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Experimental Study on Cyclic Pitch Hub

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Abstract

For the floating types of offshore wind turbine, the stability of floating platform is important. To stabilize the floating system the aerodynamic force acting on the rotor can be used as the actuator. The rotor thrust force is enough large and controlled by blade pitch setting.

This paper describes the experimental results of wind turbine with Cyclic pitch hub. The wind tunnel test is conducted with small wind turbine model with cyclic pitch hub. The balance measurement for the wind turbine nacelle is performed. As the results, proposal cyclic pitch hub can control both thrust and moment acting on the wind turbine rotor.

Objectives

Offshore wind power has huge energy potential. Currently offshore wind power is utilized in shallow water by foundation based type. However there are not enough shallow water area around Japan for utilizing offshore wind energy, so floating offshore wind turbines are expected to be introduced. In order to introduce floating wind turbine, the wind turbine motions by fluctuating force are important. To suppress undesired turbine's motion, the rotor thrust control is one of options.

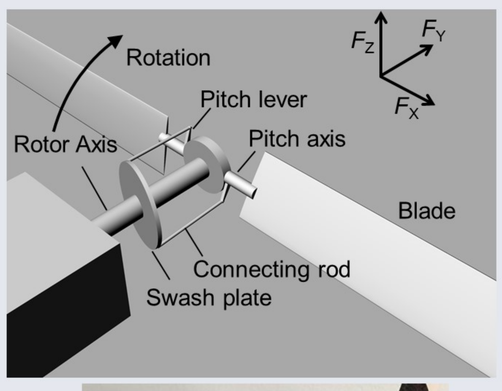
This study deals the possibility of thrust control to obtain the dynamic stability of floating offshore wind turbines. In this study, the rotor thrust was controlled by cyclic pitch control. The idea of apply cyclic pitch control system to the wind turbine was supposed to decrease load of wind turbine. This study shows the aerodynamic characteristics of the wind turbine's rotor which operated in cyclic pitch control by a wind tunnel testing.

Methods

In this experiment two kinds of pitch controls were tested. One is a collective pitch control and the other is a cyclic pitch control. The collective pitch control sets the blade pitch angle independent from for azimuthal position. The cyclic pitch control sets the blade pitch angle dependent on blade azimuth.

Fig.1 shows the rotor hub and support mechanism. The blade pitch angle is set by a pitch lever connected to swash plate. If the swash plate stays perpendicular to rotational axis, the blade pitch is collective. If the swash plate inclines to rotational axis, the blade pitch angle is cyclic. The model wind turbine support have free yaw and tilt mechanism. For the balance measurement, the free yaw and tilt support are fixed.

Fig.2 shows experimental apparatus. The experiment is performed in an open-jet type wind tunnel with outlet diameter of 1.67m. A two-bladed horizontal axis downwind turbine with diameter of 0.7m is set in the test section. Test blade is no tapered and no twisted blade. The blade chord length is 32.4mm. The thickness of airfoil section is 14 percent. To detect the aerodynamic forces on the rotor, a 6-components balance is mounted on the top of tower. The measurements are performed at fixed wind speed of 7 m/s. The rotor azimuth angle is defined as zero when target blade is vertically upward. The azimuth angle is positive in rotational direction. Fig.3 shows power performance test results. The results shows that the maximum power coefficient is 0.31 at pitch angle θ=4° and λ=8.3. This optimum condition is used as reference.



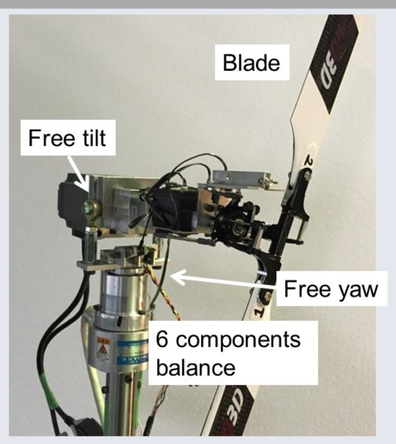


Figure 1 Rotor hub and support mechanism

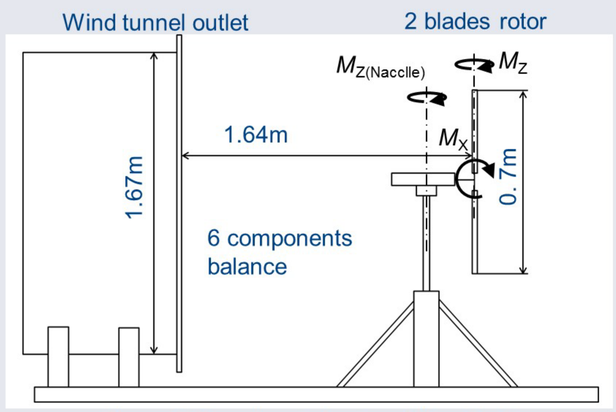


Figure 2 Experimental setup (side view)

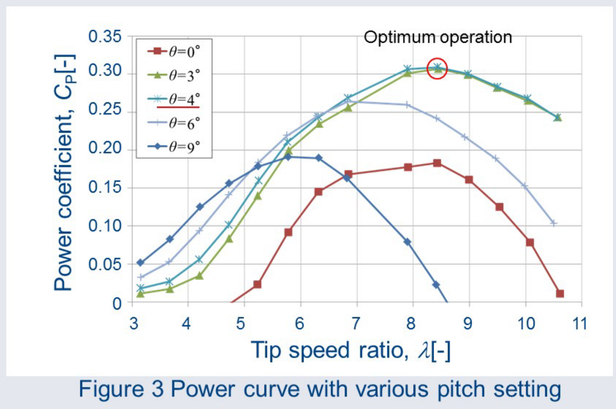


Figure 3 Power curve with various pitch setting

Results

1.Collective pitch for thrust control

Fig. 4 shows the thrust control test results with collective pitch. The free stream velocity is set at 7m/s and rotational speed of rotor is fixed at λ=8.3. As increase of pitch angle, the thrust coefficient decreases with almost linear function. The rotor thrust force can be controlled by collective pitch control. Power coefficient (Fig. 5) is maximum at pitch angle θ=4° and the power coefficient is gradually decreased, when pitch angle change from optimum.

2.Cyclic pitch for yaw moment control (ξ=135° , b=2°)

Fig. 6 shows relation between azimuth angle and pitch angle. Fig.7 shows the relation among tilt moment coefficient C_{MX}, yawing moment coefficient C_{MZ} and pitch amplitude. From the figure, C_{MX} decreases linearly as increase of pitch displacement. However, C_{MZ} shows stable. Therefore, the direction of moment can be arbitrarily controlled by using cyclic pitch control.

Fig. 8 shows relation among nacelle yaw, tilt and pitch displacement. The yaw angle decreases with increase of pitch amplitude. During yaw angle change by cyclic pitch control, the tilt angle does not change. Then, the cyclic pitch control with free yaw system enables the control of nacelle yaw.

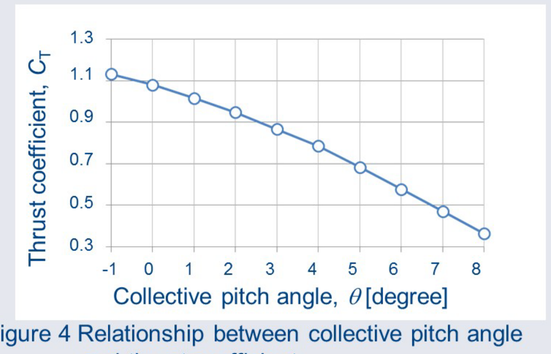


Figure 4 Relationship between collective pitch angle and thrust coefficient

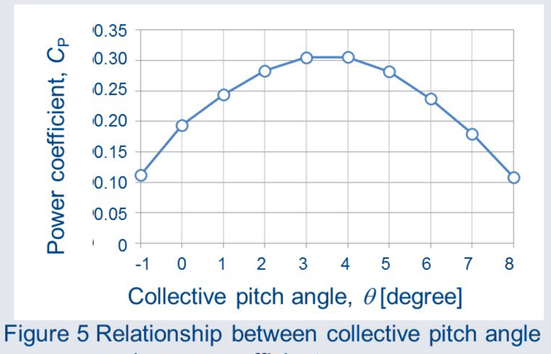


Figure 5 Relationship between collective pitch angle and power coefficient

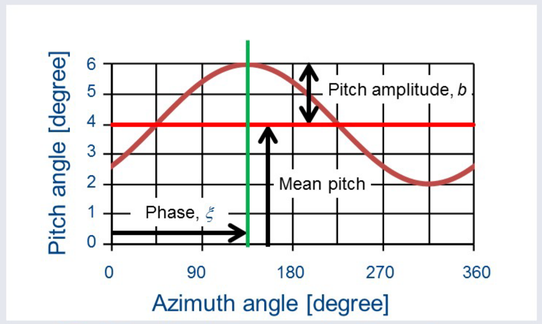


Figure 6 Relationship between azimuth angle and pitch angle

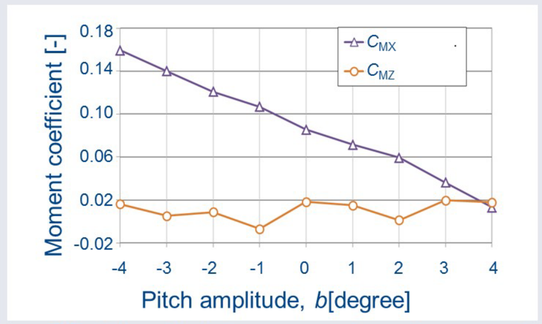


Figure 7 Relationship between aerodynamic moment and pitch amplitude

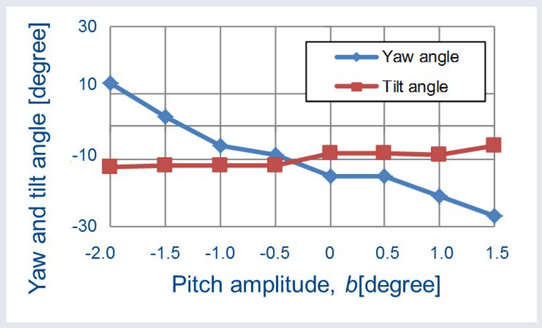


Figure 8 Relationship among Yaw, Tilt and Pitch amplitude with free yaw and tilt support

Conclusions

From the wind tunnel experiment, the rotor thrust can be controlled cyclic and collective pitches. The conclusions are shown below:

(1) Thrust force and wind turbine power can be controlled by collective pitch control.

(2)The direction and magnitude of rotor moment can be arbitrarily controlled by cyclic pitch control.

(3)With free yaw system, the cyclic pitch control enables to change yaw of nacelle.

References

1.Kohei IIDA, Yasunari KAMADA, Takao MAEDA, Junsuke MURATA, "Basic Study of the Horizontal axis Wind Turbine with the Cyclic Pitch Mechanism", Proceedings of Grand Renewable Energy 2014 International Conference