Computer Control System for CC-DR Process*

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Synopsis

The Muroran No. 3 Continuous Casting Machine, which started operation in November 1981, is a slab/bloom combination caster (with twin-strand operation for bloom). The time required for the process from tapping molten steel from the BOF to coiling strip into hot coils is 3.5 hr.

Integrated process control of the continuous caster (CC) and the heat holding furnace (HF) is performed by a single process computer.

The process computer control functions for the CC-DR process are described below.

1) Casting speed guidance
2) Present control for each steel grade
3) Secondary cooling control models
4) Calculation and setting of cutting length
5) Collection of data on quality
6) HF pacing
7) Automatic operation of the HF

The CC/HF process computer is contributing greatly to the stable operation and quality improvement of the CC-DR process.

I. Outline of the CC-DR Equipment

Figure 1 shows the layout of the CC-DR process with the No. 3 CC machine as the basis. The flows of molten steel and slab/bloom are described below by referring to this layout.

The molten steel from the BOF is transferred by crane and traverser to the RH system, where it is degassed. The RH-degassed molten steel is then transferred by crane to the CC machine, where it is cast and cut. This CC machine is a slab/bloom combination caster. The cut slabs/blooms are transferred by claw-crane and charged into the HF.

After extraction from the HF the slabs and blooms go to different places.

(1) The blooms go to the blooming mill by the table—traverser—table route. In the blooming mill, the blooms are sized, cut, and then sent out to the billeting mill for billeting.

(2) The slabs go to the slabbing mill by the table—traverser—table route. In the slabbing mill, the slabs are sized. The sized slabs go to the hot strip mill, where they are rolled into hot strip. The time taken from tapping molten steel from the BOF to coiling strip into hot coils is 3.5 hr.

Tables 1 and 2 show main specifications of the CC machine and the heat holding furnace. The process computer for the No. 3 CC machine performs integrated process control for both the caster and the furnace. (This computer is herein called the CC/HF process computer.)

II. Computer Control System for the CC-DR Process

Figure 2 shows the computer network for the CC-DR process. Each equipment (or block of equipment) from the BOF to the hot strip mill shown in Fig. 1 is provided with a process-computer.

The central business computer performs general control of this process. The process computers have data communication with this central business computer, and perform the receipt of casting schedule and casting orders, and sending the process results.

In addition to the above data communication with the central business computer, the process computers have data communication with the process computers for the upstream and downstream processes. The information transmitted between process computers is mainly used to control the matching of processes.

Figure 3 shows the configuration of the CC/HF process computer system. This system that also incorporates the RH process computer system is composed of two CPUs. One is used for the CC/HF computer system, and the other for the RH computer system.

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Because this CC machine is highly automated by computer control, it stops operation if the process computer fails. If one CPU fails, therefore, the other normal CPU is used for the CC/HF computer system.

Figure 4 shows the CC/HF process computer hierarchical system configuration and shares of functions. The CC/HF process computer has the central business computer as its upper machine and microcomputers and sequencers as its lower machines. All these machines are equipped with digital control devices for higher sophistication in automation.

The functions are shared by these machines based on the concept of "the centralization of information and the decentralization of control", and are determined so that the advantages of the individual machines can best be utilized.

**III. Process Control by the CC/HF Process Computer**

The process control functions of the CC/HF process computer are outlined in Fig. 5.

Noteworthy system functions, particularly those for the CC-DR process, are described below.

1. **Casting Speed Guidance**
   - Optimum casting speed is calculated from the following conditions, and guidance is given to the operator.
   - Limiting speed from the quality point of view, determined by the superheat temperature of the molten steel and steel grade
   - Matching speed with the upstream process obtained by the expected time of the next arrival of molten steel for the smooth operation of continuous-continuous casting
   - Matching speed with the downstream process to prevent the slab/bloom from delay before charging into the HF

2. **Preset Control for Each Steel Grade**
   - As many grades of steels are produced in small quantities, the following operations are preset by process computer for each grade. (Mold cooling, mold oscillation, EMS, etc.)

3. **Secondary Cooling Control**
   - Surface temperature of slabs/blooms is controlled for optimal cooling patterns by using cooling control models to obtain high-temperature, high-quality slabs/blooms.
(4) Calculation and Setting of Cutting Length

1. Cutting length is determined for optimizing the overall process in consideration of the billet-cutting-length logic at the blooming mill.
2. Switching and adjustment are made between strands to maintain the mill schedule for the downstream process.

(5) Collection of Data on Quality

Quality data of slabs/blooms are collected to assure the quality.
- Automatic collection: 33 items
- Manual input: 63 items
- Process data: 30 items

The following operations are performed based on this quality information.

1. Quality classification and rolling specification of slabs/blooms in the HF by central business computer
2. Automatic separation of abnormal billets by blooming mill process computer

(6) HF Pacing

Calculation and setting of optimum extraction pitch to prevent extracted slabs/bloom from delay on the line causing temperature drop.

(7) Automatic Operation of the HF

1. Fully automatic operation of the furnace from charging to extraction
2. Automatic rejection of low-temperature slabs/blooms

More detailed descriptions are given below of integrated temperature control and the slab/bloom quality classification system, both of which are important features of this computer system.

IV. Slab/Bloom Temperature Control

The CC/HF process computer performs integrated temperature control of slab/bloom for the overall process from CC to transfer from the HF. Temperature control is effected mainly by the use of CC secondary cooling control models and the slab/bloom temperature monitoring function of the HF.

Figure 6 shows the flows of temperature control. The general flows are described below from the upstream side.

1. Cooling control models are used to control CC secondary cooling. The surface temperature of slab/bloom is controlled for optimal cooling patterns.
2. As initial information using the mean temperature of the sections, the temperature monitoring function of the HF supervises the charging temperature, in-furnace temperature, extraction temperature and after-extraction temperature of every slab/bloom.
3. Control of furnace temperature, judgment of slab/bloom temperature and automatic rejection of low-temperature slabs/blooms are effected based on information collected by the temperature monitoring function of the HF. Although thermometers are provided ahead of the CC machine cutter and on the extraction side of the HF, values of temperature calculated by process computer are always used for operations (for both slabs and blooms).

The control method using secondary cooling control models is described below.

Secondary cooling in conventional CC machines is generally performed by spraying water, and the flow rate is determined in proportion to the casting speed.

\[ Q = AV^2 + BV + C \]

where,  
- \( Q \): water flow rate (l/min)  
- \( A, B, C \): parameters  
- \( V \): casting speed (m/min)

This method in which the flow rate of spray water is determined by the above relation is applicable to the same cooling pattern only when the casting speed is steady. When the casting speed is not steady, at the start and the end of casting, and at changes in casting speed, no constant cooling pattern can be maintained.

The secondary cooling control models were developed to control the secondary cooling with optimal cooling patterns even during non-steady-speed casting.

Figure 7 shows the basic flow of secondary cooling models. Based on the information on cooling history for every slab/bloom length of 40~80 cm, the quantity of cooling water is determined. Control based on cooling history makes it possible to perform control...
with optimal cooling patterns.

Although an adjustment period of 6 months were necessary before the cooling control models were fully applied to the No. 3 CC Machine, these models are presently used for all steel grades (to control 4~6 zones).

V. Slab/Bloom Quality Classification

Figure 8 shows an outline of the quality classification system using the CC/HF process computer and the central business computer.

1. Quality information collected by the CC/HF process computer is transmitted to the central business computer as information on a heat basis and information on a slab/bloom basis. Those quality abnormalities which will lead to rejection are used to the calculations of cutting length in the CC/HF process computer.

2. The central business computer performs the quality classification of slabs/blooms based on the information supplied by the CC/HF process computer and the information supplied by the process computer for the upstream process. The quality classification is followed by product assignment. All this processing is effected while the slabs/blooms are in the HF.

3. The CC/HF process computer receives the final quality classification again from the central
business computer and uses it for temperature control, temperature judgment and temperature monitoring.

(4) The results of quality classification and product assignment performed by the central business computer are supplied as rolling specifications to the process computer for the downstream process. These rolling specifications include the quality information collected by the CC/HF process computer and permit the tracking of abnormal places of slabs/blooms. The quality information are also utilized to enable automatic rejection on a billet basis.

VI. Performance of the System

Figure 9 shows the transition of production and CC-DR ratio since the start-up of the No. 3 CC Machine. The CC-DR ratio has steadily increased to the present high level.

Figures 10 and 11 show the effects of secondary cooling control models as examples of the effects of computer control.

Figure 10 shows the variations in HF charging temperature; (a) shows the case of model control, and (b) shows the case of speed parameter control. In model control, temperature variations are small on both the high-temperature and low-temperature sides, with the result that the mean temperature is high.

Figure 11 shows the rates of occurrence of surface longitudinal cracks on slab/bloom samples taken at the time of cutting; (a) shows the case of model control, and (b) shows the case of speed parameter control. In model control, the occurrence rate of surface cracks is low.

As is obvious from Figs. 10 and 11, the application of secondary cooling control models enables the casting of high-temperature, high-quality slabs/blooms.

As many steel grades of small quantities are continuously cast at Muroran Works, the setting and controlling functions of the process computers according to grades are effectively utilized. The control application ratio has been also very high as a result of sufficient tuning after the start-up. The data collected by the process computer have been used for the automatic quality classification system since the start-up. The CC/HF process computer is thus contributing greatly to the stable operation and quality improvement of the CC-DR process.