COMPUTER CONTROL SYSTEM FOR DRAWING MACHINE IN HORIZONTAL CONTINUOUS CAST SET①

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ABSTRACT A computer control system for drawing machine in horizontal continuous cast set was introduced. The operation features of the drawing machine were analyzed, the hardware configuration and principles of interface circuit for stroke measurements were given out. An effective method was provided, which made the process parameters progressively optimize under the software environment using friendly interface of person-and-computer communication. This method was also adaptable to optimize parameters of other production process which are hard to model.

Key words horizontal continuous cast drawing machine drawing parameters optimization

1 INTRODUCTION

Horizontal continuous cast is an advanced technology for casting production. It has such advantages as high-efficiency of production, great energy-saving, low-cost of equipment. It has been developed fast since the 1980's. At present, horizontal continuous cast can produce different sizes of copper board (strip), copper tube(pipe) and steel pipe castings etc. Horizontal continuous cast sets are composed of holding furnace, crystallizer, drawing machine and finer equipment. The superficial quality and internal crystal structure of castings are profoundly related to such factors as temperature of metal fluids in holding furnace, cooling states of crystallizer, operational modes of drawing machine. In the practical production, we control operation conditions of drawing machine to obtain high-quality castings. Owing to the limits set up by crystallizing speeds of metal fluids and cooling strength of crystallizer, drawing machines must work in draw-stop-back circle continuously.

This paper analyses operational modes of drawing machine, illustrates configurations of the computer control system and principles of interface circuit-board of stroke measurement, using the drawing machine of the horizontal continuous cast set of copper strip castings in some factory as an example. Because the mathematical model of horizontal continuous cast process is difficult to be built up, the design methodology is illustrated finally, which optimizes the drawing process parameters gradually with the help of friendly person-and-computer interface.

2 THE OPERATIONAL FEATURES OF DRAWING MACHINE

The operation of drawing machine can be represented by speed curve in Fig. 1. From the Fig. 1, we know that the drawing machine operates in draw-stop-back circle periodically. A circle-time of drawing is T_D, which includes three processes: draw, stop and back, represented in three parameters: drawing stroke S_D, stop time t_H and back stroke S_B, where $S_D > S_B$. Because the drawing stroke is rather short, it is always set as 12 mm to 14 mm.

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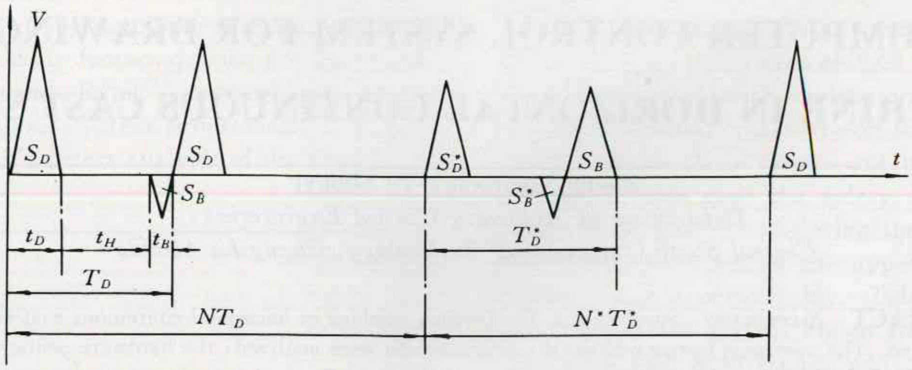

Fig. 1 Speed Diagram of Drawing Machine

The speed curves of both drawing and backing are triangle waves. The average speed is:

$$\overline{V}_d = \frac{S_D - S_B}{T_D} \quad (1)$$

where $T_D = t_D + t_H + t_B t_D$; t_H and t_B, are draw, stop, and back time respectively.

If S_D, t_H and S_B are setting values, while decreasing the drawing time t_D and back process time t_B, we can increase $\overline{V}_d$ to improve the productivity of horizontal continuous cast sets. In order to improve crystal structure quality of castings, experiments show that the drawing machines should perform the two processes as fast as possible, reach the stroke control precision as well as not allow the overshoot and vibrant phenomenon.

3 STRUCTURE CONFIGURATION OF THE COMPUTER CONTROL SYSTEM

The configuration diagram of computer-control system is showed in Fig. 2. It uses the IPC industrial computer as the kernel, including an SCR dc drive set SIMOREG V_5, magneto dc servo-dynamo and built-in tachometer, photo-electric encoder and stroke-measurement circuit.

3.1 IPC *Industrial Computer*

The main computer is chosen as IPC-286N, which suits operation under industrial environment. The CPU is Intel 80286, RAM is 2M. It has abundant software support and strong program-developing ability, since it is compatible with IBM PC/AT. The main chasis is also equipped with ADA MS-1215, pulse counter /timer, switch I/O and RAM expanded board (with back-up battery).

3.2 ADA MS-1215 *Board*

It includes 16 channels A/D and 2 channels D/A converters. The resolutions are all 12 digits. The A/D channels are used for inputting analog signals as temperatures of strip castings surface and copper fluids in holding furnace. DA0 of D/A channel outputs speed control signal to control system of drawing machine, assuring it operates under the set values.

3.3 *Pulse Counter/Timer Board*

There are four Intel 8253 PC (programmable counter) chips consist of three counters and timers. The counter inputs pulse signal as the stroke feedback of drawing machine. Three timers are set as timers interrupt source by initial programs. The interrupt circle are 20 ms (stroke control of drawing machine), 200 ms (temperature sampling) and 1 s (calendar clock).

3.4 *Switch I/O and Expanded* RAM *Board*

It includes 16 I/O channels and 8 KB RAM with back-up battery. I/O channels are equipped with photo-electrical isolation to restrain disturbance. It inputs the operational states of horizontal continuous cast set, checks whether it operates normally, outputs control signal to lock or open drive pulse of SIMOREG V_5 drive set. 8 KB expanded RAM stores parameters of drawing modes. It has back-up battery to avoid data losing in power failure, and thus to help parameters optimization.

4 STROKE MEASUREMENT AND CONTROL SYSTEM

4.1 *Stroke Measurement System*

The stroke measurement of drawing machine is made up of photo-electrical encoder and interface circuit of pulse counter/timer. LMA-400 photo-electrical encoder inputs 5 V dc voltage, outputs two square wave signals (P and Q) with an electrical phase difference of 90°. While drawing machine is rotating forward (drawing), P is ahead of Q and while it is rotating backward P is behind of Q. It outputs 400 pulses per rotation. From the data, we know the pulse resolution is 11 μm/pulse. The interface circuit of pulse counter/timer includes two parts: pulse counter and timer. The principle circuit is showed in Fig. 3. Every part is composed of two Intel 8253 chips with appropriate peripheral circuit. Every 8253 chip includes 3 counter channels, whose operational mode can be set by program.

Pulse counter circuit is composed of direction identification circuit and pulse counter. Pulse counter includes two counter. They are both 32 digits binary counters. One receives the pulse signal Up, another receives the pulse signal *Down*.

Direction identification circuit is showed in Fig. 4, which is composed of U_1, U_2 and U_3 IC chip; and U_1 is 74LS175, U_2 and U_3 are 74LS08. They convert the two phase pulse P and Q into counter pulse Up and *Down* according to their phase relations. From Fig. 4, we know that the logic arithmetic relation is as follows:

$$Up = (P_{n-1} \cdot P_n)(\overline{Q}_{n-1} \cdot Q_n) = (P_n \cdot Q_n)(P_{n-1} \cdot \overline{Q}_{n-1}) \quad (2)$$

$$Down = (Q_{n-1} \cdot Q_n)(\overline{P}_{n-1} \cdot P_n) = (P_n \cdot Q_n)(\overline{P}_{n-1} \cdot Q_{n-1}) \quad (3)$$

The wave forms of different output points of direction identification circuit are showed in Fig. 5. While the drawing machine is rotating forward, Up output pulses, whose frequency equals to that of P pulse and *Down* is always low level. While the drawing machine is rotating backward, the *Down* output pulses, whose

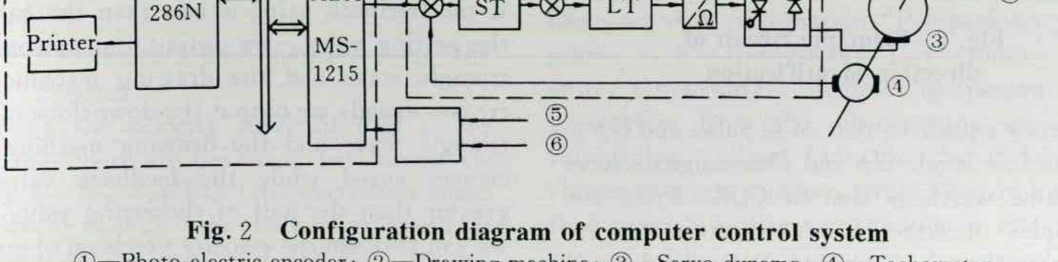

Fig. 2 Configuration diagram of computer control system

①—Photo-electric encoder; ②—Drawing machine; ③—Servo-dynamo; ④—Tachometer; ⑤—temperature in holding furnace; ⑥—Temperature of casting surface

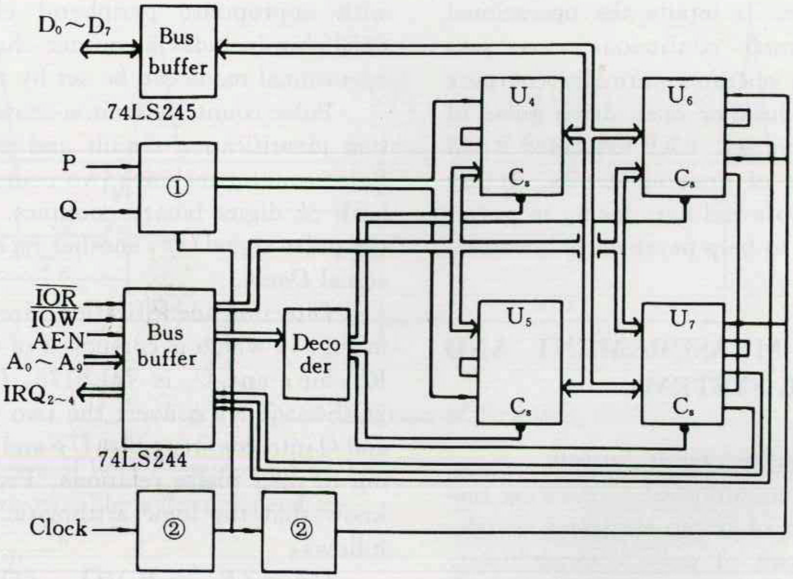

Fig. 3 Schematic circuit of impulse counter/timer interface

①—Discriminator circuit of direction; ②—Freguency divider

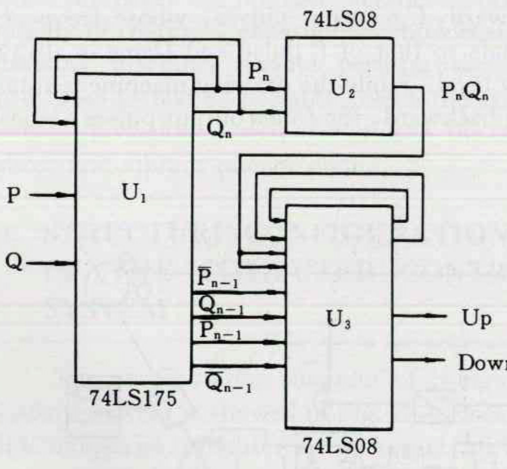

Fig. 4 Principle circuit of direction identification

frequency equals to that of Q pulse and Up is always low level. Up and $Down$ signals have the same width as that of CLK. From the principles of direction identification circuit, we know that the identified pulse signal P and Q have the highest frequency of 300 kHZ.

4. 2 *Stroke Control System*

The stroke measurement control system is composed of DA0 of MS-1215, SCR drive set of SIMOREG V_5, dc servo dynamo and stroke measurement. To ensure the drawing machine to operate in a drawing-stopping-pulling back circle according to the velocity picture of Fig. 1, we trigger the timer, which interrupts at every 20 ms. IPC industrial computer reads the stroke feedback value by the interruption sevice sub-program, and compares it with the stroke setting values. After being judged by the computer, the velocity setting voltage of triangle wave outputs from the DA0 channel to control dc servo dynamo. If the feedback value is less than the half of the setting value, we output the upslope of triangle wave and the drawing machine increases speed; we output the downslope of the triangle wave and the drawing machine decreases speed while the feedback value is greater than the half of thesetting value. So we can perform the velocity precision of stroke control in the shortest time without over -

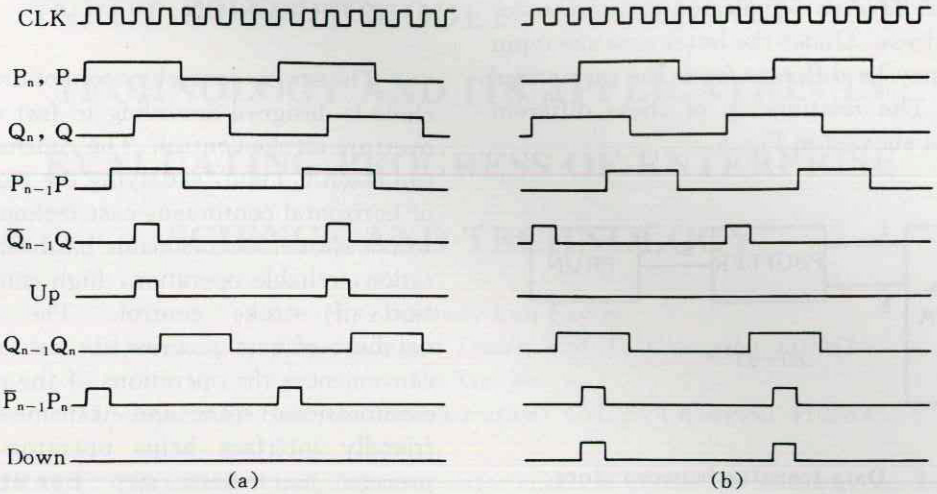

Fig. 5 Output wave form of direction identification

shoot[2].

5 OPTIMIZATION OF PROCESS PARAMETERS

Because the mathematical model of the process is very complicated and the casting quality is affected by many factors, it's very difficult to find the definite relations between them. The process is then classified as difficult-in-model building production process. For such a process, in order to optimize its parameters, we need verify parameters according to the experience gained through practice by operators in the production and process to guarantee the optimum or sub-optimum operational conditions. In the view of this, the friendly interface is important to convenient parameters verification, storation and utilization.

5.1 *Parameters and Database of the Process*

From the velocity curve of Fig. 1, we know that there are ten major parameters effecting S_d, t_H, S_B, V_{mD} (the maximum speed of drawing), V_{mB} (the maximum speed of backing), S_D^*, t_H^*, S_B^*, N and N^*, where, those with "$*$" are parameters of restoration circle. For the convenience of parameters transmission and verification in group, we set up a database in memory. It is divided into three sections that named run-section (PRUN), buffer-section (PBUFFER) and store-section (PARA-AREA), where PRUN store the parameters under running, PUFFER stores those under displaying used for the parameters modifying and setting (PRUN and PBUFFER are of a group parameters length of 40 bytes), PARA-AREA stores back-up parameters. A group of parameters is named a program. There are altogether ten groups, coded from 0～9, used for calling and indexing. They are stored in RAM with back-up battery in case of data-losing in power failure.

5.2 *Process Parameters Modification*

When modifying parameters, CRT notifies user with information "P = back-up program: x, S = transmission I, I = input, F = store, C = modify". In order to transmit the parameters from the store-section into the run-section, please first use the P key to choose program number, press I key to input, then press S key to transmission it into run-section without modification, to control the drawing machine, or press C key to modify parameters and sent back to memory after pressing E key, with indicated program number to address. Under the latter case the input number may be different from the memorized number. The relationship of these different sections is showed in Fig. 6.

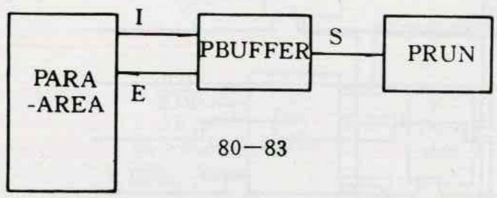

Fig. 6 Data transfer between store areas of parameters

Operators can get the optimized parameters by gaining operational experience, as the parameters, displaying, modifying, storing and transmitting are easily performed. And operators can use different numbers to input these groups into PARA-AREA.

6 CONCLUSION

The stroke control system of drawing machine is designed according to fast digital no-overture stroke control. The control precision can reach 0.1 mm, satisfying the requirements of horizontal continuous cast technology. The whole system has resonable hardware configuration, reliable operation, high control precision of stroke control. The parameter database of cast process has its features. It conveniences the operations of the parameters modification, store and transmission. The friendly interface helps operators optimize process parameters step by step. This methodology is also applicable to control system design of other difficult-in-building-model industry process.

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