Wind Turbine Blade: LES with Natural Inflow Turbulence

Optimization of Aerodynamic Profiles for Wind Turbine Blades by Means of Numerical Simulation with Natural Inflow Turbulence at High Reynolds Numbers

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In Short

- Selection of a suitable method for the generation of synthetic wind with atmospheric turbulence.
- LES simulation for the detection of transition on wind turbine blades at high Reynolds numbers.
- Optimization of the aerodynamic design of wind turbine blades.

The production cost of the electricity generated by wind turbines is undergoing a steady reduction. Plant manufacturers achieve this reduction in cost of energy on the one hand by a constant enlargement of the plants, but on the other hand, by a load-specific optimization, that is, material saving of individual components. After the tower, the rotor blades are the parts with the largest individual cost. They are also the determining component for both performance and loads.

To obtain a high efficiency [1], there is an increased use of special aerodynamic profiles which have large areas of low-resistance, which means laminar flow is maintained. In order to design such profiles using computational fluid dynamics and achieve a comparably good agreement with experiments, such as in the wind tunnel [2] or in the free atmosphere [3], it is necessary to include the laminar-turbulent transition in the 3D simulation of wind turbine blades.

With the completion of phase three of the MexNext [4] project in 2017, the first comparisons between measurements and simulations were carried out and documented on a rotor model with a diameter of 5m in a wind tunnel. During the course of the MexNext project, transition was also successfully detected from the collected experimental data [5]. Measurements on a rotor blade 15m in length was carried out in the free atmosphere to study the behavior of the boundary layer within a specific zone on the suction side at different operational states as seen in [3]. In July 2018, microphone and pressure sensor measurements to study transition on a blade of 45m were collected [6]. For these measurements, large-eddy simulations (LES) shall be carried out.

In consultation with the Helmut-Schmidt University of Hamburg, it is intended to use the LESOCCC (Large-Eddy Simulation on Curvilinear Coordinates) code developed by Breuer [8]. This code has already been complied on the HLRN servers during the last month.

LESOCC is a CFD code developed for the simulation of complex turbulent flows (see Fig. 1) using either direct numerical simulations (DNS), large-eddy simulations (LES) or hybrid RANS-LES methods such as the detached-eddy simulation (DES).

The final goal is to run wall-resolved simulations for the detection of transition at high Reynolds numbers > $10E6$, preferably in comparison with experimental results from the recent experiments conducted by FH Kiel on a MM92 turbine [6]. However, for the resolution of the boundary layer at these high Reynolds numbers, the grid resolution leads to numbers of grid points in the order of hundreds of millions. Therefore, it is planned to begin the simulations at lower Reynolds numbers of around $10E5$, an order of magnitude lower than the final goal. There are a few reasons to do this:

1. Determine the level of coarseness of the grid that sufficiently resolves the boundary layer to observe laminar-turbulent transition.
2. Determine the optimal CFL number [9], as this is one of the factors that determines the number of time steps and hence resources that would be needed for a simulation.
3. Compare the effects of a change in the atmospheric inflow turbulence for various Reynolds numbers.

   It is planned to initially run the simulation at two different angles of attack and at two different atmospheric inflow turbulence conditions, the specifications of which would be decided based on the experimental data analysis. Using the resources provided by HLRN, wall-resolved LES would be carried out to simulate and then analyze the laminar-turbulent boundary layer transition phenomenon.

   The successful simulation of the flow in comparison with experimental data from free atmospheric studies would take this methodology a step further, with the final goal being the optimization of aerodynamic profiles for wind turbine blades at high Reynolds numbers under the condition of natural inflow turbulence.

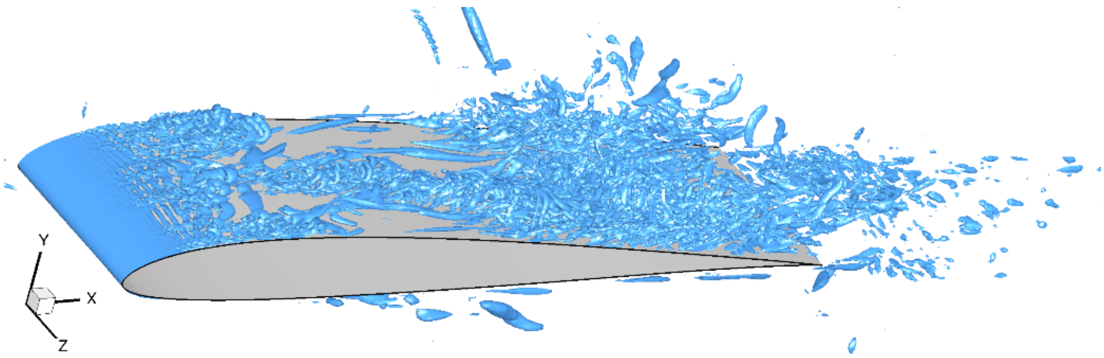

Figure 1: *LES simulation with high (11.2%) inflow turbulence, Reynolds number = 60,000 [10]*

WWW

https://www.fh-kiel.de/index.php?id=schaffarczyk

More Information

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Project Partners

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