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The Design and Analysis of Passive Pitch Control for Horizontal Axis Wind Turbine

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Abstract

The purpose of this thesis is to design and analysis of passive pitch control. Design a mechanics to control different revolution of blade's pitch angle. The use of small wind turbines gradually popularization, but how to overcome the low wind speed start-up and the operation under high wind speed, that is the difficult problems encountered by designers. In order to extend the use and the safe of wind speed, this design is required. This paper is focus on the mechanism design of the passive pitch control for the small horizontal axis wind turbine (HAWT). When the wind speed is fast, the rotation speed is also faster and faster. The system uses centrifugal force to make Pulley disk driven the pitch angle of the blade. It can achieve the effect of passive pitch control. The mechanism is our laboratory's patent. Through the experiments in wind tunnel, it can be observed the variation of the performance curve when the pitch rotation. This system not only successfully operates under high wind speed but also has better performance at low wind speed.

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Keywords: Passive pitch control, Horizontal axis wind turbine (HAWT), Centrifugal force, Pulley disk;

1. Introduction

Wind energy is proving to be a promising energy source to complement conventional energy systems in meeting global energy demands, and is currently one of the fastest growing renewable energy sources. Since the dynamic characteristics of the wind is usually changing more than ten micro seconds. The wind turbine systems cannot respond in time. Pitch control can be divided into two categories. One is active pitch control, mainly used in large number of megawatt wind turbines; another is passive pitch control, mainly with small wind turbines. In the small wind turbine market, installing passive pitch mechanism is costly and not that widely used. But it is great value in academic research.

This paper is divided into three parts. The first part is the blade design and software development. The second part is the mechanical design of pitch control. The third part is the experiment in wind tunnel. Through the complete planning and experiments, that can verify the feasibility of the institutions and the

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system stability. The environment testing at outdoor is very important for wind turbine. But this paper focuses on the laboratory stage of development.

Nomenclature

R	radius of blade	λ	ratio of the blade tip speed
c	chord length	θ_p	angle of the blade for each section
Q	torque of blade	α	attack of angle

1.1. Blade design and software development

The flow chart is shown as Figure 1. The defined angles of 2D airfoil are shown in Figure 1 [1]. This paper integrates all the formulas to develop software by using graphical user interface (GUI) of matlab. Through the formula, the torque can be calculated at each wind speed and rpm. Figure 2 is the develop software. Input rated wind speed, rated power and power coefficient (Cp) can get the radius of the blade.

Through the BEM theory [2], the blade can get the parameter of the geometric. Substituting into the GUI can get the torque of the blade, as shown in Figure 2. The total torque on the section at a distance, r, from the center is:

$$dQ = B\frac{1}{2}\rho U_{rel}^2 \left(C_L \sin\varphi - C_D \cos\varphi\right) crdr \tag{1}$$

The SD8000 of the airfoil is used in this paper. Lift (C_L) and drag (C_D) are calculated by using XFOIL (software), which is an interactive program for the design and analysis of subsonic isolated airfoils. B is number of blades. U_{rel} is relative wind speed. It's worth noting that Equation (1) is an integral equation. It must be calculated by volume. This paper uses center of mass from each two section of blade geometric. Therefore, the parameters of the Figure 2 (a) and Figure 2(b) have a little different. The GUI of Figure 2 is the develop software in this paper. Enter the region of the wind speed, rpm and pitch control angle; it can observe the change of the performance curve. It can quickly and easily get the performance curve after calculation of the GUI.

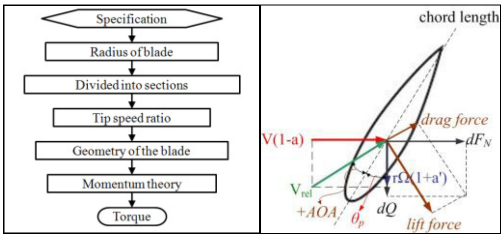

Fig. 1. (a) The flow chart of blade design; (b) Angles analysis on 2D airfoil [1].

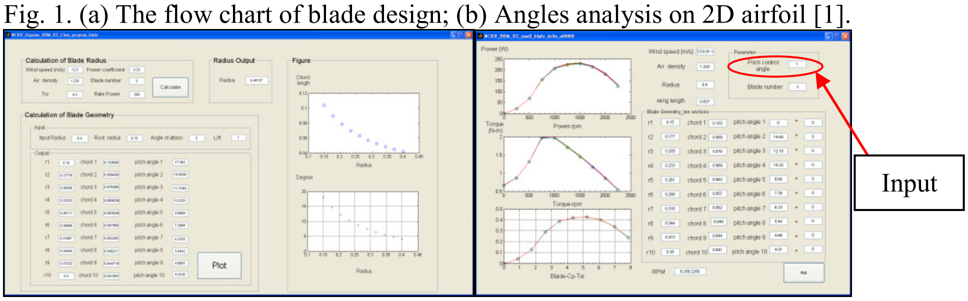

Fig. 2. (a) The blade geometry of GUI from matlab; (b) The blade torque of GUI from matlab

1.2. Mechanism design of pitch control

In order to make wind turbine blades' pitch angles, this paper uses the theory of the pulley disk when the system rotates at high wind speed. Using centrifugal force approach enables mechanism to drive the blade angle at high rotation. The mechanism design of the pitch control is shown in Figure 3. The linear bearing is used in positioning. The spring and weight of the roller are the most parameter in this mechanism, as shown in Figure 4. By adjusting the parameters, it can be set in any situation. The Figure 5 is the relation of the spring, weight of the roller and distance in experiment. Through the experiment, it can be found the relation of the spring, weight of the roller and distance, as shown in Figure 5.

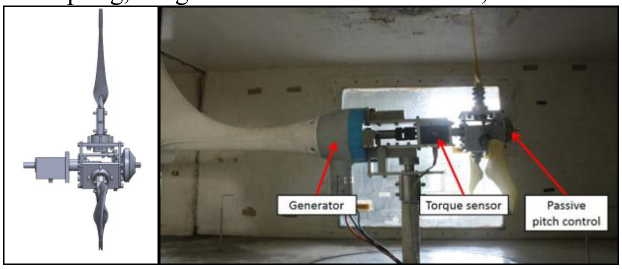

Fig. 3. (a) The mechanism design of pitch control; (b) The system of the wind turbine


Fig. 4. (a) The roller of the parameter; (b) The spring of the parameter

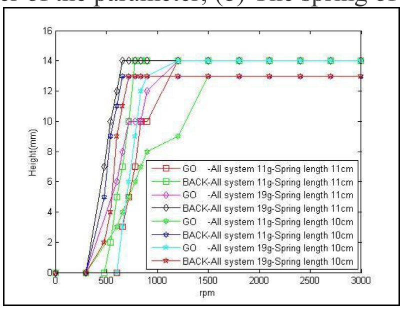

Fig. 5. The relation of the spring, weight of the roller and distance in this system

1.3. Experiment in wind tunnel

. The size of the wind tunnel is shown as Figure 6. From the data of the experiment, it can find the mechanism has successfully driven, as shown in Figure 7. Through the electronic load, it can measure the voltage, current and rpm. When the mechanism has driven, the system generated the stable power.

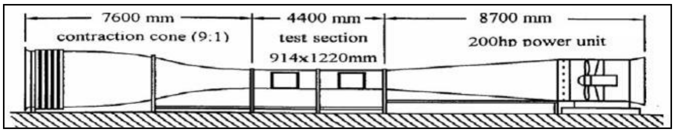

Fig. 6. The size of the wind tunnel

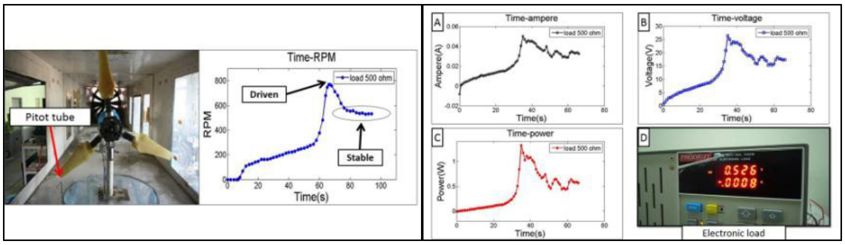

Fig. 7. The experiment in wind tunnel

1.4. Conclusions

Through the blade design and analysis process, that can significantly know the performance of the system when GUI inputs the pitch angle. Then the passive pitch control system has designed from this paper, it uses centrifugal force to drive the mechanism. It has been successfully completed testing in wind tunnel, and through the experimental parameters can be set at any wind speed. According to the needs of the system, it will be able to achieve the purpose of the stable power.

Acknowledgements

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