

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

- Generation and insertion of synthetic wind with atmospheric turbulence into the flow domain.
- 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 reduction in cost of wind energy is in part due to the load-specific optimization, that is, material saving of individual components. The rotor blades are 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 45m in length were collected [6]. For these measurements, large-eddy simulations (LES) shall be carried out.

In consultation with the Helmut-Schmidt University of Hamburg, the LESOCCC (Large-Eddy Simulation on Curvilinear Coordinates) code developed by Breuer [7] is used. LESOCC is a CFD code for the simulation of complex turbulent flows using either

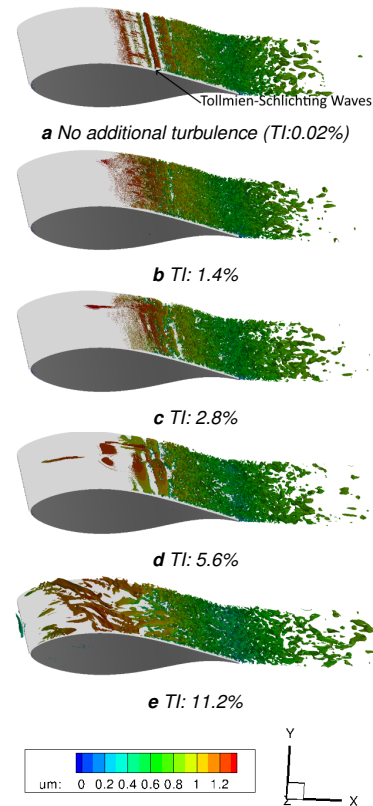


Figure 1: Instantaneous iso-surfaces of the dimensionless Q -criterion ($Q = 100$) coloured by mean stream-wise velocity for a Reynolds number of 100,000. The Q -criterion is commonly used for the illustration of vortices.

direct numerical simulations (DNS), large-eddy simulations (LES) or hybrid RANS-LES methods such as the detached-eddy simulation (DES).

The goal is to run wall-resolved simulations for the detection of transition at high Reynolds numbers $> 1E6$, preferably in comparison with experimental results [6] and to possibly determine a frequency range of inflow disturbances that influence transition for the particular case under consideration. For the resolution of the boundary layer at these high Reynolds numbers, the grid resolution leads to number of grid points in the order of hundreds of millions. Therefore, as planned simulations at lower Reynolds numbers of around $1E5$, an order of magnitude lower than the final goal were first run. 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. Compare the effects of a change in the atmospheric inflow turbulence for various Reynolds numbers.

3. Determine the CFL number [8] for future runs.

Included here are some results from the simulations run at a Reynolds number of 100,000 and at four different turbulent inflow conditions with turbulence intensities of 1.4%, 2.8%, 5.6% and 11.2% to study the effect of turbulence intensity on transition.

For the generation of atmospheric inflow turbulence, the turbulence inflow generator by Klein et al. [9] was extended by a source term formulation that allows to inject the turbulence closer to the region of interest [10].

Figure 6 illustrates the development of the flow under the different inflow conditions using the non-dimensional Q-criterion and it is coloured by the mean stream-wise velocity. The Q-criterion is widely used for the illustration of vortices.

A common process of laminar to turbulent transition for flow around airfoils with low atmospheric inflow turbulence (< 1%) is by the growth of Tollmien-Schlichting waves [11]. This mode of transition can be seen in figure 1 corresponding to the case of no added atmospheric turbulence where very distinct Tollmien-Schlichting waves are seen along the span.

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More Information

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Project Partners

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