OPERATIONAL IMPROVEMENT OF A SUBMERGED ARC FURNACE IN KASHIMA WORKS (KF-1)

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ABSTRACT

The №1 Submerged Arc Furnace at the Kashima works (KF-1) produces high-carbon ferromanganese using charges of hot raw materials. To achieve stable operation at a higher power load, we revamped the power supply to achieve carbon-saturated operation, improved the lining configurations based on numerical modeling of heat flows, and introduced tap hole opening using mechanical drilling, from 2006 [1].

Further improvements have increased our operational maximum power load from 25.5 MW to 27.0 MW, while reducing costs by using the less expensive electrical power available at night.

The improvements to be implemented are as follows:

1. The procedures for cleaning the runners after metal and slug tapping could be improved with steeper slope of runners and introduction of construction machines. These operational improvements could increase the number of tapping cycles per day (metal tapping from three to five times, slag tapping from three to four times) without increasing manpower requirements, which would increase the electrical resistance (550→650 μΩ) by keeping the appropriate residual amounts of metals and slag in a furnace. We could increase our operational maximum power load and maintain suitable electrode positions.

2. When the electrical resistance decreases due to unstable tapping conditions or excessive coke in the unit, the secondary electrical current reaches the limit of the transformer's capacity and we are forced to decrease the power load. When this happens, we have planned to use brief cold raw material charges, skipping the rotary kiln stage and increasing the electrical resistance. Those actions allow the electrodes to penetrate deeper into the furnace, and the power load recovers to our maximum operational value more quickly.

3. To maintain the self-lining coating on the refractory material around the metal tap holes, which determines the service life of the lining, water-cooled copper pipes were inserted in the tap holes when the nearby refractory temperatures reached their operational specified value. This cooling procedure quickly and effectively restored the self-lining coating.

As a result of those improvements, the actual night-time average load could be increased from 22.8 MW to 24.7 MW.

1. INTRODUCTION

The No.1 Submerged Arc Furnace at the Kashima works (KF-1) produces high-carbon ferromanganese using charges of hot raw materials. Figure 1 shows the production flow of KF-1. Raw materials are heated to about 700°C in a rotary kiln that consumes less electricity due to water removal and a reduction in the amount of Mn ores [2]. Hot raw materials are charged into the furnace with chalk feeds from elevated bins. Some characteristics of KF -1 are shown in table 1.

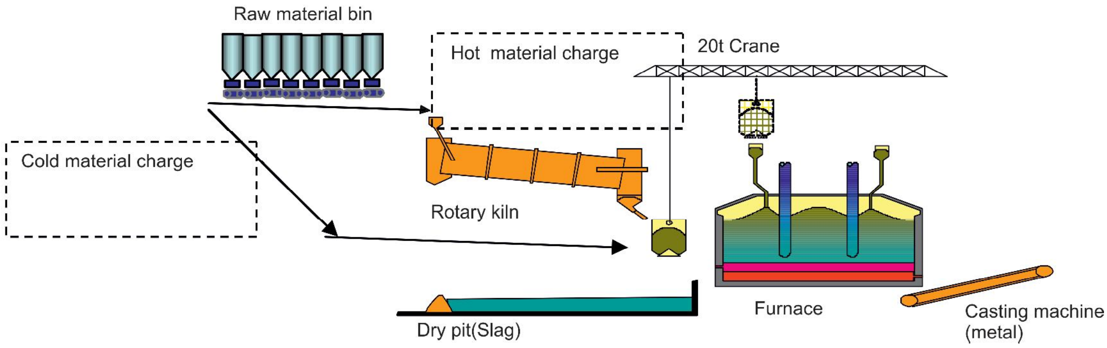

Figure 1: Product flow of KF-1

Table 1: Characteristics of the KF-1 facility

Item		Specifics
Tap hole		Two metal holes (M1,M2) One slag hole
Exhaust gas system		Closed type with venturi scrubber
Transformer capacity		49,500 KVA
· Secondary voltage		218 V
· Secondary current		131 kA
Electrode diameter (D)		D = 1.7 m
· Distance between electrode surface and lining		1.2 D
Raw materials charge		Rotary Kiln (Heats to 700℃)
Shell cooling	Wall	Water-cooled (shower)
	Bottom	Air-cooled (blower)

2. MEASURES TO INCREASE OUR MAXIMUM OPERATIONAL POWER LOAD FROM 25.5 MW TO 27.0 MW

2.1. Increasing the number of tap cycles per day while reducing the labor required for runner cleaning

To ease the burden of cleaning the metal tap runner, the residual metal scum in the runner was reduced by shortening the paths of runner and modifying their shape (figures 2, 3). In addition, we introduced a machine to clean up the runner from the metal and slag taps. These improvements could increase the number of tapping cycles per a day (metal tapping from three to five times, slag tapping from three to four times) without any increase in manpower. As the amount of metal that accumulated in the furnace was reduced, the electrical resistance increased from 550 μΩ to 650 μΩ. We could then increase our operational maximum power load from 25.5 MW to 27.0 MW and remain within secondary current limitations.

	Before	After	Difference
M1 tap hole	17.9 m	13.4 m	-4.5 m
M2 tap hole	16.1 m	14.2 m	-1.9 m
Angle	4°	7°	+3°

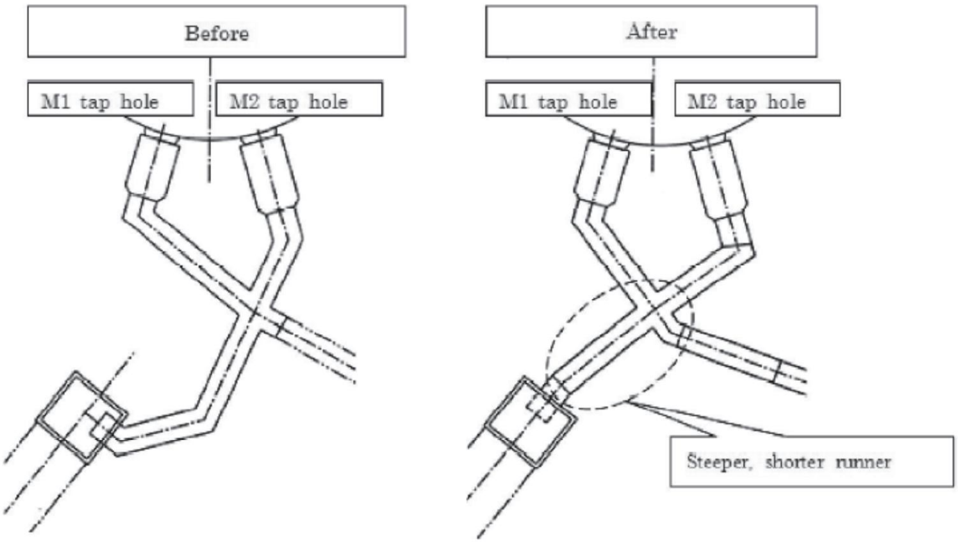

Figure 2: Modification of the metal tapping runner

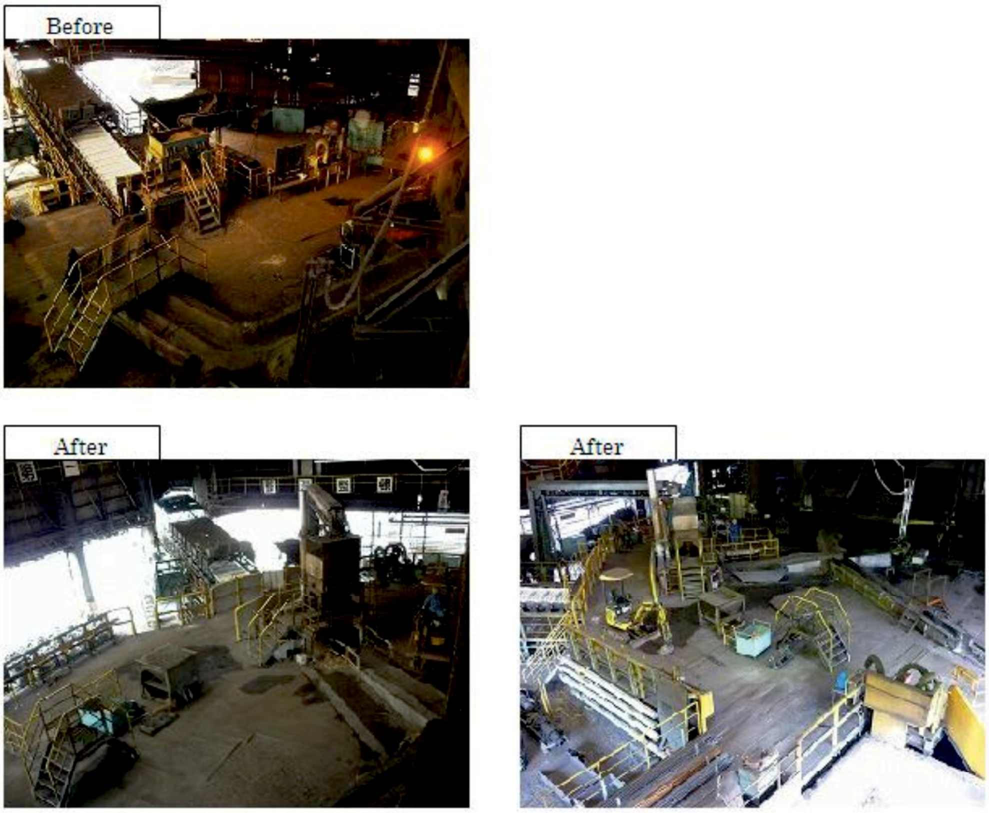

Figure 3: Overviews of the KF-1 tapping floor, before and after modification

2.2. Adjusting operational fluctuations and maintaining high power load by briefly charging with cold raw materials

2.2.1. Conventional procedures

When an electrode moves upward and stays high due to operational fluctuations such as unstable tapping and/or excess coke addition, we are forced to further destabilize operations with an unfavorable temperature distribution in the furnace. Conventionally, we reduce the coke consumption gradually to reduce the electrical resistance, and try to move the electrode down to a better position. This conventional procedure imposes a significant delay before returning to our maximum operational power load.

2.2.2. Concepts underlying brief cold raw material charging

Dhainaut calculated the electrical current distribution in a typical industrial furnace (figure 4), showing that if the electrode penetration is deep, the proportion of current flowing through the lower part of the furnace increases, leading to stable tapping conditions with higher slag and metal temperatures [3, 4].

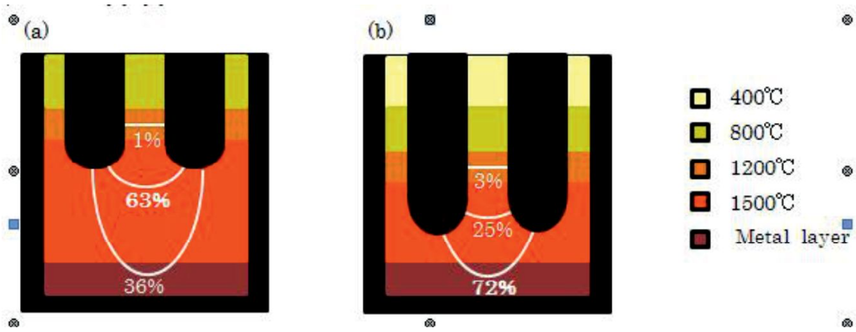

Figure 4: Current flow path and resulting temperatures with:
(a) Higher electrode tip (b) Lower electrode tip. Dhainaut (2004)

Figure 5 shows that the electrical resistance of charging raw material increases with decreasing temperature, especially from 700 °C to 400 °C [5]. Briefly charging cold raw materials skipping the rotary kiln, we can expect deeper electrode penetration and increased electrical resistance.

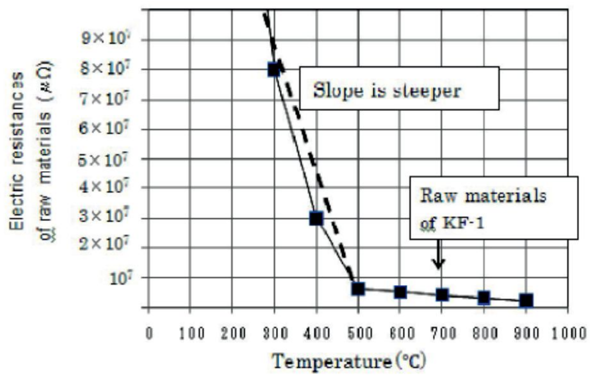

Figure 5: Relation between electrical resistance and temperature of high-carbon ferromanganese raw material. M. Kiriyama (1969)

2.2.3.Operational results from the brief use of cold raw materials

Figure 6 shows the effect of the brief use of cold raw material charges.

When the electrode position remains high, the proportion of current flowing through the lower part of the furnace is insufficient, leading to unstable tapping conditions and further decreases in the power load, while exceeding the current limitations of the transformer. In this event, charging cold raw materials skipping the rotary kiln allows the electrode to move down, and the power load recovers in 8 hours. This procedure allows a quick return to stable operations and a maximum operational power load.

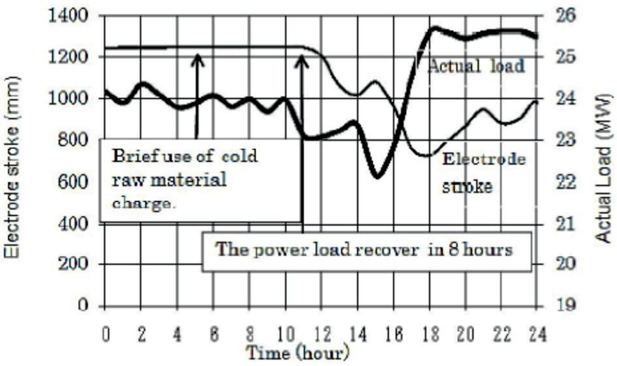

Figure 6: Effect of short-term cold raw material charging

2.3. Measures to maintain self-lining coating in the furnace and increase maximum operational power load

2.3.1. Conventional procedures

We have paid special attention to maintaining the self-lining coating on the refractories around the metal tap hole, the erosion of which determines the life of the lining. Conventionally, when the temperature near the metal tap hole exceeded a specified value, to restore the self-lining coating we reduced the power load or stopped the operation until the temperature returned to the required level. It took quite long time to return to the maximum operational power load with those procedures because of insufficient cooling effects.

2.3.2. A water-cooled copper pipe in the tap hole

A schematic diagram and photo of a water-cooled copper pipe inserted in the tap hole are shown in figures 7 and 8.

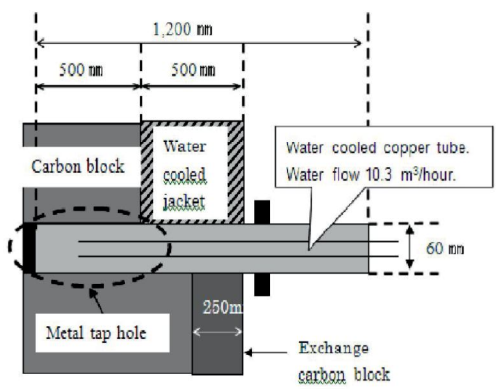

Figure 7: Schematic diagram of the water-cooled copper tube inserted in the tap hole

Figure 8: Water-cooled copper tube in the tap hole

We estimate the heat removal by the water-cooled copper pipe to be 7.9 MJ/hr, calculated from the in/out water temperature change.

When the refractory temperature threatened to exceed the allowable value, the pipe was inserted in the tap hole. This lowered the temperature of the refractory sooner than the conventional method would have, and without decreasing the power load, and the cooling restored the self-lining coating effect, as shown in figure 9.

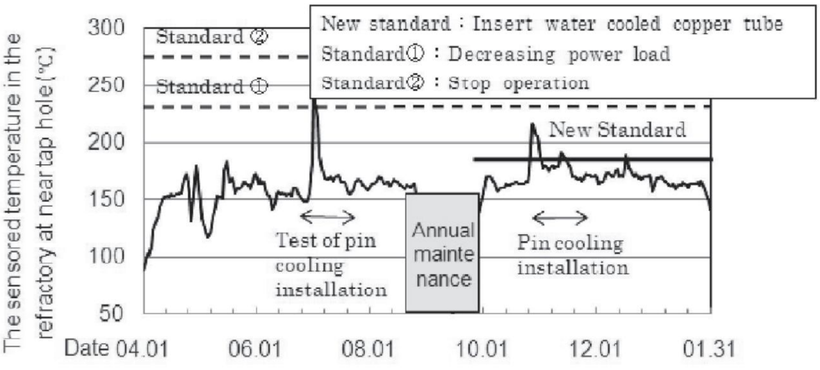

Figure 9: Effects on of the water cooled copper tube inserted to the tap-hole

3. OPERATIONAL RESULTS ON THE POWER LOAD

3.1. Electrical resistance

By increasing the number of tapping cycles per day (metal tapping from three to five times, slag tapping from three to four times) and the brief use of cold raw materials, the electrical resistance could be increased from 550 μΩ to 650 μΩ which increased our operational maximum setting load from 25.5 MW to 27.0 MW for the almost same electrode positions, as shown in tables 2 and 3.

Table 2: Electrical resistance and current

Setting power load	25.5 MW	27.0 MW
Resistance (μΩ)	550	650
Secondary current (kA)	115	106
Power factor (%)	51.0	54.1

Table 3: Change in the position of the electrode

Setting load	25.5 MW	27.0 MW
#1 pole (mm)	640	704
#2 pole (mm)	766	777
#3 pole (mm)	576	574

3.2. Actual average power loads

Increasing the maximum setting for the power load from 25.5 to 27.0 MW with these improvements allowed the actual night-time average load to increase from 22.8 MW to 24.7 MW, as shown in figure 10.

The before/after differences between our maximum setting power loads and the actual power loads at night are shown in figure 11. The raw material slipping and the lack of raw material feeding capacity are the main causes of decreasing actual power loads at our maximum setting power load of 27.0 MW. As the shortfall in feeding capacity occurs just after raw materials slipping, we now concentrate on reducing raw material slipping with the introduction of an automatic shutdown gate for raw material feeding shooters into the furnace.

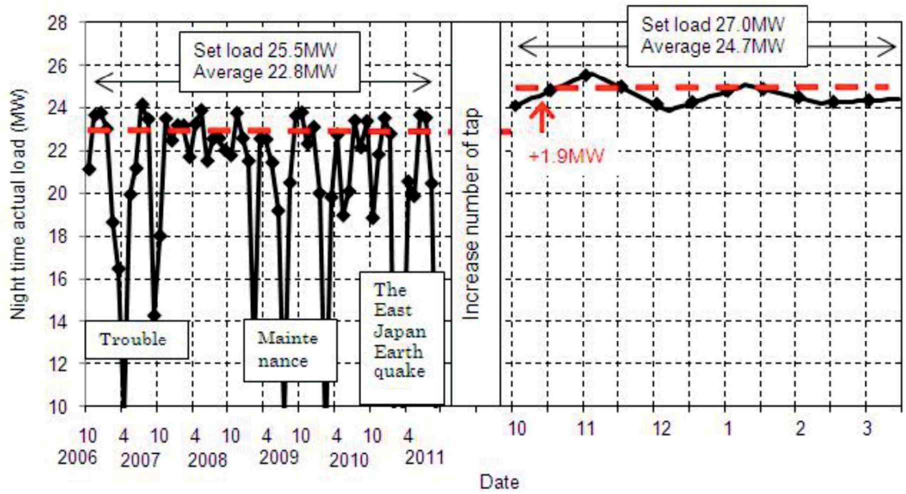

Figure 10: Night time actual load

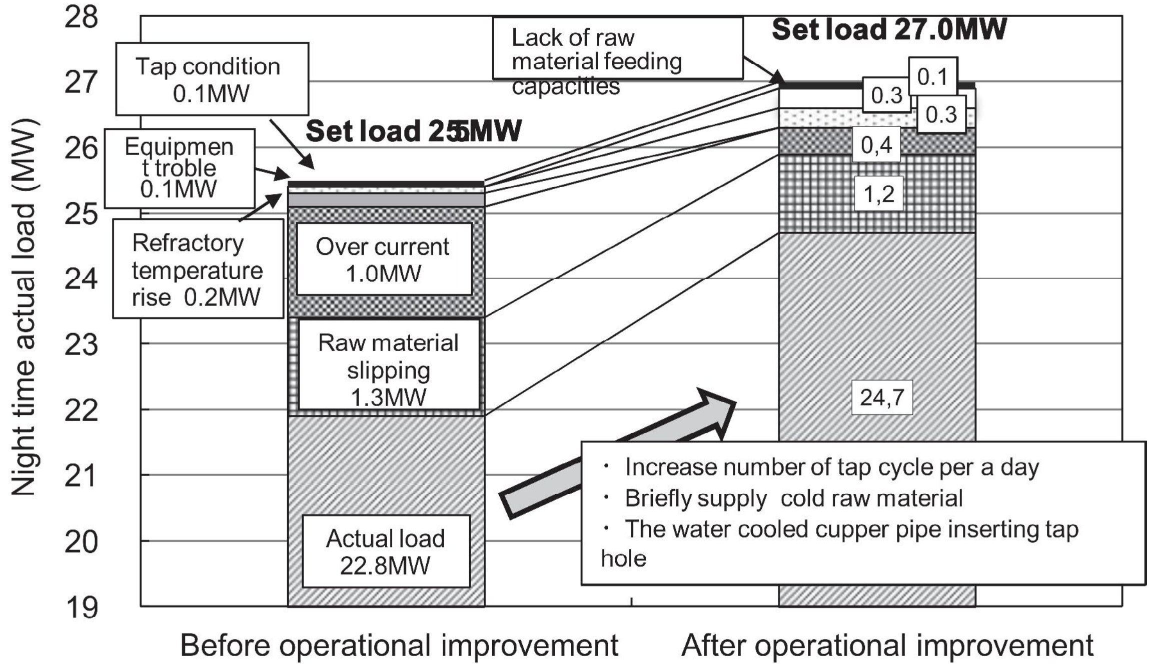

Figure 11: Analysis of difference between actual average power loads

5. CONCLUSIONS

1. Modifying the design of runners and introducing construction machines allowed us to increase the number of tapping cycles per day (metal tapping from three to five times, slag tapping

from three to four times) using the same manpower, which increased the electrical resistance (550→650 μΩ). We could also increase our operational maximum power load from 25.5 MW to 27.0 MW by maintaining optimal electrode positions.

2. When the electrical resistance decreases due to factors such as unstable tap conditions or excessive coke, the secondary electrical current reaches the transformer's capacity and we are forced to decrease the power load. When this happens now, we briefly supply cold raw material charges (skipping the rotary kiln) and thereby increase the electrical resistance. These actions allow the electrodes to penetrate deeper into the furnace, so they quickly and effectively return to stable operating conditions and the maximum operational power load.

3. By inserting a water-cooled copper pipe in a tap hole when the maximum allowed refractory temperature is approached, we have been able to maintain the self-lining coating near the metal tap holes, which determines the lining life.

4. As a result of those improvements, the actual night-time average load was increased from 22.8 MW to 24.7 MW.

5. However, the actual average power load cannot approach closer to the maximum setting power load than 2.3 MW. Now we are concentrating on reducing raw material slipping as the main factor reducing the actual average power load, by introducing an automatic shutdown gate for the raw material feed into the furnace.

6. REFERENCES

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