

Application test of a Detection Method for the Enclosed Turbine Runner Chamber

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Abstract. At present, for the existing problems of the testing methods for the key hidden metal components of the turbine runner chamber, such as the poor reliability, the inaccurate locating and the larger detection blind spots of the detection device, under the downtime without opening the cover of the hydropower turbine runner chamber, an automatic detection method based on real-time image acquisition and simulation comparison techniques was proposed. By using the permanent magnet wheel, the magnetic crawler which carry the real-time image acquisition device, could complete the crawling work on the inner surface of the enclosed chamber. Then the image acquisition device completed the real-time collection of the scene image of the enclosed chamber. According to the obtained location by using the positioning auxiliary device, the position of the real-time detection image in a virtual 3D model was calibrated. Through comparing of the real-time detection images and the computer simulation images, the defects or foreign matter fall into could be accurately positioning, so as to repair and clean up conveniently.

1. Introduction

A plurality of hydropower plants at home and abroad have been occurred serious accidents, such as cover rubbing and damaged fault [1-3]. To prevent major accidents of the turbine, it is necessary to carry out the technology research of the fault detection and protection monitoring for the key components under the turbine cover. However, it is a time-consuming and labor-intensive work to open the cover of the turbine runner chamber [4-6]. So the cover is just opened during A-type repair (usually every 5 to 8 years). When making short period B-type or C-type repair in hydropower plant, the endoscope is often used to extended into the chamber under the closed cover from the vacuum breaking valve hole above or the relief hole below to observe the key components such as the decompression panel and the water board in the enclosed turbine runner chamber, as shown in Fig. 1. Since the endoscope hose manual operation, the length and angle of the inserted probe cannot be controlled, it is difficult to determine the specific location of the inner chamber of the detection probe. Therefore, it is impossible to determine the position and properties accurately. Even if the defects or foreign matter is observed, it also cannot effectively guide the maintenance staff to repair. In addition, there is a big blind spot observation [7-10].



In this paper, an automatic detection method for the enclosed turbine runner chamber based on real-time image acquisition and simulation comparison techniques was proposed. The magnetic crawler with permanent magnet wheel could carry the real-time image acquisition device to complete the crawling work on the inner surface of the enclosed chamber. Then the image acquisition device completed the real-time collection of the scene image of the enclosed chamber. According to the obtained location by using the positioning auxiliary device, the position of the real-time detection image in a virtual 3-D model was calibrated. Through comparing of the real-time detection images and the computer simulation images, the defects or foreign matter fall into could be accurately positioning, so as to repair and clean up conveniently. It has important practical value to realize the automatic detection of the difficult demolition and complicated metal components of the enclosed turbine runner chamber, to solve the detection problems of common concern of hydropower manufacturing industry at home and abroad.

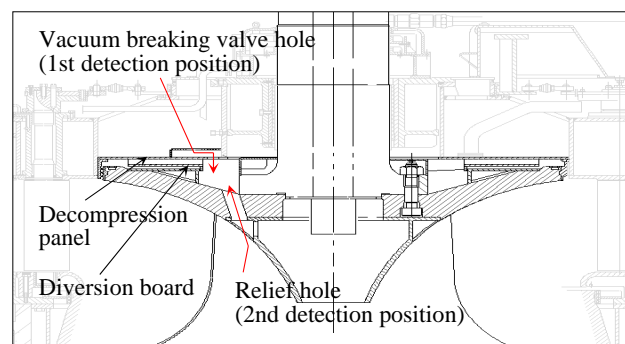


Figure 1. Detection position diagram of the turbine runner chamber

2. Design of detection system

The detection control system contains the motor control system and the data acquisition and processing system, which could realize the coordinated control of the motors and complete interactive communication with data acquisition and processing module. The detection control system contains 4 motors, and a half of them are used to control the motion of the magnetic crawler, and the others are used to achieve the perspective control of the image acquisition and illumination device.

2.1. Motion control

The magnetic crawler has 2 driving wheels (or rear wheels) and 2 driven wheels (or front wheels). The driving wheel and the driven wheel on the same side are connected with the belt and the 2 driving wheels are controlled by 2 motors respectively. Through coordinated control of the 2 motors, it could be realized to control the magnetic crawler to forward, backward and steering.

2.2. Viewing angle control

The steering and transmission device contains 2 motors. One of them is used to achieve the 360 degree rotation around the z-axis direction, and the other is used to achieve the 180 degree rotation around the x-axis direction. It can be realized to achieve the real-time image acquisition of 180 degree viewing angle through coordinated control of two motors.

2.3. Comparison

The simulation comparison system is used to establish the 3-D structural model of the enclosed turbine runner chamber. By using the positioning and distance measuring device, the characteristic parameters which contain the real-time position coordinates of the magnetic crawler and the acquired image could be obtained. Then the observation point and the position of the image could be calibrated in the corresponding 3-D simulation model, to realize the split-screen display of the real-time acquired image and the simulation image.

2.4. Split-screen display

According to the positioning and distance measuring device, the real-time acquisition feature image could be positioned. Then the position of the corresponding feature image in the virtual model could be calibrated and the real-time acquisition feature image and the corresponding feature image in the virtual model could be split-screen display in the computer control interface. As a result, the corresponding virtual image with the same size virtual foreign matter would be displayed on another screen at the same time.

3. Application test

3.1. Design of magnetic crawler

During the whole detection system, the magnetic crawler is one of the most important components, whose stability and reliability have direct influence on the scope and detection performance of the system. The schematic diagram of the magnetic crawler and the transmission device is shown in Fig. 2.

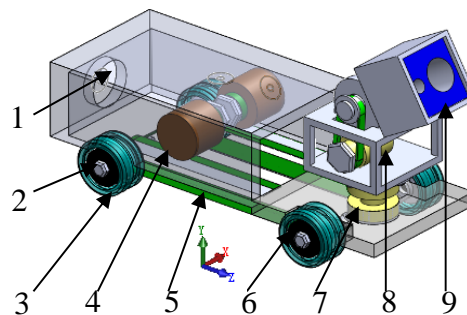


Figure 2. Schematic diagram of magnetic crawler and transmission device: 1- Cable interface, 2- rear wheels(drive wheels), 3- wear-resistant rubber wheel, 4- drive motor, 5- belt, 6- front heels(driven wheels), 7- motor around y-axis, 8- motor around x-axis, 8- image acquisition device.

The magnetic crawler contains the front wheels (driven wheels), the rear wheels (drive wheels), the drive motor, the belt and the wear-resistant rubber wheel. All the wheels are made by the permanent magnet, and the magnetic crawler which carries the real-time image acquisition device could complete the crawling work on the ferromagnetic surface of inclination angle of less than 55 degrees.

3.2. Processing magnetic crawler

The processing physical photo of the magnetic crawler is shown in Fig. 4. The cables are used to supply energy and achieve communication connection with computer control system. The magnetic crawler has compact and airtight structure and be able to meet the testing requirements of the hydropower plant turbine runner chamber.

3.3. Detection of hydropower plants turbine runner chamber

Taking the 6th turbine of a hydropower plant as a testing example, the relief hole below of the turbine runner chamber is as shown in Fig. 3. First of all, the virtual 3-D model of the turbine runner chamber must be established due to the actual structure and size parameters. And then, putting the magnetic crawler into the relief hole below of the turbine runner chamber and connecting with the computer control system, the magnetic crawler was controlled to walk forward. Meanwhile, the machine perspective in virtual model followed up according to the acquired real-time position parameters of the magnetic crawler. As a result, it was realized that the real-time acquisition of images and the virtual extract images split displayed comparably, as shown in Fig. 4.

The test results show that the magnetic crawler has stable, reliable and well real-time operation, and the detection system has clear image, stable signal and well synchronization transmission, to be

suit for internal inspection of the turbine runner chamber without opening the cover of the hydropower turbine.



Figure 3. Photo of relief hole below

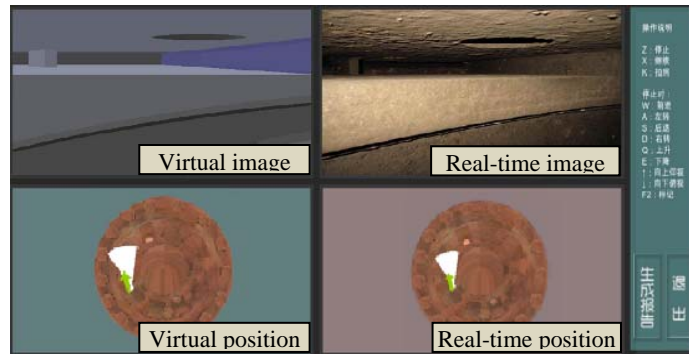


Figure 4. Split screen display interface of system

4. Conclusion

According to the designed detection device, the problems of the existing testing methods for the key hidden metal components were improved significantly. The application test showed that the designed automatic detection device could calibrate accurately and clean up the defects or foreign matter conveniently without opening the cover of the enclosed hydropower turbine runner chamber. According to the existing testing technical problems for the key hidden metal components of the turbine runner chamber, such as the poor reliability and the larger detection blind spots, it is proved to be effective of the proposed automatic detection method by using the simulation comparison system.

Acknowledgments

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