KAWASAKI STEEL TECHNICAL REPORT
No.18 (May 1988)

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Kawasaki Steel has developed a new sintering energy control system, SECOS, which can detect and control the thermal energy level rapidly within an allowable range. The system is applied to No.3 and No.4 sintering plants in Chiba Works. It uses two parameters. One is a carbon quantity of sinter mix which is burnt on pallets. This is calculated through carbon balance by detecting the waste gas volume and composition. Another is a hot zone ratio of the sinter cake cross section at the discharge end measured by an ITV camera. The system executes overall evaluation of the thermal energy level with these two parameters and controls the level within an allowable range by adjustment of the coke blending ratio. This contributes to reducing the fluctuation of sinter quality and productivity.

The body can be viewed from the next page.

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1 Introduction

In the production of sintered ore, minimizing fluctuations in carbon content is essential, not only in stabilizing sintering thermal energy and the quality of sintered ore, but also in reducing production costs.

The coke blending ratio has to date been controlled on the basis of variations in carbon content as judged from the results of product experiments and direct observation of the condition of the sintered cake at discharge. The major drawbacks of this method of control are the delay in detecting fluctuations and individual differences among operators. The need for an automatic control system providing quick, reliable control of the coke blending ratio has long been recognized. On the occasion of the replacement of the instrumentation system of Nos. 3 and 4 sinter plants as part of the new ironmaking information system[1-3] at Chiba Works, **SECOS** (Sintering energy control system) was developed. This system detects fluctuations in carbon content in the sinter mix and performs automatic adjustment of blending amounts within an allowable range.

The introduction of this system has brought about improved quality stability and reduced production costs.

This paper describes the functions of the system and the results of its application.

2 Background

2.1 Necessity of Carbon Content Control

The sintering energy control system, SECOS, was originally developed for No. 3 sinter plant. At No. 3 sinter plant, the control of the carbon content of the

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sinter mix was urgently required because of the effect of variations in carbon content on quality and yield. The following were important considerations:

(1) About 20 kinds of dust generating by the Works are recycled. Variations in the carbon content in such dust causes variations in the carbon content of the sinter mix.

(2) Low coke consumption and low productivity operation is in effect at the No. 3 sinter plant, which has no waste heat recovery equipment. Production is concentrated at the No. 4 sinter plant to minimize the total production costs incurred by the sinter plants at Chiba Works.

2.2 Developing Process

This system, as described in detail below, Sec. 3, consists of two functions, real carbon (RC) and hot zone ratio (HZR), which had been proposed for independent practical use. The RC system was conceived as a means of detecting fluctuations in the carbon level, while HZR was to be used in controlling nonuniform sintering[4]. However, due to a lack of computer capacity, complete on-line operation had not been realized. The start of the operation of the sinter subsystem (**Fig. 1**) as part of the new ironmaking information system afforded an opportunity to realize SECOS. This sinter subsystem includes a DDC (Direct digital control) system, an integrated process computer system[2] and a large-scale data base in the central computer system at Chiba Works.

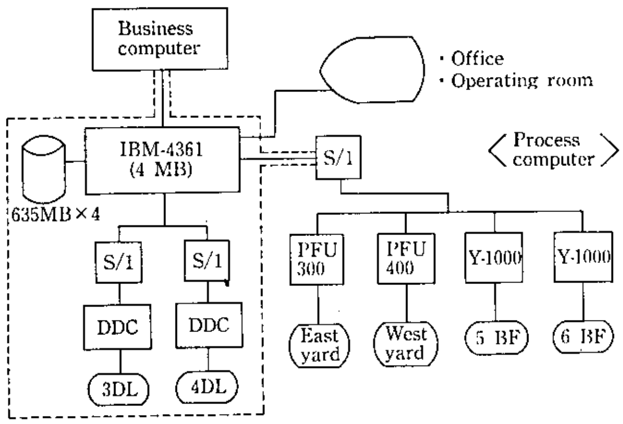

Fig. 1 System construction at the first step

3 Configuration of Control System

3.1 Outline of System

SECOS is a system which controls the coke blending ratio automatically by detecting fluctuations of sinter thermal energy level on the basis of a combination of the following two parameters.

RC: Carbon content of sinter mix actually utilized for sintering, estimated from the carbon balance obtained from waste gas analysis.

HZR: Ratio of the area of the sinter cake cross-section at temperatures above 600°C to the total area, measured by ITV monitor at the discharge side of the sintering machine.

To describe of the SECOS in more detail (**Fig. 2**):

(1) RC and HZR are calculated every five minutes. According to the deviation of calculated values from

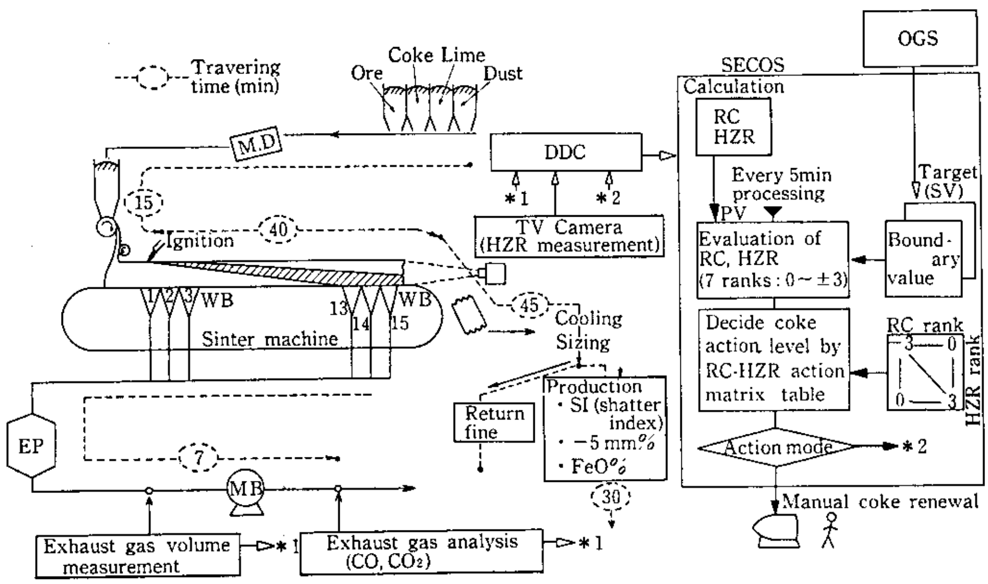

Fig. 2 Schematic diagram of SECOS function

the target, RC and HZR are classified into seven ranks. The sintering thermal energy level is evaluated RC and HZR action matrix.

(2) Based on these synthesized evaluation results, an optimum coke blending value is calculated and given to the DDC system as a set value for the coke feeding ratio.
(3) The individual boundary value of each of the seven ranks used in evaluating the current levels of RC and HZR changes according to production rate and required sintered ore quality. Boundary values are revised using constants and standard deviations calculated every 30 min.

The features of this system are as follows:

(1) High reliability of thermal energy level judgment by use of a combination of different types of sensors
(2) Rapid detection of fluctuations of thermal energy level, which are detected during the sintering process
(3) Automatic calculation of boundary values used for level judgments.

3.2 RC System

3.2.1 Definition of RC

The RC denotes the calculated blending ratio of coke in sinter mix based on the total carbon content obtained from the concentrations of CO and CO_2 of waste gas and waste gas flow rate. Carbon amount, contained in the CO_2 generated by the combustion of mixed gas (mixed gas of blast furnace gas and coke oven gas) at a ignition furnace and by the decomposition of carbonate, is excluded. The RC equation is shown in the following:

$$RC(\%) = [V_{ex}(CO + CO_2) - V_{CaCO_3} - V_{Dolo} - V_{MG}] \times \frac{12}{22.4} \times \frac{1}{M \times FC} \times 100 \cdots\cdots\cdots\cdots(1)$$

where,

V_{ex}: Waste gas volume (dry) (Nm^3/h)
CO: Concentration of CO in waste gas (Nm^3/h)
CO_2: Concentration of CO_2 in waste gas (Nm^3/h)
V_{CaCO_3}: CO_2 generated by the decomposition of limestone (Nm^3/h)
V_{Dolo}: CO_2 generated by the decomposition of dolomite (Nm^3/h)
V_{MG}: CO_2 generated by the combustion of mixed gas (Nm^3/h)
FC: Free carbon concentration in coke
M: Sinter mix consumption (kg/h).

3.2.2 Waste gas analysis

The analysis of waste gas is performed by the instruments listed in **Table 1**. A gas sampling probe is installed on the delivery side of the main exhaust fan to prevent adverse effects of dust and the drift current of gas in the duct.

Table 1 Specifications of exhaust-gas analyzer

Analysis \ Plant	No. 3 Sinter Plant	No. 4 Sinter Plant
Method	Gas-chromatography	Infrared ray
Measuring range	CO : 0~ 2% CO_2: 0~ 10% O_2: 0~ 25% N_2: 0~100%	CO : 0~ 5% CO_2: 0~15%
Cycle	5 min/sample gas	Continuous
Accuracy	±1% FS*	±2% FS*

* FS: Full scale

3.2.3 RC calculation

All data in Eq. (1) is inputted from the DDC system at intervals of 2^ns (2^6s at present). In the RC calculation, the following points are taken into consideration to ensure accuracy and reliability.

(1) About 30 min is required for the ore discharged from the bin to be sintered and have an effect on the composition of the waste gas. The limestone and dolomite consumption in Eq. (1), therefore, are used with the consideration of the delay.
(2) The sinter mix consumption M in Eq. (1) is obtained by:

$$M(t/h) = PS \times H \times W \times \rho \times 60 \cdots\cdots\cdots(2)$$

where,

PS: Sintering machine speed (m/min)
H: Raw material layer thickness on the sintering machine (m)
W: Width of the sintering machine (m)
ρ: Calculated raw material density on the sintering machine (t/m^3).

Prior to evaluation processing, the RCs calculated at 5 min intervals are filtered to minimize the effect of external disturbances.

3.3 Measurement of HZR

3.3.1 Definition of HZR

The HZR is a ratio of the red hot zone of temperatures higher than 600°C to the entire sinter cake cross-section, calculated on the basis of images of the cake cross-section of sintered cake taken by ITV monitor (**Photo 1**) at the discharge side of the sintering machine directly before the cake drops down.

3.3.2 HZR measurement

Figure 3 shows the hardware composition of the HZR instrumentation system. Image signals transmitt-

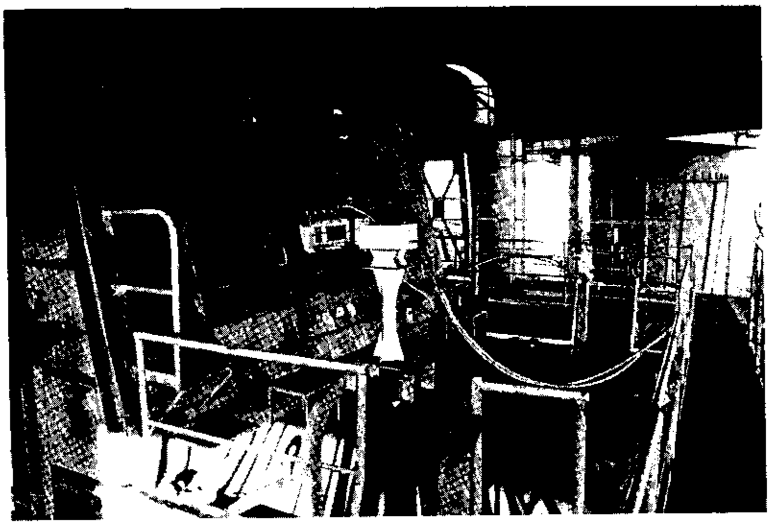

Photo 1 ITV monitor

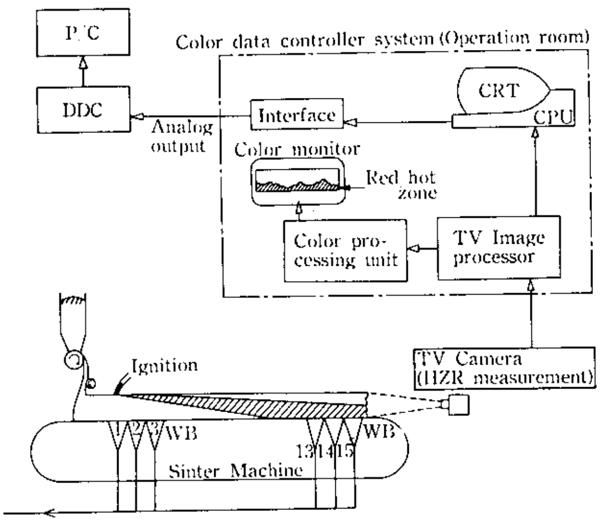

Fig. 3 Hardware composition of HZR

ed from a camera equipped with a solid element CCD (Charged coupled device) are processed by an image processing device and pseudo-color device, and an image with colors signifying the temperatures of the cake face is displayed on a monitor, as shown in **Photo 2**. At the same time, the hot zone ratio, which is separated by the image processing device, is calculated and transmitted to the integrated process computer.

3.3.3 HZR calculation

In the calculation of HZR, no accurate HZR can be obtained if a remaining portion of the falling sinter cake impedes the formation of a new cross section. The following measures, therefore, are taken.

(1) HZR is calculated every second, and the maximum value for each pallet is used as a control value.
(2) Prior to evaluation processing, the maximum value

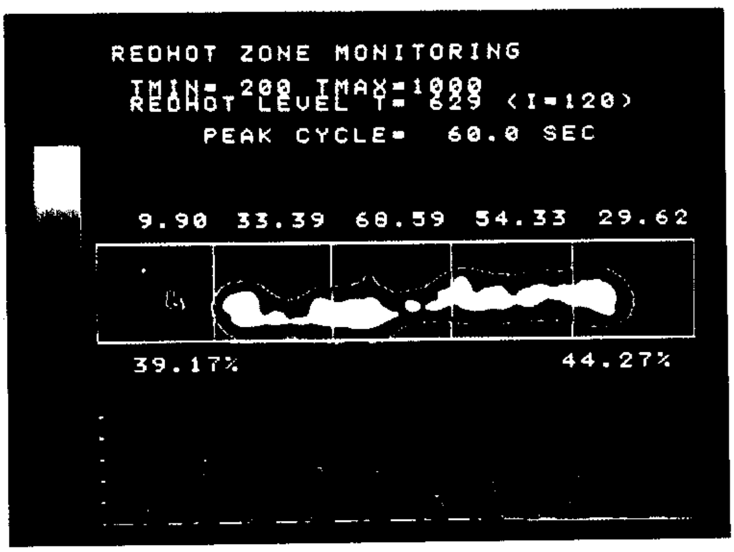

Photo 2 HZR display on color monitor

S3 572　　　*** NO 3 SINTER OGS ﾁｮｳｶｲﾁ ｼﾞｮｳﾎｳ　　　PAGE = 2　　DATE: 03.04　TIME: 11.37

ｶﾝﾘ	HHH	HH	H	L	LL	LLL	MODE	ｼｸﾞﾏ
RP	3.50	3.20	3.00	2.60	2.20	2.00	AUT	0.53
DP	1500.	1477.	1457.	943.	923.	900.	AUT	33.78
TEP	130.00	124.05	118.63	101.37	95.95	90.00	AUT	8.88
Q	321.03	314.20	309.69	291.38	286.87	280.04	AUT	13.66
TCL	80.00	76.65	73.60	36.40	33.35	30.00	AUT	5.99
T11WB	214.25	197.47	192.23	150.28	145.03	128.25	AUT	26.52
T14WB	391.72	359.11	348.93	267.41	257.22	224.62	AUT	50.95
PRO	240.80	236.43	229.04	212.80	205.41	201.04	AUT	12.12
S.I	93.00	92.23	91.52	88.98	88.27	87.50	AUT	1.15
-5MM	16.00	14.85	13.81	12.19	11.15	10.00	AUT	1.71
RET	19.90	19.56	18.95	17.05	16.44	16.10	AUT	0.95
FEO	8.50	7.93	7.41	5.09	4.57	4.00	AUT	0.85
RDI	46.00	44.27	42.69	33.31	31.73	30.00	AUT	2.58
RC	4.32	4.25	4.13	3.89	3.77	3.70	AUT	0.19
HZR	24.17	22.73	20.28	15.32	13.59	12.59	AUT	4.01
LEVEL	95.00	87.45	79.91	90.09	82.55	75.00	AUT	5.90
COKE	3.75	3.74	3.30	2.30	1.86	1.85	AUT	0.09
H	684.43	683.88	660.00	600.00	576.12	575.56	AUT	5.01
F.S	3.03	3.02	2.80	1.15	0.93	0.92	AUT	0.05
DAMP	100.00	100.00	100.00	10.00	10.00	10.00	AUT	0.60

PF1 : MODE ﾍﾝｺｳ　PF2 : ﾋｮｳｼﾞ ｷﾘｶｴ　PF3 : ﾃﾞｰﾀ ﾆｭｳﾘｮｸ PF4 : DATE　ENTER : ﾋｮｳｼﾞ

Fig. 4 Boundary value maintenance display

is filtered in the same manner as with RC.

3.4 Control Mechanism

3.4.1 Evaluation of current RC and HZR

The calculated values of RC and HZR are evaluated and classified into seven ranks according to the degree of deviation from the target values (**Fig. 4**). These ranks are indexes from 0 to ±3, according to which all evaluation 0 means that the current carbon content is within the target range, while an evaluation −3 is an markedly lower than the target value.

3.4.2 Action matrix

A synthesized evaluation is carried out based on the evaluation results of RC and HZR using the two-dimensional RC/HZR matrix shown in **Photo 3**. The synthesized evaluations, 0 to ±3, give the magnitude—a value by which the standard unit is multiplied to adjust the necessary amount of coke—and the direction of coke feeding. Action, however, is taken only when both RC and HZR deviate in the same direction.

3.4.3 Control method

In this system, the actual amount of the final coke adjustment is determined incorporating PID control in order to improve control of fluctuations in carbon content. The control of the coke feed amount is executed by modifying the set value in the DDC system. To compensate for the delay before the effect of these actions appears in the process, a "dead time" has been created, during which subsequent adjustments of the coke amount are temporarily suspended. **Figure 5** shows the results of an investigation of RC and HZR response time when the blending volume of a dust high in carbon content is rendered in pulse form. RC responds quickly to changes in carbon content—about 30 min—and shows good sensitivity. On the other hand, the response lag with HZR is great due to the time required for the sinter mix to travel through the machine (about 85 min). In addition, because of its susceptibility to factors other than carbon content, HZR is not suited to the detection of sudden fluctuations. As a means of coping with this drawbacks, it is possible to switch the RC-HZR matrix to independent RC control.

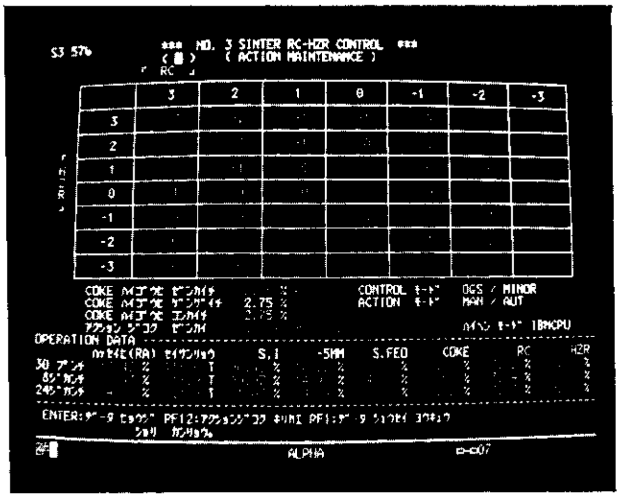

Photo 3 Action matrix display

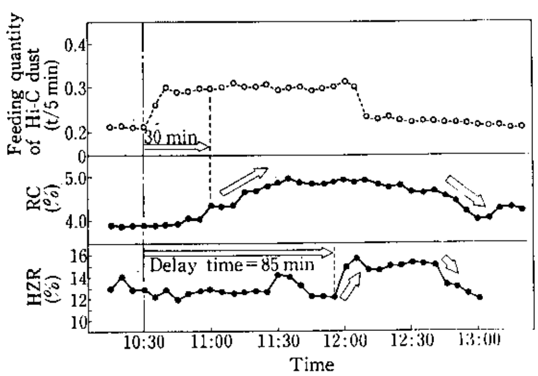

Fig. 5 Results of response test

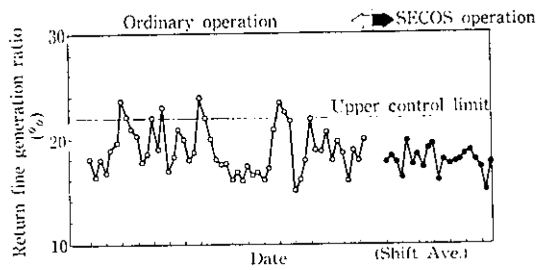

Fig. 6 Transition of return fine generation ratio

4 Results of Online Operation

Use of this fully-automated coke-blending-ratio control system began in July 1986; results are shown in **Figs. 6 and 7**.

Figure 6 shows the trend of eight-hour average values of the return-fine generation ratio, an indication sensitive to variations in the thermal energy level of the sintering layer. SECOS has made it possible to reduce this variation.

Figure 7 shows the trends of RC, HZR, and quality before and after SECOS operation was introduced. By permitting more precise control of coke blending, SECOS is contributing to the reduction of variations in sintering thermal energy and sintered ore quality.

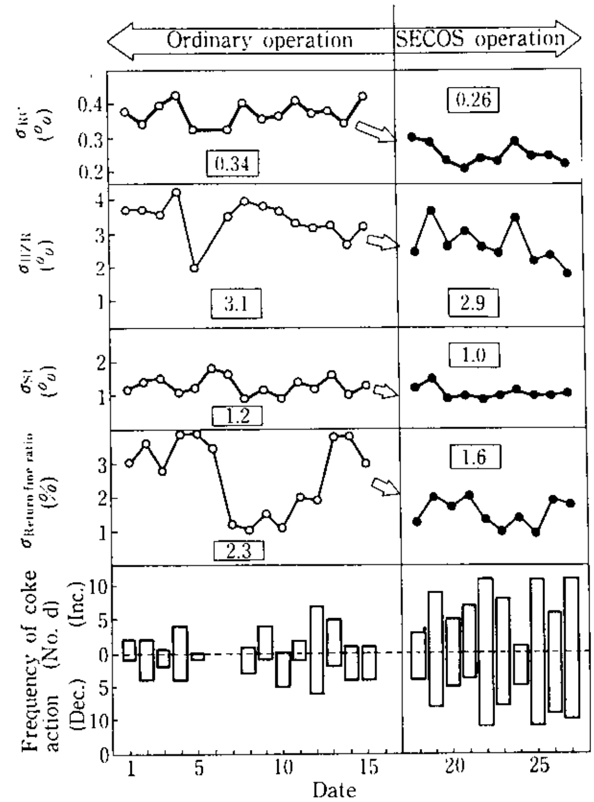

Fig. 7 Transition of standard deviations and coke action frequency

5 Conclusions

In the sinter plant of Chiba Works, the sintering energy control system (SECOS), the function of which is to detect variations in the carbon content of the sinter mix and to adjust this automatically, within an allowable range, has been developed. This system uses two parameters for judgment of sintering thermal energy level; real carbon (RC), actually utilized in the sintering process and derived from waste gas analysis, and the hot zone ratio(HZR) of the sinter cake cross section at discharge as measured by ITV monitor. Overall evaluation of the sintering thermal energy level and adjustment to the optimum coke blending ratio are carried out using an RC-HZR action matrix.

This system has realized rapid and accurate detection and control of fluctuations of the carbon content of the sinter mix and contributed to the stabilization of quality and product yield since July 1986.

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