Wind wave interaction investigated with two different CFD methods for wave representation - Solid surface and moving mesh vs. VOF

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1 Introduction

Recent research has shown that the marine atmospheric boundary layer (MABL) is influenced by waves to a larger extent than previously thought. In offshore wind energy industry, the influence of the moving waves on the wind profiles and turbulence levels extends up to the swept rotor area [1][2]. Therefore, waves have a significant influence on the performance of offshore wind turbines; they can contribute to increased power output [3], and at the same time they may negatively affect the fatigue life of a wind turbine [4]. Even if it is acknowledged that waves affect the MABL, the phenomenon is however poorly understood. It is usually not taken into consideration when estimating power production and in design calculations since the wind profile of the MABL is traditionally modeled as stationary logarithmic profile (Fig. 1) which omits the dynamic effect of the waves on the wind profile and turbulence levels. The wind-wave interactions and the implications on offshore wind turbines was studied by Kalvig by the use of CFD modelling [3]. Kalvig used a solid surface with a moving mesh to represent the wave. In this work, this method is compared against a more realistic approach by the use of VOF and compare the flow physics for the two methods.

2 Method and models

This work compares two approaches for modelling wind and wave interaction in a 2D domain by the use of the OpenFOAM CFD toolbox. The first approach considers solid sinusoidal waves with a moving grid to resolve the ocean waves. The OpenFOAM solver developed in Kalvig’s PhD work, pimpleDyWTurbineFoam, is applied, which is a solver based on pimpleDyMfoam [3]. This solver was used in combination with a moving mesh, which represents the wave as a solid surface. However, this is a crude simplification of a real wave surface. The aim of this study is to apply Kalvig’s method and a more realistic approach by the use of VOF and compare the flow physics for the two methods. In the VOF method, the two-phase air/water flow is fully resolved, so how the wind affects the wave is also included in the simulation. The inlet conditions for the approaches are set as similar as possible for better comparison between the two. The wave signal in the wind field is further investigated by a study of the wind profiles. The waves are generated using the waves2foam framework [4].

3 Wind flow over waves

The wind profiles and turbulent kinetic energy profiles will depend on the direction of the waves relative to the incoming wind field. As a base case, simulations with wind over sea with low roughness, i.e. no waves, is generated. Additional cases with wind aligned with sea swell and wind opposing the swell are performed.

4 Results and discussion

The expected results should show how large impact the simplified approach of representing the wave as a solid surface with prescribed motion has on the results.

5 References