Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 13 (6): 944-947, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.944.947

Experimental Research for MW Wind Turbine Blade

[1]Fu Jie, [1]Song Lin-Hui, [1]He Bin and [1,2]Fan Qin-Shan
[1]Division of Mechanics, Nanjing University of Technology, Nanjing, China
[2]School of Aerospace, Tsinghua University, Beijing 100084, China

Abstract: The objective of this study was get acquiring dependable results of MW wind turbine blade performance at work condition to design new-style blade. Most of the research study on structural analysis of wind turbine blade by make model test and use the finite element, but there were certain differences from real MW wind turbine blade. Therefore full-scale experiments were employed in the research, the strains, stresses and displacements of all parts were gained. The test results shown that the stress distribution was different at every direction and work condition and 12~18 m of the blade is the dangerous area.

Key words: Wind turbine blade, full-scale experimental, stress distribution, strip theory

INTRODUCTION

Wind power is an important component of renewable energy, It will to bear the burden of energy saving and emission reduction and optimization energy structure. Grid-connected wind turbine is developing rapidly in our country. The most basic components of the wind turbine is blade, the good design, reliable quality and superior performance of the blade is the keypoint of the normal and stable operation. This year China is on track to pass the United States as the world's largest market for wind turbines,but the design techniques also rely on foreign sources (BP Group, 2012).

In practical working conditions, the wind flow past wind turbine blade with wind shear and instantaneous changes (Burton *et al*., 2001). By this the load of blade is ever-changing also. For safety, all factors were considered at loads calculate include wind shear, centrifugal force, pitch control delay (Lesihman, 2002; Jie *et al*., 2011). The variation features of blade loads were discussed based on strip theory. The effects of gravity, wind shear and pitch control delaying were analyzed. A method of the equivalent coefficient for wind rotor loads considered turbine practical efficiency was present. The results showed the calculation precision was high enough to meet the demand of project design.

The objective of this study is having a detailed understanding of turbine blade state of stress and strain. The load is firstly calculated by a method proposed by authors, then get the information by full-scale blade experiment.

MODEL OF LOAD CALCULATION

Strip theory: Strip theory starts with the four equations derived from momentum and blade element theories. In this analysis, it is assumed that the chord and twist distributions of the blade are known. The angle of attack is not known, but additional relationships can be used to solve for the angle of attack and performance of the blade. The forces and moments derived from momentum theory and blade element theory must be equal. Equating these, one can derive the flow conditions for a turbine design (Jonkman and Butterfield, 2009; Spera, 2009).

From axial momentum:

$$dT = 4\pi\rho r U_\infty (1\text{-}a)a\ dR$$

From angular momentum:

$$dM = 4\pi\rho r^3 U_\infty (1\text{-}a)a\ dR$$

From blade element theory:

$$\begin{cases} dF_N = \frac{1}{2}B\rho W^2 (C_l \cos\phi + C_d \sin\phi)cdr \\ dM = \frac{1}{2}\rho W^2 (C_l \sin\phi - C_d \cos\phi)crdr \end{cases}$$

where, the thrust, dT, is the same force as the normal force, dF_N. Thus, equation from blade element theory can be written as:

$$dF_N = \frac{B}{2\pi}\left(\frac{c}{r}\right)\frac{U^2(1-a)^2}{\sin^2\varphi}(C_l \cos\varphi + C_d \sin\phi)rdr$$

$$dM = \frac{B}{2\pi}\left(\frac{c}{r}\right)\frac{U^2(1-a)^2}{\sin^2\varphi}(C_l \sin\varphi + C_d \sin\phi)r^2dr$$

Corresponding Author: Fu Jie, Division of Mechanics, Nanjing University of Technology, Nanjing, China

The force of blade at different wind speed can be calculate by this theory. On the other hand, combine with the equivalent coefficient method, we determine the scheme of loading at the test (Jie *et al*., 2013).

FULL-SCALE BLADE TEST

Loading modes: In the test, there are five loading point, 15 m (F1), 21 m (F2), 25.5 m (F3), 30 m (F4) and 34.4 m (F5) distance from blade root. Direction of loading is Flap edge of the blade. The method of loading is multi-stage loading from 30, 60, 80, 100, 106 and 110% of limit load. Figure 1 depicts the distribution of loading point.

Figure 2 is the photo of experimental field. In the photo, the tested equipment is full-scale wind turbine blade. The total length of blade is 37.5 m, the power of turbine is 1.5 MW.

Location of detecting: In order to effectively observation the blade structural behavior with loading, chose 22 point to set up observation point at five different sections (0.8, 12, 23, 28 and 32 m). The specific situation see Fig. 3.

Test result

Tsection's strain of wielding positive under different loads: When the load is up to 110%, the strain diagram of the position measuring point on the both sides of the main beam of three directions (-45, 0, +45°) is as follows.

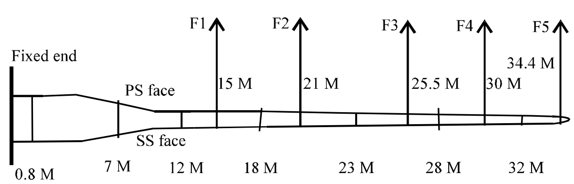

Fig. 1: Sketch of loading point

It can be obviously observed from the Fig. 4 and 5 that the strain of the blade under the condition of wielding forward in the direction of a 0° angle (along the direction of main beam) is larger. Due to the change in angle of the ply, the strain of other two directions is relatively slightly smaller. On the whole, we can find that SS surface is under tension strain and PS surface is under compressive strain when leaves waving the positive.

Test section's principal strain of wielding positive under different loads: The principal strain of each measuring point on main beam SS surface under load at all level is shown in Fig. 6.

It can be shown in Fig. 6 the SS surface's main strain of the main beam on the blade under the condition of wielding positive concentrate on the place at the range of 7 and 28 M. In the place of 7 M, the pressure strain at maximum is - 3163.80 $\mu\varepsilon$ when the tensile strain at maximum is 3359.51 $\mu\varepsilon$ at 18 M. The strain of two places

Fig. 2: Photo of experimental field

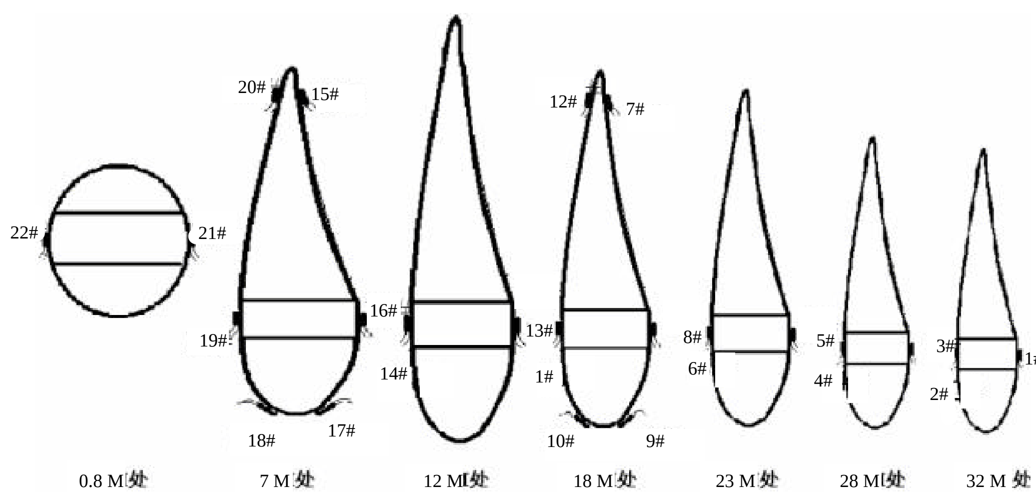

Fig. 3: Sketch of observation position

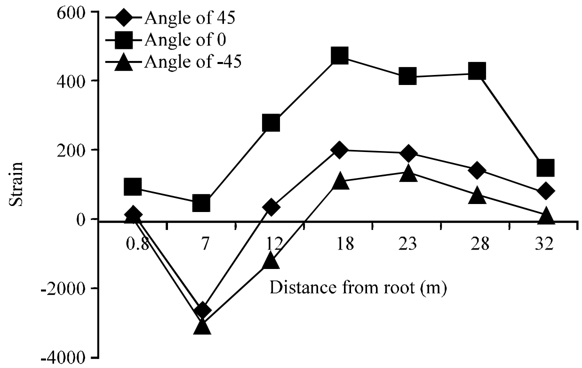

Fig. 4: Strain distribute of blade's SS surface at full loading

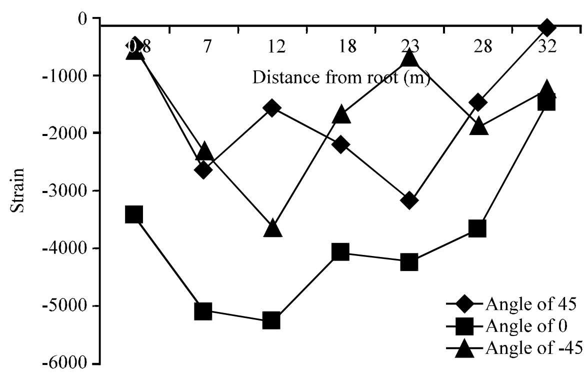

Fig. 5: Strain distribute of blade's PS surface at full loading

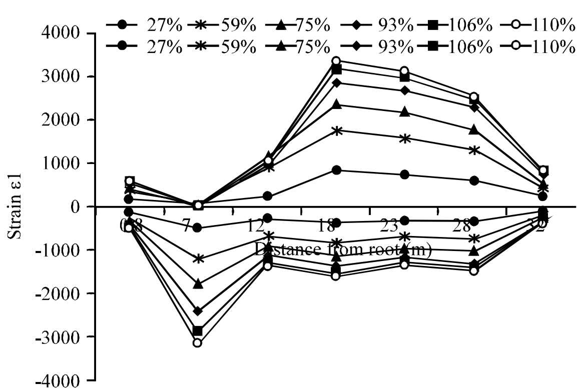

Fig. 6: Main strains of blade's SS surface at different loading

grows linearly. It is mean that the increase ratio of strain and the reapportion of growth under the external load are basically the same. It shows that all test points of the SS surface are within the range of linear elastic.

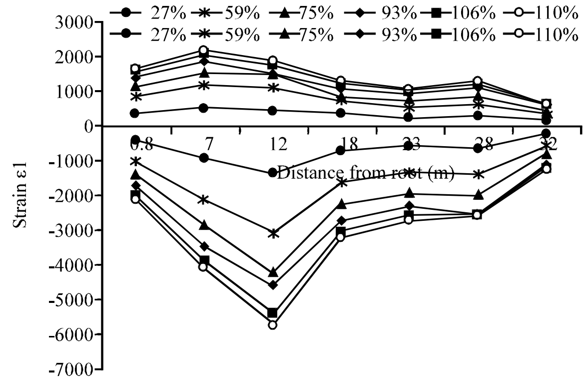

Fig. 7: Main strains of blade's PS surface at different loading

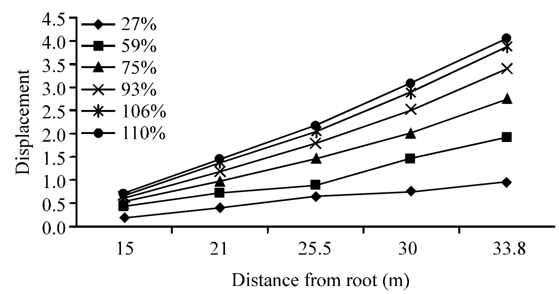

Fig. 8: Blade displacements at different loads

All measuring points' principal strain of the main beam's PS surface at all levels of load is shown in Fig. 7.

It can be shown in Fig. 7 that PS surface's strain of the main beam concentrate on the place at the range of 7 and 28 M when leaves is on the static load experiment of wielding positive. Among them, the compressive strain at maximum is -5737.35με at 12 M and the tensile strain at maximum is 2169.80με at 7 M. And the strain at 12 M increases linearly. Due to Leaves are shell structure, when leaf surface appeared buckling phenomenon in the previous experiments, so the leading edge of blade section and the trailing edge of the two test interface (at 7 and at 18 M) of the blade section of larger are also monitored on this test.

All load points' displacement under different loads of Waving positive.

All load sections when leaves is in waving a positive conditions appear the phenomenon which the displacement of the leaves' roots is smaller and the end is larger. Based on field observations and the actual measurement, it can be known that the displacement of all sections is nearly linear, shown on Fig. 8. The displacement at maximum at the end of blade is 4.03 M when the section of 33.8 M is at full load.

CONCLUSION

This study examined the importance of load on structure damage. This experiment which loads be applied include different value and distance. It can draw conclusions based on the calculation and analysis of the experimental data:

- The strain of the blade under the condition of wielding forward in the direction of a 0° angle is larger than the direction of a 45° angle. The strain is smaller at the range of 0 M (root) and 7 M. It increased at the range of 7 and 28 M. And then it gradually return to the smaller. On the whole, we can find that SS surface is under tension strain and PS surface is under compressive strain when leaves waving the positive
- The SS surface's strain of the main beam on the blade under the condition of wielding positive at the range of 0 and 12 M is mainly compressive strain and the pressure strain at maximum is -3163.80με at 7 M, when the strain at the range of 12 and 32 M is mainly tensile strain and the tensile strain at maximum is 3359.51 με at 18 M
- The PS surface's strain of the main beam on the blade under the condition of wielding positive is mainly compressive strain as a whole. The strain at the range of 0.8 and 12 M gradually increases and the strain at maximum is - 5737.35με at 12 M when the strain at the range of 12 and 32 M gradually decreases and the strain return to minimum is -1249.62με at 32 M
- All load sections when leaves is in waving a positive conditions appear that its displacement gradually increases from the root to the tip. The displacement at maximum is 4.03 at 33.8 M

REFERENCES

BP Group, 2012. BP statistical review of world energy. BP Group, London.

Burton, T.S., N. Jenkins and E. Bossanyi, 2001. Wind Energy Handbook. Wiley, New Jersey, USA.

Jie, F., H. Bin and A. Yi, 2013. Research on calculation method for equivalent coefficient of rotor wind load. Renew. Energy Resourc., 31: 19-23.

Jie, F., Z. Hui-ling, H. Bin and F. Qin-shan, 2011. The effect of wind shear and pitch control delaying on wind turbine blade loading. Proceedings of the International Conference on Electric Information and Control Engineering (ICEICE), April 15-17, 2011, Wuhan, pp: 5485-5489.

Jonkman, J., S. Butterfield, 2009. Musial Definition of a 5-MW Reference Wind Turbine for Offshore System Development. Golden Colorado, NREL.

Lesihman, J.G., 2002. Challenges in modeling the unsteady aerodynamics of wind turbines. Wind Energy, 5: 85-132.

Spera, D.A., 2009. Wind Turbine Technology Fundamental Concepts of Wind Turbine Engineering. 2nd Edn., ASME, New York.