Advances in Machinery, Materials Science and Engineering Application X
M. Giorgetti et al. (Eds.)

doi:10.3233/ATDE240684

Research and Development of Defect Detection Device for Deep Hole and Large Thread Based on Rotating Linear Array CCD

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Abstract. With the attention of the country to the ecological environment, nuclear energy has been vigorously developed, and the deep internal thread on the nuclear reactor dome cover is easy to appear scratches and collapse problems during operation. In order to solve the defect identification problem of deep hole internal thread, this paper puts forward a system to identify the defect of deep hole internal thread by using rotating linear array CCD. The system includes the image acquisition module of internal thread surface, the core control module of motion mechanism and the defect identification module. The experimental prototype of the detection system is used to complete the drive control of the rotating linear array CCD, and the defect detection system of the deep inner thread is verified by using multiple thread images, which meets the expected requirements. The acquisition method of the surface image of the deep internal thread proposed in this paper has a certain reference significance for the acquisition of two-dimensional planar expansion of the internal thread. The designed defect detection algorithm has a certain reference value for recognizing the defect images containing texture features.

Keywords. Linear CCD, deep hole thread, defects, detection

1. Introduction

In order to meet the peak carbon neutrality and the demand for electricity in the whole society, the installed capacity of nuclear power in China will reach about 150 million kilowatts by 2035, accounting for about 10% [1] of the country's total power generation. With the development of nuclear energy, the deep hole large thread on the nuclear reactor dome cover appears in the operation process scratches and collapse and other problems, the reliability of thread connection is crucial for the overall quality of the nuclear reactor, once the screw thread on the dome cover appears scratches, broken teeth and other defects, in the case of excessive dynamic load, the thread connection may cause serious damage. Even lead to serious production safety and environmental pollution problems. Therefore, it is particularly important to test the thread of the

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connector regularly. In order to protect the nuclear reaction device, non-contact non-destructive testing of surface defects is used for maintenance testing. The main methods of non-destructive testing are magnetic particle detection, magnetic leakage detection, penetration detection, ray detection, eddy current detection, ultrasonic diffraction time difference detection, ultrasonic pulse reflection method, etc [2]. It is difficult to ensure an efficient and accurate detection effect when detecting defects on threads with complex surfaces. Through the rapid development of computer hardware and software, its data processing ability has been geometrically improved, making machine vision technology shine [3] in the field of defect detection. In this paper, the two-dimensional surface map of deep hole and large thread is taken as the research object of defect detection, and the main aspects of mechanical mechanism, CCD detection module, optical path and control system are deeply studied. It is found that this method has high detection accuracy, low cost and low requirements for operators' experience, and is suitable for deep hole internal thread defect detection. Therefore, the research of deep hole thread defect detection system based on rotating linear array CCD has great engineering application value and economic value.

2. Overall Scheme Design

In this paper, the image acquisition device extends into the threaded hole, the motion rotation device drives the image acquisition device to do circumferential rotation, and the core control module of the lower computer issues the open acquisition command to the image acquisition control module every 200ms. Until the image acquisition device stops sending the open acquisition command after rotating 360° inside the thread hole, and transmits the collected digital information to the processing module of the upper computer. The upper computer synthesizes the received digital signal into a two-dimensional image, and then obtains a clear image of the surface of the internal thread. After image processing and defect detection related algorithms [4], finally the completed image will be displayed on the main interface of the host computer. The method of acquiring the surface image of internal thread is shown in figure 1. Because CCD is a linear array optical detection, the scanning component must be rotated for surface scan detection, which includes a linear array CCD, an optical path camera component and an image sensor, as shown in figure 2. The main controller accepts the massive data of the sensor, and processes it and then uploads it to the remote controller, and the remote control filters the image into the picture. The remote controller sends instructions to the master controller to make the CCD rotate and the linear array CCD form the picture.

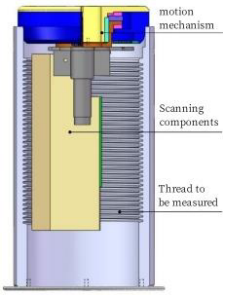

Figure 1. Mechanical structure of the detection device.

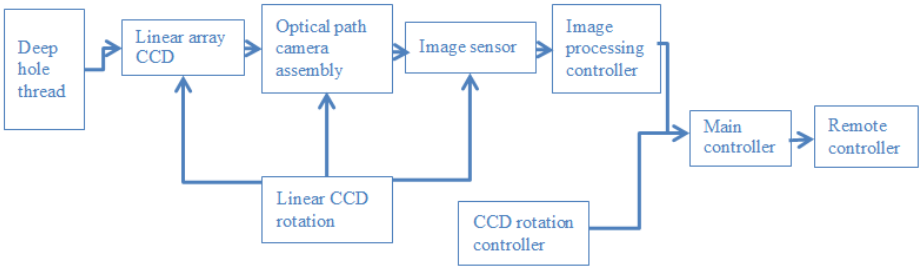

Figure 2. Topology of the detection device.

3. Imaging System Optical Path Design

This paper uses a lens with a focal length of 10mm and a thickness of 10mm. The distance between the thread to be scanned and the objective lens is 125mm, and the distance between the image sensor and the objective lens is 14mm. Therefore, the total optical path of the imaging system is 150mm.

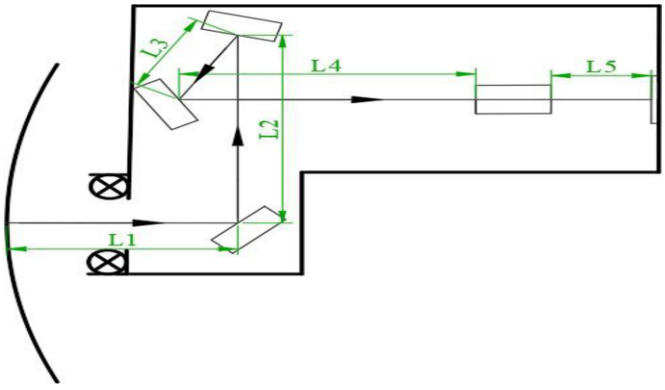

Figure 3. Design of folded optical path.

The image acquisition device needs to be fully extended into the threaded hole inside, due to the limited internal space, the volume of the image acquisition device must be compact, according to the imaging principle of the plane mirror, the reflector can be used to increase the object distance to reduce the volume of the image acquisition device, imaging light path is certain, the more the number of mirrors, the smaller the volume of the optical system. However, with the increase of the number of mirrors, the imaging quality will be affected, the imaging system uses three planar mirrors to meet the design requirements. The position or Angle of the plane mirrors is different, and the final optical path structure will be very different. After repeated adjustment and interference check of 3D modeling, the optical path structure as shown in figure 3 is designed. In figure 3, L1 is the distance between the first mirror and the thread middle warp, and its value is 31mm; L2 is the distance between the second mirror and the first mirror, with a value of 39mm; L3 is the distance between the third reflector and the second reflector, its value is 15mm; L4 is the distance between the main plane of the object side of the objective lens and the third reflector, its value is

39mm; L5 is the distance between the photosensitive element of the image sensor and the main plane of the object lens of the objective lens, and its value is 14mm.

4. Research on Defect Detection Algorithm

In the previous chapter, the hardware and software design of the lower machine of the defect detection system are introduced, and the image acquisition function of the internal thread surface is realized. This chapter will study [5] the defect recognition and detection algorithm based on the internal thread surface image. In order to realize the defect recognition, the image needs to be preprocessed to remove the noise in the image, image enhancement to remove the thread background information, image segmentation to highlight the defect and identification and detection of the defect edge.

In the process of transmission, the image is easily affected by the noise of electronic components, and the important information in the image will be changed in serious cases, which will have a great impact on the follow-up research results. Therefore, before image processing and without changing the basic information of the image, it is very necessary to remove the noise contained in the image to the greatest extent. In the process of image acquisition, the noise contained in the image is mainly the nonlinear pulse noise (salt and pepper noise) introduced by mechanical motion, optical devices and electronic components, and the median filter can effectively remove the pulse noise in the image. The median filter algorithm is a statistical sorting principle [6]. First, the size of the rectangular module needs to be determined, and all pixel values in the rectangular module are sorted. The value of the center pixel of the matrix module will be replaced by the median value obtained after the sorting, and the matrix module slides in turn until all pixels of the image are traversed.

After the median filtering, the salt and pepper noise in the image is removed, and the effect before and after filtering is shown in figure 4 and figure 5.

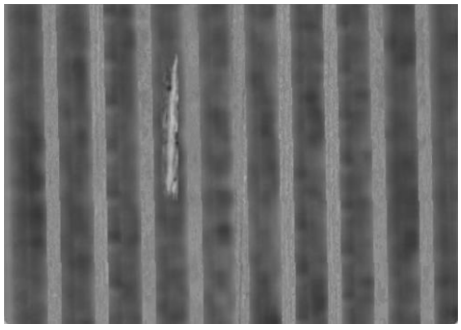

Figure 4. Part of the original image.

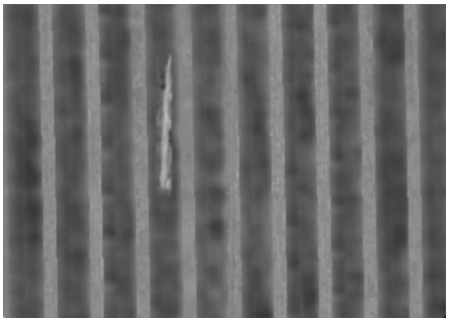

Figure 5. Image after median filtering.

5. Prototype Test System Test

After setting up the prototype system, the thread defect detection system will be tested [7]. In this paper, a deep internal thread with a middle diameter of 174.40mm and a material of No. 20 steel is selected as the test object. Due to the larger surface image of the internal thread collected, the larger the calculation amount of defect detection data

is. After repeated testing, the detection time of the whole image is about 89.4s. In order to reduce the detection time of the system, this paper divides the whole internal thread image into 8 small images of the same size, and then detects the 8 small images respectively. After testing, the detection time of this method is about 38.6s. The defect detection system proposed in this paper can only detect and recognize the pits, scratches and chipping defects existing in the internal thread image. In this paper, 80 images of thread were used to verify the accuracy and stability of the system, including 30 image with defects at the bottom, 30 images with defects at the top and 20 images without defects.

The detection results are shown in table 1.

Table 1. Statistical results of thread defect detection.

Classification	Number oftests	Number offalse detections	Number of missed checks	Correctly identified number	AccuracyRate
Bottomdefects	30	0	2	28	93.33%
Top defect	30	1	3	26	86.67%
No defects	20	1	0	19	95%

After system test, it takes about 22.5min to collect an image of the surface of the internal thread. There are 6750*3648 pixels in the whole thread image, of which each pixel corresponds to an actual distance of 81.17um. The minimum length of defects detected by this system is 11 pixels. This system can detect defects with actual length greater than 0.893mm. Through the above analysis, it is not difficult to find that this system can effectively detect the thread images with or without defects. It can be seen that the system proposed in this paper is feasible for the defect detection of deep internal threads. The testing interface is shown in figure 6.

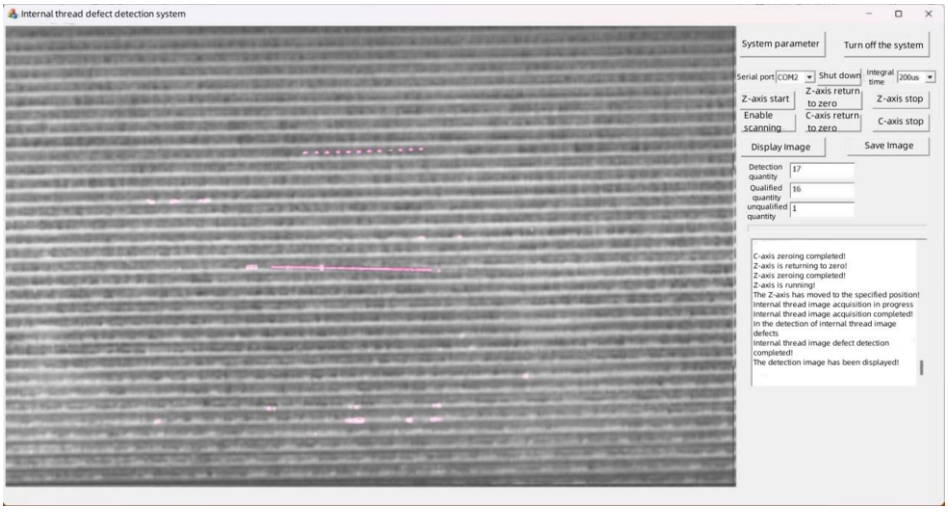

Figure 6. Effect diagram of defect detection Conclusion.

6. Conclusion

Aiming at the directional texture characteristics of the internal thread surface image, a suitable defect detection method is designed, the median filtering method is used to remove pulse noise in the image, the DCT method is used to enhance the image to remove the thread background information to the maximum extent, and the statistical process control binarization method is used to segment the image to separate the defect features from the image background. The improved Canny defect detection algorithm is used to mark the defect edge in the image. According to the system design prototype, the CCD drive timing and linear array CCD drive control are completed, and the accuracy of the thread defect detection system is verified by using the thread images with defects in the top and bottom of the thread and without defects, and the detection results are analyzed. In the whole system designed in this paper, the time of defect detection is 38.6s, while the image acquisition time of the internal thread surface is as long as 22.5min. The image acquisition seriously affects the response time of the whole system. The hardware and algorithm of image acquisition can be improved in the future.

Acknowledgement

This project is supported by Anhui Natural Science Foundation, No. KJ2019A0989; No. 2023AH051444.

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