Research on steel ball surface defect detection device based on machine vision

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Abstract. Based on machine vision technology, aiming at the characteristics of steel ball surface defect detection, a set of steel ball surface defect detection device is designed and built. The device designs a V-shaped groove unfolding mechanism which is composed of a turntable, an inner ring and an outer ring, through the intermittent rotation of the inner ring and the outer ring at different speeds, the steel ball can be rapidly deployed in the whole region, so the image collected by the system can cover the whole surface of the steel ball. In order to solve the halo phenomenon of steel ball picture and the mapping of surrounding objects, based on the principle of diffuse lighting, the bowl-shaped dome light source with adjustable brightness is selected, the quality of steel ball surface image and the effective area of detection are effectively improved. Based on LabVIEW software platform, a software is developed to collect and process the surface image of steel ball and identify the surface defect features. Test surface the device can accurately identify whether there are defects on the tested steel ball surface.

1. Introduction

Bearings as key components in mechanical equipment, widely used in a wide variety of mechanical equipment[1-4]. It can be seen in the "China Manufacturing 2025" released by the State Council. In the industrial base project, the first place in the mechanical basic components is the bearings. It can also be seen here that the key direction of industrial development is also high-speed high-precision bearings[2]. Therefore, in a sense, the bearings are the foundation of the machinery industry, and the bearings are used as the basic industry, and the development of bearings has an extremely important impact on my country's machinery industry. Steel balls are used as the most widely used rolling bodies in the bearings, and their processing quality, especially surface defects, will directly affect the accuracy and life of the bearing finished product[5].

During the production of steel balls, due to the influence of raw materials, heat treatment, technology, precision of processing equipment and processing environment, subtle defects will occur on the surface of steel balls[6]. According to the industry standard JB/T 10861-2008 "Surface Defectline of Rolling Bearing Steel Sphere", the surface of the steel ball is typically defective with numbers, scratches, pits[7]. If the steel ball is defective, then its dynamic performance is difficult to reach a higher level, which affects the bearing precision, so it is crucial to the detection evaluation of steel ball surface defects.

How to quickly and efficiently test steel ball surface defects is a problem for manufacturers. At present, many domestic steel balls and bearing production enterprises are sampled from finished products, and the judgment detection is performed by manually pairing if there is defect on the surface
of the steel ball. This approach needs to use a microscope and a magnifying glass through the human eye, and a comparison of the defect category is compared to the defect sample, and the steel ball is defective [8]. Obviously, this method will produce a lot of drawbacks and shortcomings, low detection speed, easy to misunderstand and errors, and seriously affect the production efficiency of enterprises, and the test of steel ball surface defect has become a bottleneck affecting the development of enterprises [9].

Based on the above reasons, in order to solve the problem of steel ball surface defect detection, this paper built a machine visual inspection system consisting of camera, single-chip microcomputer, and computer, designed a rapid area of steel ball, and applied a diffused light. The lighting principle selects the light source to achieve fast and automatic and efficient steel ball surface defect detection.

2. Steel ball surface defect detection device
Based on machine vision technology to detect the influencing factors of steel ball surface defects mainly: steel ball surface expansion mechanism, steel ball surface light effect, image acquisition processing method, surface defect recognition method, control portion and mechanical structure coordination, etc. Among them, the expansion method of the steel ball and how the steel ball is illuminated is the difficult point and focus of the device construction process.

2.1. Design of steel ball surface expansion mechanism
Whether the steel ball surface expansion mechanism guarantees that the steel ball surface is completely engaged in the key factors of the surface defect detection of steel ball. In the test engineering, if the expanded mechanism does not complete the steel ball, it will cause the surface of the steel ball collected by the camera to be incomplete, so that the defective parts cannot be detected, so that the number of missions is increased, which greatly reduces the effectiveness of the detection and accuracy. The device designed a V-shaped groove deployment mechanism composed of intermittent rotation motion of different vents of the carousel, inner ring and the outer ring, and realizes the rapid all-regions of the steel ball. As shown in ‘figure 1, figure 2’, a steering disk and a V-shaped slot expansion disk expansion mechanism with an internal and external split body , and the V-tank between the circular ring and the outer ring is 120°, the inner ring and the outer ring. The discharging of the steel ball surface is completed by a batch rotation movement of different velocity of the carousel, the inner ring and the outer ring.

![Figure 1. The circular ring and outer ring.](image)
![Figure 2. A steering disk.](image)
![Figure 3. Schematic of steel ball rotation.](image)

After connecting to the motor, the steel ball is connected to the motor. After the steel ball feeds, the motor drives the turntable to rotate, so that the steel moves from the feed position to the detection position, and the turntable remains no longer rotated when the steel ball is transported to a fixed position. When detected, the interior circle and the outer circles were intermittently moved, and the inner ring did not move, the outer circle rotate, and the steel ball is rotated around the A direction; the outer circle does not move, the inner circle rotation can make The steel ball rotates in the direction of the B direction; so that the surface of the steel ball is fully engaged by the movement of the two rings. The rotation position of the steel ball during detection is shown in Figure 3. After the detection is completed, the turntable continues to rotate, and the steel ball is driven away from the exhibition.
mechanism to the sort position, the system drives the sorting mechanism to complete the classification of good or bad surface defects on the surface of the steel ball.

2.2. Light source structure

The spherical structure of the steel ball and the characteristics of surface reflection make the light source structure a key factor affecting the image quality of the steel ball. For different steel ball surface defects, the angle and intensity of the light source irradiation produce different image shapes and features, bringing different results to subsequent image acquisition processing and defect identification, clear steel ball surface images facilitate defect feature accurate extraction and identification, the structure of the light source is critical to the entire device. Therefore, it is necessary to comprehensively analyze factors such as the shape, brightness, uniformity of the light source structure required for steel ball shooting.

After the steel ball is completed, the surface roughness is very low, approximate the mirror, so that the steel ball surface has a high reflectivity. Thus, the object around the steel ball is mapped to the surface during the shooting process, and the steel ball surface is the characteristics of the spherical surface, and the light of the light source will produce a significant "halo" of the captured picture. "Halo" covers some of the defects, such as improper handling of steel balls and misconduct, affecting the accuracy of the test results. In order to solve the problem of "halo", it is necessary to apply the principle of reflected light, so that the light can enter the imaging lens from different directions, thereby avoiding the appearance of the spot. Further, according to the principle of reflection, in order to make the light intensity uniform, the camera is consistent with the area of the steel ball, as shown in figure 4, which requires the light source to be spherical.

Comprehensive steel ball reflective halo phenomenon and cause analysis and surface light structure analysis, to ensure that steel ball surface defects can be clearly collected, based on diffusion light illumination principle and spherical characteristics, the brightness of the brightness adjustable DOME ‘figure 5’, The light is diffusely reflected to the steel ball surface on the surface, and the light is uniformly reflected from the steel ball surface to the lens, and the brightness of the illumination is adjusted according to the need to adjust the brightness. Such a light source can effectively solve the problem of halo on the surface of the steel ball and the problem of surrounding objects, which significantly improves the image quality of the collected steel ball surface.
2.3. Prototype structure

![Prototype structure](image_url)

The steel ball is shown in ‘figure 6’, the steel ball enters the turntable B from the inlet A. The turntable rotates the steel ball to the light source, the inner ring of the mechanism F and the outer ring intermittent rotation movement, drive the steel ball surface fully expand, camera D shoots the surface of the steel ball, judges the surface defects after collecting, processing, and identifying surface defects by computer software, and the turntable is transferred to the sorting mechanism C, whether or not the steel ball is Surface defects are selected.

3. Steel ball surface defect image processing and identification

3.1. Image processing and identification method

Another key content of the entire device system research is how image processing and feature recognition. Root Industry Standard JB/T 10861-2008 "Surface Defectline of Rolling Bearing Steel Sphere", steel ball surface defects include several typical defects such as spar, scratches, pits. The system is based on the virtual technology of the LabVIEW software platform for processing and defective feature identification. During the actual steel ball surface image acquisition, camera sensitivity, shooting speed, light source light intensity, uniformity of the union, the movement of the mechanism is slow, the position of the steel ball in the center of the picture, the consistency of steel ball, etc., It will result in a collection of pictures to generate some distortion, and the picture is not enough, and the quality of the picture is low. How to accurately extract a variety of defect information from the steel ball image is a more difficult problem, which is also a key issue that guarantees the reliable work of this system. To ensure the accuracy of surface defect identification, image processing flow and defect feature extraction is a very important issue. To this end, the image processing flow adopted by the device is image grayscale → ROI extraction → edge detection → image segmentation → pattern recognition.

First, the CCD camera takes a real-time photo on the surface of the steel ball, the image collected is a color picture, and the color picture is difficult to perform image segmentation and feature identification. At this stage, image grayscration is widely applied to process color pictures. Currently used gray image segmentation techniques are: histogram threshold, clustering, regional growth, edge detection, blur, neural network, etc., these methods will appear color discontinuities in the conversion to grayscale. The phenomenon of continuity affects subsequent processing results. This device is an image conversion algorithm for avoiding the above-described phenomenon using the HSI color space. After the collected pictures are treated by grayscale, then extract it for the region (ie, ROI extraction, region of interest), which is a valid area that truly need to detect feature recognition.

During the surface defect detection, according to the collected steel ball image, the comparison of the comparison of the commonly used edge detection operator is obtained by comparing the common edge detection operator. The image segmentation is one of the most important steps before analyzing the processing, and its main goal is to divide the image into an integral part of the object or region containing the real world or region. The gray level threshold is the simplest segmentation process. Many objects or image areas are characterized as the constant reflectance or the absorption rate of its
surface light, and a brightness constant, that is, a threshold, is to divide the object and the background. Threshold calculations are widely used due to small cost, fast speed and so on. After the steel ball surface defect image acquisition analysis, set reasonable thresholds extract the image feature completely.

3.2. Surface defect identification image
This paper applies the neural network algorithm of the LabVIEW software platform, and the typical steel ball surface defects, scratches, pits are used as the defective template, and the standard defect features are extracted after image processing and identification, thereby determining steel. Whether the surface of the ball is defective and the defect feature. Typical defect identification pictures are shown in figures 7-10.

![Figure 7. Pitting ball defect identification.](image1)

![Figure 8. Dent ball defect identification.](image2)

![Figure 9. Scratch ball defect identification.](image3)

![Figure 10. Normal free laminated ball identification.](image4)

4. Device control system
The steel ball surface defect detection device includes an intramographic mechanism, a steel ball deployment mechanism, a sorting mechanism, an image acquisition module, an image processing, and an identification. This paper develops surface defect detection software to achieve image acquisition, measure data display, defect identification, automatic storage data, etc., based on this, the control system is studied, and the steps between the modules of the device can make qualified steel balls. Successfully subjected to a test device, and the surface defective steel ball is exactly selected. On the basis of accurate identification of steel ball surface defects, various surface defects of the steel ball surface are statistically. When the device occurs an abnormal condition, the control system enables the device mechanism to stop. In addition, the control system can transmit the steel ball surface defect detection information in real time to the production line control system through the network, coordinate the rhythm of the steel ball surface defect detection device and the production line, and the coordination of the production line.
5. Test results
The device test selected a bearing steel ball of 400 diameters of 15 mm and precision grade G16 as a test sample, with 200 surface defects, there are 200 steel balls, and 200 in spots, scratches, pits 200. As shown in Table 1, the test results showed 185 steel balls, 184 normal steel balls were detected, and 93% of the comprehensive detection accuracy. Through analysis of misunderstandings, due to small defects of some defective steel balls, especially smaller defects, the steel ball surface defect position is random, and there is a certain gap with typical surface defect template images, and the image segmentation process the valve selection is not suitable, causing defective steel ball erroneous; further discovery normal steel ball misjudgement is because the surface of the steel ball is adhered to dust, resulting in misjudgement. Therefore, further investigation should increase the introduction of typical defect templates, improve shooting image clarity, set reasonable image thresholds, and should first be clearly detected, thus improving detection accuracy.

Table 1. Test results.

| Sample         | Measured | Check out | Misuse | Accuracy |
|----------------|----------|-----------|--------|----------|
| Defect steel ball | 200      | 188       | 12     | 94%      |
| Normal steel ball | 200      | 184       | 16     | 92%      |
| Total          | 400      | 372       | 28     | 93%      |

6. Conclusions
A machine visual inspection system consisting of a camera, a single chip microcomputer, and a computer is designed, and a steel ball surface expanded by the inner ring and the outer ring is designed, and the bowl-shaped DOME light source is selected as a steel ball. Light source. And develop related testing software, the steel ball is first detected, and the CCD camera collects a moving image, and then processes, analyzes and identify the image detection software, and finally drive an actuator to complete the detection and sorting. In terms of software development, the framework of image detection system is established based on the LabVIEW software platform, developing a functional module such as image acquisition, image processing, edge detection, segmentation, identification, and execution system. The device is convenient, the operating speed is fast, the detection efficiency is high, and the automated operation is high, the surface of the steel ball is clear, the light is clear. Further research and improvement will improve the system operation stability and detection accuracy, can be widely promoted to steel ball manufacturers.

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