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Validation of a CFD wake model based on the actuator disk technique and the thrust coefficient. Preliminary results

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ABSTRACT

A simplified CFD wake model based on the actuator-disk concept is used to simulate the wind turbine, represented by an actuator disk upon which a distribution of forces, defined as axial momentum sources, are applied on the incoming flow. The rotor is supposed to be uniformly loaded, with the exerted forces as a function of the incident wind speed, the thrust coefficient and the rotor diameter. The model is validated through experimental measurements downwind of a wind turbine in terms of wind speed deficit. Validation on turbulence intensity will also be made in the near future.

KEYWORDS

Actuator disk, thrust coefficient, turbulence modelling

1 INTRODUCTION

Wind turbine rotor effect has been modelled using several types of approaches, from analytical engineering models to the 3D CFD full rotor modelling [1]. During the last years and due to the need of modelling the far wake and wind turbines interaction in challenging environments such as complex terrain and offshore, new proposals have arisen through the so-called 'back to the basics' concept. An elliptical approach based on coupling the actuator disk technique and CFD can make a fair simplification of the rotor without leaving the main essence of its physics. This paper represents the first stage of a series of single-rotor validation processes of this technique for different turbulence model parametrizations in order to optimize more advanced releases for modelling wakes interaction in wind farms.

2 NUMERICAL MODELLING

A non-uniform flow is modelled in a computational domain (30Dx7.5Dx5D) representing the surface boundary layer, in which the Monin-Obukov theory is solved from the Reynolds Average Navier Stokes equations and the turbulent transport terms from the k-ε method. The wind turbine is considered as an actuator disk upon which uniformly distributed forces, defined as axial momentum sources, are applied.

3 RESULTS

A three bladed Nibe-B 630 kW wind turbine with a 40m diameter and located at hub height of 45m is simulated. An upstream velocity of 8.5m/s and a turbulence intensity of 11% is used for the incoming flow, giving a value of C_t=0.82 for the axial thrust coefficient at the rotor [2]. Different parametrizations of the 2 equations k-ε turbulence model are used in order to control the excess of turbulent diffusion in the wake and therefore the wind speed deficit and added turbulence intensity. A compromise must be found between the optimum parameters for the modelling of the wind at the surface boundary layer and the rotor wake aerodynamics.

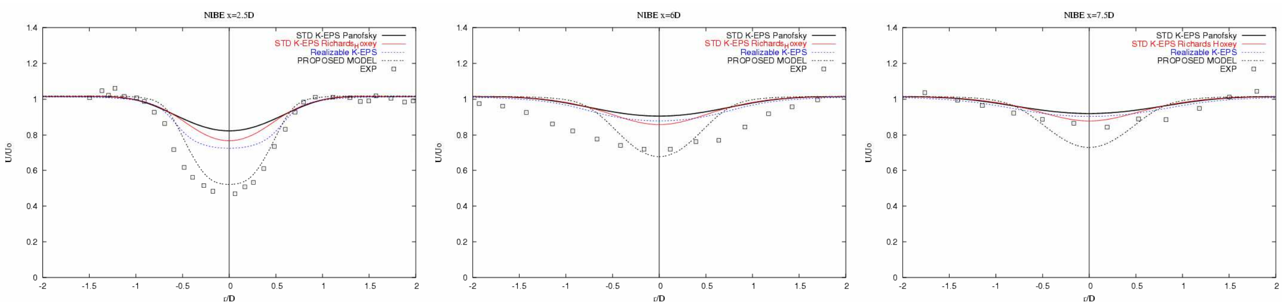

Figure 1: Wind speed deficit at the wake of Nibe-B wind turbine rotor

The proposed model is based on the work of El Kasmi et. al. [2] and Chen and Kim [3] but corrected by using a set of constants which keeps the hypothesis of equilibrium in the wall. The model is compared with other configurations of the standard k-ε turbulence model (set of constants proposed by Panofsky and Richards-Hoxey) and with the realizable k-ε turbulence model. A good agreement is found for the proposed model on the first sections, whereas in the far wake some deviations start making the other options more appropriate.

4 CONCLUSIONS

A validation of an elliptic model based on the actuator disk technique and thrust coefficient is presented. The results are especially sensitive to the parametrization of the turbulence model, with deviations depending on the type of modelling and on whether it is near or far wake. Further work will consist on extending the validation to other experimental cases with different turbulence model parameters preserving the accuracy of ABL wind simulation and optimize multi-rotor configurations in order to analyze wakes interaction inside wind farms.

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