Journal of Mechanics Engineering and Automation 13 (2023) 143-153
doi: 10.17265/2159-5275/2023.05.003

Discussion on Maintenance Cases of Wind Turbine Components

Huang Ren-Jen

Central Branch, Department of Power Equipment Repair and Maintenance, Taiwan Power Company, No. 643, Sec.2, Jinma Rd. Changhua city, Taiwan, Email address: u592749@gmail.com

Abstract: At present, the greenhouse effect is caused by excessive emission of carbon dioxide. As a result the Arctic ice has melted and sea levels have risen. If it continues to deteriorate, it will cause human catastrophe. In order to avoid direct crisis and development, green energy is the only necessary way. Here, wind power plays an important role. Onshore wind power has been developed in Taiwan for more than 15 years. There are 341 onshore wind turbines that have been built so far. The total installed capacity is 678 MW high. Among them, Tai power occupies a total of 169 stations with a total installed capacity of 294 MW. Offshore wind turbines are also under construction. By 2025, the capacity will be 5 to 6 GW. It can be seen that the supply of wind power in the overall power market will become an important area in the future. Therefore, how to improve the availability and capacity factors of wind turbine power generation will become a top priority for owners. Since most of the world's best wind farms are in the Taiwan Strait, this is a unique feature of Taiwan, although Taiwan lacks traditional fuels, petroleum, coal, natural gas and other resources. If these abundant solar and wind energy resources can be effectively utilized, in addition to reducing carbon emissions and contributing to the world, the development of green energy can also drive the development of the domestic green energy industry, also through the development of green energy to establish domestic operation and maintenance technology for wind turbines.

Key words: Gear box, Gearbox repair, Wind turbine blade, Hub, Visual inspection.

1. Foreword

According to the plan by 2025, all offshore wind power plants in Taiwan will be completed. By then, green energy will account for 20% of power generation as shown in Fig. 1. This will bring about major changes to the generation, power supply, transmission and dispatch of electricity. Mainly wind and sunshine are not controlled by manpower. This change is in addition to a major challenge for traditional power plant owners, the same is true for owners of green energy farms. Therefore, an effective maintenance plan is required to improve the availability and capacity factors of wind turbines. The major key components of wind turbines are gearboxes, generators, and blades. If these components are damaged during operation, it will cause serious failure of the wind turbine and no operation. In addition, there are many mechanical and electronic control related components. The condition of these components will affect the availability of the wind turbine. In addition, environmental factors affecting wind turbines include salt damage, sunlight, earthquakes, typhoons, wind blowing sand, etc. These factors will accelerate the damage of the wind turbine. Therefore during the annual regular inspection of wind turbines, check the component damage that may be caused by the above factors to prevent all possible damages before they happen.

2. Regular Inspection Items for Wind Turbine

There are the following items: Rotor, Ground Controller, Nose Cone, Hub Controller, Pitch System, Hub and Blade Bearing, Blades, Main Shaft Arrangement, Torque Arm System, Gearbox, Gear Oil System, Composite Coupling, Brake, Generator, Rotating HYAC-Heat Contact, VCS-Water Cooling, HV Transformer and

Corresponding author: Huang Ren-Jen

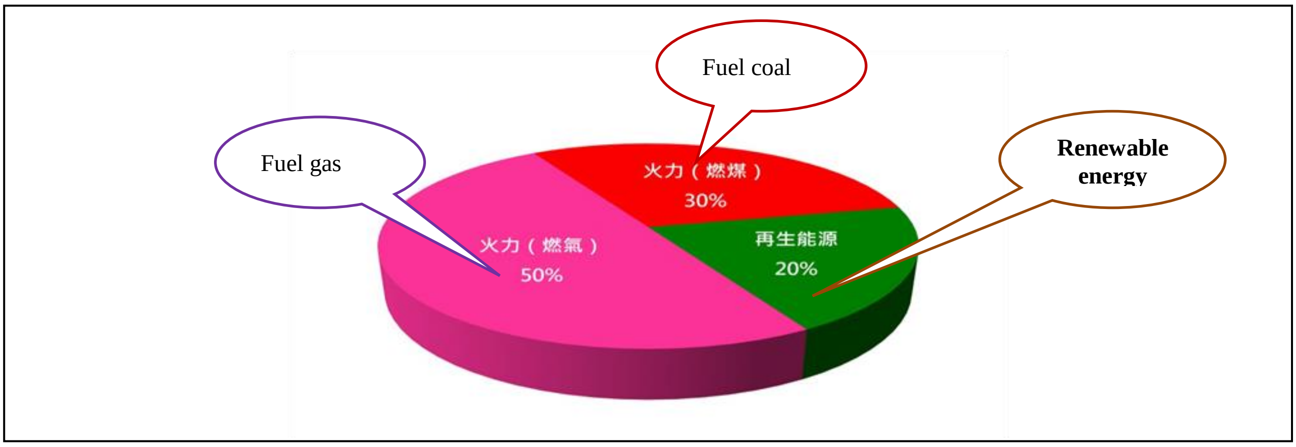


Fig. 1 2025 government power generation target proportion.

Transformer Room, Hydraulics, Yaw Gear, Yaw Bearing System, Nacelle Cover, Ultrasonic Wind Sensor, Top Controller, Tubular Tower, Service Lift, Surface Treatment, Crane, Anchorage Points, Safety Components, Visual Inspection of Electric Cables, etc. Each of the above-mentioned regular inspection items for wind turbines is tested in accordance with the procedure, regular inspection cycle is once every quarter. The following will discuss the maintenance of gearboxes, blades, and hub support frames.

3. Gear Box Inspection and Repair

The appearance of Vestas V80 is shown in Fig. 2; The internal configuration is shown in Fig. 3; Simplified diagram is shown in Fig. 4.

According to the driving mode of the generator, wind turbine can be divided into direct drive and non-direct drive. Direct drive is the wind turbine rotor which directly drives the generator rotor to generate electricity. In non-direct drive type, the wind turbine

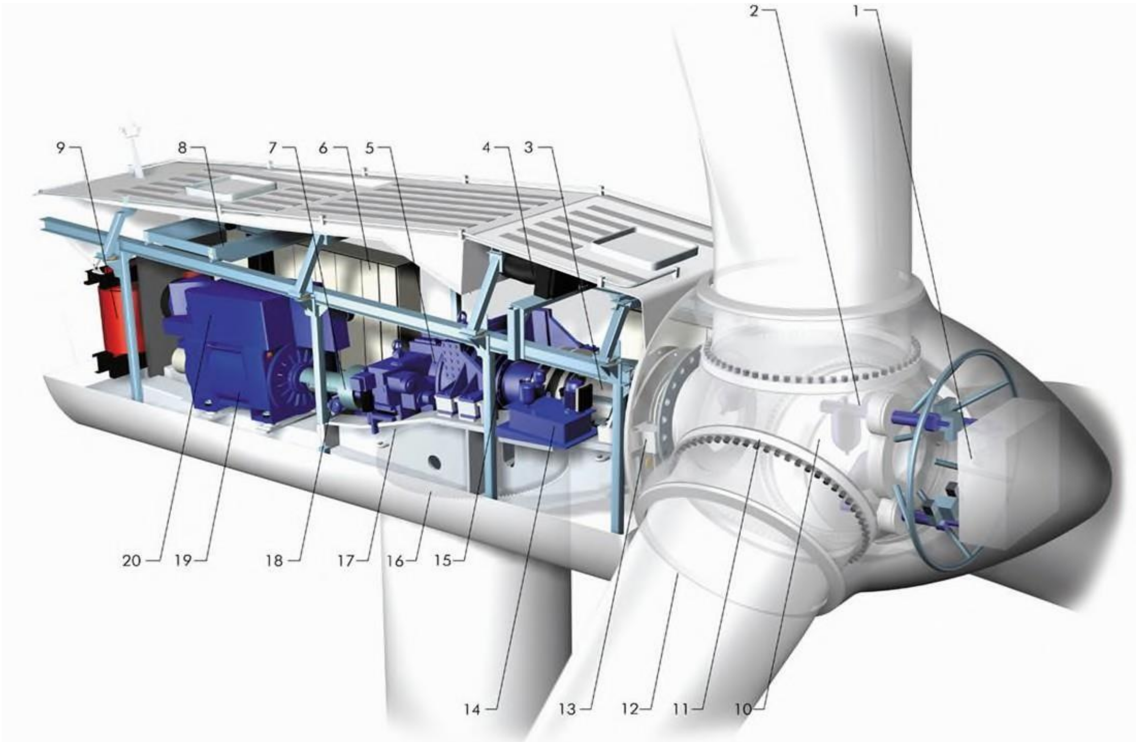


Fig. 2 Appearance of Vestas V80.

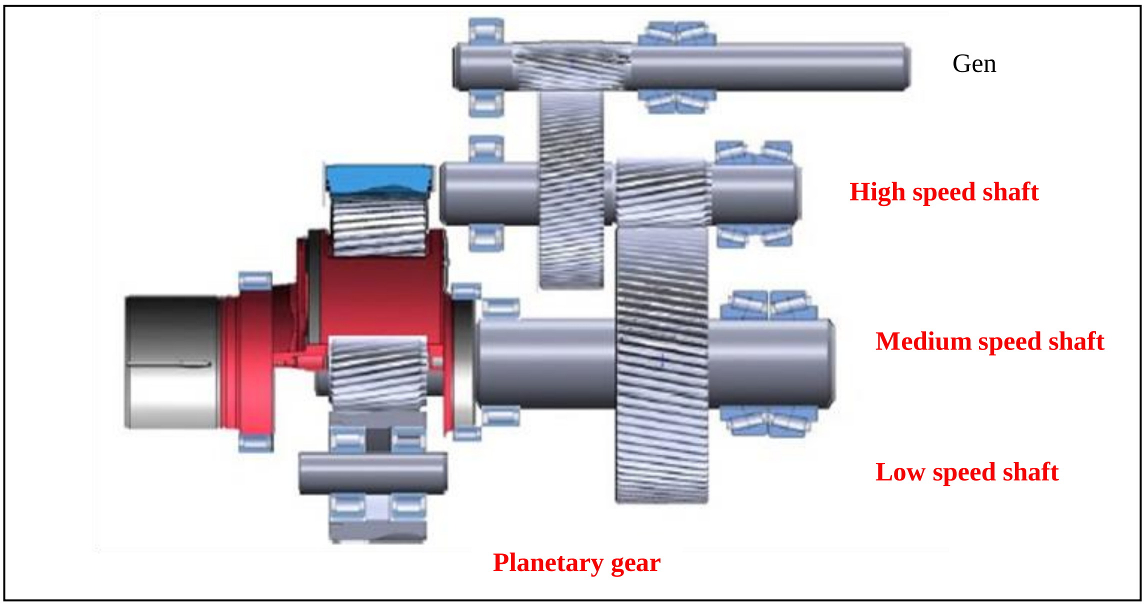


Fig. 3 Internal configuration diagram of gearbox.

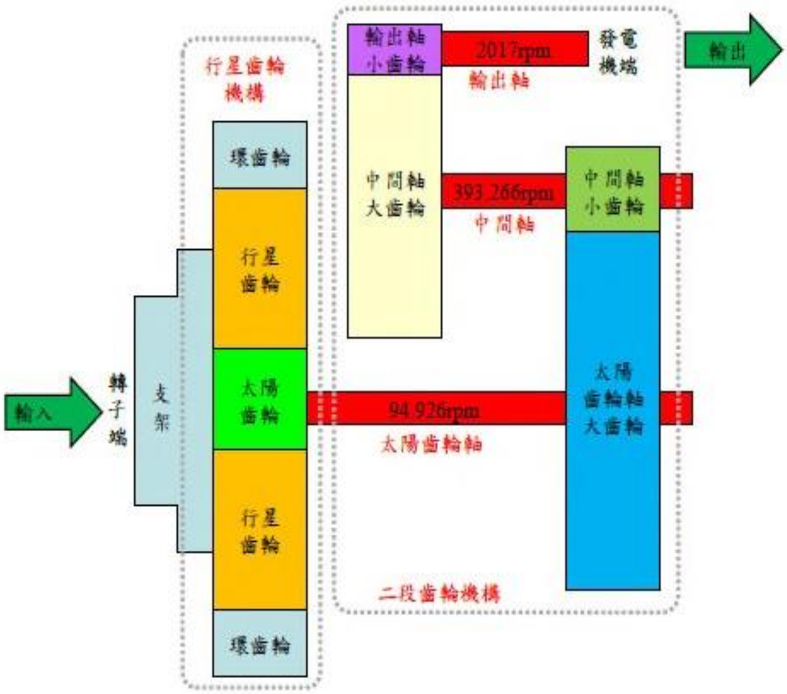


Fig. 4 Simplified diagram of gearbox.

rotor is accelerated by the gearbox and then drives the generator rotor to generate electricity. Vestas V80 is a non-direct drive generator, the gearbox is relatively large and complex. Because the gearbox is the core of the wind turbine power transmission and conversion, and there is a lot of lubricating oil inside. If the interrupted teeth are not dealt with as soon as possible, a large number of teeth will be broken, the high, medium and low speed shafts will be displaced, and the gear box will even be broken and the lubricant will overflow, this is very likely to cause a fire and burn down the entire wind turbine. Therefore, important items for the regular inspection of gearboxes need to be implemented to ensure the safe operation of the wind turbine.

Fig. 5 Visual inspection of gear body and gear teeth.

Fig. 6 Gear PT detection.

4. Gearbox Inspection

During each regular inspection, open the observation hole of the gear box and use the endoscope or auxiliary tools to perform the gear body and gear teeth inspection., as shown in Fig. 5. When the gear teeth are found to be cracked, use penetrant testing to check the position and length of the defect, as shown in Fig. 6. Since the gear is immersed in lubricating oil during operation, the oil in the cracks should be removed with a cleaner before the penetrant testing.

In addition, in order to prevent the PT material from contaminating the untested area it should be covered before application.

5. Grinding of Defective Gear Teeth

Due to the long time for the purchase of gearbox spare parts, in order to ensure that the wind turbine can to generate electricity, after consolation and evaluation by the wind turbine team of our department, the cracked gear teeth are first ground and repaired as shown in Fig. 7, then, use PT to detect the abrasion area, as shown in Fig. 8, remove the cover, then use a magnetic rod to remove the iron chip, and complete the reassembly work. In order to ensure that the gear can run safely in the case of missing teeth, first run at 1/4 load, and then stop for inspection after a week. After observing that there is no abnormality around the missing teeth area, then increase the load to 1/2 load operation. This treatment method has been tested by Zhanggong Wind Farm for many times, and a standard operating procedure has been formulated as a basis for handling when the gear teeth are found to be cracked and there are no replacement parts. This approach not only increases the availability of wind turbines in the wind farm, but also increases its capacity

Fig. 7 Remove cracked teeth and grind.

Fig. 8 PT detection.

Table 1 The power generation and income increased.

Year	Number of failures	Increase power generation (kw)	Increase income (NT$)
2011	4	6,050,419 kw	15,730,000
2012	2	1,621,656 kw	4,210,000
2013	5	3,257,281 kw	8,460,000

factor, while also reducing power generation costs and increasing the profitability of wind turbines, In this way, Zhanggong Wind Farm's increased power generation and revenue before the arrival of spare parts, as shown in Table 1.

6. Load Evaluation of Gears in the Absence of Teeth

The force condition of the surrounding gear teeth and the most appropriate load calculation in the case of gear teeth missing, calculate the allowable load during operation after the teeth of gearbox of the wind turbine is broken. For this calculation, first it is assumed that the proportions of broken teeth are 20%, 40%, 60%, 80% respectively, as shown in Fig. 9. Usually the location of the tooth cracks is mostly on the big and pinion gears of the intermediate, as shown in Figs. 9 and 10. In addition, it can be seen from Fig. 11 that the position of the maximum stress point is also the easiest initial point for cracks and can be used as an area to strengthen weak point detection later.

Entrusted by the Ship and Ocean Research Center, to calculate the proportion of broken teeth with 20%, 40%, 60%, 80%, the calculation result shows the relationship between the rotational speed and the force during operation, as shown in Fig. 13, comparing the load of the defective tooth and the non-defective tooth, when the depth of the defective tooth is less than 60%, the load has little relationship with rotation speed of the shaft. But when the depth of missing teeth is greater than 60%, the force on the tooth surface will increase sharply when running without speed reduction or load reduction. At this time, if the speed or load is reduced by 20% and 40% respectively, it can be seen that the force on the tooth surface will decrease as the speed decreases.

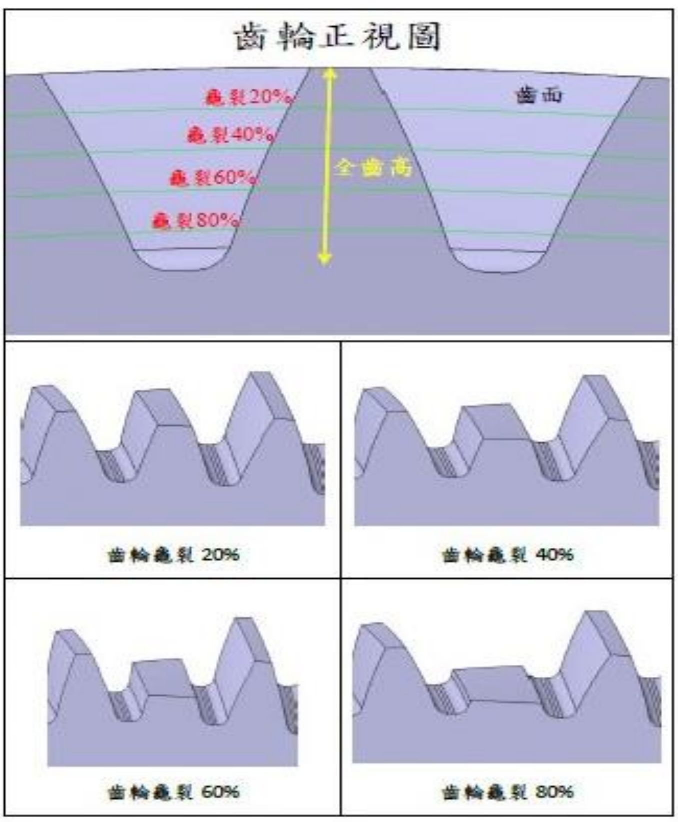


Fig. 9 Schematic diagram of the percentage of missing teeth.

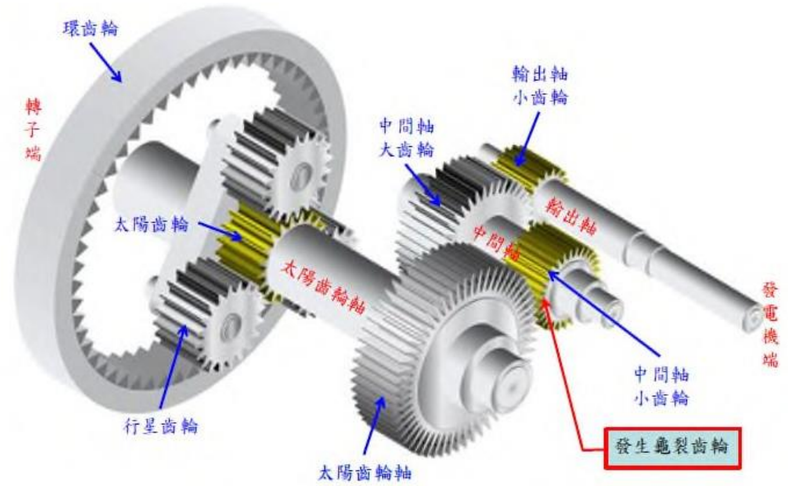


Fig. 10 Big broken tooth.

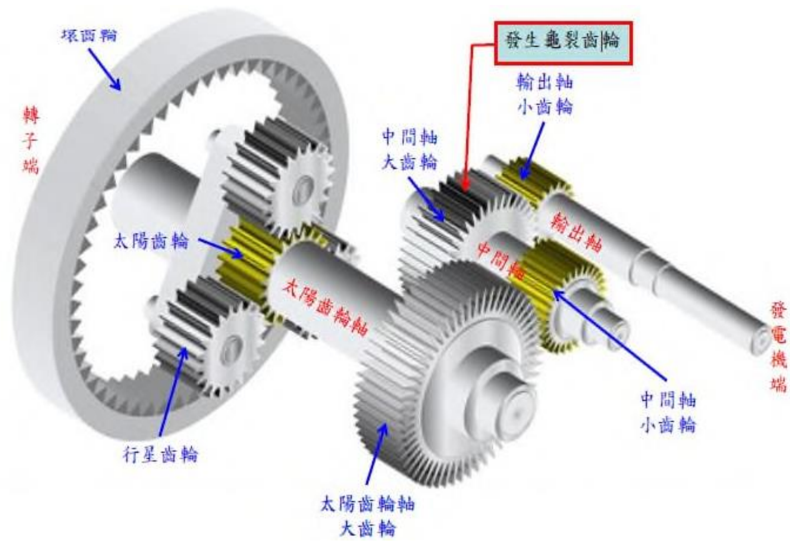


Fig. 11 Pinion broken tooth.

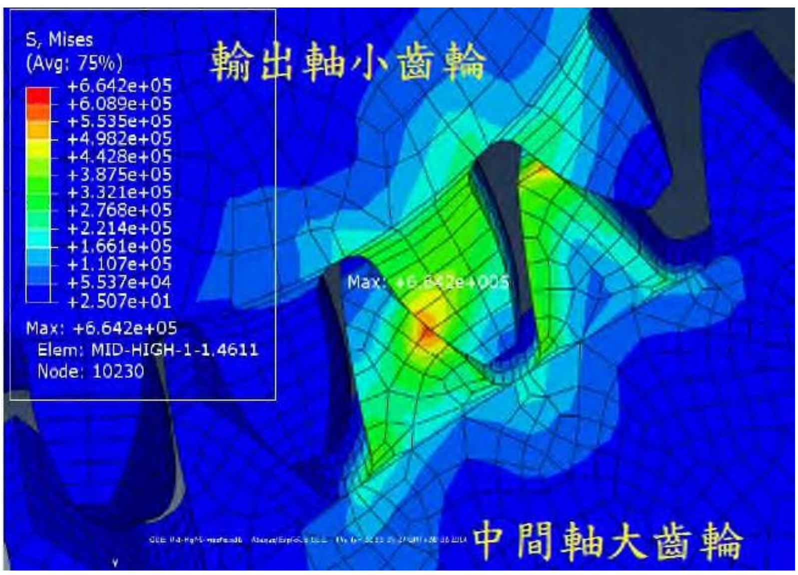
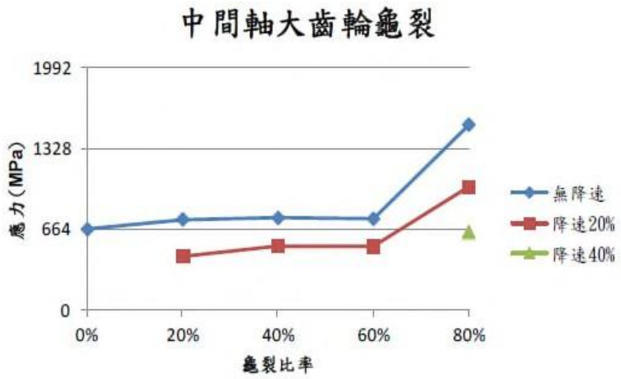


Fig. 12 Maximum stress point of tooth surface.



齒龜裂比重	最大應力(MPa)	最大應力增加比率(%)	最大應力(MPa)	
	無降速		降轉速 20% (限載 400kW)	降轉速 40% (停機)
0%	664	-	-	-
20%	745	12.2%	442	-
40%	757	14.0%	526	-
60%	750	13.0%	523	-
80%	1527	130.0%	1012	642

Fig. 13 The relationship between the percentage of missing tooth depth and force.

The result of this calculation can be used as a reference for the operation of gears with broken teeth.

7. Hanging and Installation of Gearbox

The department has been in charge of wind turbine operation and maintenance for more than ten years, during this period, in addition to implementing the localization of a number of components, maintenance technology for wind turbine gearboxes and generators has also been established, taking root in the operation and maintenance technology of wind turbines in Taiwan, it has taken the first step. For the repair and maintenance of the broken tooth gearbox, the first thing to overcome is the hanging project. It is necessary to ensure that personnel and equipment can be carried out under safe conditions, and the work is completed as scheduled and with quality. Therefore, the establishment of SOP and the training of personnel must be strictly required before they can be achieved. Fig. 14 shows the hanging project of the wind turbine gearbox.

Fig. 14 Wind turbine gearbox hanging project.

Fig. 15 Gearbox maintenance project.

Fig. 16 Non-load test after gearbox overhaul.

8. Gearbox Repair

The repair of the gearbox includes the replacement of broken gears and the replacement of damaged bearings, as shown in Fig. 16. After the assembly is completed, the gear lubricant should be filtered and monitored, and perform 30% (600 rpm), 65% (1,300 rpm), 100% (2,000 rpm).

Non-load running tests, measure the vibration and temperature of the bearing, as shown in Fig. 16. The test results must meet the acceptance standards of the before they can be sent back to the wind farm for reinstallation work.

9. Wind Turbine Blade Maintenance

At present, most of the domestic wind turbines are located on the seashore. Therefore, during the northeast monsoon each year, the wind turbine blades must withstand the "particle erosion" caused by wind blowing sand. Over time, the surface of the blades will be severely blown and eroded, which will affect the strength of the blades, pay attention to inspection during each regular inspection, the inspection of wind turbine blades is carried out in accordance with the regulations of the procedures. The length of the blade is about 39 m, and the names of the various parts of the blade are shown in Fig. 17. Telescopes are used to detect and record the abnormal phenomena found in photos, as shown in Fig. 18. In addition to visual inspection, when the wind turbine is in operation, people can stand under the wind turbine and listen to whether there is any abnormal sound. If the surface of the blade is peeled off, the abnormal sound can be heard.

When the blade inspection finds cracks or peeling of the surface layer, the repair work can be carried out after the assessment does not affect the structural strength. This work needs to be performed by qualified personnel. Fig. 19 is a certificate of conformity. The repair also needs to be executed in accordance with the original factory's SOP, the execution process is shown in Fig. 20.

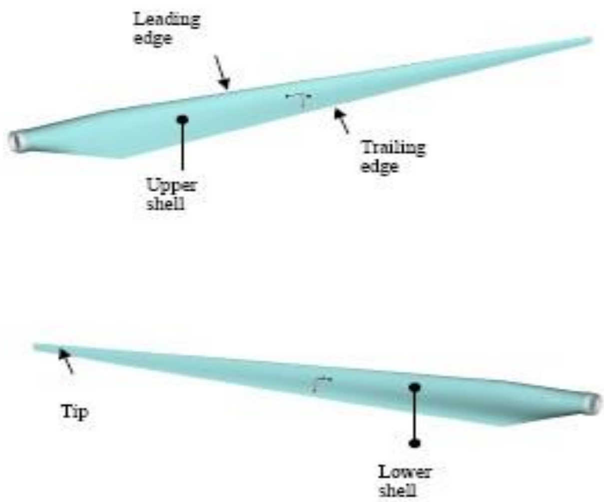
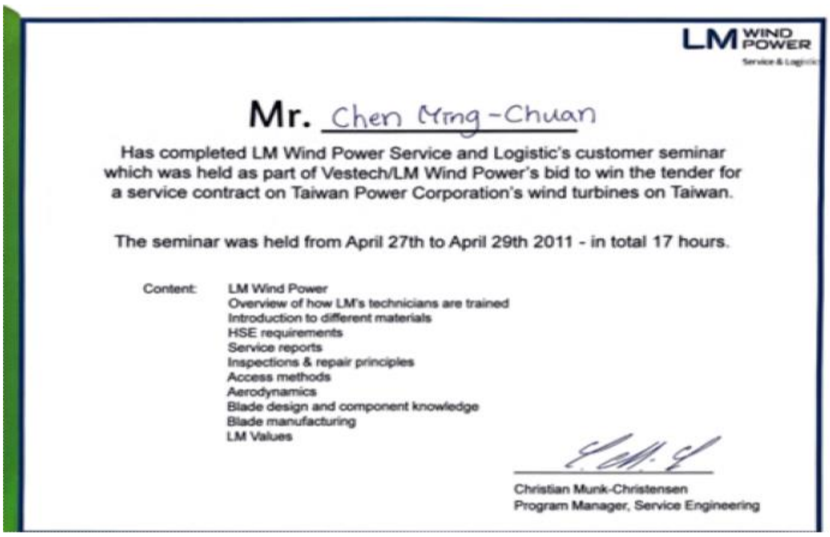


Fig. 17 Name of blade position.

Fig. 18 Defective blade.


LM WIND POWER

Mr. Chen Ming-Chuan

Has completed LM Wind Power Service and Logistic's customer seminar which was held as part of Vestech/LM Wind Power's bid to win the tender for a service contract on Taiwan Power Corporation's wind turbines on Taiwan.

The seminar was held from April 27th to April 29th 2011 - in total 17 hours.

Content: LM Wind Power
Overview of how LM's technicians are trained
Introduction to different materials
HSE requirements
Service reports
Inspections & repair principles
Access methods
Aerodynamics
Blade design and component knowledge
Blade manufacturing
LM Values

Christian Munk-Christensen
Program Manager, Service Engineering

Fig. 19 Wind turbine blade repair certificate.

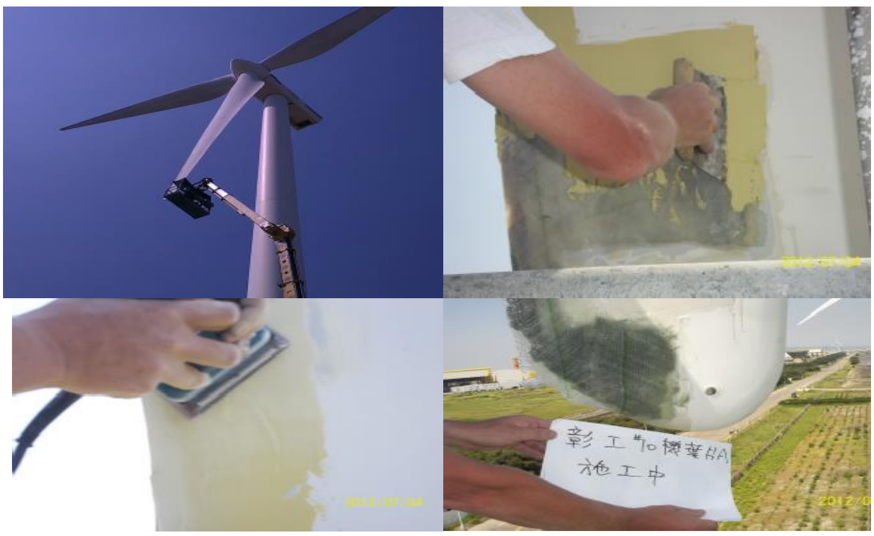


Fig. 20 Wind turbine blade repair project.

10. Hub Support Inspection and Repair

The function of hub is to join the structure of three blades, as shown in Fig. 21. The failure situation is that the support frame used to fix the component is broken. Therefore, in the routine inspection, the integrity of all supporting members must be checked in detail. If cracks or fractures are found in the supporting members, a repair plan shall be adopted, because the entire hub has to support the dynamic and static loads of the three blades, if the support frame breaks, it will cause soft feet, resulting in unbalanced support and affecting operational safety.

Regarding the repair of cracks or breaks in supporting members, firstly remove the defects, fix them with stiffening plates, and then repair them by welding. Since the wind turbine nacelle and blades are made of flammable FRB, the surrounding area must be covered with a fire-resistant blanket before welding. The welding process must avoid welding slag splashing, and all safety protection measures must be taken. The whole process is shown in Figs. 22-25. Because the wind turbine is in operation, its related components are subjected to an amplitude stress, so the wind turbine components often suffer from fatigue. As fatigue is a failure mode without warning,

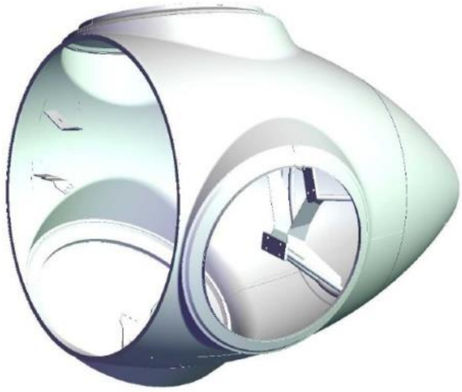


Fig. 21 Vestas V80 Hub.

Fig. 22 Weld preparation.

Fig. 23 Fixed with stiffer.

Fig. 24 Welding work.

Fig. 25 Welding is complete.

it can cause personal injury and equipment damage to be unpredictable. In order to prevent problems before they occur, inspection work is even more important.

11. Conclusion

According to the government's plan, offshore wind turbines will have a capacity of 5 to 6 GW in 2025, 10 to 12 GW in 2035, and 20 to 22 GW in 2050. There are also numerous onshore wind turbines. From the scale of the aforementioned onshore and offshore wind turbine construction plans, in the future, a wind turbine industry chain cluster will be formed in the domestic, especially in the central region of Taiwan. The Department of Wind Power Engineering is a highly technology-intensive industry that combines machinery, electronics, electrical machinery, control, material, chemistry, civil engineering and financial management, etc. Only the close cooperation between the government and the private sector will enable the development of this industry to grow steadily. From a domestic point of view, although the wind power industry has the operation and maintenance experience of onshore wind turbines in the past ten years, it is not yet able to form an industrial cluster due to insufficient scale, but the past wind turbine operation and maintenance experience can be used as the follow-up wind turbine industry development's basis.

Due to space limitations, this article only discusses the maintenance of wind turbine gearboxes, blades and hub support frames, takes effective treatment to the defects generated in these components to prevent the defects from continuing to deteriorate and cause major accidents and losses. Through the maintenance of accident cases, the department has also accumulated the maintenance capacity of the turbines. However, if you want to more effectively grasp the quality status of the wind turbine, you must make a plan for wind turbine components, and give a detailed plan for the possible damage of various components, the location of best inspection method and the inspection cycle, etc., detailed records and establishment of case data of individual components of the wind turbine, so that the maintenance of the wind turbine can be more complete, this is to make maintenance plans more timely and effective in the event of a wind turbine accident. The implementation of wind turbine operation and maintenance technology is a step-by-step work, and it should not be rushed forward. Only by learning from each case can we achieve a more perfect state.

References

[1] Taiwan power company wind turbine maintenance operation procedure

[2] Taiwan power company gearbox maintenance practice

[3] Taiwan power company Technical Seminar Report

[4] Taiwan power company Offshore Wind Power Report

[5] Ship and Ocean Research Center, calculation report for calculating the allowable load of the wind turbine gearbox after the tooth is broken