The Measurement of a Wheel-Flange Wear Based on Digital Image Processing Technology

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Abstract—*we demonstrate the measurement of the wheel-flange wear based on digital image processing technology. The detail algorithm of the edge extracting and boundary tracking are given and the corresponding experimental results are also demonstrated. It is proved that the measurement accuracy and speed are improved, compared with traditional static measurement schemes, and the real time measurement is realized at the same time. The proposed measurement technique satisfies the requirements of the automatic measurement and can be applied in real measurements.*

Keywords- image processing; wheel-flange wear; automatic measurement

I. Introduction

The real time measurement of all parts of train wheels, especially the wheel flange wear, became particularly prominent because of the revolution of railway construction and the high speed of our trains[1]. So far, these measurements are still manual based in China. The manual measurements are not only complex but also inaccurate because of the poor tools, including calipers and rulers. So, it is urgent to propose some new technologies to realize the accurate and real time measurement of the wheel flange wear to guarantee the safe operation of trains and prevent accidents[2]. Here we demonstrate the measurement of the wheel-flange wear based on digital image processing technology in this paper. The proposed measurement is with the characteristics of high speed and accuracy and it satisfies the requirements of the automatic measurement and can be applied in real measurements.

II. Priciple and construction of measurement

The measurement system consists of lighting device, image acquisition system and image processing system. The lighting device and the image acquisition system are started when the wheels pass the switch on rail. The wheel images are collected and sent to the image processing system in order to extract the contours of the flange and tread when the wheels pass the CCD camera.

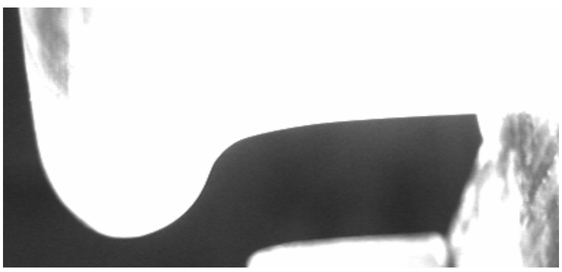

Fig. 1 Collected image of wheel flange

The parameters of wear flange and tread are achieved after correction. There are third steps needed in order to get a corrected and clear wheel flange contour. Firstly, the binary image of wheel flange contour is achieved. Secondly, its image edge is extracted. Finally, the final results of the height and width of the flange and the wear of tread are calculated and exported according to the results in first two steps. An image of the wheel flange, achieved from image acquisition system, is shown in Fig. 1.

III. algorithm of image processing

A. Binarization of Image

The purpose of the image binarization is to divide the image into two parts, object and background. The image binarization is achieved by defining the appropriate threshold for the histogram. The method is based on the assumption that each image region is composed of the pixels with many similar gray levels. However, gray level differences between object and background are obvious. We use the image binarization threshold approach for the type of variances[3][4], the processing steps are as follows:

a) to Calculate the histogram of the input image

b) to Calculate the mean gray *Ave*. *Phs(i)*,represent gray-level probability function

$$Ave = \sum_{i=0}^{255}(i-1)Phs(i)$$

c) to Calculate the mean gray class *Aver(k)* and the histogram class *W(k)*

$$Aver(k) = \sum_{i=0}^{K}(i+1)Phs(i)$$

$$W(k) = \sum_{i=1}^{K}Phs(i)$$

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d) to Calculate class separation index *Q(k)*

$$Q(k) = \{[Ave * W(k) - Ave(k)] \wedge 2\} / [W(k) * (1 - W(k))]$$

e) to Seek the values of *k* when the value of *Q* is maximum, the threshold, used to separate the object and background, is *T=k-1*.

B. Edge Extracting

The image edge is the most basic features of images. Edge refers to collections of pixels around the pixel gray value of step change and roof change. The image edges exist between object and background and between different objects. The image edges are important features for image segmentations. The image edges are based on discontinuity of the image gray value. The classic method of the edge extraction is to investigate the changes of gray value of each image pixel by checking the variation of first-order or second-order directional derivative.

There are several edge detection methods, including First-order differential operator method, Gradient operator method, Second-order differential operator method and LOG operator method. Here we choose Roberts[5][6] edge detection operator of the first-order differential operator method, which utilize the local differential to find the edge. It is given by the formula below:

$$g(x,y) = \left\{ \left[\sqrt{f(x,y)} - \sqrt{f(x+1,y+1)}\right]^2 + \left[\sqrt{f(x,y)} - \sqrt{f(x-1,y-1)}\right]^2 \right\}^{1/2} \quad (1)$$

Where *f(x, y)* is the gray value of the input image with integer pixel coordinates. The square root in equation (1) is to make the processing similar to the human visual system. The 2 by 2 operator can achieve the best response to a steep low-noise image and high processing speed and ensure the connectivity of the extracted edge.

C. Refine Image

The purpose of boundary tracking of image is to achieve a single pixel image contour, which need a few steps. The identification of the object contour pixels has to be achieved according to some strict "detecting criteria" at first. And other pixels of the whole object boundary are identified by a certain "tracking criteria". An algorithm[7] of the image contour tracking is presented as follows.

First step is to find out the point on the bottom boundary and to identify the boundary. Each point of the boundary can be expressed by the open angle between the currently edge point and the previous boundary point because the edge is continuous. The tracking guidelines are to start from the first boundary point and to define the initial search direction along the upper left direction. If the upper left point is an edge point, it is identified as a boundary point. Otherwise, the searching direction is rotated clockwise by 45 degrees until the first edge point is found. Then the edge point is used as a new boundary point. A second boundary point is searched by rotating 90 degrees counterclockwise based on first searching direction. The searching method of the next boundary point is same to the first one's. The entire border region can be found by this method. The image contour is obtained by tracking the boundary shown in Fig 2. The smooth single-pixel boundary is achieved and there is no breakpoint.

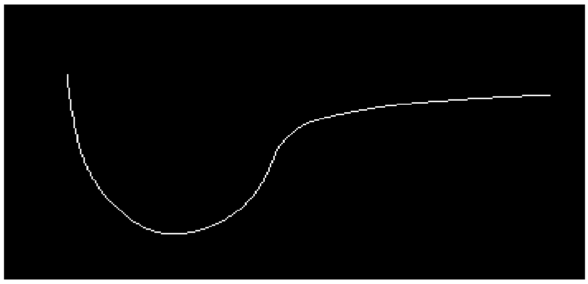

Fig. 2 Refining image after boundary tracking

The measurement results based on our algorithm is given in Table 1. The measurement accuracy is within 0.3mm which meets the precision requirements in engineering.

Table 1. Measurement of tread wear and wheel flange thickness

	1	2	3	4	5	6	7	8
Tread wear	0.42	0.43	0.44	0.42	0.41	0.44	0.41	0.42
Flange thickness	32.6	32.6	32.5	32.6	32.6	32.7	32.6	32.6

IV. CONCLUSION

We demonstrate the measurement of the wheel-flange wear based on digital image processing technology. An algorithm of the edge extracting and boundary tracking is described and the corresponding experimental results are given to demonstrate the precision of higher 0.3mm. All processing can be finished with a few seconds, which satisfy the requirements of the real time measurement and the automatic detection. The proposed system is expected to have broad application in railway engineering.

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