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Research of Aerodynamic Performance based on Wind Turbine Vibration Performance

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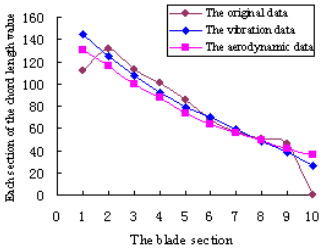

Abstract: **Wind turbines is one of the most important components of the wind turbine, design for wind turbines with good wind turbines is the basis of high wind energy utilization coefficient and large economic benefits. Using the theory of Wilson pneumatic designed 100 W horizontal axis wind turbine, in the process of design and design parameters on the vibration performance correction. Finally on rotor vibration modal experiment and pneumatic external characteristic experiment, the experimental results show that the design of the wind turbine at low wind speed can meet the design of the wind energy utilization coefficient, and the wind machine to avoid the resonance region speed at run time, extend the life of the rotor, so as to reduce the design cost.**

Keywords: Wind turbine; Design; The aerodynamic performance; Vibration performance

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1. Introduction

Blade is the most complex stress in wind turbine components. It constantly rotating, all sorts of exciting force are almost conveyed through leaves. Or are considering wind field under the premise of the probability distribution of wind speed, with the goal of maximizing the wind turbine in energy output of the optimization design and so on [1-2]. Now only consider aerodynamic blade design technology has been more mature. But wind turbines work in complex atmospheric environment, the frequent faults. People and through to the existing is used to identify the modal parameters of the blade to find the cause of blade fracture and puts forward improving methods. In this regard, the United States since the 1980 s, and USES the many kinds of methods to study the structure of the wind turbine experimental methods [3]. Shantou University in China, Shenyang University of technology and so on also USES the experimental method of the modal experiment and the single blade got a single blade natural frequency and modal vibration mode.

2. The Blade Design

2.1. Wind Turbine Blade Aerodynamic Design

(1) The basic performance parameters of the leaf

Rated power: 100 w; The rated wind speed: 8 m/s; The rated speed: n = 620 r/min; Starting wind speed: 3.4 m/s; Leaf number: B=3; Electrical and mechanical efficiency: 80%; wind energy utilization coefficient:

$C_P = 0.35$

(2) Calculate the rotor diameter D

$$P = 0.5\rho V_1^3 \pi (D^2/4) C_P \eta_1 \eta_2 \qquad (1)$$

The diameter of the rotor can be obtained D =1.2m.

(3) The tip speed ratio λ_0

$$\lambda_0 = \omega R / V_\infty \qquad (2)$$

Can calculate the tip speed ratio wind turbine was $\lambda_0 = 4.87$.

Using the gradient estimation, here leads out the weight vector of LMS algorithm:

$$w(n+1) = w(n) - \frac{1}{2}\mu \hat{g}(n) = w(n) + \mu e(n) u(n) \quad (3)$$

Choose $w(0)$ given the prior knowledge of tap weight vector, otherwise set $w(0)$ zero.

The constraint condition is:

$$w^T(n+1)u(n) = d(n) \qquad (4)$$

The updated increment of the tap vector under this constraint condition is:

$$\delta w(n+1) = w(n+1) - w(n) \qquad (5)$$

Using the Lagrange multiplier method, we get a updated form of the weight vector of the normalized least mean square (NLMS) Algorithm:

$$w(n+1) = w(n) + \frac{1}{\|u(n)\|^2} u(n) e(n) \qquad (6)$$

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To control the increment of the tap weight vector not changing the direction of the vector, we introduce a positive divisor, then:

$$w(n+1)=w(n)+\frac{\bar{\mu}}{\|u(n)\|^2}u(n)e(n) \quad (7)$$

Table 1 Blades of geometric parameters distribution

No	r(mm)	λ	C_P	a	b	BCC_L/r	C	θ
1	105	0.85	0.0035	0.3210	0.5968	4.3086	145	18.5
2	160	1.29	0.0192	0.3338	0.2007	2.4375	125	14.2
3	215	1.75	0.0476	0.3375	0.0974	1.5527	107	11.5
4	270	2.19	0.0882	0.3391	0.0568	1.0631	92	9.5
5	325	2.64	0.1405	0.3408	0.0371	0.7584	79	7.6
6	380	3.09	0.2038	0.3437	0.0263	0.5747	70	5.9
7	435	3.53	0.2765	0.3493	0.0197	0.4232	59	4.2
8	490	3.98	0.3238	0.3617	0.0158	0.3056	48	2.6
9	545	4.42	0.3342	0.3953	0.0140	0.2175	38	1.4
10	600	4.87	0.3500	0.0303	0.0013	0.1352	26	0.5

In order to overcome the problem when the input vector u(n) is smaller, we introduce a tiny constant $\delta > 0$, we correct the formula above as:

$$w(n+1)=w(n)+\frac{\bar{\mu}}{\delta+\|u(n)\|^2}u(n)e(n)$$

(8)

The revised by the MATLAB language programming calculation, blade of basic parameters is shown in Table 1.

2.2 Based on the Vibration Performance Optimization Design Parameters

Revised figure as shown below:

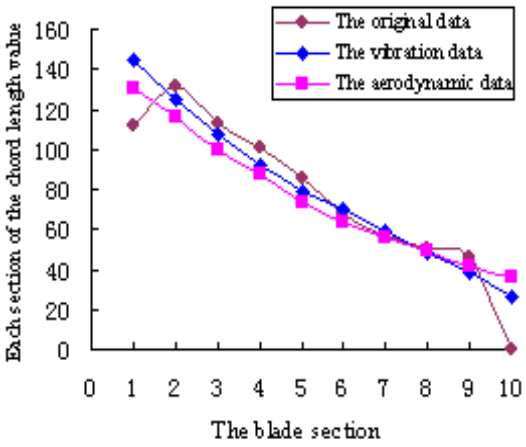

Figure 1. The figure of chord modify

3. Experimental Study

3.1. Rotor Modal Parameters of the Experimental Study

Arrangement of measuring points is shown in Figure 1, test flow chart is shown in Figure 2.

3.2. Rotor Aerodynamic External Characteristic Experiment

Formula is as follows:

Wind turbine speed $n = 60 f / P$

The tip speed ratio $\lambda = \omega R / V_1$

F - alternating current frequency, HZ; P - generator logarithm, the generator is 4 to experiment.

This experiment used experimental apparatus is shown in Table 2.

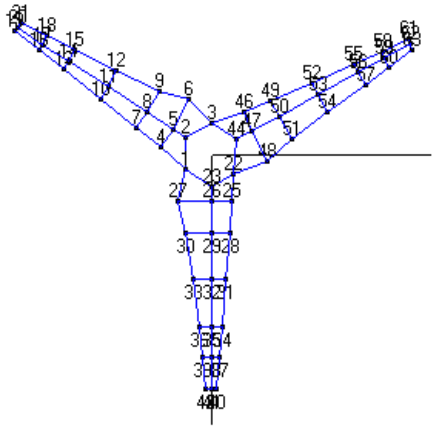

Figure 2. The shape of wind turbine

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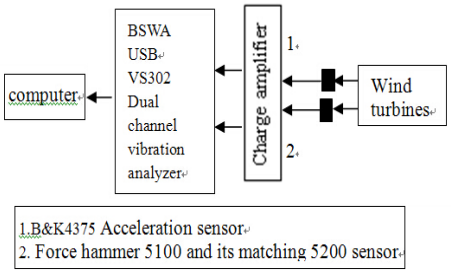


Figure 3. The flow chart of modal test system

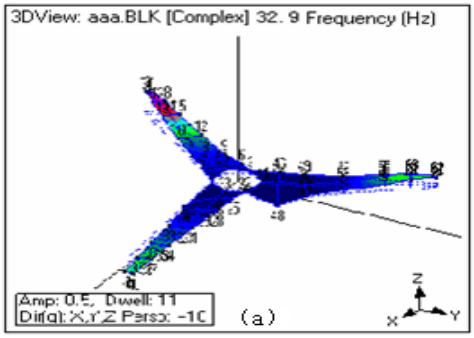
4. The Test Result

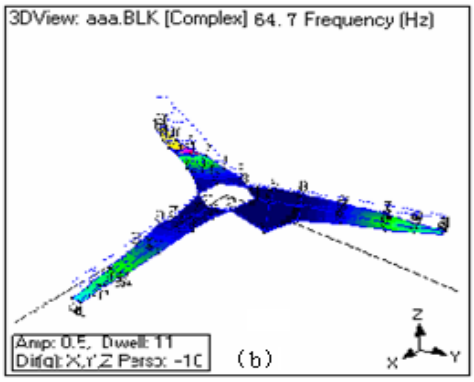
4.1. The Vibration Performance Test Results

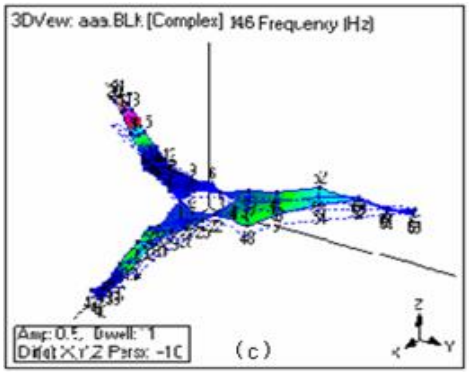
Can be seen from the mode diagram each order modal and node distribution is reasonable. Within the scope of the 2 HZ to 400 HZ, the impeller a total of four order modal, the measured result is shown in Figure 3, vibration mode as shown in Figure 4.

Table 2 Experimental apparatus

The main parameters in wind tunnel			slide rheostat		dc ammeter		voltmeter		oscilloscope		
type	Exit no	Silent period	Maximum range	conductor	precision	Maximum range	precision	Maximum range	type	Scale range	Image resolution
B1/K2	D=2.04m V=17m/s	0.9m	440Ω	some	0.5	5/10A	0.5 level	75/150V	PY2000	0.005-20KHz	10-5Hz







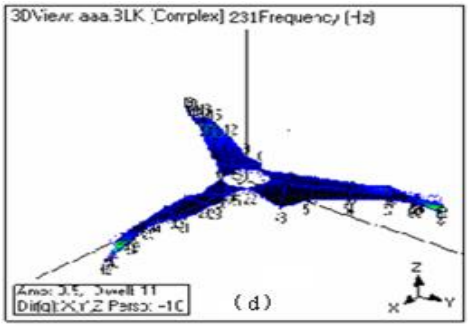


Figure 4. Mode shape of 3-blade turbine

4.2. The Pneumatic Performance Experimental Results

The test results and analysis are as follows:
Test results as follows Figure 5:

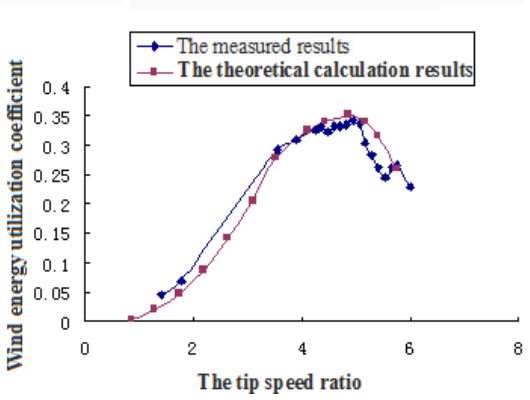


Figure 5. Compares the measured value with the theoretical value of coefficient of power under the rated wind speed

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The maximum error is 17%. To analyze the causes of error that may be caused by the following two parts:

(1) Due to in the process of manufacturing blade, to facilitate the processing and manufacturing made some correction, that there is a deviation value and actual value of the blade design.

(2) Because of the wind turbine in the process of running condition is not very stable, so the reading range is big.

5. Conclusion

(1) Design wind turbine impeller into account both vibration characteristics and aerodynamic characteristics will help wind turbine can work more smoothly.

(2) This experiment studies the wave vibration modes of the blade, for the rotation of the vibration here not to discuss. At the same time the experiment for the future analysis of the vibration of the rotating rotor is laid a strong foundation.

(3) From the aspects of rotor aerodynamic characteristics of the experimental studies find that small wind energy utilization coefficient of wind turbine are relatively low, this experiment found that the maximum wind energy utilization coefficient of the wind turbines only can reach 0.34, but the theory of basic can meet the design requirements.

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