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# Development of Level 2 Auto Pacing Control in CSC No.1 HSM

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**Pacing control in CSC (China Steel Corporation) No.1 HSM (hot strip mill) utilized push rate table which was hardcoded in the Level 1 system to determine the pacing time after the last revamping of the electrical and process control system. However, calculating pacing time based on the push rate table does not take the status of equipment and desired time interval at the finishing group into consideration and decreases the accuracy of pacing time. Inaccurate pacing time not only leads to insufficient heating time in the furnace, which causes quality issues but also increases potential collision risk, which degrades the availability of equipment. A new Level 2 Auto Pacing Control mechanism which considers major pacing bottlenecks, mill status, traveling time and Level 1 push rate table is proposed to calculate accurate pacing time, which significantly reduces the effort of manual intervention.**

**Keywords: Pacing, Hot strip rolling, Productivity**

## 1. INTRODUCTION

Since pacing control determines the productivity and the quality of hot rolled strips, a pacing control setup and feedback system have been developed in CSC No.1 HSM. However, after the Electrical and Process Control System revamping of CSC No.1 HSM in 2012, mill pacing was still controlled by the Level 1 push rate table due to the Level 2 pacing system provided by the vendor being different from the operators' work practices. The push rate table was adopted to control the time interval between furnace discharges. This table only reflects the experience of operators and is not associated with the actual condition of the mill.

CSC re-designed the Level 2 Auto Pacing Control in No.1 HSM which considers mill status, traveling time, production bottlenecks and Level 1 push rate table to achieve maximum productivity, finest quality and minimal desired time interval. The production bottlenecks in CSC No.1 HSM mainly consist of five categories.

(1) Reheating furnace bottleneck
(2) Roughing mill entry bottleneck
(3) Roughing mill bottleneck
(4) Finishing mill bottleneck
(5) Down coiler bottleneck

## 2. PRODUCTION BOTTLENECKS

Due to the mill layout creating production bottlenecks, Figure 1 shows CSC No.1 HSM layout for later individual bottleneck introduction.

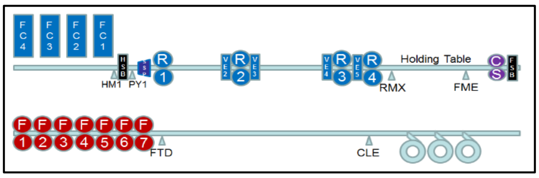


**Fig.1.** Mill layout of CSC No.1 HSM.

### *2.1 Reheating Furnace Bottleneck*

Considering the reheating time needed for slabs to heat up, it appears that furnace heating capability is the most crucial part. The final soaking time is calculated by the RTC (Reheating Temperature Control) system. The requested heating time varies by different types of products. Hence, pacing time should not only be connected to the next to-extract slab. RTC calculates the time intervals needed for each slab to obtain enough heating time. For every single slab, it calculates the remaining time needed to heat up if the previous slab was discharged from this furnace. Then, this result should be corrected by its position and extract order. Finding the maximum time interval after correction in the furnace will be considered the pacing bottleneck time for this furnace.

### *2.2 Roughing Mill Entry Bottleneck*

The time interval between furnace discharges is determined by a thoroughly newly designed push rate table. This table is related to the effect of steel types, length, and width. Push rate also takes into account the different numbers of furnaces in operation.

In order to avoid a collision, it is required that the previous piece should have left the first roughing mill stand before the current piece enters the roughing mill entry. This bottleneck should take both the push rate and the time the previous piece left the first roughing mill stand into consideration.

### *2.3 Roughing Mill Bottleneck*

The second RM (roughing mill) stand is a reversing stand, in which pieces will be hot rolled back and forth several times. Production is limited by this stand at the roughing mill area. The previous piece must have done R2 passes before the current piece enters the first roughing mill stand. The R2 pass number and RM rolling speed determine this bottleneck.

### *2.4 Finishing Mill Bottleneck*

As a continuous tandem mill, only one piece is allowed to simultaneously be in the finishing mill. A piece could only enter the F1 stand after the previous one has left. The rolling speed of the finishing mill determines this bottleneck. Typically, at the F1 stand, we prefer a time interval of 15-25s between the two pieces. After roll change, this gap should be longer for the first few pieces to warm up the rolls so that the quality remains stable. The pacing control system should automatically adjust time intervals to meet quality requirements.

### *2.5 Down Coiler Bottleneck*

CSC No.1 HSM is equipped with three down coilers. In addition to considering the time interval between each piece to avoid collision, it is necessary to take the number of down coilers in operation into account. When only one down coiler is in service, it takes about 160-170s to finish coiling, conveyor transferring, and getting ready for the next piece. The pacing control system should automatically adjust time intervals based on the number of coilers in operation.

## 3. TRAVELING TIME PREDICTION

The traveling time prediction basically employs the concept of Transport Director to simulate the slab's length and speed change when passing through stands and tables. When the head and tail position of the slab can be calculated based on the simulation, the traveling time can be predicted. The concept of Transport Director and TVD (Time-Velocity-Distance) calculated by models is applied for alternative precision double check.

Transport Director works between Level 1 and Level 2 systems as a slab guiding system. In Transport Director, the whole mill is divided into several sections by conveyor tables, stands, and sequences of production as shown in Table1. Each section has its own speed and acceleration setup when the slab arrives. The speed and acceleration reference are sent to Level 1 by Transport Director, and measured speed and acceleration from Level 1 feedback to Transport Director.

The pacing system receives setups, forward slips, and backward slips of sections from the Transport Director and calculates predicted travel time for relative bottlenecks.

## 4. FEEDBACK CORRECTION

The actual process time of the specified section is recorded in the database after production. The signals from hot metal detectors, pyro meters, and load relays of stands are used to determine the timing of each process. The errors between setup traveling time and actual time in HM1, PY1, R1, R2, R3, R4, and F1 of this piece are considered corrections and will be applied to the next piece just like a proportional controller. For these sections, maximum and minimum correction limits are defined to avoid illogical correction due to error signals or database crashes. As a result, the error between predict and feedback traveling time is correlated to the number of furnace and slab lengths. Feedback correction could reduce errors between predicted and real traveling time.

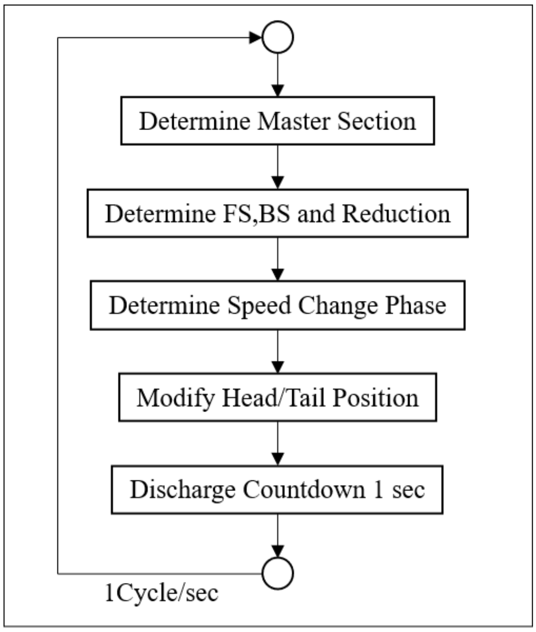


**Fig.2.** Flow chart of timer procedure.

**Table 1** Sections of mills.

| SECTION | SECTION AREA | SECTION | SECTION AREA |
|---|---|---|---|
| 1 | Rolling start | 27 | [R2 pass 7] R2 forward pass |
| 2 | Enter RME to HSB Entry | 28 | [R2 pass 7] Stop |
| 3 | Transfer HSB & SSP Entry stop | 29 | [R2 pass 8] Restart |
| 4 | SSP restart to slab leave SSP exit | 30 | [R2 pass 8] R2 backward pass |
| 5 | [R1 Exit] SSP END -> R1 Stand | 31 | [R2 pass 8] R2 stop |
| 6 | [R1 Exit] R1 Stand Pass | 32 | [R2 pass 9] Restart |
| 7 | [R1 Exit] Transfer | 33 | [R2 pass 9] R2 forward pass |
| 8 | [R2 pass 1] R2 threading | 34 | R2 Del Table Transfer |
| 9 | [R2 pass 1] Stand R2 pass | 35 | R2 to R3 Entry |
| 10 | [R2 pass 1] Stop | 36 | [R3 Stand] Master Section |
| 11 | [R2 pass 2] Rev Start | 37 | R3 -R4 |
| 12 | [R2 pass 2] R2 Backward pass | 38 | [R4 Stand] Master Section |
| 13 | [R2 pass 2] Stop | 39 | R4 Del Table Transfer |
| 14 | [R2 pass 3] Restart | 40 | Holding Table Transfer |
| 15 | [R2 pass 3] R2 forward pass | 41 | FM Entry Transfer |
| 16 | [R2 pass 3] Stop | 42 | FM threading |
| 17 | [R2 pass 4] Restart | 43 | F1 Stand |
| 18 | [R2 pass 4] R2 backward pass | 44 | F2 Stand |
| 19 | [R2 pass 4] Stop | 45 | F3 Stand |
| 20 | [R2 pass 5] Restart | 46 | F4 Stand |
| 21 | [R2 pass 5] R2 forward pass | 47 | F5 Stand |
| 22 | [R2 pass 5] Stop | 48 | F6 Stand |
| 23 | [R2 pass 6] Restart | 49 | F7 Stand |
| 24 | [R2 pass 6] R2 backward pass | 50 | F7 - DC |
| 25 | [R2 pass 6] Stop | 51 | DC |
| 26 | [R2 pass 7] Restart | 52 | Rolling End |

## 5. TIMER PROCEDURE

The timer procedure is triggered every second and calculates for slabs which are discharged from furnaces and have not arrived at the F1 stand.

A. Determine master section

The master section is mainly determined by the stand, and secondarily by the table. This means if a piece is not in a stand, the section where the head or tail of the current piece resides will be used as the master section based on the slab's moving direction. This section will be used as the primary speed reference for calculation.

B. Determine Forward Slip, backward slip and reduction

When master section is a stand, reduction creates FS (Forward Slip) and BS (Backward Slip) which are applied to calculate the entry speed and exit speed of the stand.

C. Determine speed change phase

Each table has its maximum and minimum rate of acceleration. If the speeds of two adjacent tables are different, it is considered a speed change phase. This process calculates the distance after one second of acceleration.

D. Modify head/tail position

This process is utilized to update head and tail positions based on the former calculated distance.

E. Discharge countdown

After each cycle, the discharge countdown will be decreased by one second. If the countdown reaches zero and the mill status is expected, a discharge permit signal will be sent to Level 1.

## 6. TESTING

The results indicate that the prediction is indubitably reliable because the actual time almost matches the prediction. According to our statistics, the average error is -0.34s at the F1 stand and the standard deviation is 3.51s. These results reveal the predicted time is profoundly accurate and the pacing control is trustworthy.

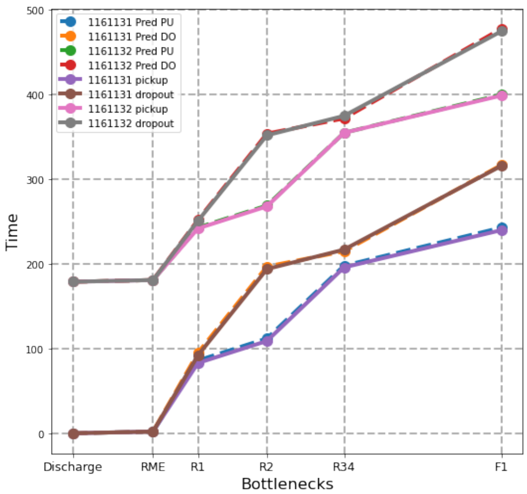


**Fig.3.** Predict and actual time of pacing in CSC No.1 HSM.

## 7. CONCLUSION

The Level 2 Auto Pacing Control makes production more automatic. Operators no longer need to manually control pacing time during production, even if one piece of equipment is down. It is easier to maintain quality by obtaining enough heating time without any manual operation. This system prevents rust issues due to temperature drop caused by stopping the slab from moving for possible collisions. By combining the concept of Level 1 push rate table with traveling time and bottleneck check, past experiences of operators, and particular grade or hard-to-produce products could also automatically slow the pacing without operator intervention to avoid unnecessary cobble or kick-off. When the desired push rate is set to zero, maximum productivity is achieved and the mill standby time is shortened. As a result, CSC successfully improves the rolling efficiency and stabilizes the quality in No.1 HSM at the same time.

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