

An Accurate Three-Dimensional Deformation Measurement Method in Wind Turbine Blade Static Loading Test

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Abstract

The accurate deflection measurement of wind turbine blade is one of the key step in its full-scale static loading test. In order to measure the blade deflection accurately in the threedimensional space, an effective spatial displacement measurement mathematical model has been established on the basis of geometric transformation method. At the same time, the finite element method is used to calculate the change of the blade deflection under the static loading force. Based on the above three-dimensional deflection measurement model, corresponding data measurement system was development. In the end, the three-dimensional measurement method was applied to wind turbine blade static test for blade tip measurement. The test results show that the maximum error rate of the three directions is only 4.1

Index terms— measurement methods; mathematical model; three-dimensional deformation; wind turbine blade; static loading test

1 Introduction

he wind power industry is becoming a focus of the national new energy industry. The blade as one of the core components of the wind turbine, its quality determines the healthy development of wind power industry. Due to the blade not only to withstand strong wind load, but also to bear the impact of sand and gravel, ultraviolet radiation and other external erosion in the process of work (Chen et al., 2014; Kong et al., 2005; Lee et al., 2015; ??hi et al., 2011; Liu et al., 2013), coupled with wind power accidents occurred in recent years, so the wind vane full-size structure detection has become very important in the areas of research. The static test is the most important part of the blade certification in order to verify whether the blade is under ultimate load (such as 50 a worst hurricane). According to the third party authority Certification body Germany GL (Germanischer Lloyd) classification of the Guideline for the Certification of Wind Turbine (Germanischer Lloyd, 2003) and IEC61400-23 Full -scale Structural Testing of Wind Turbine Blades Testing standard, static load evaluation is the essential link of blade structure performance Testing. For the new development or process to make major changes in the leaves, is required to do a full-size static loading test, which the purpose is to verify the static strength of the blade. However, field tests show that the coupling force is stored between the loading force during the static test, loading force of any node changes, resulting in irregular fluctuations in the loading force of other nodes, resulting in the uncoordinated and uniform change between the loading forces. Resulting in serious distortion of the test data, so the coordinated control between the loading force becomes very important. Deflection measurement is a key parameter that must be collected during the static loading test. It is an important theoretical basis for checking whether the blade structure design is qualified. Most domestic and foreign scholars focus on testing control methods and equipment development, that is, how to improve the loading precision and made no mention of the blade deflection measurement. The adaptive sliding mode control algorithm is proposed in the literature (Benitro and Hedrick, 2009), which is applied to the three axis swing table control system, and a better control effect is obtained. The distributed control method is proposed in ??Hua et al., 2010), and the feasibility of the method is proved by the theoretical analysis and experimental results. Currently in the process of static testing, only one rope sensor / laser rangefinder is usually used to realize single direction deflection measurement. For example, the full scale static test of large-scale wind turbine blade is only in a single direction of the deflection

According to the above measurement scheme, this paper developed a space trajectory measurement system based on the mathematical model which is constructed above. The system consists of three pull rope type displacement sensors (Range: 0-30m, 4-20mA current output) and PLC analog acquisition module, the monitoring interface using software (MCGS) to configure. The pull rope type displacement sensor will transmit the analog signal to the PLC controller. The control system will get the precise deflection value after the mathematical operation, and will be transmitted to the man-machine interface through the RS485 Bus, which is shown in Fig. ???. Take the blade tip as an example, the test site is shown in Fig. ??. Three pull rope type displacement sensors were fixed on the ground, and the active ends of the three ropes were connected to the tip of blade. Test parameters were shown in Table In the process of static loading, the blade produces irregular space torsion, and all of them have deformation in three directions. Under the action of the above static load, the deflection measurement of the four stages in the static test of the blade is carried out respectively. The test results are shown in Fig. 7 From Fig. 7, it can be found that the blade has deflection in three directions. With the increase of loading load, the trend is increasing. By comparing the results of the finite element calculation with the test, the error of three directions is only 4.1%, 3.8% and 4.3%, which verifies the accuracy of the mathematical model.

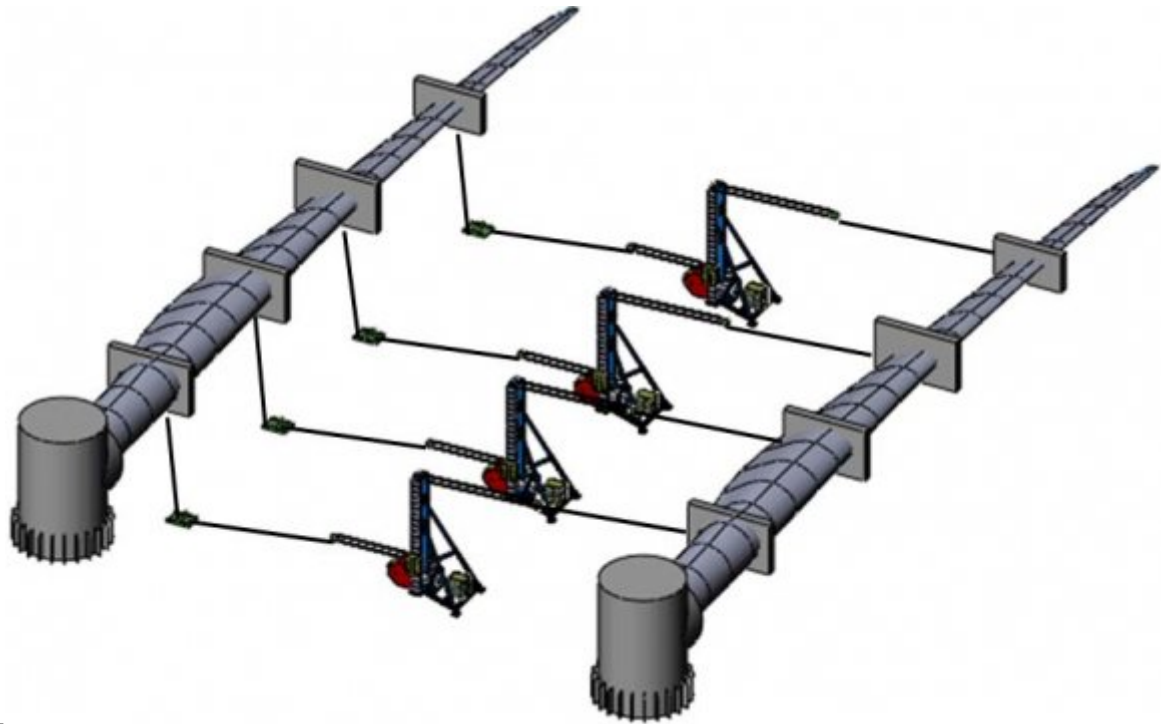
6 V.

7 Conclusion

There are complex nonlinear and strong coupling characteristics under the wind turbine blade full-scale static test. The deflection is used as a key parameter to check whether the blade is qualified. At present, the measurement of its deflection is usually done with a rope sensor or laser range finder, this traditional method is not only poor precision, but also get the deflection change of a single direction. In this paper, a precise mathematical model of the threedimensional deflection of the blade is developed, and then the experimental verification is carried out, and the following conclusions are obtained.

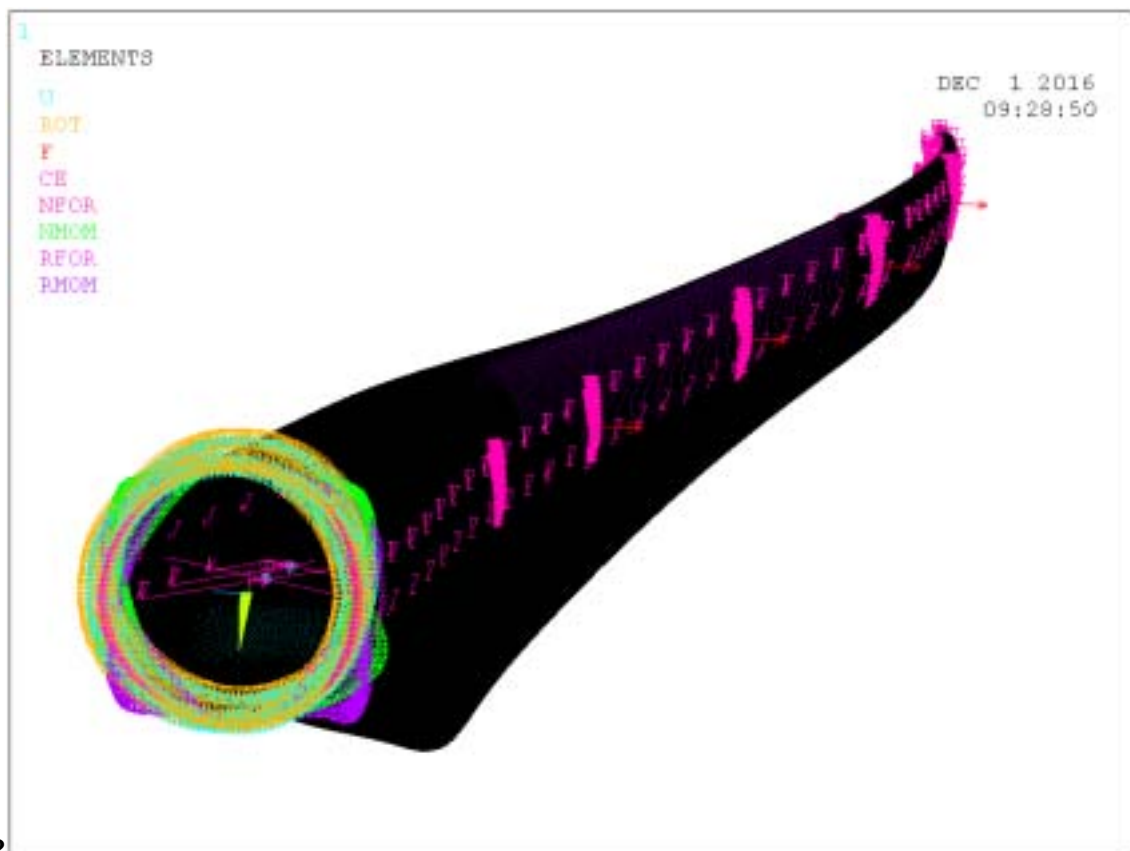
1. Using three pull rope type displacement sensors and spatial geometric transformation method, a mathematical model of precision spatial deflection is deduced, which can calculate the accurate deflection change in three directions at the same time.
2. Based on the mathematical model, a set of spatial deflection measurement system was developed. The blade tip change which in a certain type of wind turbine blade static test as a testing object, and the tip system was measured by the measuring system. The results show that the system can track the spatial trajectory of the blade tip, and the data acquisition result is stable and accurate. In addition, since the rope sensor has been stretched during the test, it does not produce severe jitter and improves the stability of the test results.
3. The mathematical model and system can not only measure the irregular torsion caused by the static test of wind power blade, but also apply to the space deformation measurement of irregular parts such as cantilever beam, which has extremely wide application prospect of engineering application.

It was successfully applied to the full-scale static test of four nodes wind turbine blade. The above research results can provide a solid theoretical basis and detailed experimental data for the next step of blade re-design, which has great engineering application value.



1

Figure 1: Fig. 1 .



2

Figure 2: Fig. 2 :

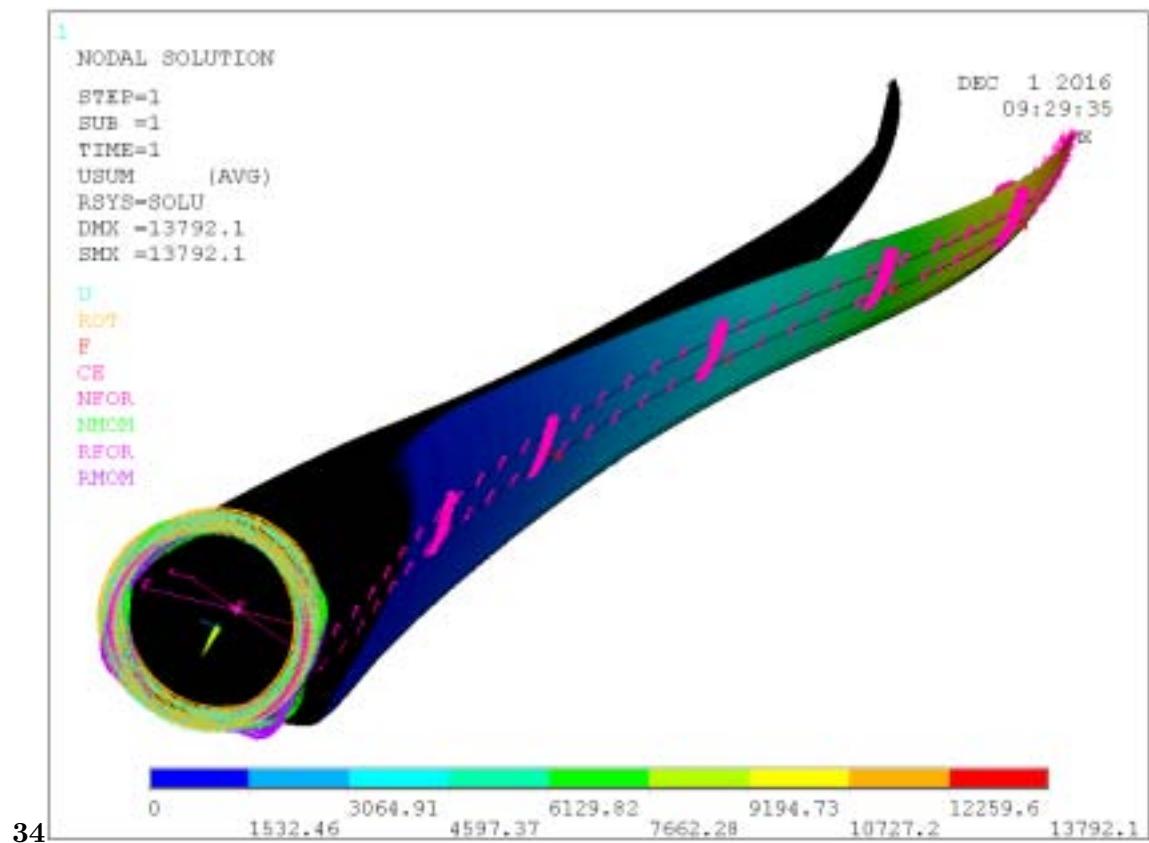


Figure 3: Fig. 3 :Fig. 4 :

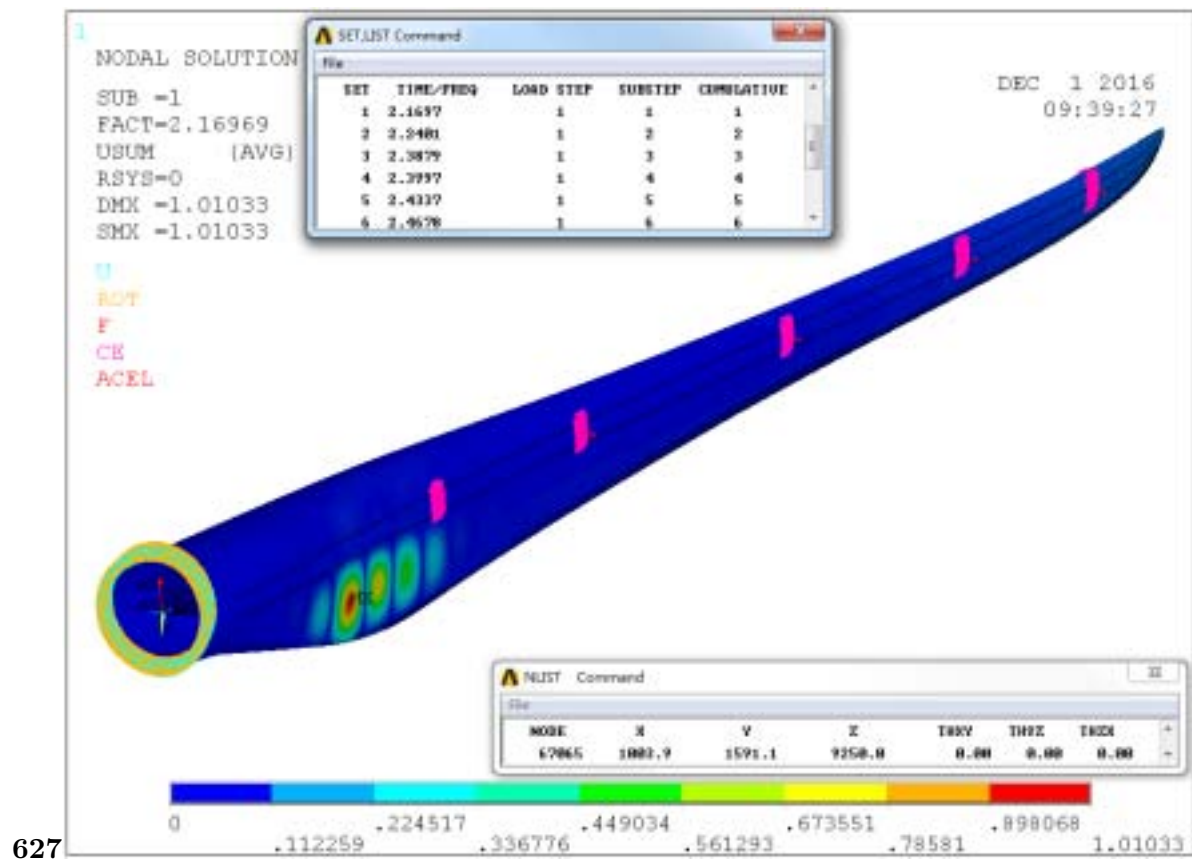


Figure 4: Step 6 : 2 dStep 7 :)



Figure 5:



Figure 6: 3 .IFig. 5 :Fig. 6 :

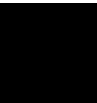


Figure 7:



Figure 8: Fig. 7 :

1

Load Step	13.0m	24.0m	33.0m	46.0m
40% up/KN	37.85	39.07	27.34	53.09
60% up/KN	56.78	58.24	40.42	79.98
80% up/KN	75.71	78.13	52.78	106.87
100%/KN	94.63	97.60	67.76	134.47

Figure 9: Table 1 :

2

Location	28m	42m	57m
x direction/m	0.258	1.015	5.045
y direction/m	0.143	0.305	1.256
z direction/m	2.431	6.045	17.032
III. Three-Dimensional Measurement			
Mathematical Model			

Figure 10: Table 2 :

3

Parameter	Value
Blade rated power /MW	2.5
Blade length/m	57
Number of loading nodes/ea	4
Tension sensor model	DBSL- 25T
Maximum capacity of loading nodes/KN	250
Room temperature/?	29
Humidity/RH	56
b) Result analysis	

Figure 11: Table 3 :

.1 Acknowledgments

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