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Session:

Hybrid RANS/LES capabilities of the Flow Solver FLOWer - Application to Flow around Wind Turbines

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Introduction

In recent years, considerable progress in computational performance has rendered possible to employ eddy resolving methods for simulation of the flow around wind turbines. The latter can be rather complex featuring flow separation in the inner part of the rotor or the interaction with atmospheric turbulence. In order to account for these effects, the Detached Eddy simulation (DES) approach poses a reasonable trade-off between accuracy and computational effort. In this field, only few studies have been published. The objective of the present study is to investigate the potential of DES for flow around a rotating wind turbine at stalled operational conditions. Loads and wake shall be compared with the classical URANS approach and experimental data [1]. For this purpose the DLR flow solver FLOWer [2] has been extended by the state of the art DES models for various background RANS models [3-5]. The LES capabilities of the solver shall be assessed using the decaying isotropic turbulence test case of Wray [6]. The validation of the new implementations shall be conducted first, for the well-known test cases backward facing step [7], shown in the full paper and airfoil at high angle of attack [8], before increasing the complexity, simulating the flow around a whole wind turbine.

Decay of Isotropic Turbulence

The DNS data of Wray [6] filtered in k-space to 128^3 at a Reynolds number Re_λ=104.5 serves as initial condition for assessing the capabilities of FLOWer to simulate the turbulent cascade. The results in Figure 1 compare the 3D kinetic energy vs. wave number for different numerical schemes using the SAO background turbulence model (C_{DES}=0.65) forced to LES mode. It was found that the standard Jameson method is too dissipative to resolve the inertial subrange. The latter can only be adequately captured with the higher order reconstruction scheme WENO. In particular, when employing the recent low Mach number Riemann solver *l2Roe* [9].

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Flow around the NACA0021 Airfoil in Deep Stall

The second validation is based on the DESider NACA0021 at 60° incidence test case [8]. Here, the unsteady, three-dimensional high Reynolds number flow around an airfoil in deep stall is investigated. The structured, O-topology grid was kindly provided by New Technologies and Services LLC (NTS) and is used with a span size of 4*c*. Computed mean aerodynamic coefficients averaged over 500 convective time units are listed in Table 1. Figure 2 shows the power spectral density (PSD) of the lift coefficient. These first IDDES results are in good agreement with experimental data. More DES models will be discussed in the final paper.

Flow around the MEXICO wind turbine

The main part of the paper will be dedicated to analyses of the flow around the MEXICO model wind turbine operating at low tip speed ratio in the stall regime. The meshes for the blades and the wake are adapted for DES incorporating approx. 150×10^6 cells. A grid study will be shown in the full paper. The vortex structures in the wake are depicted in Figure 3 for URANS (left) and IDDES (right). While the tip vortices show similar shape for both models, the separated wake reveals major differences, where IDDES, in contrast to URANS is capable of predicting the interaction of the vortices leading to break down into very small scales farther downstream. In the full paper wake properties as well as loads and pressure distributions will be shown and compared to measurement data.

References

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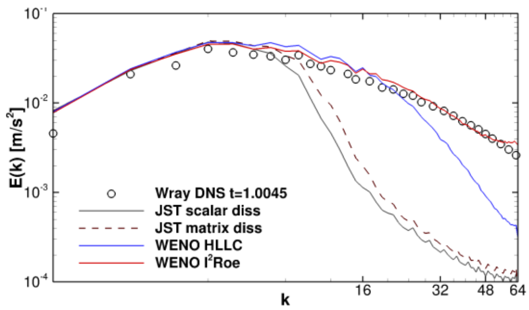

Fig. 1 DIT for different numerical schemes.

Table 1 Mean lift and drag coefficients.

	C_L	C_D
Experiment	0.931	1.517
FLOWer SST URANS	1.433	2.449
FLOWer SST IDDES	0.903	1.350

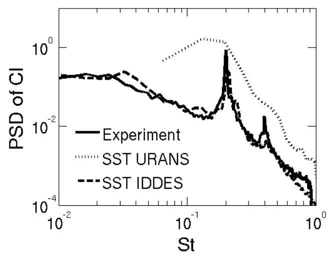

Fig. 1 Span-averaged PSD of Cl.

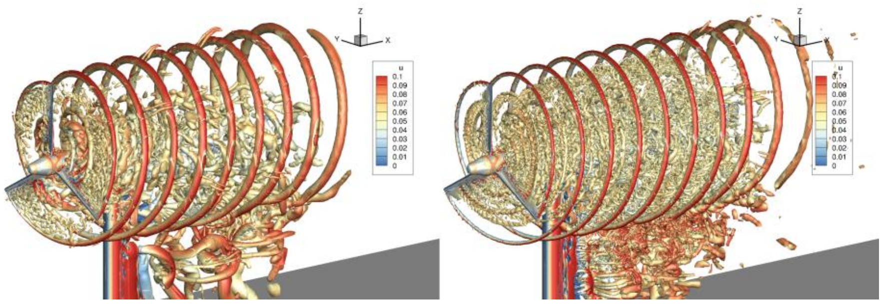

Fig. 2 Wake of the MEXICO wind turbine left URANS, right IDDES.