Steel sheet location tracking and automatic sorting self-adaption control model

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Abstract

The sorting control system is the critical procedure in the final product line of cold rolling mill. Taking the tinning steel sheet sorting control system of shearing production line of WISCO's cold rolling plant as an example, the process of steel sorting control system is introduced. The running principle and control concept of steel sheet position tracking and sorting are particularly presented. The practical application proves that the system can position the tinning steel sheet which is moving in high speed, which is of high controllability and reliability.

Keywords: sorting control, position tracking, magnet system, self-adapt regulating, dropping posture control

1 Introduction

The primary task of cold rolling plant shearing production line [1] is to automatically detect the sheet defects, and shear the sheet to specified length, then automatically separate the finished products from the inferiors, finally pack manually and deliver. The steel sheet sorting system [2] is the key step in the whole production process. The Figure 1 and Table 1 are the process flow of sheet sorting system ().

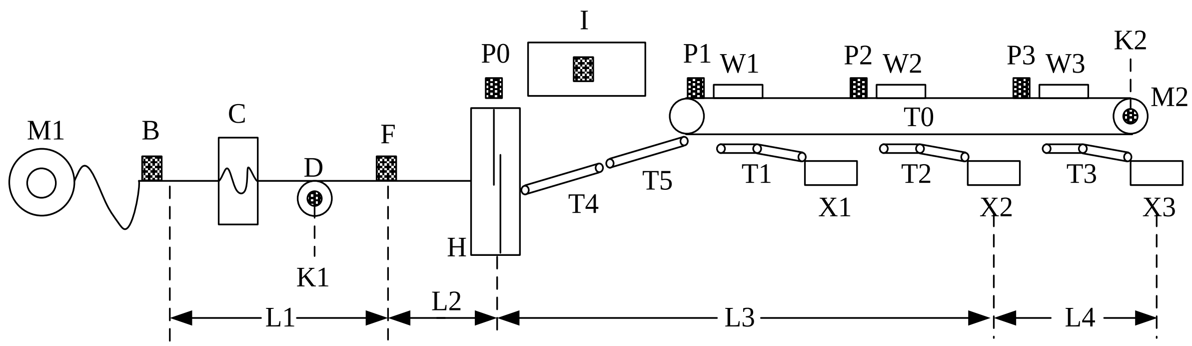

FIGURE 1 Sheet sorting system process flow

TABLE 1 Symbols description of sheet sorting system process flow

Symbol	Description	Symbol	Description
M1	Decoiler	T0	Main transmitting belt
K1	Speed encoder	T1,T2,T3	1#,2#,3# Stacking table belt
B	Thickness gauge	T4,T5	4#, 5# Entry belt
C	Straightener	W1,W2,W3	1#,2#,3# Stacking table magnet system
D	Pinch roll(S roll)	P0	Flying shear phototube
F	Pinhole detector	P1,P2,P3	1#,2#,3# Stacking table phototube
H	Flying shear	X1	1# Inferior stacking table
M2	Recoiler	X2,X3	2#,3# Quality stacking table
K2	Speed encoder	I	Examining table

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2 Process flow and control principles of the system

2.1 SYSTEM PROCESS FLOW

The system process flow [3] is: steel coil is uncoiled by decoiler, then going through the thickness gauge {B}, straighttener, pinch roll and pinhole detector {F}, and be feeded into flying shear. The steel coil is cut to specified length steel sheets by flying shear, and then transmitted to belt transportting system to automatically select [4]. The steel sheets are separated into quality products or the inferiors, and then stacked to specific stacking table, transmitted to packaging roll, finally packing and transport manually [5].

When a new steel coil is uncoiled and sheared [6], the previous sheets are identified as inferior sheet, the operator press the inferiors falling button and drop the previous sheets into inferior stacking table [7].

The thickness gauge {B} detects the sheets' thickness on-line [8]. If the sheet thickness exceeds the positive and negative deviation range, the certain segment sheets are identified as inferior products. The pinhole detector {F} includes left and right pinhole detecting units [9]. If any detecting unit inspects the pinhole defect, the certain sheet is identified as inferior products. On the examining table [I], the quality control inspectors inspect each sheet. If the sheet has surface defect, the certain sheet is identified as inferior products. All the defect sheets will be stacked into inferiors stacking table.

The flying shear cut the steel coil into specified length sheets [10], the sheets are conveyed into main transmitting belt {T0} by the 4#, 5# Entry belt {T4, T5}. Several permanent magnet steel bodies are installed in the middle part of main transmitting belt so as to attract the sheets just beneath the main transmitting belt. There are three magnetic field control systems {W1, W2 and W3} in the main belt above the stacking table belt [11]. When the system working in certain time frame, the system's magnetic field can counteract the permanent magnet steel bodies' magnetic field. Then the sheets under the permanent magnet steel bodies will drop onto the stacking table belt, and transmit to corresponding stacking tables.

The sheet box can be automatic adjusted to appropriate length and width, so as to contain the sheets. When the sheet quantity of quality stacking table reach the specified quantity, the sheets can be automatic packaged and transported.

2.2 SYSTEM PROCESS FLOW

The key points of the sorting control system are:

1) The system should accurately track the position of sheets, which is transmitting at a high speed (300 m/min), so as to find the inferior sheets detected by the pinhole detector and thickness gauge and make it drop into the inferior stacking table.

2) The system should be adaptive to the speed of three belts {T0, T4, T5} according to the sheet's length. The sheets' distance can be extended to a proper value, so as to be easy for the phototube to track the sheets.

3) Because the system's running speed is very high, the magnetic control system should control the sheets' dropping location and dropping location accurately according to the sheets' length and running speed, so as to avoid the pile-up accident.

3 Self-adaption sorting control model

3.1 DEFECT SHEETS POSITION TRACKING

The key point of the whole sorting control system is sheets' position tracking, especially the inferiors sheets' position tracking.

The three stacking table and flying shear {P0, P1, P2 and P3} are equipped with four phototubes, through which the sheets number can be counted and tracked.

Supposing:

- N_0: flying shear phototubes' counting number;
- N_1, N_2, N_3: P1, P2, P3 phototubes' counting number;
- L_1: the distance between thickness gauge {B} and pinhole detector {F};
- L_2: the distance between pinhole detector {F} and flying shear{H};
- L_0: the length of sheet.

We define a array R to save the defect sheet counting number.

If at the T_1 time, system detected a thickness defect sheet [12], and then thickness defect sheet counting number at the current time can be calculated according to formula (1) and storage to array R:

$$X_1 = \mathrm{RND\_}(\frac{L_1 + L_2}{L_0}) + N_0 + 1 . \quad (1)$$

If at the T_2 time, system detected a pinhole defect sheet [13], and then pinhole defect sheet counting number at the current time can be calculated according to Equation (2) and storage to array R:

$$X_2 = \mathrm{RND\_}(\frac{L_3}{L_0}) + N_0 + 1 , \quad (2)$$

where the symbol RND_- represents rounded down operation.

The distance L_3 is actual sheet length between pinhole detector and the head of the next sheet.

Namely: $L_3 = L_2 + L_4 - L_5$, where L_4 is the distance between flying shear and the head of the next sheet.

The system real-time collects the counting pulse signal of pinch roll {D} speed encoder {K1}. Supposing that the counting pulse value of K1 per rotation is n_1, pinch roll's diameter is Q_1. Then corresponding distance s1 of each K1 pulse can be calculate as:

$$s_1 = \frac{Q_1 \times \pi}{n_1} , \quad (3)$$

Figure 2 is the schematic plot of calculating distance L_3. Supposing, at the time of P0 rising edge, counting value of K1 is M_1. At the time of F rising edge, counting value of K1 is M_2. The distance L_4 can be calculated as: $L_4 = (M_2 - M_1) \times s_1$.

The distance L_5 is distance correction factor, $L_5 = V_l \times 0.1666$, where V_l is pinch roll's line speed.

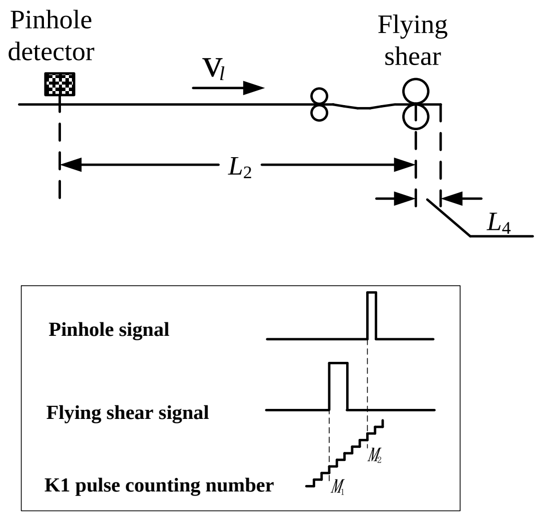

FIGURE 2 Schematic plot of calculating distance L3

Assuming the pinhole locating between the two sheets, the system make the following processing, supposing distance:

$$\Delta L = L_3 - RND\_[L_3 / L_0], \tag{4}$$

if $\Delta L < 0.1$, then the current sheet and previous sheet are all defected sheets, the counting number X_2 and X_2-1 will be stored into the array R;

if $\Delta L > 0.9$, then the current sheet and next sheet are all the defect sheets, the counting number X_2 and X_2+1 will storage into the array R;

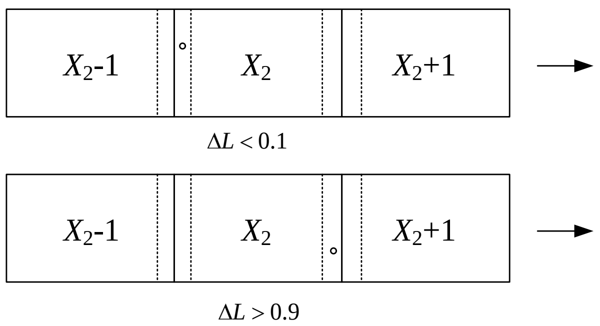

FIGURE 3 The situation of the pinhole locating between two sheet

Every time array R receiving a new element, system will sort the array R to maintain the defected sheet counting number value from small to large.

When P1 detects the counting number $N1$ to be equal to the detect sheet counting value in array R, mean: $N_1 = R[i]$, then system will drop this defect sheet into inferior stacking table.

3.2 TRANSMITTING BELT SPEED CONTROL

The system should adaptive control the speed of three belts [T0, T4 and T5] according to the sheet's length [14].

The distance between tow sheets should be extended to a proper value, so as to be easy to phototube tracking the sheets [14]. Consequently, the sorting control system can run in high speed. Thus, the speed of S roll and six belts should be real-time controlled.

Supposing:

- V_0: the max speed of main belt T0; V3
- V_1: the max speed of S roll; V0
- V_4: the max speed of belt T4; V1
- V_5: the max speed of belt T5; V2
- V_s: the max speed of stacking belt T1, T2, T3.

The speed of V_1 can be ascertained according to the sheet length. Then the other speed can be calculated as follows:

$$V_0 = V_1(1+k_0), \tag{5}$$

$$V_4 = V_1(1+k_4), \tag{6}$$

$$V_5 = V_1(1+k_5), \tag{7}$$

where k_0, k_4, k_5 is the speed scale factor, which can be calculated through algorithm of Figure 2. p_0, p_4, p_5 is the setting initial value of k_0, k_4, k_5, which is the experience value according to main belt length and running speed. In this sorting system, p_0=0.25, p_4=0.1, p_5=0.2.

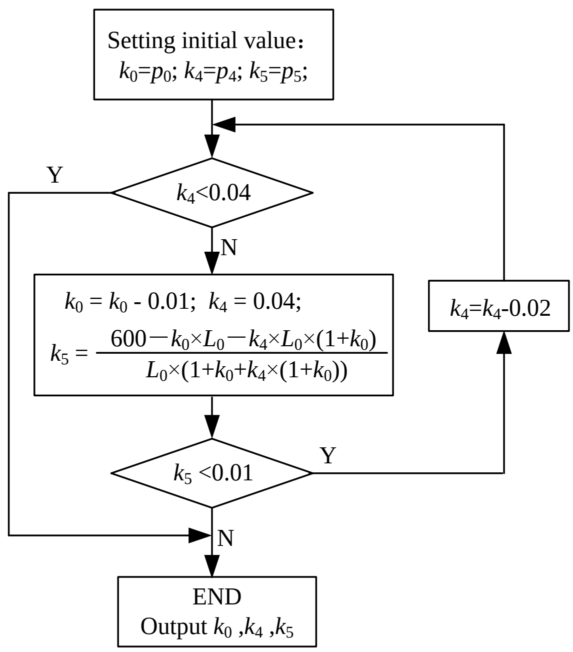

FIGURE 4 speed scale factor calculating algorithm flow

Through the above algorithm, the belt speed is getting higher and higher (the specific relationship is $V_0 > V_2 > V_0 > V_1$). So the sheets after cutting by flying shear can be extended to a certain distance (approximately 600mm), so as to be easily tracked by phototubes.

When the sheets drop into the stacking table belt, the belt conveys it to the stacking box in a lower speed V_s, $V_s = V_0/3.5$.

3.3 SHEETS DROPPING CONTROL

Because of the sheets running at the very high speed (the max speed can reach 300m/min) in the line, every dropping position and posture of the sheet must be accurately controlled, to avoid the sheets scratching with each other and piling up in the stacking box [14].

Take the 1# stacking table as an example, the principle of how to control the dropping location and posture is described as follows:

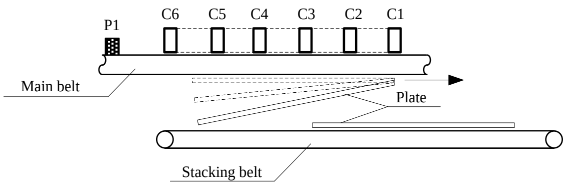

FIGURE 5 dropping control schematic diagram of 1# stacking table magnetic system

Supposing the distance between P1 and electromagnet C6 is S, the sheet length is L_0, the line speed of T0 is V_0.

The system real-time collects the pulse counting signal of the main belt encoder. Supposing that the counting pulse value of K2 per rotation is n_2, main belt roll's diameter is Q_2. Then corresponding distance *S2* of each K2 pulse can be calculated as:

$$S_2 = \frac{Q_2 \times \pi}{n_2} . \quad (8)$$

When phototube P1 detects the sheet, the system starts counting. Supposing its' counting number is *m*. When *m* satisfies the Equation (8), system will consider that the sheet reaches the dropping location, 1# Stacking table magnet system working, and the sheet drops to the 1# stacking belt.

$$m \times S_2 \geq L_0 + S_2 \text{-} V_0 \times t , \quad (9)$$

where *t* is a experience delay time.

At first, C6 losses of field, and then C5, C4, C3, C2, C1 successively loss of field delayed by a certain T period. So the sheet will drop smoothly and steadily to the stacking table belt (the sheet tail dropping firstly, the sheet nose dropping later.)

When *m* satisfies the Equation (9), system will consider that the sheet already dropped to the stacking belt, 1# Stacking table magnet system will stop working.

$$m \times S_2 \geq L_0 + S_2 + S_1 , \quad (10)$$

where S_1 is the experience delay distance.

Because the main belt speed is 3.5 times higher than the stacking belt, the current dropping sheet tail will fold to the stacking belt, and it's head will fold to previous dropping sheet's head, so as to avoid the sheets scratching with each other in high speed. The sheets fold with each other and transmit to the stacking box through stacking belt.

4 Some methods of improving sorting accuracy

In order to improve the sorting control accuracy, the following hardware and software methods can be adopted:

1) Because of the time interval between pinhole signal and phototube signal is very short and the signals are easy to be interfered, the system firstly adopts limiting shake filtering method to process these signals, then call corresponding interrupt service program to respond to these signal, so as to improve the sorting system response speed of defected sheets.

2) During the running process, system will real-time regulate the relevant parameters (mainly including delay time parameter *t* and delay distance S_1) according to the running speed and sheets separation distance.

3) In order to ensure all the defected sheets will drop into the inferior stacking table and improve the system accuracy, system adopt the following methods to dispose defect signals:

- Pinhole defect signal: when pinhole defect appears between two sheets, these two sheets will be dropped into the 1# inferior stacking table.
- Thickness gauge signal: Supposing the thickness defect signal appear at T_1 time and disappear at T_2 time, the sheets passing thickness gauge during these time (T_1 to T_2) will all drop into the 1# inferior stacking table, as well as the next three sheets.

5 Conclusions

Sorting control system is an important part of cold rolling shear production line, the system section speed and accuracy is especially worth to be further in-depth studied. The essay, based on the sorting control principle, detailed analyses the realizing method of self-adaption control model in details, mainly including sheets high speed running, sheets real-time accurately tracking, sheets dropping posture accurately control and sheets defect detecting etc. The sorting control model can be applied to the similar industrial production lines.

Acknowledgments

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