OPERATIONAL IMPROVEMENTS OF A SUBMERGED ARC FURNACE IN KASHIMA WORKS (KF-1) RELINED IN 2006

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ABSTRACT

No.1 Submerged Arc Furnace in Kashima works (KF-1), whose lining life is relative short (=6 years), produces high carbon ferromanganese with hot raw material charges. In order to improve the lining life on KF-1, we have carried out the revamping of the power supply to achieve carbon saturated operation, improved lining configurations aided by theoretical heat simulation, and applied tap hole opening with mechanical drillings.

1 INTRODUCTION

Kashima Works No. 1 submerged arc furnace (K F -1) produces high carbon ferro manganese. KF-1 has a relatively short lining life because of short distances between electrodes and the hot surface of the furnace wall and the restriction of electric current by the transformer capacity on the hot charge operation of raw materials. In the past we reinforced cooling lining, prevented lifting of linings, and reinforced coating with improved mud of metal tap hole as counter measurements. Meeting the relining of KF-1 in 2006, we have made further efforts on longer lining life and stable operations including revamping the power supply.

2 A CHARACTERISTIC OF KF-1 FACILITY AND THE OPERATIONAL PROBLEMS

2.1 Production flow

Figure 1 shows production flow of K F -1. Raw materials are heated up to about 700 °C with a rotary kiln for with water removal and prereduction of Mn ores [1]. Hot raw materials are charged into the furnace together with chalk feeds from the upper bins.

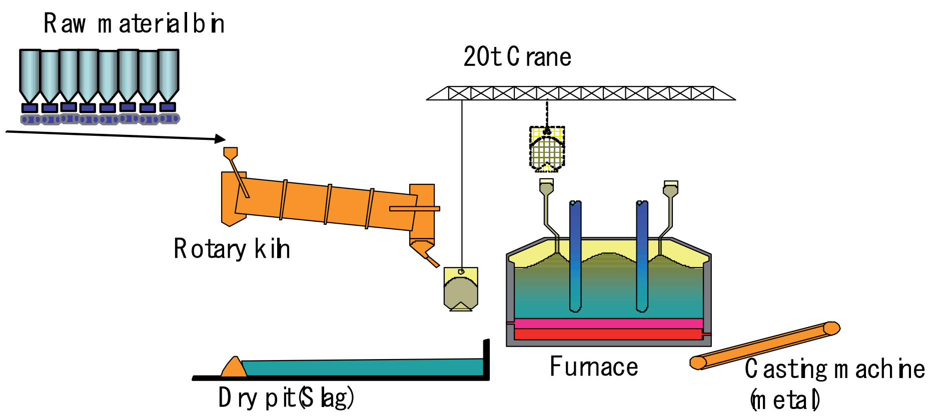

Figure 1: Production flow of KF-1.

2.2 Characteristic of facility and operational problems

Characteristic of K F -1 is shown in Table 1. The distances between the electrodes and the hot surface of the furnace wall are very narrow (1.2D) in comparison with the electrode diameter (D=1.7m).The hot lining surfaces are severely damaged by thermal load through the electrodes in spite of the reinforcement of the shell cooling system.

It is very difficult to maintain power loads with higher productivity due to the limitation of maximum electrical current of the transformer (before revamping: 106kA), especially in an electrical resistance fall on the hot charge of raw materials. We were sometimes forced to not only decrease power load but also to reduce the amount of coke to decrease electrical resistance. On the other hand, as a result of having to reduce the amount of coke, the carbon content of metal was much lower than the saturated value, which is harmful for the lining life of carbon bricks.

Table 1: A characteristic of KF-1 facility.

Item		Contents
Transformer capacity		40,000KVA (After relining 49,500KVA)
Secondary voltage		218V
Secondary current		106kA (After relining 131kA)
Electorode diameter (D)		D=1.7m
Distance between electrode surface and lining		1.2D
Raw materials charge		Rotary Kiln (Heat to 600-700^{o}C)
Shell cooling	Wall	Water-cooled (Shower)
	Bottom	Air-cooled (Blower)

2.3 Past efforts for longer lining life in KF-1

The wear of linings is monitored with drilling depth of metal tap hole and temperature in both the wall and bottom bricks. The history of improvements of lining configurations in KF-1 is shown in Figure 2.

To reduce carbon block wear, reinforcement of cooling for linings had been applied to carbon blocks next to the inner shell and vertical blocks at walls.

The horizontal blocks at the walls made slag and metals penetrate into joints of the wall carbon blocks easier, which caused the carbon blocks to move upward. For the solution of this problem the configurations of walls returned to a vertical block type in 1996.

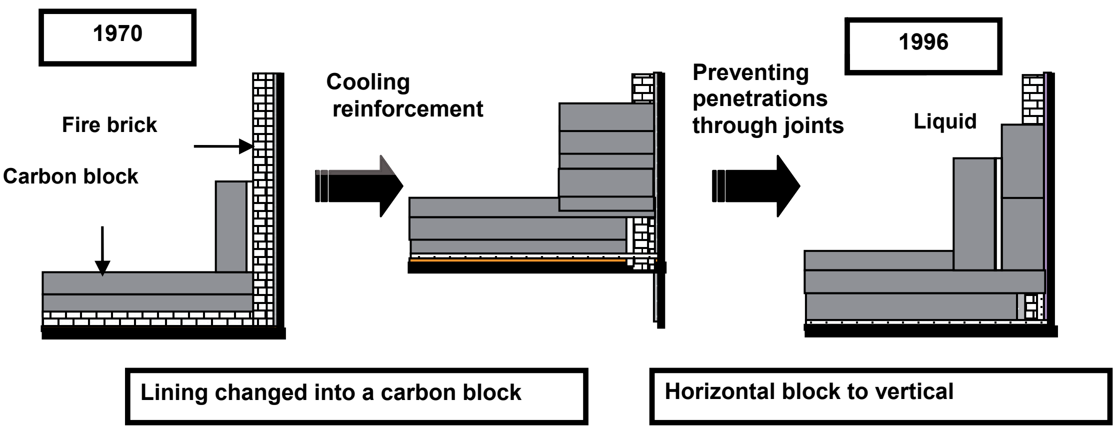

Figure 2: The history of improvements of lining configurations of KF-1.

The wear of the wall lining was improved, but still the linings near the metal tap hole were insufficient. We tried to protect the linings near the metal tap hole by coating reinforcements with tap-hole mud. A mud gun was modified for coating reinforcement shown in Table 2. In addition the composition of mud was changed to a stickier rigid one (with a few volatiles) near metal tap hole.

Table 2: Modification of mud gun.

	Conventional	Modified
Barrel capacity (litter)	40	**60**
Driving force	Electric	**Hydraulic**
Ramming pressure (ton)	26.3	**35.6**
Crimp device	Torshon bar	**Plate spring**
Crimp pressure (ton)	3.9	**7.0**

3 LONGER LINING LIFE MEASUREMENTS MEETING THE RELINING OF KF-1 IN 2006

3.1 Increase in transformer capacity

The transformer has been revamped to increase electric currents which enabled carbon saturation without a power load drop. The transformer capacity was increased from 40,000kVA to 49,500kVA which is as large as the site installation capacity. The maximum electric current increased by 24% from 106 to 131kA, shown in Table 3.

Table 3: Increase in transformer capacity.

Review		Before	After
Capacity (kVA)		40,000	**49,500**
Voltage	Max (V)	267	253
	Base (V)	218	218
	Min (V)	155	141
Maximum electric current (kA)		106	**131**

3.2 The configuration of the bottom for a deeper metal bath

The metal bath was deepened to reduce thermal load of the wall lining at metal tapping as shown in Figure 3. The shallower metal bath increased flow rates at the hot surface of walls at tapping, which accelerated wear in the hot surface of walls. Therefore, the number of bottom carbon block was changed to two from three for making a deeper metal bath. The purpose of metal bath expansion gains a flow of metal from the furnace bottom to the tap hole, and reduces the velocity of the flow passing the furnace wall surface.

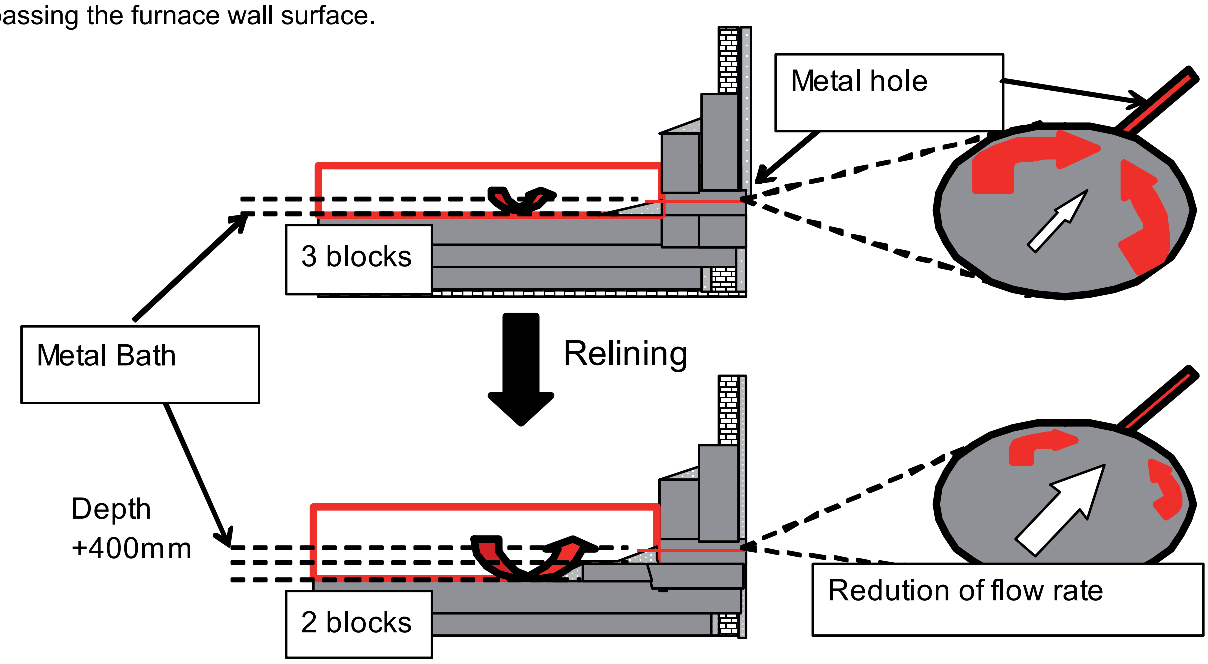

Figure 3: Modification of bottom blocks for getting a deeper metal bath.

The effect of deeper metal bath was evaluated with flow analysis beforehand. The calculation is based on the operational conditions shown in Figure 4.

- Furnace wall temperature 30 °C (water-cooled)
- Furnace bottom temperature 150 °C (air-cooled)
- Tap speed of metal 1.2 t/min
- Tap temperature of metal 1450 °C

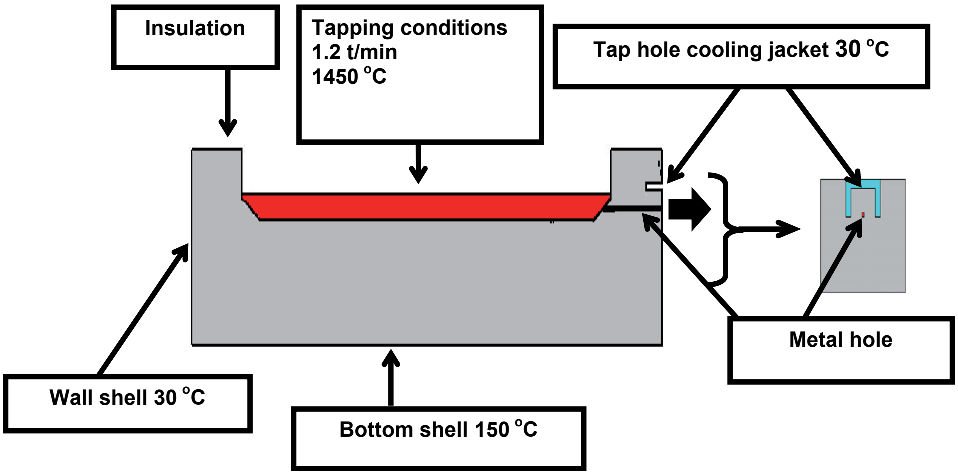

Figure 4: The conditions of the calculation on flow analysis.

Result of flow rate calculation in the lining surface is shown in Figure 5. This result confirms that a deeper metal bath helps to decrease flow rates near the metal hole at tapping.

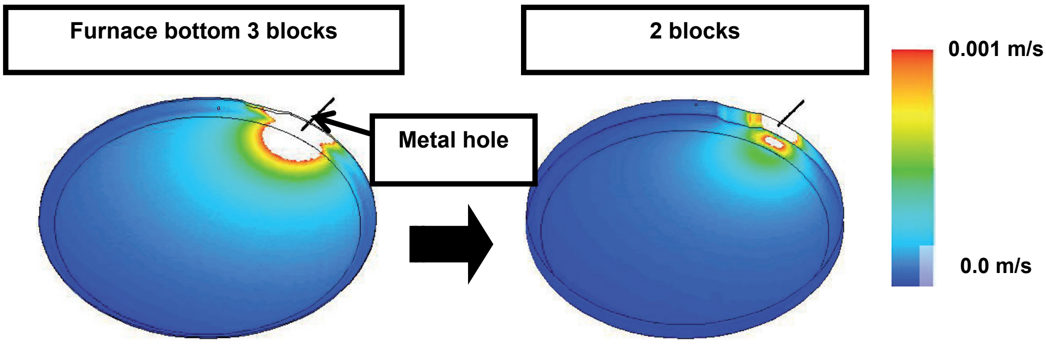

Figure 5: Metal flow distribution at the lining surface at tapping.

In addition, a decrease in lining surface temperature and metal temperature at tapping was estimated as shown in Figure 6. A decrease in metal temperature (1418 °C → 1393 °C), is negligible for our tapping work. With these calculations, we concluded that thermal load reductions were effective for the lining near the metal hole, applied to deeper metal bath.

3.3 Tap with a drill

A schematic diagram of oxygen opening and fully drilled opening is shown in Figure 7. A conventional opening method consists of first using a drilling machine until just before tap hole opening. Secondly oxygen is introduced through a pipe. An oxygen pipe bends easily in a tap hole. This causes the oxidation of the hot surface of the tap hole, and accelerates wear of the carbon block. The fully drilled opening without oxygen has been applied since 2007.

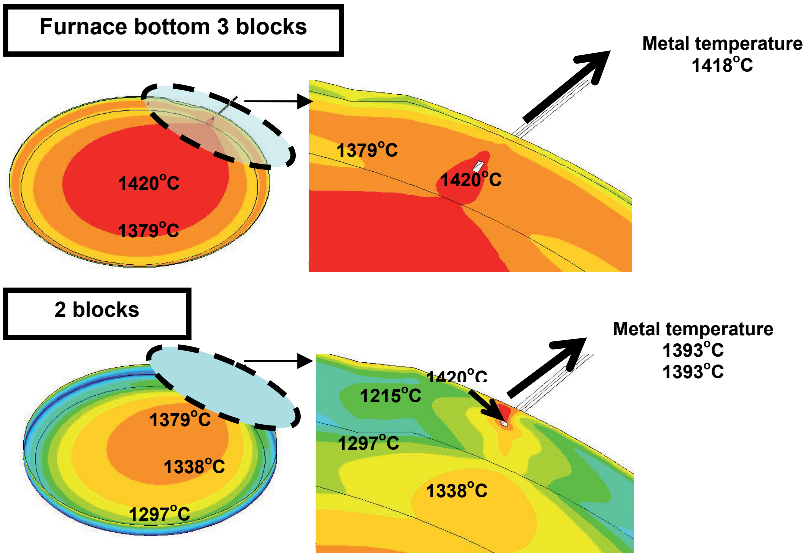

Figure 6: Temperature distribution of the lining surface at tapping.

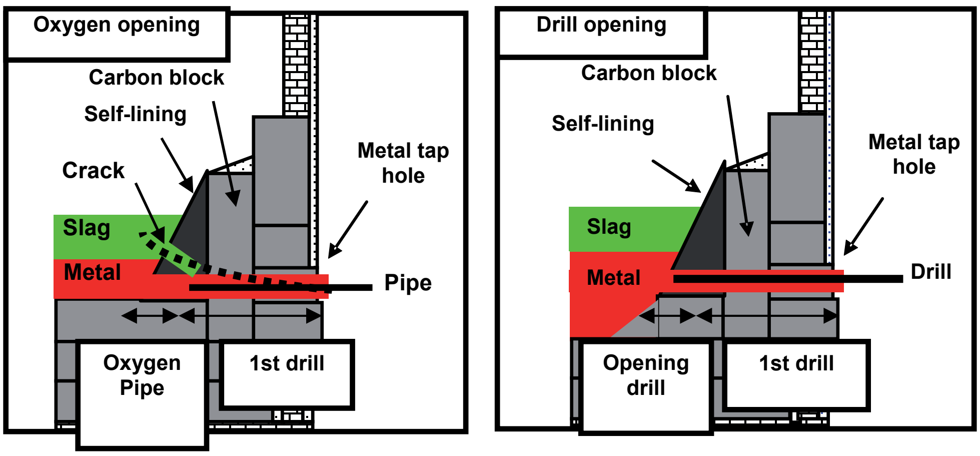

Figure 7: Schematic diagram of tapping work.

4 EFFECT OF IMPROVEMENT

4.1 Electric furnace load

The average power load at night is shown in Figure 8 [1]. The set power load increased from 23.6 MW before the relining to 25.5 MW. Average power load increased by 3 MW. The increase in the transformer capacity helped to maintain high power load.

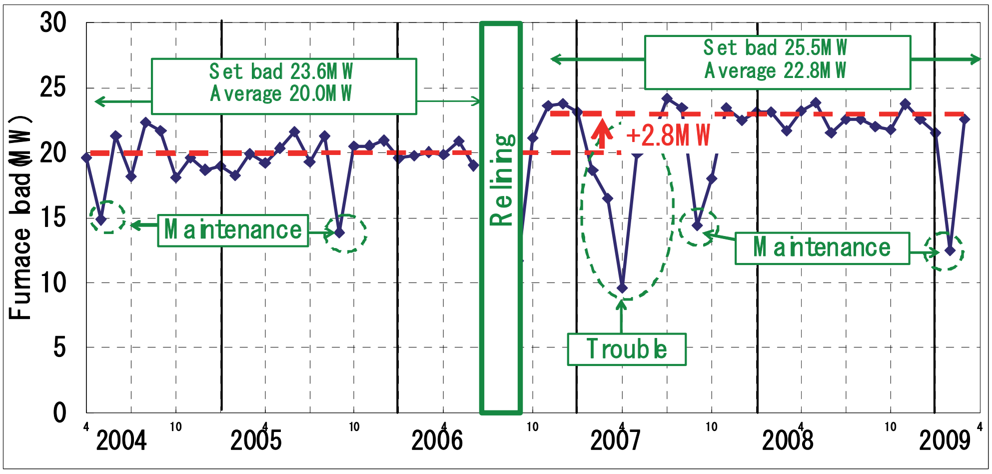

Figure 8: Average load at night time before and after the transformer capacity was increased.

4.2 The carbon content of metal

The carbon content of metal is shown in Figure 9. It increased from 6.49% to 6.66% after revamping the transformer in 2006, which has enabled carbon saturated operation.

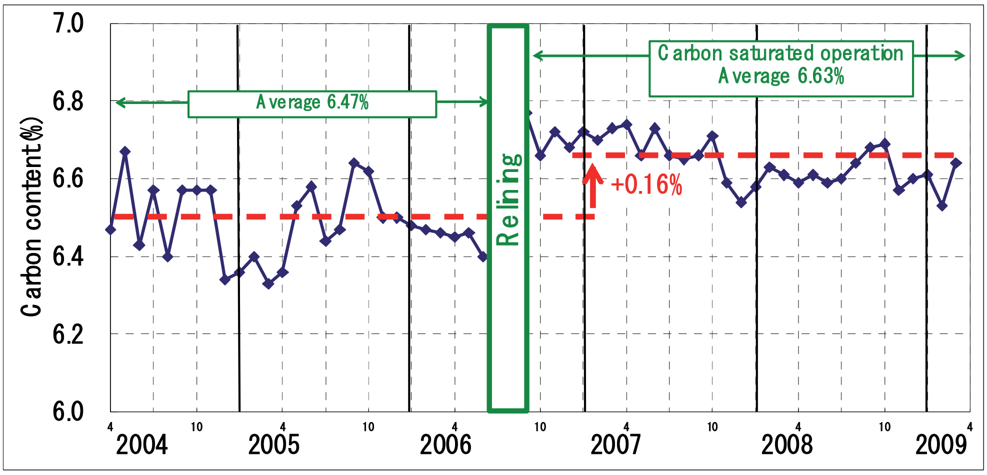

Figure 9: Carbon content of metal before and after relining and revamping the transformer.

4.3 Metal temperature at tapping

Metal temperature at tapping is shown in Figure 10. After repair, the metal temperature at tapping decreased with 40 °C and that agrees with the calculations of the flow analysis. We believe that the deeper metal bath enables lining protection near the metal hole.

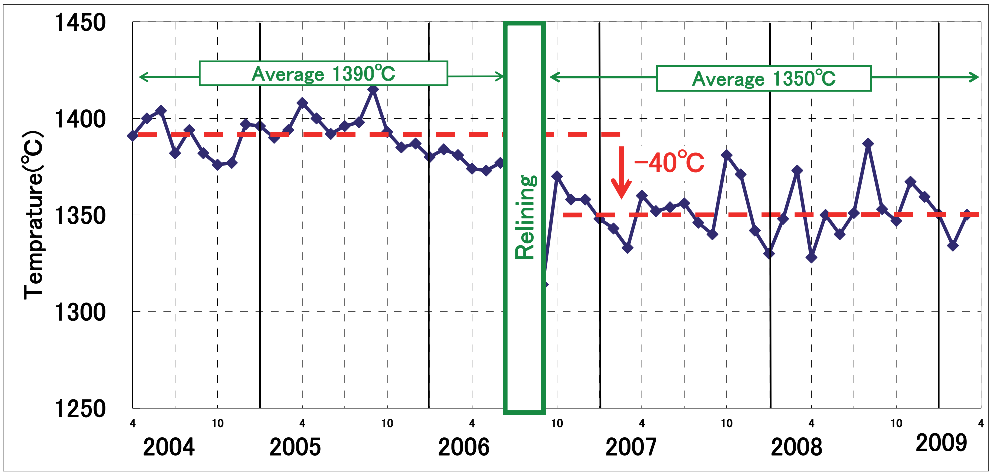

Figure 10: Metal temperature at tapping before and after relining and revamping the transformer.

4.4 Drilling depth at tapping before and after relining

The drilling depth before and after relining is shown in Figure 11. Drilling depth is the drill depth that is the most shallow in a month. In figure, as for 1.5 m, and show an operation aim of drilling depth is determined to 2.0 m compared with initial thickness between a metal hole and the inside wall lining: 1.5 m. The drilling depth after the repair in 2000 constantly decreased. However, the improvements were recognized with the mud gun reinforcement and adjustments of compositions of mud in April 2005. With fully drilled opening, first applied in 2007, drilling depth keeps stable at the operation of set power load at 25.5 MW.

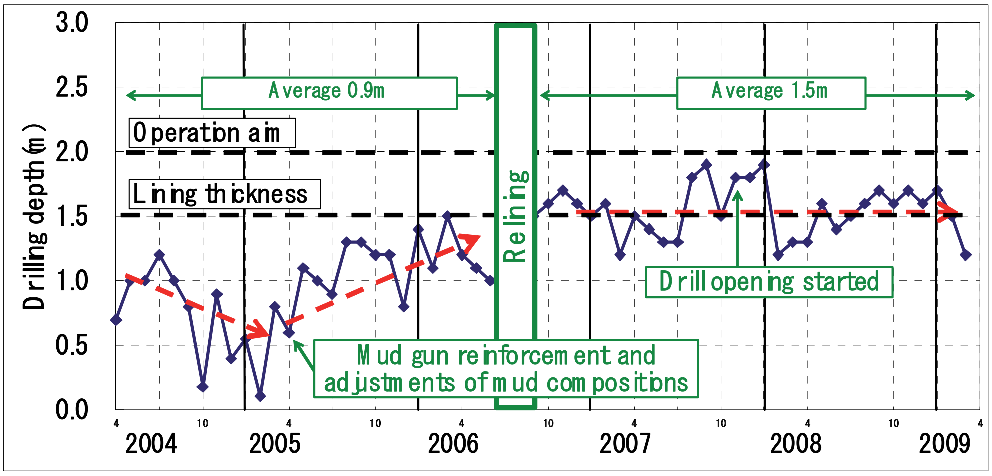

Figure 11: The most shallow drill depth in a month.

5 CONCLUSION

(1) At the relining of K F -1 in 2006, the following items were carried out to improve the lining life which was determined by wear near the metal tap hole.

- Capacity of transformer up from 40,000 kVA to 49,500 kVA
- Deeper metal bath
- Fully drill tapping

(2) The increase in transformer capacity helped to maintain high power load and allowing operation with carbon saturation. Longer lining life can be expected.

(3) A decrease of metal temperature at tapping by deeper metal bath appropriately agrees with the result of flow analysis. A thermal load reduction of the lining is expected with deeper metal bath.

(4) A stable depth of drill opening can be maintained at the initial lining thickness for the operation of set power load at 25.5 MW.

6 REFERENCES

[1] F.Yoshida, T.Homma and T.Sasaki, "Automation and reduction of labour in the operation of electric arc furnace for HCFeMn production", INFACON □,1998, pp 337-342.