Research on Automatic Positioning System of Ultrasonic Testing of Wind Turbine Blade Flaws

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Abstract. Ultrasonic testing technology has been used essentially in non-destructive testing of wind turbine blades. However, it is fact that the ultrasonic flaw detection method has inefficiently employed in recent years. This is because the testing result will illustrate a small deviation due to the artificial, environmental and technical factors. Therefore, it is an urgent technical demand for engineers to test the various flaws efficiently and quickly. An automatic positioning system has been designed in this paper to record the moving coordinates and the target distance in real time. Simultaneously, it could launch and acquire the sonic wave automatically. The ADNS-3080 optoelectronic chip is manufactured by Agilent Technologies Inc, which is also utilized in the system. With the combination of the chip, the power conversion module and the USB transmission module, the collected data can be transmitted from the upper monitor to the hardware that could process and control the data through software programming. An experiment has been designed to prove the reliability of automotive positioning system. The result has been validated by comparing the result collected form LABVIEW and actual plots on Perspex plane, it concludes that the system possesses high accuracy and magnificent meanings in practical engineering.

1. Introduction

Wind energy is one of the growing renewable energy resources. It is going to have a remarkable share in the energy market. According to the collected statistical data, it is estimated that wind power could give about 12% of global electricity supply by 2020 and achieve above 20% by 2030 [1] [2] [3].
Wind turbine system consists of numerous mechanical and electrical components including the wind turbine blade, rotor, gearbox, shaft, generator, bearings, tower, pitch and yaw system [2] [4]. Among these components, wind turbine blade is regarded as one of the most critical components [5] [6]. The common defects usually can be founded by Non-Destructive Testing (NDT) during the blade manufacturing process, which can cause a series of problems during normal operation [7] [8].

NDT is the procedure of testing, inspecting, estimating structure and components without damaging the integrity of the structure. In this case, the structure could still be used whenever NDT has been applied. Contrastively, other inspection methods are destroyable and restricted to be used in need, while they are not widely applied for the materials, elements and structures.

Detractive testing methods are usually to decide the physical characteristics of material like tensile strength, ductility and fatigue toughness. However, the material discontinuities and property differences are efficiently used by NDT. At present, NDT are widely utilized in manufacturing and in-service detecting in order to make sure the serviceability of the system, maintain the quality level and avoid a sudden failure.

There are a number of NDT techniques, such as visual [9] [10] [11], sonics, ultrasounds [12] [13] [14] [15] [16] [17], optic [18] [19], electromagnetics [20] [21] and optical thermography [22] [23]. In particular, the normal working principles applied in ultrasonic testing is same as the principles used in Naval SONAR and fish finders. To be specifically, Ultra-high frequency sound is introduced into the component for inspecting, a part of sound could reflect back to the processing unit when the sound hits the component with different material and different acoustic impedance [12] [14].

Technically, sound goes through the structure by using the ultrasonic probe which converts electrical impulses from the ultrasonic testing machine into sound waves, hence converts sound back into electric impulses. After that, they could be illustrated on the LCD screen for visual demonstration. Therefore, the distance could be measured by operator from probe to the reflector. In general, the experienced operator can decide the discontinuity which caused the reflector as the ultrasound could not go through air and liquid [12] [14].

On the other hand, it is clear that wind turbine blade is one of the main components. Regarding to the large outline and complex procedure, the blade is easy to generate the flaws or wrinkles during the placement, which could result in significant influences on the performance of blade [15] [16]. Especially, the strength might reduce about 50%, the fiber might deviate 15° and flaws might appear when the glass fibers are slightly loose. After that, the blade fracture could turn up when the wrinkles grow up on the main composite layer, which will result in a destructive damage [15] [16]. In this case, the manufacturing processes of wind turbine blade are the manual operations, which are the main reason to generate a series of unpredictable factors that essentially affect the quality of wind turbine blade. It is fact that the flaws on wind turbine blade are commonly caused by the negligence of workers. As a result, it is necessary to use automatic positioning measurement system of Ultrasonic NDT to find out the flaws, which enable to give an indication without destroying the integrity of wind turbine blade. Hence, the lifetime of wind turbine blade could be guaranteed at a high level [17].

In particular, the automatic positioning measurement system of Ultrasonic NDT is a convenient way to find out the flaws of structure, which is recently used to inspect the detection of defects of wind turbine blades. In the process of automatic positioning measurement system, the first task is to determine...
the detection location. In this case, the method is to manually draw coordinates on the surface of the test object, record the specific locations and set up an equi-spaced grid of monitoring points. This approach is a time and energy consuming as it is hard to operate when the surface of the wind turbine is sufficiently large.

In this paper, an automatic positioning system is developed to track the two-dim coordinates of the trajectory. An experiment setup will be designed to validate the reliability of automatic positioning system. This system has great performance than the traditional manual operation approach, especially in automation and efficiency of the measurement procedure.

2. System design
The automatic positioning measurement system is shown in Figure 1, which includes the Light Emitting Diode (LED), lens assembly, optical sensors, microprocessor and RF modules. The LED will reflect the surface of the testing object, irradiate through the lens assembly and finally reach the optical sensor. The optical sensor uses the Agilent ADNS-3080 optical chip to capture the continuous microscopic images of the surface of the test object. Then, it compares and determines the movement direction and location of the system, which finally sends the data back to the microprocessor. The microprocessor is a MCS-51 microcontroller chip. It receives and transmits the real time data via the RF module to the upper computer that uses the corresponding LABVIEW software to take subsequent detecting procedures according to the displacement situations. The automatic positioning system also includes a power conversion module which could convert the 5V DC power supply to a stable 3.3V and power the optical sensor chips.

![Figure 1. The schematic diagram of the automatic positioning measurement system](image)

3. Implementation
In operation, the operator is asked to hold the collection device, also move in front of the surface of the blade under test in automatic positioning system. The system will automatically measure the two-dim coordinates of the movement and send them to the upper computer. The upper computer will analyze
these coordinates and obtain the sampling distance to decide where the sampling distance is qualified. If so, the position will be the sampling position and the procedure of automatic positioning is completed.

**Figure 2.** The flow chart of automatic positioning measurement system
The detailed implementation of this system is shown in Figure 2. The system will immediately decide whether to receive the reset signal from the control terminal since the system starts to work. If yes, the internal parameter of the optoelectronic chip will be reinitialized. In this case, the horizontal direction of the chip will be defined as the X-axis, the vertical direction will be determined as the Y-axis. The initial position of the photosensitive eye of the chip will be set as the origin position (0, 0), the input displacement change will be set as x = 0 and y = 0. More importantly, the overall displacement value will be defined as Sum X = 0 and Sum Y = 0.

When the system moves, the optical sensors will obtain the microscopic surface image captured by the lens and lighting systems through the image acquisition system. Using the photographic eye, thousands of frames will be captured per second and stored according to the chronological order of the image being photographed.

The digital signal processor will process the information in the register in order and implement image processing. Meanwhile, it will determine the positive and negative directions as well as vary x, y values. If it is negative (positive) direction, the displacement changes would be subtracted (added). After that, the sum X and sum Y will be sent to the distance measuring device through the RF module to determine whether to stop or not. If the system is stopped, the control program is completed. Once the pin NCS of optical sensor chip is pulled down, the four-wire serial interface will be activated and transmit the data to the microprocessor. The microprocessor will process the changes and obtain the coordinates from origin to the stopping location, while transmit these data to the upper computer through the RF module.

The data are transformed into a DLL file and called by LABVIEW, they will be finally displayed on the upper computer program panel. Once sampling distance is qualified, it stops moving and then performs collection mission. The following sections will present the experiment procedures and results obtained.

4. Experimental analysis

In the experiment, a 30cm×30cm Perspex plane was designed and used to be scanned by using Ultrasonic NDT. The plane was meshed and 5 plots were marked for ensuring the positioning device movements. That is, (300,0), (100,100), (150,150), (250,100), (0,300). In this case, Ultrasonic NDT includes the automatic positioning device, ultrasonic device and TH-606 analyzer, as Figure 3 shows. Firstly, Automatic positioning device and ultrasonic device were combined together and were connected to TH-606 analyzer. After that, TH-606 analyzer was turned on, while the positioning device was slowly moved on the plane and operated by single person. The moving path was in Z-shape in order to cover the whole plane.
Figure 3. The experiment setup

To be specifically, TH-606 is the equipment that analyses the data from the ultrasonic probe and automatic positioning device, while it gives clear images on the screen to show the probe location and the situation of flaw detection. In this case, the result collected from the automatic positioning device will be essential.

5. Result

After the experiment, the result of automatic positioning device from LABVIEW could be observed in Figure 4. Comparing with the five plots in Figure 5, the automatic positioning device moves successfully and each plot has been scanned precisely, which also indicates that this device could provide very concise scanning movements and analyze efficiently in LABVIEW.
Figure 4. The result of automatic positioning device from LABVIEW

In other words, since targeting path has been selected and the positioning device has been moved, the system will display the real-time movement information on the upper computer panel (TH-606 analyzer) and generate a roadmap with a high accuracy movement.

6. Conclusion

The paper has clearly explained that the importance of using the automatic positioning measurement system of Ultrasonic NDT. That is, the quality of wind turbine blade could be improved and the flaws could be successfully found out by using this technique. Also, it has outlined the key components of automatic positioning measurement system. In this case, the system consists of LED, lens assembly, optical sensors, microprocessor and RF modules. In particular, the system could measure the two-dim coordinates automatically. Meanwhile, the system can immediately decide whether to receive the reset signal from the control terminal since the system starts to work. In addition, the experiment was set to prove the reliability and accuracy of automatic positing system. The result shows that automatic positioning system moves successfully, while 5 plots have been scanned precisely and accurately. More importantly, it implies that the automatic positioning measurement system could capture the real time position of the movements and store the target position in the flaw detection of wind turbine blades. This measurement system can be simply operated by a single person. Indeed, it has the number of advantages such as highly efficiency and easy to use. Also, it can be used in many fields besides wind turbine blade.

7. Reference

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