Track non-contact detection method based on pulsed eddy current array and line structured light

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Abstract: Non-destructive testing methods are used to monitor the rails in operation to ensure the safety of train operation. Compared with traditional manual testing methods, non-destructive testing technology has higher detection efficiency and detection accuracy, and can also reduce the manual operation cost of railway detection. Based on the above advantages, this article combines two modules of linear structured light and pulsed eddy current array. Linear structured light can detect rail surface defects, pulsed eddy current array can detect defects inside and deep within the rail, defect information can be obtained through image processing, and the location of the defect can be accurately located by GPS locator, thereby improving the efficiency and Accuracy, and to ensure the safety of the rail. Railway transportation enables railway maintenance personnel to find and replace damaged rails in time.

1. Project research content and technical route

1.1 Project research content

Non-destructive testing is a kind of state judgment and damage defect using a series of reaction changes caused by damage or defect of the object under the premise of not destroying the structural integrity of the object under inspection and not affecting the functional characteristics of the object under inspection.¹ Evaluation method of detection. This paper mainly uses pulsed eddy current technology for crack deep-level detection and line structured light detection technology for rail surface detection.² The main research content of this paper includes two aspects: the construction of automated testing platform and data processing. The construction of the automated inspection platform mainly includes determining the layout of each part in the work platform, the selection and design of each part, and the determination of the platform's workflow, so as to ensure the stable operation of the work platform. In terms of data analysis, this article intends to combine image processing technology, sensor array technology, signal feature analysis technology and other means to process and analyze the collected data to realize the measurement of different defects inside and outside the rail. The content of this research is shown in Figure 1.
1.2 Non-contact rail defect detection platform

The non-contact rail defect detection platform designed in this project is composed of a line structured light vision detection module and a pulse eddy current array detection module. The line structured light vision inspection module mainly uses computer vision technology and laser inspection technology to detect surface defects such as wear or scratches on the surface of the rail. The pulse eddy current array inspection module mainly uses eddy current magnetic fields to detect cracks and other defects in the rail or in the depth direction. The combination of the two detection methods can detect various types of defects that may exist in the rail.

2. Line structured light module

2.1 Line structured light detection module composition

The main goal of the line structured light module inspection in this project is the defects on the rail surface. The rail is mainly divided into three parts: the rail head, the rail waist, and the bottom of the rail. The cross section of the rail is shown in Figure 2. Common defects on the surface of rails are wear, cracks, scratches and spalling. This project mainly uses the advantages of line structured light in measuring the three-dimensional geometric shape of objects with high accuracy and strong anti-interference ability to realize the detection of surface defects such as abrasion, spalling and scratches on the rail surface.

This detection system is mainly composed of line laser, camera and lens, photoelectric encoder, counter, computer, GPS and gyroscope. The photoelectric encoder is connected to the shaft of the detection trolley wheel through a coupling, the photoelectric encoder is connected to the counter, and the counter is connected to the computer. On the one hand, it can be used as the information for
calculating the defect location, on the other hand, it can calculate the running speed of the inspection car, which can be used as the basis for controlling the inspection car to run at a constant speed. The counter is used to record the cumulative number of pulse signals sent by the photoelectric encoder. The main function of the gyroscope is to collect and detect the body attitude changes during the operation of the car, mainly the roll angle and the yaw angle. The layout method of each component in the system is shown in Figure 3.

![Figure 3 Arrangement method of various components in the system](image)

2.2 Working process of line structured light detection system

The working flowchart of the system is shown as in Fig. 4. After the system is powered on, the first step is to initialize each part of the system, such as photoelectric encoder, counter, system parameters, etc.;

The second step is to set the parameters of the system camera, including working mode, exposure time, camera trigger mode, etc.;

The third step is to set the internal and external parameters of the camera of the system, the light plane equation, the initial moving direction of the inspection car and other parameters;

The fourth step is to detect that the trolley is running on the rail to be tested. The wheel of the trolley drives the encoder to rotate and sends out pulse signals. The counter counts. When the displayed data is an integer multiple of m (sampling period), the computer sends a trigger command to the camera. Gyroscope, GPS global positioning device, respectively obtain images, detect the inclination of the car and detect the position of the car;

The fifth step is to process the image, obtain the laser image, and calculate the point cloud data according to the system calibration parameters and the position of the detection car obtained by GPS;

The sixth step is to reconstruct the three-dimensional surface of the rail to obtain its surface defects;

The seventh step is to record and save the defect information.
3. **pulse eddy current array detection module**

3.1 **Pulse eddy current array module composition**

This module is mainly based on Maxwell's electromagnetic field theory to detect rail surface and internal crack defects [5]. The module consists of a detection probe, an electronically controlled displacement device, and a data acquisition module. The composition and connection of each part of the module is shown in Figure 5.

![System operation flow chart](image-url)
The detection probe is composed of a ferrite core, a coil, and an array of Hall magnetic sensors. The array of Hall magnetic sensors is designed to arrange 8 as detection probes. The distance between the sensors is 6mm, which is a symmetrical structure. The track surface is about 1mm. The structure of the detection probe is shown in Figure 6.
3.2 Working process of pulse eddy current array detection module:

The first step is to output a 1.5A, 100HZ pulse signal with a duty cycle of 0.5 through the excitation signal source, and provide it to the excitation coil to generate a magnetic field.

In the second step, the eddy current magnetic field signal is induced by the array Hall magnetic sensor.

The third step is to collect Hall magnetic sensor signals through the data acquisition card.

The fourth step is to preprocess the collected signal, extract features, and build the relationship between signal features and defect information.

In the fifth step, the computer software displays the information of the location and depth of the crack defect.

The sixth step is to move the moving device along the rail to perform the next stage of detection.

4. Conclusion

At present, the maintenance of railway tracks in our country is still done manually. A worker often needs to patrol 10 kilometers of railway every day. In the harsh external environment, the work intensity is often very high, and workers often need to work shifts. But the high-precision rail detection platform can detect tens of kilometers of railway sections a day, which is often much more efficient than manual detection and has better safety. This project can replace traditional manual detection methods, solve the current problems of low manual detection efficiency, poor safety, and strong technical dependence on workers, thereby improving the efficiency and safety of rail detection and ensuring the normal operation of the railway system. And this project can accurately detect different defects, and provide information such as the position and shape of the defect, so as to provide a certain reference basis for the maintenance and replacement of the rail.

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