Study on the points and countermeasures of quality control in the wind turbine blades

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Abstract. There are many problems in the technological development, research investment, staff ability and industrialized level of domestic wind turbine blade. This review summarizes the quality situation of wind turbine blade in the production process and proposes some advices and solutions in the further development of domestic wind turbine blade.

1. Introduction

Wind energy, as an important renewable source of energy, possesses many properties such as wide distribution, hug reserve, non-pollution, reproducible utilization and so on. There is abundant land and sea wind energy in China which is very promising for the development of renewable power generation industry [1]. The effective utilization of wind energy also has promoted the progress of wind power industry. Wind turbine blade is an important component of wind power generation, and has been formed a complete industrial chain for the technology development to production. However, there are still many problems in the wind turbine blade due to the short technology development time, frequent replace of new turbine blade and faulty technology which limit the application of wind turbine blade. Therefore, the quality of wind turbine blade still is the key point of wind power generation in China.

Based on the current development situation and model, the review has analyzed the problems of quality control of wind turbine blade and proposed the effective measures to improve the quality control of wind turbine blade.

2. Manufacturing process of wind turbine blade

Wind turbine blade as shown in figure 1 is a composite with thin-shell structure which consists of blade root, shell and reinforcing rib/crossbeam. To meet the requirement of light weight, even mass, precise size, long-term running quality and reliable performance for wind turbine blade, the forming process needs to be controlled perfectly and effectively. The forming process of epoxy blade mainly includes vacuum perfusion and hand paste making. Considering the cost, reliability and efficiency, the universal production method of blade is vacuum filling process which not only improves the production efficiency but also reduces the cost. Moreover, the defective index of vacuum filling process is far less than that of hand lay-up process [2]. There are many advantages for vacuum filling process such as simple process, less human factors, environmental protection, high production rate, even gel content, low cost and good stability. The production processes of wind turbine blade consist of Material preparation, layup, perfusion curing, mold closing, grinding, repairing and paint spraying. All the processes are close-knit and rigorous. In addition, resin infusion, curing and mold closing process are irreversible with difficult rework process. Once the process quality control of wind turbine...
blade is not in place, the consequences are very serious with quality hidden danger or rejected product which will lead to the waste of resources and funds.

![Figure 1. Structure of Wind turbine blade.](image)

3. Controlling situation of wind turbine blade
Wind turbine blade has experienced resource conformity, thus the technical input and new product development are relatively mature. However, there are still many quality problems due to the incomplete technology transfer and poor process planning.

3.1. Improvable key technology
Recently, the development of domestic wind turbine blade is improved greatly, and the technological development has been changed from foreign imports to self-dependent innovation. However, there is still great gap between the domestic and foreign technology. For example, the domestic patents are mainly about the technical improvement and less about the key technologies such as design, framework and monitoring [3]. Although the domestic companies have invested greatly in the structural design of wind turbine blade and exploit of new blade, they still could not design the blade profile independently. In addition, no breakthrough has been made whether in cooperating with the foreign companies or adjusting the imported blade. The deficiency of aerodynamic profile design and key technology has led the lack the quality risk of blade by designer [4]. When there is defect in the product quality, it is very difficult to assess the defect. Most companies usually assess it through the design margin by software design. Currently, the running new wind turbine blade has not received effective test and some companies has not carried out the wind tunnel experiment which has led to the incomplete evaluation of wind turbine blade. Thus, there is still no supporting data to evaluate that whether the wind turbine blade is safe or not under the real conditions.

Due to the deficiency of key technology for wind turbine blade, it is hard to formulate the integrated system of design, technology and manufacture. Moreover, because of the localization of the blade materials, faultiness of manufacturing technique, short hanging life and uninspected quality, it is not easy to evaluate the risk factor of blade for better circumvention.

3.2. Immature exploit of new blade
With the development of domestic wind power industry from labor intensive to lean manufacturing, the exploit of new technology has got greatly attention. Limited by the accumulation of operation data and data collection of production test, the reliability of new blade could not be verified. After the production of new blade, there will be the problems of design deviation and un-executable design which would affect the mass production efficiency and quality.

3.3. Defective process certification
The process conversion models of domestic wind turbine blade are technical transformation, process document preparation, nesting output and parameter output. Before the on-site verification of
rationality of process specification and operation setting, the products have been put into mass production. Then, many problems have appeared such as suit cut deviation, irreducible operation requirement and so on, technological problems could not be resolved timely, which would cause the problems of layering error, locating deviation and laying fold.

3.4. Non-standard personnel management
Manual work has accounted for a large proportion in the productive process of wind turbine blade, the employee should have a deep understanding of the production process and characteristics to grasp the special requirements of wind turbine blade production process. Currently, the training of the new employees, qualification and training assessment are not normative. In addition, the large personnel mobility, scarce professional skills of new employees and insufficient professional consciousness could cause the vicious circle of employee turnover, difficult talent introduction, incomplete training and unsound system.

3.5. Hysteretic equipment replacement
Although the production of blade has been brought into China for many years, the manual operation is still the main method. The turnover of employees and unskilled operation of new employees has resulted into the unstable production quality. Moreover, the equipment input, particularly the input in molding stage is far behind the international level. It is not easy for the domestic companies to achieve the mass stability.

3.6. Non-uniform defect level
Currently, the main problems in the quality acceptance process of wind turbine blade are the non-uniform defect evaluation and repair criteria. For example, the fold defects are classified by the parameters of depth-width ratio, length and axial angle which are different for different manufacturers. For the fold defects, the processes of restoring (i.e. no layer or increasing the layers of glass fabric) have been conducted. However, due to the limited running time of wind turbine blade, the efficacy of defect level plan has not been verified which leading to the undecidable rationality of various restore project.

3.7. Detection during running is difficult
The wind turbine works under natural conditions for a long time and the working environment is poor. The temperature difference between day and night in the wind farm is relatively large, and it is affected by lightning strikes, dust, corrosion, and other factors. Even if the blade design, manufacturing, and testing meet the requirements, various quality problems will occur during the operation of the blade. Nowadays, the mostly used static non-destructive testing methods include visual method, percussion method, ultrasonic detection method, laser speckle detection method, Ray and infrared detection method. The non-destructive testing methods for blade in operation are acoustic emission, fiber grating and vibration detection. However, due to the use of composite materials for wind power blades, there are many types of structural defects, and there may also be multiple types of defects in a region. In addition, non-destructive testing technology has not yet been popularized in the detection of leaves in China, and personnel experience and detection capabilities are at the basic exploration stage [5]. Therefore, it is more difficult to detect the blade, especially the dynamic real-time detection. Due to the limitations of testing methods, and considering the power generation and value costs, wind farm operators are generally reluctant to perform downtime maintenance on schedule. After severe winds, lightning strikes, and low temperatures caused damage to the blades of the wind turbine, problems such as fiberglass cracks and cracking could not be discovered in time. When the wind turbine malfunctions and cannot be shut down, the blades are out of control, and in the case of rapid rotation, It may also cause catastrophic accidents such as the flicking of leaves or the installation of towers.
4. Suggestions and countermeasures

4.1. Improving the capability of independent innovation
The core technology of profile design of blade in China is usually imported. Therefore, the domestic companies should increase the investment in scientific research for technology and process to master the core technology of blade when bring in the foreign advanced design and production technology. Thus, only in this way can the domestic explore the dedicated airfoil and configuration independently for domestic wind field.

4.2. Defining the normative standards
As for the nonstandard/non-uniform standards of incoming inspection of raw materials and defect judgement/repairing, the manufacturing companies should improve the industry standards of blade by referring to the foreign wind power industry standards and combining the domestic development model of wind power industry. The material re-inspection project and related performance requirements also should be affirmed in the standards for the reinspection and replacement of raw materials. When the raw materials are changed, the corresponding tests need to be followed the relative standard for the whole performance testing of blade. The industrial standards should meet the requirements of shop environment, production equipment, related test item points, defect assessment and repair.

4.3. Improving capacity for independent innovation
The core technology of leaf design in Chinese wind turbine blade manufacturing enterprises is generally imported from abroad, and it is suggested that manufacturing enterprises, while introducing and absorbing advanced foreign design and production technologies, should not only make technical and technological improvements to the special environment of wind farms in China, but also increase research and development investment as soon as possible. Master the core technology of wind turbine blade design, and be able to independently develop the special Airfoil and structure that are fully adapted to the wind field environment in China.

4.4. Developing intelligent blade to monitor the quality problem
Fatigue is the main damage to the leaves, so intelligence will become the inevitable trend of wind turbine development. The current research shows that the premise of intelligent control, intelligent design, fault diagnosis and early warning of wind turbine is to have intelligent blades that perceive changes in the external environment and its own structure. Using optical fiber as sensing element, distributed in the blade structure, the blades that can output external load and their own state information are very good choices. However, due to the fact that the resin perfusion and curing are at high temperature during the fiber placement process, the accuracy of information transmission will be affected after the fiber is affected by high temperature, so it needs to be controlled and optimized in the blade manufacturing process. Moreover, with the increase of the blade length, the design and manufacturing process of the blade has become more and more complex [6]. The placement of optical fiber sensors has increased the complexity of blade manufacturing. Therefore, more in-depth research is needed to use optical fiber implantation to achieve the intellectualization of the blade.

4.5. Standardizing the staff on-job training
The manufacture of wind turbine blade is depending on the manual work, so the quality of employees has a great influence on the quality of wind turbine blade. The staff on-job training should be standardized, especially for the special requirements of key processes such as the layer, punch, inspection post, assigning the professional assessment qualified and experienced staff.

4.6. Increasing the equipment investment
The increase of the equipment investment, particularly the automatic laying device, could assure the
laying quality and improve the production efficiency.

4.7. *Optimizing the technical mode*

It is very necessary to build the new model of reforming process. In addition, the process documentation should correspond with the on-site execution. The unreasonable process set and reachless technological requirements are strictly forbidden. Combined with the field staff, device configuration and environmental requirement, it is also very necessary to configuration and technological procedure that match with the current requirements.

4.8. *Introduction of multiple types of detection*

Wind turbine blade manufacturing process is more complex, fiberglass composite material in the manufacturing process, will inevitably appear stratification, bubbles, cracks and other defects, so, wind turbine blade manufacturing in the detection level and method of the overall quality and safety of the leaves have an important impact. At present, in addition to the use of visual methods and percussion methods, non-destructive testing methods can be introduced, such as ultrasonic detection technology and infrared imaging technology. Non-destructive testing technology has high accuracy and no damage to the leaves [7]. Although there is no specific method for leaf detection in the wind turbine certification specification, it can be seen from the production process and process of the leaves that there are many types of defects such as whitening, stratification, and lack of glue in the process of perfusion, solidification, and molding of composite materials. Using more advanced non-destructive testing technology, not only can the quality of the control blade be integrated throughout the process, but also can be used as an important technical means to ensure the stable operation of the blade during its service life.

4.9. *Use of multiple detection techniques*

The detection method in the process of wind turbine blade manufacturing has an important influence on the overall quality assurance. At present, in addition to the use of visual methods and percussion methods, non-destructive testing technologies should be introduced, such as ultrasonic detection technology and infrared imaging technology [8] And so on, its detection accuracy is high, and there is no damage to the wind turbine blade. Although there is no specific content of leaf detection in the wind turbine certification specification, it can be seen from the production process and process of wind turbine blades that there may be many types of defects such as whitening, stratification, and rubber deficiency in the process of composite material perfusion, solidification, and molding. Adopt more advanced nondestructive testing technology, not only can the whole process of wind turbine blade quality, but also can be an important means of evaluating the operating quality of wind turbine blade.

5. Conclusions

The wind power industry has saturated, so the the urgent development of manufacturing industry is promising. This review has analyzed the current quality control status of wind turbine blade industry and proposed some solutions which is expected to give some suggestions for the quality control of wind turbine blade.

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