Available online at www.sciencedirect.com
ScienceDirect
Journal of Hydrodynamics
2016,28(1):95-101
DOI: 10.1016/S1001-6058(16)60611-X
www.sciencedirect.com/science/journal/l0016058

Investigation of the effects of platform motion on the aerodynamics of a floating offshore wind turbine*

Yuanchuan LIU[1], Qing XIAO[1], Atilla INCECIK[1], De-cheng WAN (万德成)[2]
1. Department of Naval Architecture, Ocean and Marine Engineering, University of Strathclyde, Glasgow, UK, E-mail: yuanchuan.liu@strath.ac.uk
2. State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai 200240, China

(Received September 17, 2015, Revised November 5, 2015)

Abstract: Along with the flourishing of the wind energy industry, floating offshore wind turbines have aroused much interest among the academia as well as enterprises. In this paper, the effects of the supporting platform motion on the aerodynamics of a floating wind turbine are studied using the open source CFD framework OpenFOAM. The platform motion responses, including surge, heave and pitch, are superimposed onto the rotation of the wind turbine. Thrust and torque on the wind turbine are compared and analysed for the cases of different platform motion patterns together with the flow field. It is shown that the movement of the supporting platform can have large influences on a floating offshore wind turbine and thus needs to be considered carefully during the design process.

Key words: floating offshore wind turbine, superimposed platform motion, aerodynamics, OpenFOAM

Introduction

Over the last few decades, wind energy has been widely adopted as a clean and renewable energy source. According to a report published by the European Wind Energy Association[1], the share of renewable energy in total new power capacity installations in the European Union has grown from 22.4% to 72% during 2000 and 2013. Of all 385 GW of new power capacity installations in the EU since 2000, over 28% has been wind power. While offshore wind business is growing rapidly, new generation floating offshore wind turbines are rapidly developed which are planned to be installed in deep water areas[2-5]. The main advantages of floating wind turbines include: the shallow water sites for fixed wind turbines are limited, wind source far off the coast is even more abundant and the public concerns about visual impacts caused by onshore turbines can be minimized.

Unlike its fixed counterpart, a floating wind turbine must be supported by a floating platform which, however, further complicates the design process. The upper turbine and the lower supporting platform are coupled/integrated in one way or another. For example, the thrust and torque acting on the turbine influences the dynamic response of a floating platform while the movement of the latter also affects the position and orientation of the turbine thus its aerodynamic performance. As far as the authors are aware of, most research on the aerodynamic analysis in this area has been performed by decoupling the movement of the platform from the turbine system as a simplification. For instance, Jeon et al.[6] adopted a vortex method to simulate a floating wind turbine undergoing a prescribed pitch motion. It was shown that when the platform moves in the upward direction to the position at a maximum velocity, thrust reaches a maximum due to the large relative velocity. In their paper, the impacts of the pitching motion on the induced velocity were also studied. De Vaal et al.[7] investigated a floating wind turbine with a prescribed surge motion using the BEM method with various dynamic wake

* **Biography:** Yuanchuan LIU (1990-), Male, Ph. D. Candidate
Corresponding author: Qing XIAO,
E-mail: qing.xiao@strath.ac.uk

models as well as the actuator disk method. Their results show that the integrated rotor loads obtained by various methods were nearly identical, indicating that the existing engineering models to deal with wake dynamics are sufficiently accurate to cope with the additional unsteady surge motion of a wind turbine rotor in terms of its global force analysis. In the work of Tran and Kim[5] and Tran et al.[8], commercial CFD software packages were used to study the aerodynamic performance of a FOWT experiencing a platform pitching motion. Results were compared with those from other simplified models and demonstrated that the aerodynamic loads of the blade change drastically with respect to the frequency and amplitude of platform pitching motion.

It is seen that most existing research has focused on a prescribed single degree of freedom (DoF) motion of the floating platform. However, from the perspective of a floating structure in reality, among all the six degrees of freedom of motion responses, surge, heave and pitch are usually present at the same time. By taking these three degrees of freedom into conside ration simultaneously, a more realistic representation for the motion of platform could be made, and thus the impact of the platform motion on the aerodynamic performance of a floating wind turbine could be better illustrated.

In this paper, the open source CFD framework known as OpenFOAM[9] is adopted to study the effects of the supporting platform motion on the aerodynamics of a floating wind turbine. The platform motion responses, including surge, heave and pitch, are superimposed onto the rotation of the wind turbine.

1. Methodology

In the present study, the pimpleDyMFoam solver in OpenFOAM is used which is able to solve the transient, incompressible and single-phase flow of Newtonian fluids with the moving mesh capability[9]. The incompressible Reynolds-averaged Navier-Stokes (RANS) equations with the k - ω SST turbulence model are discretised using the finite volume method (FVM). The PIMPLE (merged PISO-SIMPLE) algorithm is applied to deal with the velocity-pressure coupling in a segregated way. A second-order backward scheme is used for the temporal discretisation and a second-order upwind scheme is applied for the convective term.

OpenFOAM implements a sliding mesh technique called arbitrary mesh interface (AMI) for rotating machinery problems[10], which allows the simulation across disconnected, but adjacent, mesh domains either stationary or moving relative to one another. The AMI method is adopted in the present study to deal with the rotation of wind turbine. The prescribed surge, heave and pitch motion are applied to the whole computational domain including the rotor in such a way that the position and rotation of the turbine rotor are determined by the superimposed motion of its own rotation and the 3DoF platform movement.

2. Computational model

2.1 *Geometry*

The NREL Phase VI wind turbine is adopted in the present study. Though this model was initially designed for the application in onshore scenarios, the availability of experimental data[11] from the National Renewable Energy Laboratory (NREL) makes it a popular validation case to verify various modelling results for aerodynamic performance of wind turbines. Taking this advantage, the NREL Phase VI model is used in the present study for validation first and then as a base model for cases with prescribed platform motion.

The NREL Phase VI wind turbine is a two-bladed upwind model and each blade adopts the NREL S809 airfoil profile as shown in Fig.1 at most of its span-wise cross sections. The length of the blade is 5.029 m from tip to the rotation axis. Of all the configurations tested by NREL, a tip pitch angle of 3° is used and zero yaw angle is applied consistently in the present study. A CAD model for the wind turbine is shown in Fig.2. The hub, nacelle and tower are not considered here for simplicity. Detailed geometric parameters can be found in the NREL report[11].

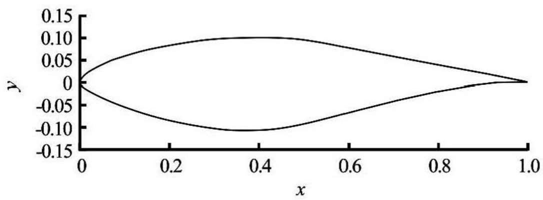

Fig.1 Profile of NREL S809 airfoil

Fig.2 CAD model of NREL Phase VI wind turbine

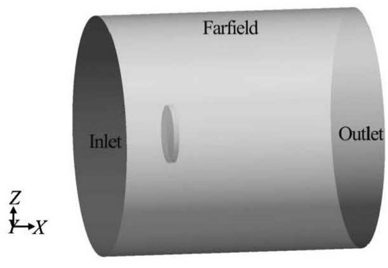

Fig.3 Overall computational domain