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Online Repair Device for Wind Turbine Brake Disc Based on Remanufacturing Technology

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Abstract: *Yaw system is one of the important components of wind turbine, its frequent operation will lead to important parts of yaw brake disc wear, resulting in loss of power generation, reduce the service life and operation stability of the fan. The existing maintenance methods of fan brake disc have some problems, such as long time, high cost, high risk of replacement, inconvenient disassembly and transportation, difficult to guarantee installation quality, and a lot of power generation will be lost during maintenance. Based on the surface repair technology in remanufacturing technology, the device adopts the solution of online repair, and realizes online repair without shutdown through auxiliary brake module, online repair module and shock absorber module.*

Keywords: *Yaw system, yaw brake disc, wear, power generation loss, remanufacturing technology, surface repair technology, online repair*

1. Introduction

1.1. Research background of works

With the development of the global wind power industry, the wind power operation and maintenance industry is also developing rapidly, according to PRNewswire reports that in the 2021-2031 period, the market size of the wind power operation and maintenance industry will grow at a compound annual growth rate of 9%, and the global wind power operation and maintenance market value can reach 39.8 billion US dollars in 2031. As of the first half of 2022, China's cumulative installed capacity of wind power exceeded 350GW, has become the world's largest wind power generation country, according to the Central Credit Research Institute forecast, by 2025, China's wind power operation and maintenance industry market size will reach 3.57 billion, it can be seen that wind power operation and maintenance industry has good prospects for development. As an important part of wind turbine, yaw system can ensure that the impeller of wind turbine is always in a positive windward state, receives the maximum wind power, and the wind utilization efficiency is the highest, so as to maximize the use of wind energy and greatly improve the power generation efficiency. It is necessary to ensure its normal operation through operation and maintenance.

1.2. Research significance of works

Yaw system is one of the most important components of wind turbines. According to relevant data, the annual yaw system operation and braking times of a typhoon electromechanical group are about 50,000 to 90,000 times, the average number of braking times per day can reach 197 times, and the highest number of yaw braking times per day can reach 468.4 times. The statistical analysis of yaw system faults is shown in Figure 1. Frequent operation of the yaw system will lead to wear of the yaw brake disc of important parts, which cannot meet the damping torque required by the yaw system operation, thus increasing the fan operation error, losing power generation, and reducing the operation stability. At the same time, due to improper operation and maintenance, some fans will also have gearbox oil leakage accidents, affecting the operation effect of the fan electrical group. The existing solutions are mainly two kinds, one is to replace the friction plate, taking 1.5MW wind turbine as an example, to replace 10 yaw brake 20 friction plates, generally require 4-5 people to work 15 hours non-stop, while the cost of friction plates up to tens of thousands of yuan, and the program is a temporary

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program, there is a risk of increased wear of the brake disc; The other is to lift the brake disc for maintenance and replacement, the construction period is as long as one month and the cost is as high as 300,000 yuan, and there are problems such as high replacement risk, inconvenient disassembly and transportation, difficult to ensure installation quality, and the maintenance process will also lose a lot of power generation.

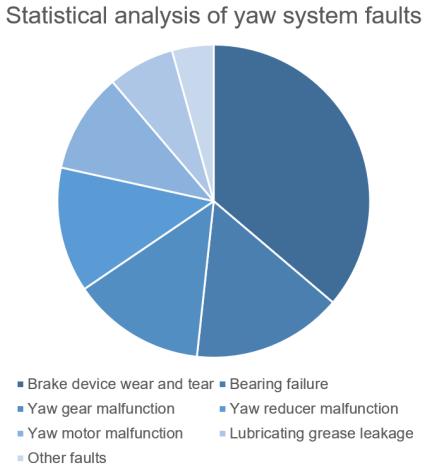

Figure 1: Statistical analysis of yaw system fault.

In order to solve the above problems, an online repair device for fan brake disc based on remanufacturing technology is designed in this paper.

2. Project research content

This paper introduces an online repair device for fan brake disc wear based on surface repair technology in remanufacturing technology, which can realize the function of online repair wear without stopping. The specific research contents include the following aspects:

(1) Describe the current situation and market prospects of fan operation and maintenance at home and abroad, summarize the common maintenance methods for fan brake disc wear and the existing problems and hidden dangers, investigate and analyze three common remanufacturing technologies for wear repair, and select the metal repair agent scheme suitable for this device after comparing the feasibility of various methods;

(2) According to the structural characteristics of the internal structure of the fan yaw system and site conditions, a device structure suitable for online wear repair of the fan brake disc is proposed, and the installation process and maintenance method of each module of the device are elaborated, as well as the realization process of relevant innovative functions. At the same time, important components used in the structure are discussed. Such as guide rod, screw, motor, electromagnetic track and other preliminary design, establish a preliminary model of the device, and in the follow-up through the simulation of structural strength feasibility analysis;

(3) Using the working characteristics of the yaw system, the laser displacement sensor is used to design an online monitoring system for the wear of the fan brake disc; In order to ensure the reliability of the device, the damping device is designed in the auxiliary brake module, and the working principle and application effect of the module are described[1-2].

3. Technical route

3.1. Overall scheme design

This device is composed of an auxiliary braking module and an online repair module, which replaces the traditional method of disassembling and re-manufacturing brake discs at factories with a non-lifting on-site online repair device. The overall structure diagram of the device is shown in Figure 2. It ensures the normal operation of the wind turbine for power generation during the repair period, and compared to traditional shutdown maintenance methods, it offers better energy-saving and

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emission-reduction benefits.

The auxiliary brake mechanism includes a caliper, screw, guide rod and motor, and the entire auxiliary brake module is composed of a plurality of auxiliary brake mechanisms, which is convenient for transportation and installation. The auxiliary brake mechanism is connected with the brake disc brake clamp mounting hole by bolts, and is soft connected with the online repair module by an electromagnetic guide rail. The online repair module includes cutter head, mixing and smearing device, feed structure and power system. The cutter head and mixing and smearing device are connected and installed on the transmission belt of the feed mechanism through a fixed bracket, which can realize the lifting, starting and stopping of the cutter head and the mixing and smearing of metal repair agent; The feed mechanism and its power system include X-axis motor, Y-axis motor, transmission belt and fixed bracket, which can realize the transmission of cutter head and mixing and smearing device.

The main function of the auxiliary brake module is to maintain the normal operation of the yaw system, and ensure that there will be no interference between the two modules during the work of the repair device and the yaw system. The outside of the online repair module has a protective cover covering the working area to reduce the impact on other parts of the wind turbine. The inside of the module adopts the surface repair method of metal repair agent. For the brake disc with less serious wear and groove depth, the process of surface pretreatment, surface roughening treatment before repair, mixed application of metal repair agent and post-repair treatment is adopted. The brake disc was repaired online in different areas.

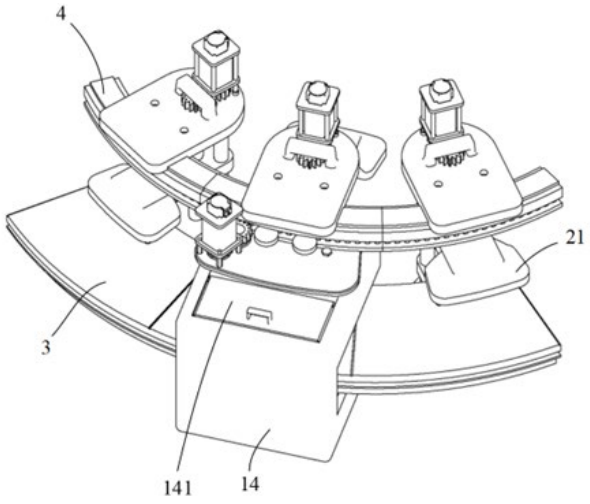

Figure 2: The overall structure diagram of the device.

3.2. Auxiliary brake module

Structure diagram of auxiliary brake device is shown in Figure 3. The module is mainly composed of the upper and lower clamp, screw, guide rod, stepper motor, guide rail and other mechanisms, using portable design, the whole module is divided into multiple identical sub-devices according to the number of fan brake clamp.

When installing this module, the fan yaw system needs to be adjusted to the maintenance mode, that is, the yaw system continues to brake, and the work of the yaw system is suspended for a short time. Then, the workers will disassemble the original brake caliper one by one inside, and use the original mounting holes to immediately install the sub-device of the module, that is, when the last brake caliper is removed, the module is also installed. This method can ensure that the normal and stable braking ability of the yaw system will not be affected during the short replacement process, and it is also convenient for the maintenance and replacement of the device.

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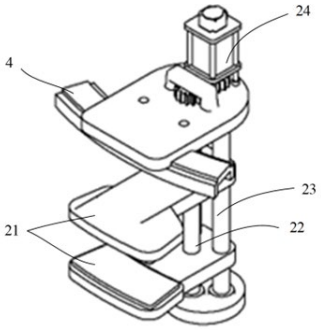

Figure 3: Structure diagram of auxiliary brake device.

3.2.1. Yaw braking

This module inherits the braking function of the original brake caliper, and can replace the original brake caliper during the operation of the device, leaving enough space for the installation and fixing of the device. Since the replacement cycle of the brake pads is much less than the replacement cycle of the brake caliper, the replacement of the brake caliper can complete the replacement of the brake pads at the same time to avoid the loss of additional power generation caused by the maintenance of the friction pads.

This function is mainly realized by the upper and lower jaws, screw, guide rod and stepper motor. The screw mainly controls the movement of the upper and lower jaws, and the guide rod mainly stabilizes the jaws in the movement and provides steering force in the mechanism avoidance. Because the screw threads of the upper and lower parts are opposite, when the stepper motor drives the screw to rotate unidirectional, the movement direction of the upper and lower jaws is opposite. The clamping brake or disengagement of the submodule can be controlled by controlling the motor rotation. During the working cycle, due to the collision avoidance repair module, the total number of temporary brake calipers online is one less than the total number, but it can still meet the operation needs of the yaw system.

3.2.2. Mechanism avoidance

In the process of repair module, due to the need of yaw system operation, the sub-device of this module also has independent collision avoidance function.

When the sensor on the electromagnetic rail senses the approach of the repair module, the adjacent brake calipers in the transfer direction will enter the avoidance state. At this time, the motor drives the screw to rotate, and the upper and lower jaws are far away from the brake disc, so that they are spatially staggered with the corresponding jaws on both sides to prevent the movement interference of adjacent submodules. Subsequently, the turntable drives the two guide rods to rotate half a circle around the screw, that is, the two pliers rotate and transpose the collision avoidance repair module in the rear space. When the repair module is far away, it is immediately reset to the original state according to the original path to continue to ensure the normal operation of the yaw system.

3.2.3. Repair module move

The repair module should be fixed on the surface of the brake disc when repairing the brake disc. When the work is done at the location, it is necessary to move to the next sector in a controlled manner. Therefore, the repair module and the module are soft-connected, and the electromagnetic guide rail is used to move. The guide rail is divided into several sections and distributed on each sub-device.

Cross section diagram of ring guide rail and on-line repair device is shown in Figure 4. When all the sub-devices are installed, the adjacent sub-sections of the guide rail are connected to form a complete ring guide rail. Because the drive part is installed above the repair module, the guide rail structure is simple, and after splicing, it can improve the stability of the module device and improve the fault tolerance rate of workers. At the same time, a supporting device of position sensor is distributed on the guide rail to sense the position change of the repair module in motion.

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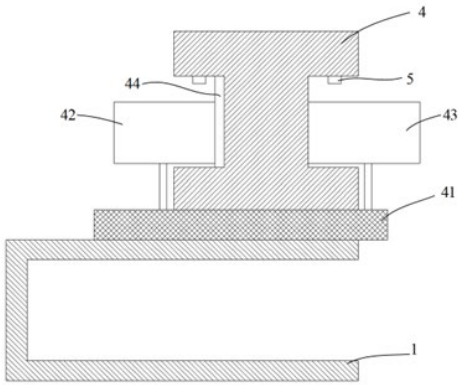

Figure 4: Cross section diagram of ring guide rail and on-line repair device.

3.2.4. On-line status detection

When the fan yaws, the upper and lower clamp are loosened to provide dynamic friction to the brake disc. At this time, the laser displacement sensor can detect the complete disc surface of the brake disc and upload the detected wear signal to the controller, which then feeds back the wear signal to the remote control center. The feedback wear data is analyzed and processed by the relevant algorithm. When the surface wear of the brake disc reaches 3mm, the device can be started for online repair[3].

3.3. Online repair module

The online repair module uses metal repair agent to repair the damaged surface online. The module is covered with a protective cover covering the working area. In order to ensure its strength and corrosion resistance, the material is made of engineering plastic polycarbonate. The module includes a cutter head, a mixing and smearing device, a feed structure and a power system. Structure diagram of online repair device is shown in Figure 5.

The cutterhead contains a convertible sandpaper structure and grinding machine to complete the surface roughening process and post-repair treatment. The mixing applicator contains a flat-mouth putty knife for simultaneous retouching of metal restorers. The contact area between the metal repair agent and the surface to be repaired is increased by pre-repair treatment. After mixed application of the metal repair agent, the surface can meet the corresponding roughness requirements by post-repair treatment.

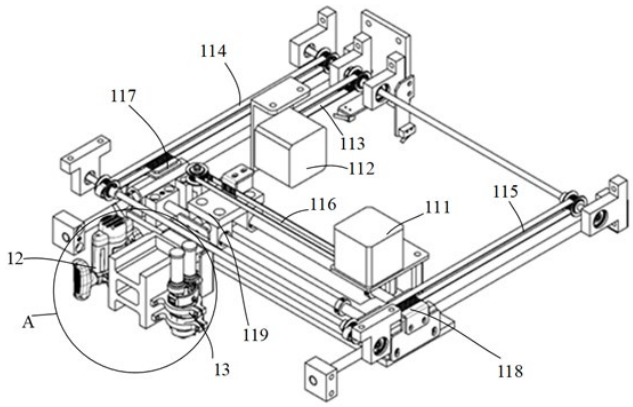

Figure 5: Structure diagram of online repair device.

3.3.1. Pre-repair treatment

Due to the large amount of oil and some dust in the working environment of the yaw system, and in order to improve the contact area between the metal repair agent and the brake disc, it is necessary to clean and roughen the surface of the brake disc before repair. The grinding wheel moves in the circular direction along the track, and the sandpaper with more than 120 mesh is installed on it to polish the damaged part of the brake disc to make its surface as rough as possible, and the grinding depth is controlled to be greater than or equal to 0.8mm of the damaged surface. After grinding, use a scraper to clean the surface again, and scrape the dust into the ash storage box to expose the unique bright color of

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the metal matrix on the surface of the brake disc. Leave for a while to ensure that the surface of the brake disc is dry.

3.3.2. Mix and apply metal restorers

The device uses titanium alloy metal repair agent, the repair agent is a two-component paste, press 3:1. It is an epoxy repair agent with titanium alloy as strengthening material. Titanium alloy inside the repair agent can greatly improve the working strength and hardness of the repair agent. The repair agent is evenly applied on the damaged surface of the brake disc, and the cured repair layer has high wear resistance, corrosion resistance, heat resistance and machining properties. Can meet the surface roughness design requirements. The upper end of the mixing and coating device is two cylindrical cavities, which are used to separate the two components of the repair agent. The cavity contains an upper piston and a lower piston, between which the component paste is placed. The bottom of the lower piston contains a sealing bowl and a disk spring to ensure that the middle cavity is in a vacuum state. The mixing chamber in the middle of the device contains a rotating mixing structure, which can press the mixed repair agent to the flat mouth and apply it to the damaged position of the brake disc. After the flat mouth, a flat ash knife is fixed to scrape and compact the repair agent. Enlarge diagram at A of Figure 5 is shown in Figure 6, which displays the detailed internal structure[4].

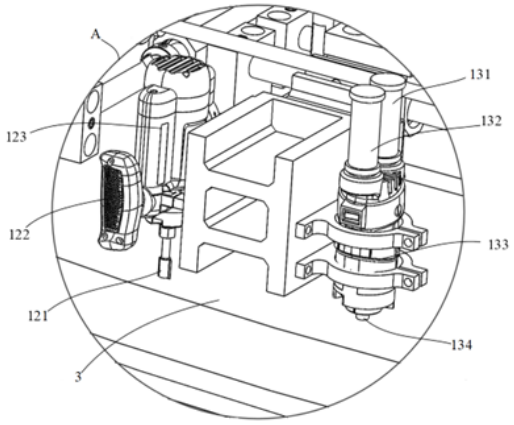

Figure 6: Enlarge diagram at A of Figure 5.

3.3.3. Post-repair treatment

In order to avoid affecting the mechanical strength of the surface of the brake disc after application, the grinding wheel should be used to polish and modify the shape after the repair agent has cured. Because the hardness of the metal repair agent will increase with the growth of time, considering that the surface treatment after complete solidification will cause damage to the abrasive tool and affect the repair effect, it should be processed when the hardness of the metal repair agent is within the processable range. It should be processed about 10h after the repair agent is applied, which is conducive to ensuring the processing accuracy. The grinding wheel with different purposes can be switched inside the device, and the 100-mesh sandpaper is used for fine grinding to ensure that the surface roughness reaches Ra6.3, the flatness reaches 0.2mm, the parallelism with the other side reaches 0.2mm, and the runout relative to the mounting surface of the yaw brake is less than 0.2mm.

4. Conclusion and prospect

In this project, the metal surface repair technology is applied to the wear repair of the fan yaw brake disc, and an adaptive auxiliary brake module is designed for autonomous obstacle avoidance, which realizes the online repair of the brake disc at high altitude, and solves the difficulties of long working hours and high cost of traditional lifting methods, as well as the temporary effect of replacing friction disc methods and the hidden danger of increasing wear. At the same time, the device designs a maintenance mode applicable to the normal operation of the yaw system, which can realize the online repair and realize the non-stop work of the wind turbine, greatly reducing the loss of power generation.

According to the survey data, when the brake disc of the wind turbine fails, the maintenance time of the onshore wind turbine needs 2 to 4 days, and it needs to be lifted and replaced after serious wear and tear, which requires a construction period of about one month. However, this device can realize non-stop maintenance, and when the average yaw error is 15°, it will lead to the loss of 5 to 13% annual

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power generation of a single generator set. Taking 2MW wind turbine as an example, according to the prediction of fan life and the calculation of wear amount, the number of fan electrical failures in a year is about 3 times. Calculated according to the shutdown and maintenance for 3 days, the loss of power generation can be saved by 432,000 degrees of shutdown and maintenance, and the loss of power generation due to yaw error can be saved by 540,000 degrees.

The global wind power market is huge, and the fan maintenance industry derived from it has broad prospects. Among them, for the brake disc wear failure problem, the current solution is mainly hoisting and disassembling, transported back to the factory for remanufacturing. But at present, there are some problems such as the loss of shutdown power generation and the impact of substandard installation accuracy on power generation. The device adopts a new solution of online repair, which conforms to the development trend of wind power industry and has good market potential and application prospect. In addition, the device realizes online repair of the brake disc based on remanufacturing technology, which can be applied to the field of aircraft repair and automobile repair of the fan brake disc, and can also be applied to the field of processing and recycling of damaged metal products such as the brake disc. Therefore, the device has important scientific significance.

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