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Strip Steel Bundling Control System Based on Image Process and Communication Technology

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Abstract: In order to solve the manual bundling problem of a strip steel end, an automatic control system of bundling strip steel based on machine vision is designed. The hardware system is composed of a color camera, an image capture card, a PC, a PLC and actuators.The image process technology is the key to identify and locate the steel end. Graying, contrast-enhancement and smoothness of the image are adopted in the process of pre-processing and in the process of partition and drawing out characteristics of image, edge enhanced and two-value process are used. The communication between PC and SIEMENS PLC is also important problem to implement the motor control and coordinate the actions of the entire system. By programing the communications procedures provided by VB software, Strip steel end bundling process canbe monitored amd managed effectively. Many experiments have been done and the results proved that, this control system has the advantages of low cost, versatility, high efficiency of communication and meeting the requirements of accuracy and reliability.

Key words: Strip steel, control system, communication, VB

INTRODUCTION

The strip steel is an important industrial raw material, which plays an important role in the national economy. Bundling process, in the strip steel production, will directly affect the packaging and transport of the strip steel.

In China, the manual positioning and bundling by strapping machine, is the common way in the large steel plants. Because when the strip steel enters the roller table, the position of its end is random. So it is difficult to determine the best location for bundling. Bundling at a bad position, the end of the strip steel can not be fixed well and it won't meet the standard of baling strip. It is very difficult to recognize the end of the strip relying on normal sensors lonely.

As image detecting has many advantages such as no contact, intuitionistic, amount of information and so on, a control system of strip steel localization and bundling based on computer vision is designed. This control system solves above problem successfully. Using image process technology, high-resolution camera is used to identify the end of the strip steel automatically. According to the position of the end of the strip steel, the control signal is sent to the motor by the PLC and the end of strip steel is adjusted at the bundling position with the motor rotating. Finally, the tying machine complete bundling task. Using this method, the end of strip steel can be identified well and truly and the position of the steel end can be controled. The experiment results showed that the bunding quality met the demand for strip steel bundling.

The system includes the following functions: an input part of getting images and digital processing; a calculating part of processing operations on the pixel array; a storage part of storing input data and processing results; an ouput part to display the processing result and the decision result; a part of motor control which is used to complete the end positioning. Obviously, identification of the strip steel by image process algorithm is the vital problem to be solved (Peng *et al*., 2009; Lee *et al*., 2011). During the running of the control system, the control of the motor is done on PLC amd the image process is completed on PC(named as upper monitor), the position data of the strip steel end should be sent from PC to PLC and the bundling result should be sent from PLC to PC. Thus,the communication between upper monitor and PLC is also a key problem to solve (Huang *et al*., 2009). This paper focuses on the solution for both key issues.

THE IDENTIFICATION AND LOCALIZATION METHOD OF STRIP STEEL END

The hardware of the control system is made up by some parts shown as Fig.1. The hardware system is composed

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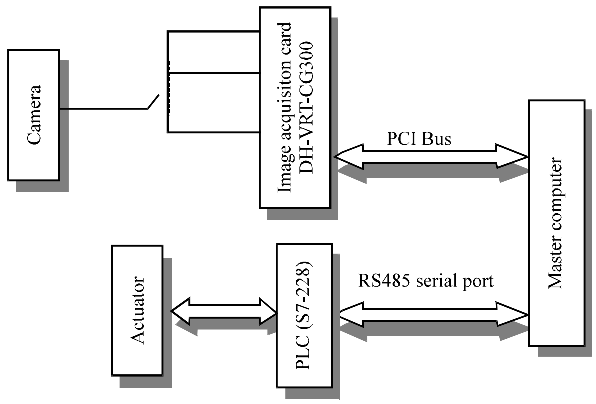

Fig. 1: System hardware configuration

of a color camera, an image capture card, a PC, a PLC and actuators. SIEMENS S7-200 series PLC is a modular compact PLC with an RS485 communication/programming port, which is used to complete motor control(actuators). The image process should be done on PC.WV-CP450 made by Japan Panasonic is adopted in our system, which resolution is 480. The camera captures images and then the image is digitized by the image capture card. DH-VRT-CG300 made by Beijing Daheng company is used as image capture card, which is high speed and colorized. It's operating principle is that the input colorized video signal should be processed by Digital decoding, A/D conversion, scaling, cutting out and Color space transform, then transform from PCI to VGA to real time display, or to computer memory to real time storage (Yu *et al*., 2011). After digitizing, the information mode is YUV 4:2:2.

The end identification of the strip steel: Image Gray histogram can change the centralized gray intervals to the average distribution in the whole gray range. Enhanced function shown as Eq. 1 is used to enhance the points of the image Spatial domain:

$$T = EH(s) \tag{1}$$

T, s is the pixels of the target image and the original image, respectively.

During the image equalization, two conditions should be satisfied:

- EH(s) should be a monotonic increasing function in the range of 0 = s = L-1
- According to the range 0 = s = L-1, it should be ensured that 0 = EH (s) = L-1

The first condition ensures the gray marshalling sequence doesn't be changed as enhanced process. The second condition ensures the gray consistence of the dynamic range during the transfering process:

$$t_k = EH(sk) = \sum (ni/n) = \sum ps(si), (k = 0, 1, 2 \cdots L-1) \tag{2}$$

The above summation interval is from 0 to k. Using Eq. 2, the gray values of all pixels can be obtained directly after the histogrm equalization.

The Light conditions at the workshop and the exposure of the image captured by the camera is not uniform. This kind of image can't be used to identify the end of strip steel. Basing on the morphological image enhancement method, the fault of histogram equalization canbe overcome. That means, not only the Image statistical characteristics is considered, but also the local position information of the pixels are took into account. Suppose f represents the gray image, f (m,n) means the gray at the point (m, n) int the image f. Suppose the sets A, B are convex set defined on Z_2 and make A⊆B. B is divided into two subsets: hard core A and flexible edge B\A. here '\' means set difference. A and B are both structural elements.

The k_th small value in Eq. 3 is the value of flexible forms corrosion:

$$f\Theta[B, A, k](x) = (\{k\Diamond f(a) | a \in A_x\} \cup \{f(b) | b \in (B/A)_x\}) \tag{3}$$

The k_th big value in Eq. 3 is the value of flexible forms expansion.

The open and close operation of flexible forms can be completed using Eq. 4 and 5:

$$f \circ [B, A, k] = (f\Theta[B, A, k]) \oplus [\hat{B}, \hat{A}, \hat{k}] \tag{4}$$

$$f \bullet [B, A, k] = (f \oplus [B, A, k]) \Theta [\hat{B}, \hat{A}, \hat{k}] \tag{5}$$

In that, $\hat{B}$ and $\hat{A}$ are reflection set, respectively. As the image processed by expansion and corrosion has obvious gray difference, especially, the gray jump area at the edge should appear obvious change, the difference got by the comparison before and after the image change can be used to detect the edge.

The image is detected by Canny edge detection operator and the zero crossing point of second-order directional derivative is used as edge point. Gaussian filter is used to filter the image first, the noise is wiped off. Then the modal shown as Eq. 6 is adopted to calculate gradients value M and the direction Q:

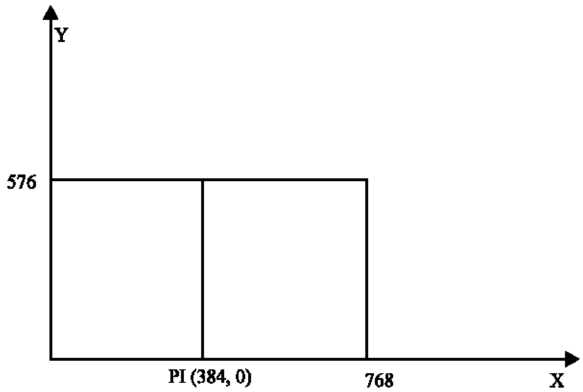

Fig. 2: the coordinate position of the central point

$$P = \frac{1}{2} \times \begin{bmatrix} -1 & 1 \\ -1 & 1 \end{bmatrix} \quad Q = \frac{1}{2} \times \begin{bmatrix} 1 & 1 \\ -1 & -1 \end{bmatrix} \qquad (6)$$

Then the gradient value M and the dierction Q can be calculated by Eq. 7 and 8:

$$M\,(i, j) = \sqrt{P^2\,(i, j) + Q^2\,(i, j)} \qquad (7)$$

$$\theta\,(i, j) = \arctan\left[Q\,(i, j) / P\,(i, j)\right] \qquad (8)$$

non-maximum suppression is made to the gradient. The larger the amplitude image array is, the corresponding image gradient value is large.

THE LOCATING CONTROL OF BOUNDLING POSITION

The strip steel is sent to the position of the bander by the roller and then is clamped and fixed under the bander by four clamping bars which is drove by the air motor drives. The camera is installed under the roller. When the camera receives the command signal from PLC, it begins catching pictures. If the end of the strip steel is found, the end localization control is done; otherwise, the rotating require signal is sent to the PLC and the motor will rotate 120 degree. When the rotating degree is completed, PLC sends the command of catching pictures again. The image process is done by the PC and the position from the steel end to the central axis is calculated. Then the timer of the PLC controls the rotating time of the roller until the steel end is localized at the certain position. Lastly, PLC sends the bundling signal and bundling task is completed.

The window of the CRT is 768*576. Set the coordinate origin is at the bottom left P (0,0), thus the center coordinate of the input window is P1 (384,0). This point is the position of the camera and the visual angle of he camera is 120°, which is shown as Fig. 2.

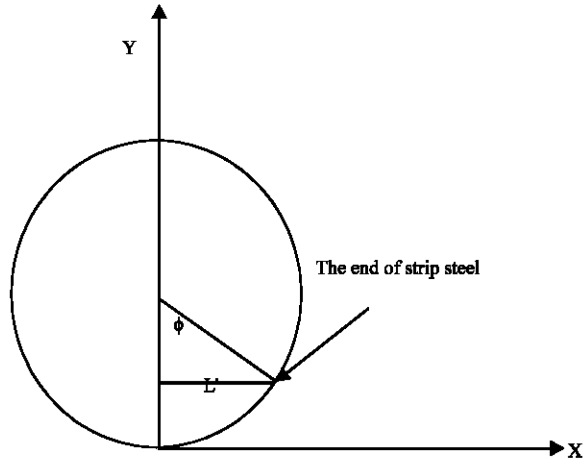

Fig. 3: The end localization of the strip steel

When the end of the strip steel is found by image process, its position is set as P'(X,0). There are several situations should be thought of.

- The end of the strip steel is at the left of P1, that is , X<384. Then the position from the end to the central axis is X' = -|X-384 |. The minus means the point P'is at the left of the central axis
- The end of the strip steel is at the right of P1, that is , X>384. Then the position from the end to the central axis is X' = |X-384|
- The end of the strip steel is not at the frame plane. If it is this situation, the motor is controled to rotate the trip steel 120° and the new frame is caught again

According to the Gauss imaging Eq. 9 and 10, the position from the end to the central axis can be obtained:

$$1/L+1/L' = 1/f \qquad (9)$$

$$L = L'*f/(L'-f) \qquad (10)$$

In that, L: object distance; L': image distance, L' = X'; f: The focal length of the lens

The rotating time of the motor is also the linchpin to ensure the bundling position. If the motor used in the control system is octopole and the Speed down ratio n = 21.5. The rotating direction is clockwise, so the rotating speed of the stip steel is 21.6° sec. Suppose the end of the steel is identified and the postion from the end to the central axis is calculated (Fig. 3), the rotating time of the roller canbe calculated with three cases:

In Fig. 3, Sinφ= 2L?/D, -90°< φ<90°:

- When $-90° < \varphi < 0°$, that is P'is at the left of the central axis, then:

$$T = (360°+\phi)/\varphi = [360+\arcsin(2L'/D)]/21.6°$$

- When $0° < \varphi < 90°$, that is P'is at the right of the central axis, then:

$$T = \phi/\varphi = \arcsin(2L'/D)]/21.6°$$

- When the end is not found in the frame, then:

$$T = 120°/\psi = 120°/21.6° = 5.6s$$

COMMUNICATION BETWEEN PC AND PLC

The host computer uses VB6.0's Active X controls -Microsoft Communication control (Li *et al*., 2003; Zhou *et al*., 2008). It can easily achieve the communications between the PLC in Windows.

In many small distributed control systems, if professional industrial configuration softwares are used (such as INTOUCH, FIX, WINCC) to make the host computer monitoring interface and the special PLC communication interface modules, as well as the DDE Server recommended by its manufacturer are used to link the upper computer and PLC, it is very expensive. So the direcet communication between PC and PLC is a good technical solution.

In the Windows, we can take advantage of the C language to complete the design of the software with the application program interfaces provided by Windows SDK to develop industrial PLC communications, but it will be very complex. However, it will be very simple to program when we use communications control provided by Visual Basic to develop serial communication procedures. Programming is very simple, a high communication efficiency can be got and VB design of the interface is very concise.

So when we developed baling positioning control system of strip steel based on image processing technology, the communications control MSComm structure provided by VB are used to communicate with the PLC.

Design of the communication flow: The composition of the whole control system is shown in Fig. 1. SIEMENS S7-200 series PLC is a modular compact PLC with an RS485 communication/programming port; it has three types of communication: PPI communication protocols, MPI communication protocol and free communication. Free communication is a unique feature of the S7-200 PLC. It allows S7-200 PLC to communicate with any other equipments or controllers which opens their communication protocols. In the other word, the communication protocols of S7-200 PLC can be defined by the user (for example, ASCII protocol) for receiving interrupt, sending interrupt, sending commands (XMT) and receiving the instruction (RCV) to control a communication operation by ladder program. Therefore it will greatly increase the communication range and the control system configuration will be more flexible and convenient. This communication can communicate with peripherals that equiped with serial interface.

The communication port RS485 provided by CPU224 uses half duplex communication. It only needs two data lines TXD and RXD to send and receive data, so there is no hardware handshaking communication. We can only adopt software handshake to keep the synchronization of data transfer between PC and PLC. As free PLC communication format is adopted, the baud rate can be set as 9600 kbps, data transmission format is without parity bit, 8 bits ASCII code per character. During transmission, there may be interfered and distorted and the transmission result is wrong. To ensure the security of the communication, we use the BCC check method, i.e., add the frame check code in the sending data frame. We xor and sum the ASCII code of the string to form the frame check code and transmit them in bytes. The frame check code is sended as the part of the information. In the same manner, when the serial port of the PLC receives the data, it will xor and sum the receiveed string and compare it to the frame check code. If the values □ □ are equal, it represents that the received command is correct. If the values □ □ are different, the communication error, retransmission is required. PLC sends "retransmission" signal to PC and waits for the host machine retransmission consent signal, until the command is correct. The communication flow charts between the PLC and the PC are shown in Fig. 4 and Fig. 5.

SOFTWARE PROGRAMMING OF COMMUNICATION CONTROL TESTING BETWEEN PC AND PLC SERIAL PORT

After MSComm control is embedded in the project window. In order to control a serial port to communicate, we must also insert this control into the application of the controls. To this end, the MSComm control is inserted in a dialog box for the program and this control is called as MSCOMM1. Communication controls are used to access the serial port to send and receive data. At the same time, we need two timers controls (TimPeriodic and TimNonPeriodic) and a command button control

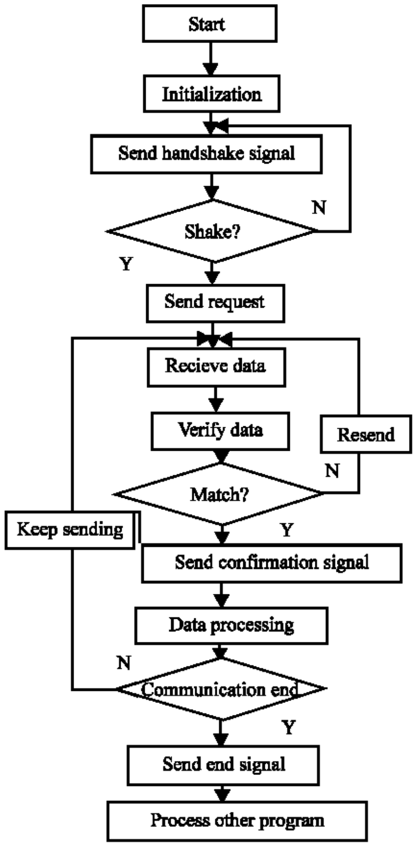

Fig. 4: PLC communication flow chart

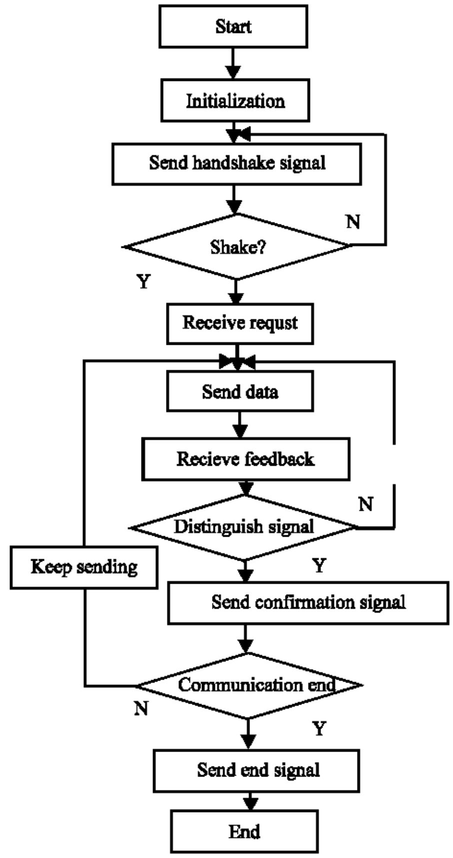

Fig. 5: Upper computer conmmunication flow chart

CmdNonPeriodic. Cycle timer control (TimPeriodic) is used to control the computer to send the periodic command to data point per second; command button control and non-cycle timer control (TimNonPeriodic) are used to send non-periodic command.

The information that PLC send back is 2 bytes per frame. The event-driven communication is adopted during programming. When serial port receives two characters, it will activate a OnComm () event. In OnComm () message processing function, there is a processing code used to read the string "START" or "ERROR" and make appropriate treatment, such as “start recording”, "resend the data" and so on.

Let RS-485 port address be serial port 2 of the PC, baud rate is 9600kbps.

In forms, the initial setup programming of controls is shown as follows (Ye, 2012; Haraikawa *et al.*, 2002):

- Sub Form_Load ()
- Mscomm1.CommPort = 2 //Select COM2 serial port
- Mscomm1.Settings = "9600, N8,1" //Set the baud rate as 9600, no parity, 8 data bits, one stop bit
- Mscomm1.InputLen = 0 // Read the entire contents of the receive buffer
- Mscomm1.Portopen = 0 //Open the communication port
- Mscomm1.InBufferCount = 0 //Clear the transmit buffer data
- Mscomm1.OutBufferCount = 0 //Clear receiving buffer data
- TimPeriodic.inteval = 1000 //set 1S timing interval, the telemetry command sent 1 times every 1S
- Tim Non Periodic.inteval = 500 //set the 0.5S timing interval to determine whether or not to active query command button and to send periodic command
- CmdPressed = False //command button is inactive
- DuringPeriodic = False 'cycle command data transmission has not yet started
- DuringNonPeriodic = False //aperiodic command data transmission has not yet started
- End Sub

EXPERIMENT RESULT

The test results of image process: In experiment, the camera made by Japan Panasonic with the type WV-

Table 1: The success rate of the end identification

Clock	8	10	12	14	16	18	20
Times	10	10	10	10	10	10	10
Success rate	93%	95%	88%	90%	96%	94%	91%

Table 2: Test statistics of communication

Group	The times of receiving data	The times of correct receiving data without any checkout method	The times of correct receiving data with frame check code
First group	1747	497	500
Second group	1461	495	500
Third group	1145	499	500

CP450 is used to capture the frame, Image acquisition card made by Beijing Daheng company with type DH-VRT-CG300 is used to collect and preprocess the image. After digitization, the format of the output image is YUV 4: 2: 2. According to the request of the image process, YUV-RGB color space is adopted to do transformation function. After transformation the image format maybe RGB 5: 5: 5,RGB5: 6: 5, or RGB8: 8: 8. The maximal size of the input video window is 768*576. The display window should be smaller than the input video window.

During the experiment we found that the installing position of the camera should be at the middle position of the strip steel and the axis of the camera must be vertical with the plane of the steel end. Adjusting the focus of the lens is adjusted to keep the most effective image. VC 6.0 is used to program the image process part, because the Dynamic Linking Library (DLL) is easy to connect. Some steps of preprocessing, image segmentation, feature extraction and data storage are done, then the end of the strip steel can be identified accurately.

Figure 6 shows the experiment result of identifying the steel end. As the light is changed at different time, the identification result should be affected. Table 1 shows the different identification result. Ten times experiments are done at each time. It is obvious that too bright and too dark light are both unfavourable for image process. As long as the light is adjusted advisably, the end detecting is well assuring.

Communication test: When PLC receives a string of data frame, it will send a feedback. When feedback is sent, a transmission completion interrupt will start. XMT complete interrupt service routine is used to handle the transmission completion interrupt event. This interrupts program will perform some operations which will include: reset the BCC checksum correct flag, clear the BCC code register, reload the address pointer which is used to calculate the BCC checksum, clear the receive buffer bytes which is used to store data and characters (It is used to determine whether the next instruction format is correct). The success rates of the communication between PC and PLC is shown as Table 2.

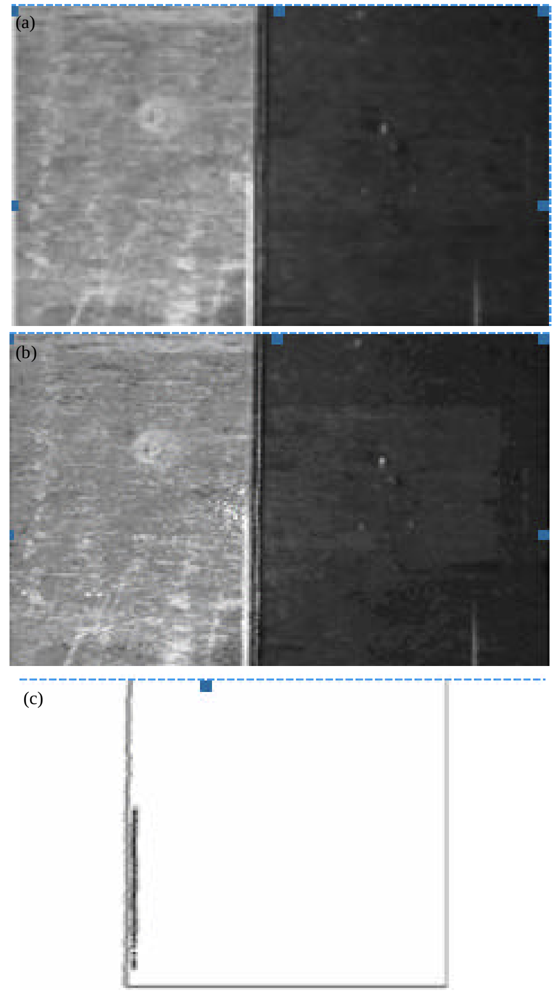

Fig. 6(a-c): End identification result, (a) Image dealing with graying arithmetic, (b) Enhanced image based on morphology and (c) Image dealing with edge enhancement and binarization processing

In Table 2, the times of receiving data mean the whole times of entering the serial port of the PLC, which includes many interference signal. The times of real communication data are 500. Without checkout method, several wrong receiving data are appeared in the test. However, the success rate reaches 100% with frame check code.

CONCLUSION

The 500mm production of heat rolling strip steel in LAIGANG Limited Company assumes advance horizontal at present in country for pan continuous heat rolling. The techinics of production is heat?dividing phosphorus?rolling?cooling?check-out?reeling?

baling?packing?entrance storage?send goods. In order to solve the manual bundling problem of a strip steel end, an automatic control system of bundling strip steel based on machine vision is designed. The Computer-Vision auto positioning control system has the below advantages: high-accuracy, quick deal-time. Some can conclude that system can be adopted widely in the manufacturing industry and the perspective will be attractive.

The image process technology is the key to identify and locate the steel end. Graying, contrast-enhancement and smoothness of the image are adopted in the process of pre-processing and in the process of partition and drawing out characteristics of image, edge enhanced and two-value process are used. In the current bundling process of strip steel, the "bottleneck"- the end locating of the strip steel is not accurate- limits the packaging quality. VB is used to realize the communication between the PC and PLC, which is helpful for monitoring and managing control device effectively. The means of communication is used to the positioning and bundling control system of strip steel, which can effectively solve the bottleneck problem and greatly improve the accuracy and efficiency of the positioning.

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