Large-Eddy-Simulation of wind turbine wake using actuator line technique.

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