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Research and Development of Automatic Width Measurement and Alignment Equipment for Cold Rolled Aluminum Strip Based on Machine Vision

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Introduction

In the cold-rolling process of aluminum strip, due to the defects of the incoming strip and some reasons of the production equipment, the aluminum sheet will inevitably show deviation in the rewinding process . In order to ensure the processing quality of the strip, it is necessary to detect and adjust the position of the aluminum strip during the cold-rolling process.

In this paper, machine vision automatic width measurement and alignment scheme is adopted for its low cost, easy maintenance, strong adaptability to the environment, full play to the hydraulic servo system response fast, high precision, driving load capacity and other characteristics; the width measurement function is added to replace the manual width measurement and reduce the workload of workers.

Design of centering device and Overview of Algorithms

The installation diagram of the centering device designed in this paper is shown in Figure 1.The detection camera is installed adjacent to the main control unit to realize image detection, signal input/output, data processing, communication and other functions. The actuator uses Parker DF Plus proportional valve to control the position movement of the uncoiling reducer. The light source adopts astigmatism lamp, which irradiates evenly on the aluminum strip, so that the brightness difference between the aluminum strip and the inclined section of the underside feed roller is bright. Which is convenient for noise filtering and edge detection of image information.

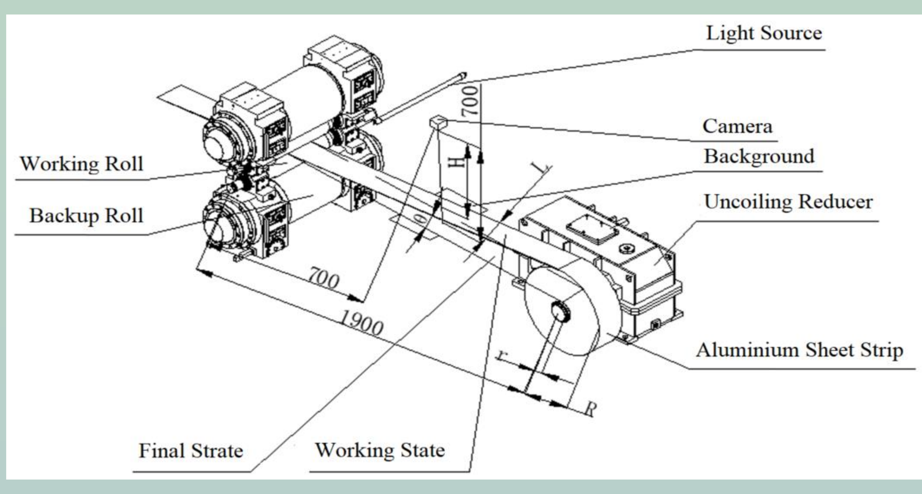

Figure 1. Schematic diagram of centering device installation

Camera calibration and coordinate conversion

The automatic width measuring and centering device in this paper extracts the edge information of aluminum strip with sub-pixel accuracy . However, with the decrease of the roll diameter of the aluminum strip, the slope of the measured aluminum strip is always changing. The Angle between the axis of the camera lens and the normal line of the measured aluminum sheet surface is also changing. This situation will lead to perspective distortion, and then affect the accuracy of edge detection. The camera lens distortion is another major error source that affects the edge accuracy .

In order to solve the problem of perspective distortion and lens distortion, this paper uses Zhang's calibration method to calibrate the camera's internal parameters: Normalized focal length $\boldsymbol{f_x},\boldsymbol{f_y}$; image main points $\boldsymbol{C_x},\boldsymbol{C_y}$; radial distortion coefficients $\boldsymbol{k_1},\boldsymbol{k_2},\boldsymbol{k_3}$; tangential distortion coefficient$\boldsymbol{p_1},\boldsymbol{p_2},$ camera external parameters: rotation matrix $\boldsymbol{R}$, translation matrix $\boldsymbol{t}$.

As shown in Figure 2, as the roll diameter of the aluminum strip decreases, the height of the strip gradually decreases as well, however the distance between the camera and the aluminum strip gradually increases. As a result, the deviation pixels corresponding to the same deviation are different at different heights. In order to solve this problem, the detection deviations of different heights were calculated according to the geometric relationship. Secondly, the edge information detected by the camera is converted from pixel coordinates to image coordinates. Once again, the image coordinates are converted to camera coordinates, and finally the camera coordinates are converted to world coordinates to obtain the actual deviation value .

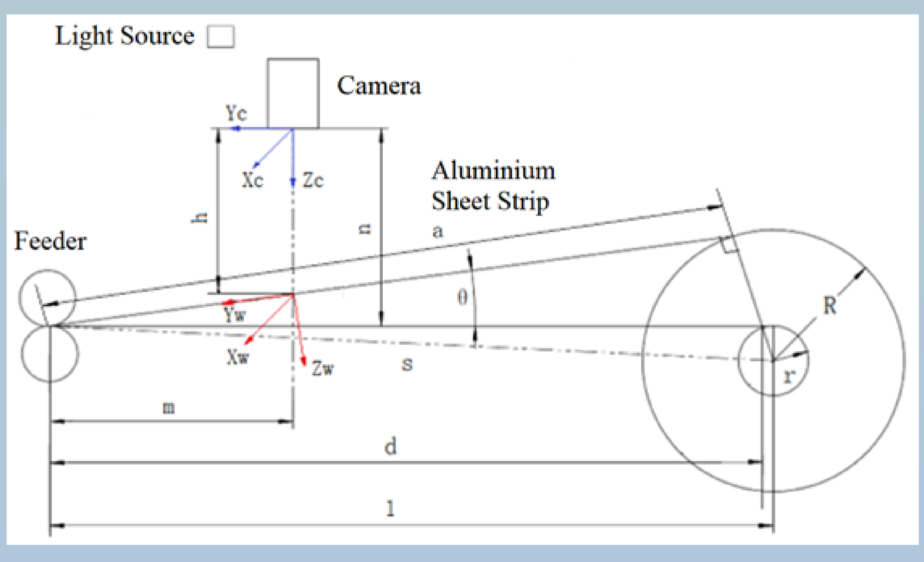

Figure 2. Schematic diagram of coordinate system transformation

According to the geometric relation in Figure2：

$$\begin{cases} R^2 + a^2 = r^2 + l^2 \\ (l-d)^2 + r^2 = \left(R - \sqrt{d^2 - a^2}\right)^2 \\ \tan\theta = \dfrac{\sqrt{d^2 - a^2}}{a} \end{cases} \qquad (1)$$

In Equation (1), r is the drum diameter of the uncoiler, in mm; R is the coil diameter of the aluminum sheet, in mm; a is the length of aluminum strip in mm; θ is the Angle, in degree, between the aluminum strip and the rolling process.

The following text will introduce the relation of coordinate system transformation, finally lead to obtain the corresponding relation between pixel coordinate points and world coordinate points and actual edge deviation and strip width of aluminum strip can be obtained, as shown in Equation.

$$\begin{pmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & \sin\theta & -h\sin\theta \\ 0 & -\sin\theta & \cos\theta & -h\cos\theta \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \dfrac{Z_c(u - C_x)}{f_x} \\ \dfrac{Z_c(v - C_y)}{f_y} \\ Z_c \\ 1 \end{pmatrix} \qquad (2)$$

Experimental Debugging and application effect

Through field experiments, the appropriate filtering value, the double threshold value of Canny edge detection and the input parameters of Hough line detection algorithm are debugged.

According to the comparison between Figure 3 and Figure 4, when the filtering value and the double threshold value of Canny edge detection are appropriate, ideal edge detection information can be obtained, but there are still interference signals, as shown in Figure 4.

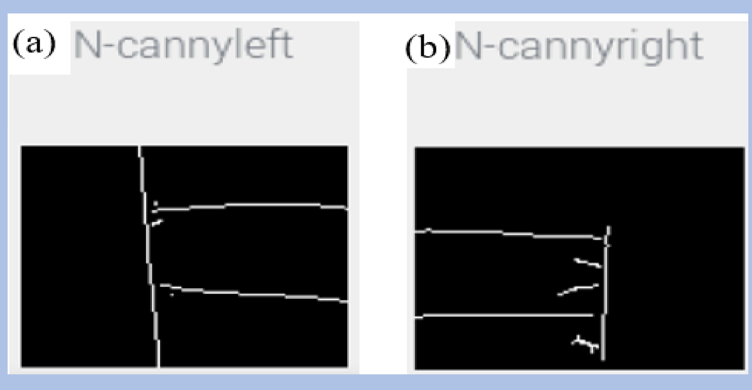

Figure 3. Edge information of aluminum strip before debugging

Figure 4. The first debugging edge information of aluminum strip

In view of the defects in edge detection, the edge information of aluminum strip is obtained and the pixel points are fitted in a straight line. Then, the slope of the fitting line is calculated and, obviously, the wrong lines are filtered out, so as to obtain the edge information of the aluminum strip with stable detection, as shown in Figure 5.

As shown in Figure 5(a), the maximum deviation of the aluminum strip before rolling is about 40mm. Based on the principle of system stability, one adjustment cannot achieve the desired effect. The automatic width measuring and centering equipment designed in this paper can complete the centering task throughtwo-time centering correction. As shown in Figure 5(b), the maximum deviation of aluminum strip after a single rolling is changed from the original 40mm to 6mm, and the effect after another rolling is shown in Figure 5(c). Which fully meets the current requirements of enterprise's aluminum strip products.

After camera calibration and conversions of coordinate systems, the width of aluminum strip measured by the automatic width alignment equipment (a) and the actual width of aluminum strip measured (b) are shown in Figure 6 below. It can be seen that the width measured by the equipment meets the production requirements of the enterprise.

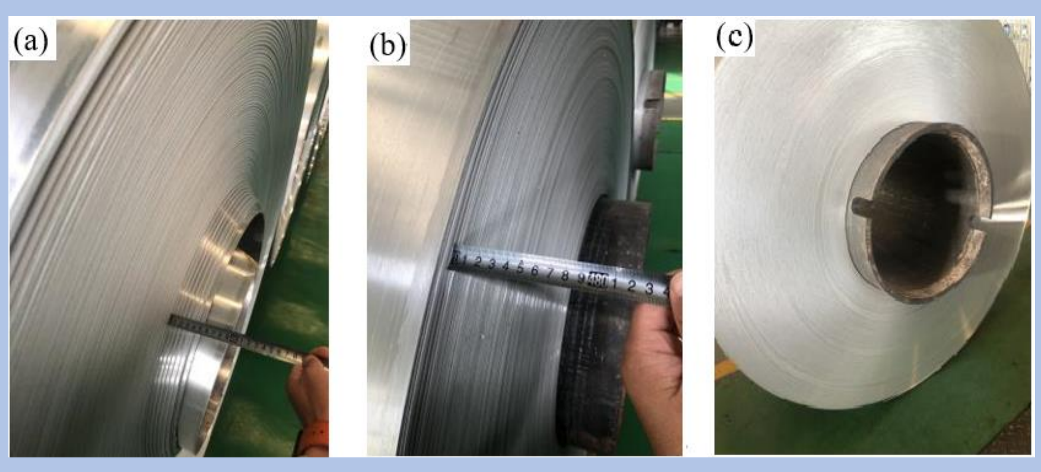

Figure 5. Edge neatness of aluminum strip

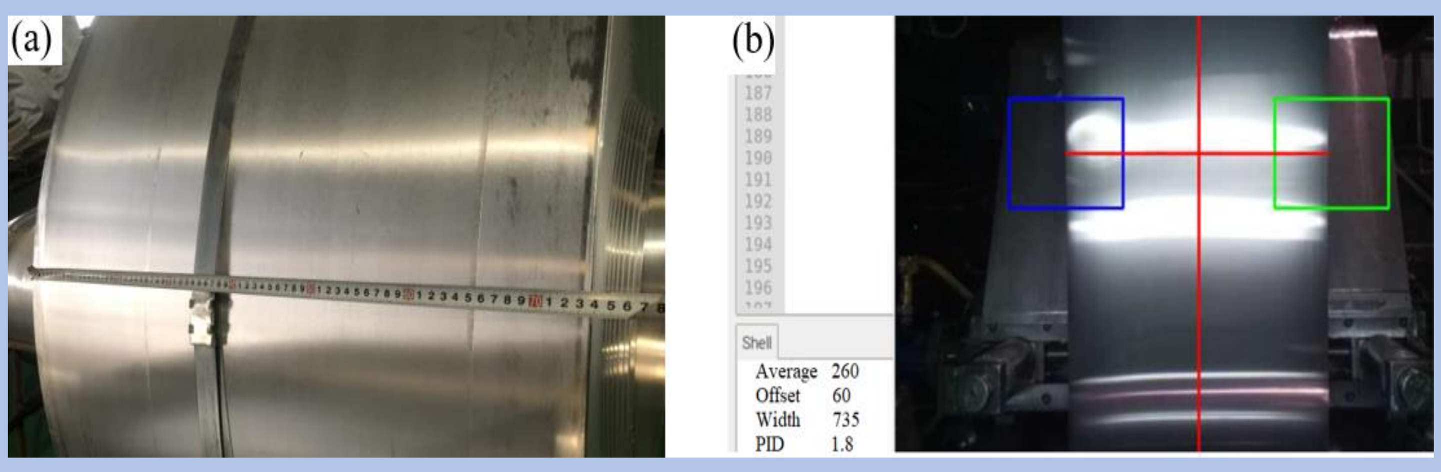

Figure 6. Width value of aluminum strip

Conclusions

Aiming at the phenomenon of aluminum strip deviation in cold rolling process, a set of automatic detection and correction scheme based on machine vision combined with the actual production is designed.

The experimental results show that the system has good stability, high degree of automation, and the centering accuracy is less than or equal to 1mm. Under the premise of ensuring the accuracy, the maximum rolling speed is increased from 240m/min to 360m/min, and the production efficiency is significantly improved.

Automatic width measurement function instead of manual width measurement, avoid manual measurement error and reduce the workload of workers.

The whole alignment process does not need manual participation, which avoids the influence of the operator's manual misoperation on the results, and improves the reliability of the aluminum strip conveying process.