Assessment and enhancement of OpenFOAM for various wind energy applications

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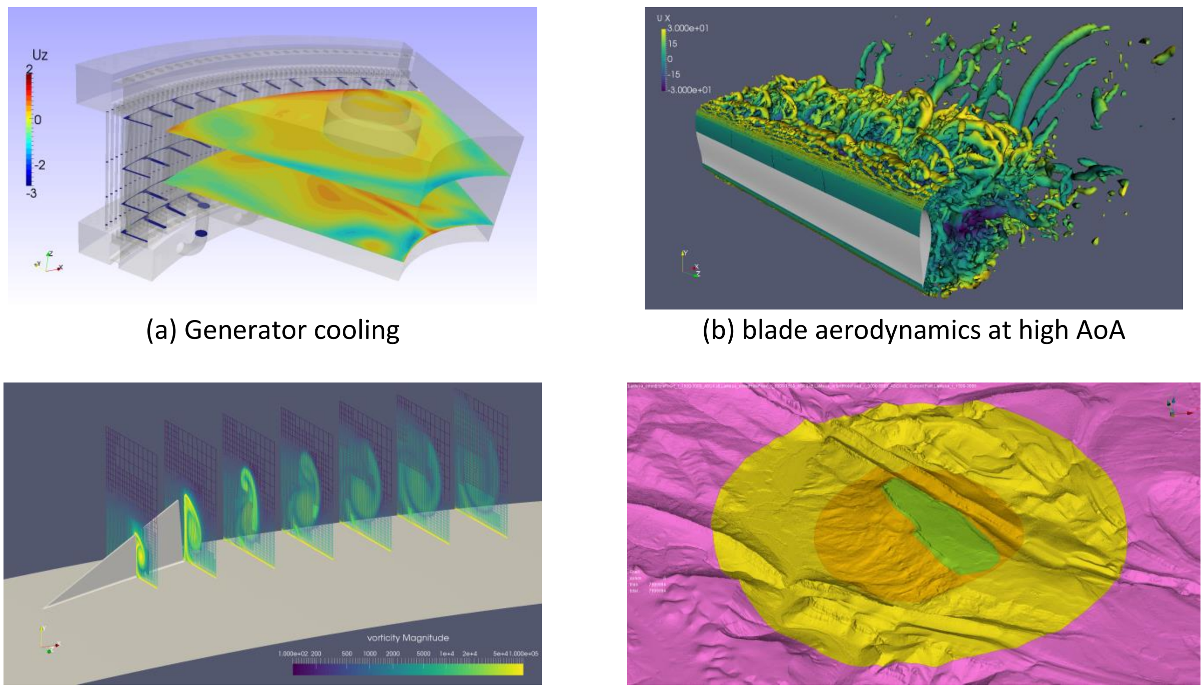
With wind energy becoming one of the fastest growing renewable energy sources in the last decades, the penetration of CFD into different disciplines of the development and optimization process has also increased dramatically in recent years. In this talk, we give an overview about work conducted within the German-funded research project AssiSt, in which we developed and evaluated CFD processes for a wide variety of problem categories in wind energy using OpenFOAM (see Fig. 1).

A core application for CFD in wind engineering concerns the aerodynamic optimization of the rotor blades. Predicting blade performance is especially challenging for larger angles of attack, where massive flow separation occurs and both steady-state RANS (modelling error) and wind tunnel measurements (high blockage) are unreliable. For this flow type, scale-resolving detached-eddy simulation (DES) has proven to be a potent tool [1] (see Fig. 1 (b)).

To extend the linear lift regime of the blade towards higher AoA, vortex generators have proven to be a powerful means for passive flow control. The relatively small size of the device in relation to the blade as well as the complex flow topology poses problems for the CFD process chain. We will present an efficient meshing strategy based on adaptive mesh refinement and OpenFOAM's Arbitrary Mesh Interface (AMI) to accurately capture both the geometry as well as the VG wake for a representative wind rotor profile of 18% thickness.

Another CFD application area concerns the flow through the generator in the nacelle. RANS is used here to predict the flow through the cooling channels for different operating points (see Fig. 1 (a)). One of the main challenges here is a reliable and efficient mesh generation for such a complex geometry with numerous high-aspect ratio components. The capabilities of snappyHexMesh for such geometries are critically assessed in the presentation.

A business-critical application area for CFD in wind energy concerns the prediction of wind yield distribution over complex terrain to optimise the turbine siting. To accurately include large scale atmospheric turbulence into the simulation, a turbulence generator method based on volumetric source terms [2] has been implemented and verified in OpenFOAM. Simulation results from scale-resolving DES will be presented for an existing complex terrain site, where both an analysis of critical wind conditions occurring at the installed wind turbines is conducted as well as a comparison to wind mast measurements.



(a) Generator cooling

(b) blade aerodynamics at high AoA

(c) Blade performance optimisation via VGs

(d) Site assessment of complex terrain

Fig. 1: Usage of OpenFOAM for different disciplines of wind engineering within AssiSt project.

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