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Multi-body dynamic analysis of offshore wind turbine using Recurdyn

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ABSTRACT

In this paper, multi-body dynamics modeling and the analysis of the offshore wind turbine are carried out with Recurdyn program. The structure of the offshore wind turbine is totally modeled on Recurdyn which is the commercial multi-body dynamics software developed and distributed by FunctionBay. The offshore wind turbine system consists of a tower, a nacelle, a hub and 3 blades. Each blade is modeled as flexible body. The external forces are applied using BEM theory and Morison equation. Aerodynamic force is calculated with the constant wind that is no variation with respect to time. Marine environment is considered with regular waves. These external forces are applied to the wind turbine model of Recurdyn. The simulation results of dynamic analysis using Recurdyn are analyzed for the stability of the wind turbine.

1. INTRODUCTION

Recently, interest in renewable energy as biofuel, solar energy, wind power, hydro power and geothermal energy had been increased. Especially, some of the countries such as China, the United States, and EU have interest in wind power. Since 1990s, wind power market has been growing rapidly. The structure of the wind turbine system is enormous. Thus it is necessarily to expect dynamic features of components such as tower, nacelle, hub and blades to secure stability and durability.

In this paper, we carried out dynamic analysis of offshore wind turbine using Recurdyn. In chapter 2, properties of the offshore wind turbine are explained. In chapter 3, external forces are explained to give the aerodynamic force acting on the blades and hydrodynamic force on the substructure. In chapter 4, analysis results, especially, the stability of the nacelle is focused on this study. Finally, the conclusion of this study has been described.

2. Offshore Wind Turbine of 5MW

2.1 Principal dimensions of the 5MW offshore wind turbine

Table 1 shows the principal dimensions used for the dynamic analysis of the offshore wind turbine of 5MW.

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Table 1 Gross properties for the 5MW offshore wind turbine.

Parameter	Value
Rating	5MW
Hub Height	80m
Cut-in wind speed	3m/s
Cut-out wind speed	25m/s
Rotor mass	114059kg
Nacelle mass	250000kg
Substructure mass	2374582kg

2.2 Blade

The offshore wind turbine has three blades. Table 2 summarizes the properties of each blade. For the modeling as a flexible body, this is divided into 10 sections.

Table 2 The properties of each blade.

Parameter	Value
Length	61.5m
Overall mass	18020kg

2.3 Substructure

There is a variety of substructure forms of the wind turbine system. The tripod type is chosen for the 5MW offshore wind turbine. Fig. 1 shows the 5MW offshore wind turbine which is modeled by Recurdyn.

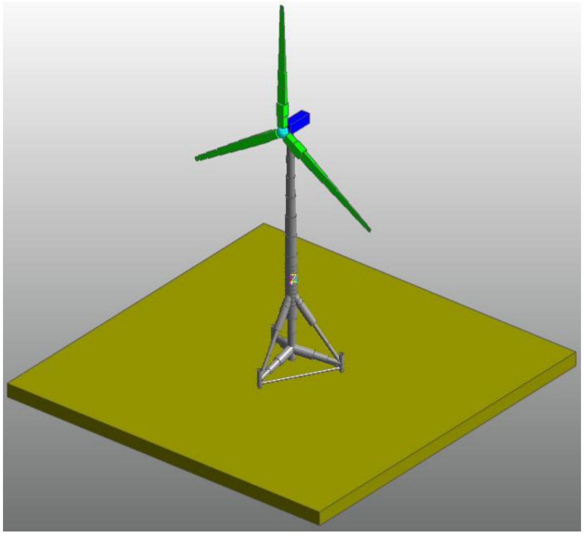

Fig.1 The 5MW offshore wind turbine using Recurdyn.

3. External forces

3.1 Aerodynamic force

The aerodynamic force on each blade is calculated according to the blade element momentum theory. This theory combines both element theory and momentum theory.

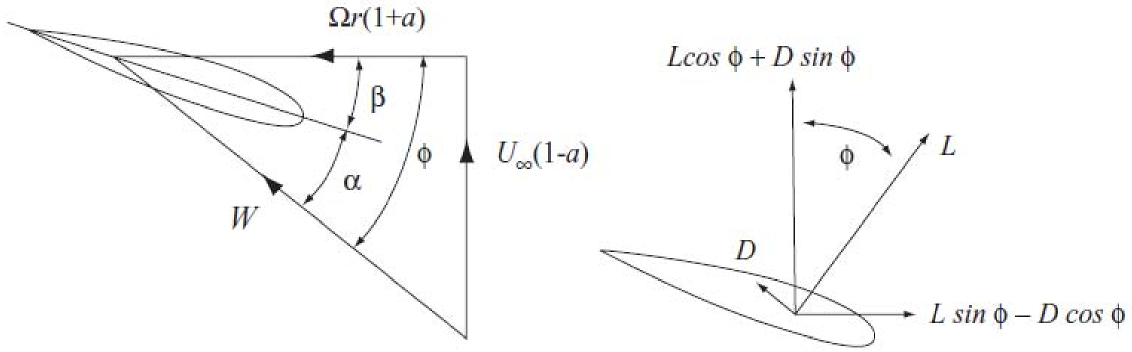

Fig. 2 The velocities and forces of blade element.

$$dF_x = \frac{1}{2}\rho W^2 B(C_L \cos\phi + C_D \sin\phi)cdr \tag{1}$$

$$dT = \frac{1}{2}\rho W^2 B(C_L \sin\phi - C_D \cos\phi)cdr \tag{2}$$

$$dF_x = 4\pi r \rho U_\infty^2 (1-a)adr \tag{3}$$

$$dT = 4\pi r^3 \rho U_\infty (1-a)a' dr \tag{4}$$

Fig. 2 shows the velocities and forces of blade element. U_∞ is the global inflow, W is the local inflow, ρ is air density, α is angle of attack, β is pitch angle and φ is local inflow angle. Eq. (1) and Eq. (2) can be derived by blade element theory in Fig. 2. dF_x is thrust force, dT is torque, B is the number of blades, C is coefficient of drag and lift, c is chord length and r is radius of the rotor. Also, Eq. (3) and Eq. (4) can be derived by blade momentum theory. A balance of axial and angular momentum is applied. In here, a is axial induction factor and a' is tangential induction factor.

These two methods give a set of non-linear equations which can be solved numerically for each section of the blades. The aerodynamic force is calculated by solving these non-linear equations. This paper is used a constant wind speed is 12m/s.

3.2 Hydrodynamic force

The Morison equation is the sum of components of two forces: an inertia force in phase with the local flow acceleration and a drag force proportional to the square of the instantaneous flow velocity. The inertia force is modelled as a functional form as found in potential flow theory, while the drag force is derived from a body placed in a steady flow.

$$f = \frac{1}{2}\rho C_D D|u|u + \rho C_I \frac{\pi D^2}{4}\dot{u} \tag{5}$$

Morison equation can be expressed as Eq. (5). In this equation, f is the wave force per unit length acting on part of the substructure, D is diameter, u is the flow velocity, ρ is water density and C is coefficient. Hydrodynamic force is calculated by integrating Eq. (5). This paper defined wave height of 3m and wave period of 15 seconds, respectively.

4. Simulation results

Fig. 3 shows the acceleration of the nacelle. It is known that the accelerations of the nacelle in all directions are in the range between -0.1 and 0.1. Fig.4 shows the displacement of the nacelle. The displacements of x and z direction are nearly -0.4m and 0.035m, respectively. The displacement of y direction oscillated between -0.05m and 0.05m.

The accelerations and displacements are very small values compared to the size of the offshore wind turbine system. Therefore, it is seen that the offshore wind turbine system is stable in this environment.

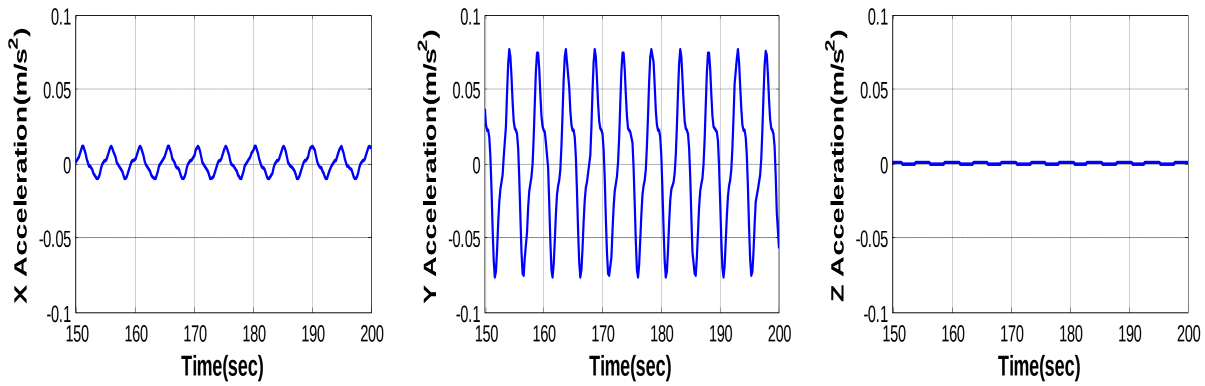

Fig. 3 The acceleration of the nacelle

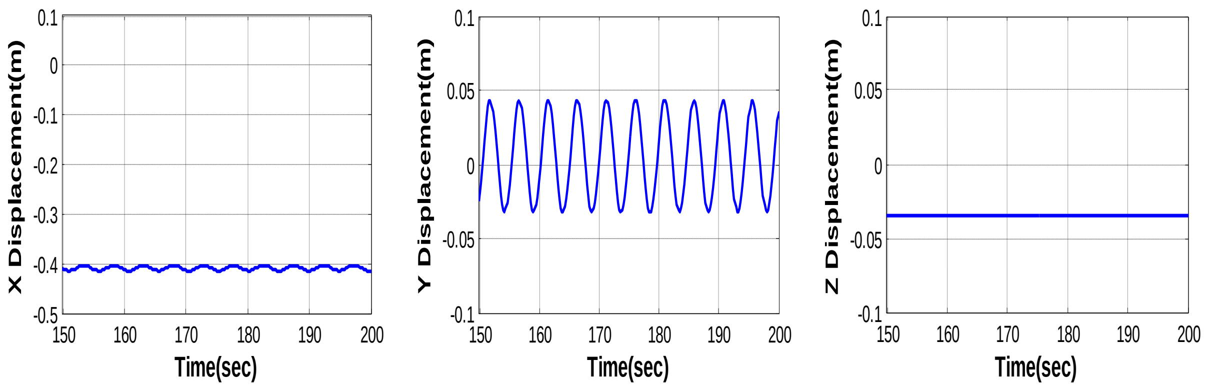

Fig. 4 The displacement of the nacelle

5. Conclusion

Dynamic responses for the 5MW offshore wind turbine system are analyzed with multi-body dynamics. The wind turbine is modelled by Recurdyn and the external forces which are the aerodynamic forces using BEM theory and hydrodynamic forces by

Morison equation. According to the results related to the accelerations and the displacements of the nacelle, it can conclud that the wind turbine system can bear the imposed conditions in this paper.

ACKNOLEDGEMENT
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