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The Effect of Reductant Moisture on the Production of 75 per cent Ferrosilicon

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An investigation was carried out over 12 months to determine the effect of the moisture content of the reductants on furnace performance for the production of 75 per cent FeSi. The three main relationships that were analysed were the effect of rainfall on reductant moisture, the effect of variability in reductant moisture on furnace performance, and the effect of total water input on process efficiencies.

Rainfall above 10 mm was found to significantly affect the more porous reductants such as metallurgical coke. An increase of 2 per cent in the moisture content of the reductant was shown to reduce the efficiency of the furnace by up to 10 per cent.

A strong correlation between total water input and power consumption was found during the study, the best case being a consistent power consumption of 8000 kWh/t for a total water input of approximately 90 kg/t FeSi.

Introduction

In recent years TEMCO has been striving to increase its furnace loads and improve furnace efficiencies in all four of its furnaces. During 1986/87, manganese furnaces Nos. 1, 2, and 3 were all uprated in load by approximately 40 per cent without any major changes to the existing system. Electrical control parameters and raw material inputs were modified, resulting in reduced coke beds and longer electrodes, to maintain a low off-gas temperature.

No. 5 furnace (75 per cent FeSi) operations have been improving steadily over 15 years, with power figures moving towards the theoretical value for FeSi production.

Higher loads and the introduction of a process-control system (approximately two years ago) have meant that control of variability has become paramount to ensure a quality product. The variation in key process parameters is now significantly less, and hence the focus is on the parameters considered inconsequential in the past.

This investigation was carried out to establish the effects of reductant moisture on the furnace performance. The following relationships were examined: the effect of rainfall on reductant moistures, the effect of reductant-moisture variability on furnace efficiency, and the total water input (via the reductants) versus the furnace performance.

Furnace Design and Operating Data

The FeSi furnace is a semi-closed rotating furnace of Elkem design, and was constructed in 1976.

Design Parameters

Transformer capacity	3 x 15 MVA
Electrode diameter	1 550 mm
Electrode spacing	3 400 mm
Furnace shell diameter	10 500 mm
Rated loading	30 MW

Operational Data

Load	27,5 MW
Electrode current	95 kA
Resistance	0,98 mΩ
Energy requirement	7 900 – 8 600 kWh/t
Tapping interval	47 000 kWh

Raw Material Input (per batch)

Material	*Dry kg/batch*	*Remarks*
Quartz	840	97,5 per cent SiO_2
Coke	190	86 per cent fixed carbon size 6 x 15 mm
Coal	230	53 per cent fixed carbon size 10 x 30 mm
Iron pellets	125	
Woodchips	330	Large size 14 per cent fixed carbon

SiO_2 input 2 t per ton of FeSi

Process Description

Moisture data for all reductants were collected for the months of November 1987 to October 1988, and collated with rainfall figures for the surrounding area. No samples were taken of the woodchips. Other information such as furnace efficiencies, tapping times, and analysis grades were gathered for statistical correlation.

Effect of Rainfall on Reductant Moistures

Rainfall figures were compared with the coke and coal moisture to determine at what level the amount of water was significant in a 24-hour period. This comparison was also carried out in order to determine the difference in the effect on each reductant.

Effects of Variation in Reductant Moisture on Furnace Performance

During the period 1987 to 1988, a closed-loop fixed-carbon-control FES (refer to the Addendum) was operating successfully on the FeSi furnace, and hence may have been compensating for instantaneous variations in reductant moisture.

Early in 1989 TEMCO experienced some severe problems with the water-cooled smokehood system, and since that time has removed the carbon-control system. Data were analysed for the period 19/05/89 to 21/05/89.

The major water source to the furnace during this time was Chinese coke. Its variation was analysed with respect to its effects on the analysis trends, furnace efficiency, and tapping interval.

Effect of Total Water Input on Furnace Efficiencies

In the past it was thought that moisture in the raw materials, in particular the reductants, might have a positive effect on furnace operations by reducing the conductivity of the charge and, hence, drawing the electrodes deeper into the furnace.

Furnace efficiencies were analysed with respect to the total water input to the furnace per tapped ton of FeSi, in order to determine whether any correlation existed.

Some simple theoretical calculations on energy consumption were carried out as a comparison with these results.

Discussion of Results

Effect of Rainfall

Typical results for variation in coke and coal-moisture contents (as a consequence of rainfall) are shown in Figures 1 and 2.

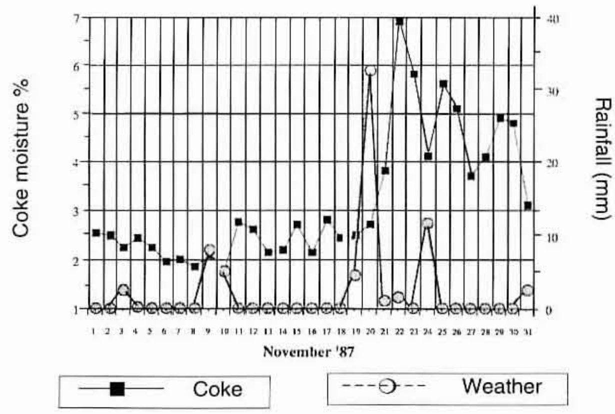


FIGURE 1. Effect of rainfall on coke moisture

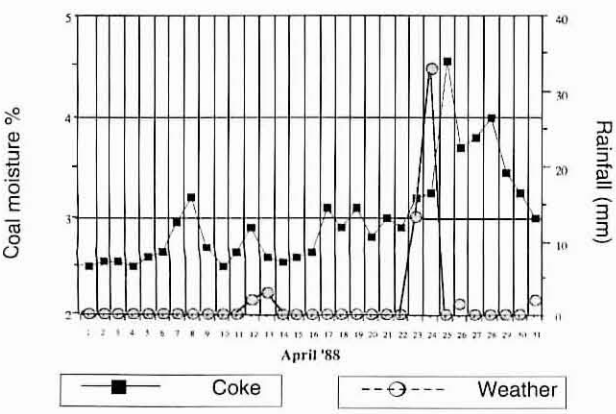


FIGURE 2. Effect of rainfall on coal moisture

The coke moisture has been shown to vary significantly after rainfall in excess of 10 mm. The size of the variation is between 1 and 5 per cent for metallurgical cokes, and between 1 and 2 per cent for the high-swell coals, depending on the intensity and size of the rainfall. This is as expected, since metallurgical coke is a very porous substance when it has the opportunity to absorb large amounts of water.

This variation correlates to an increase of between 2 and 10 kg in the dry-coke level. These values are very high when one considers that the production metallurgist may vary the fixed-carbon level by 1 per cent for a normal charge (or 4 kg of dry coke).

Effect of Variation in Reductant Moisture

Figure 3 shows an increase in the moisture content of Chinese coke from 14,5 to 17 per cent. The production metallurgist had removed 4 kg of dry coke at the same time. This therefore meant that the furnace had had a total of 8 kg of dry coke removed from the charge. As shown in Figure 4, the percentage aluminium fell from 2,5 per cent to a low of 1 per cent (severely undercoked). At the same time, the furnace energy requirement increased from 8800 kWh/t to a peak of 9 800 kWh/t.

Figure 5 shows that the tapping time increased dramatically from 30 to 40 minutes to more than 100 minutes. This fact, together with the increase in loss of SiO gas, resulted in poor furnace efficiencies.

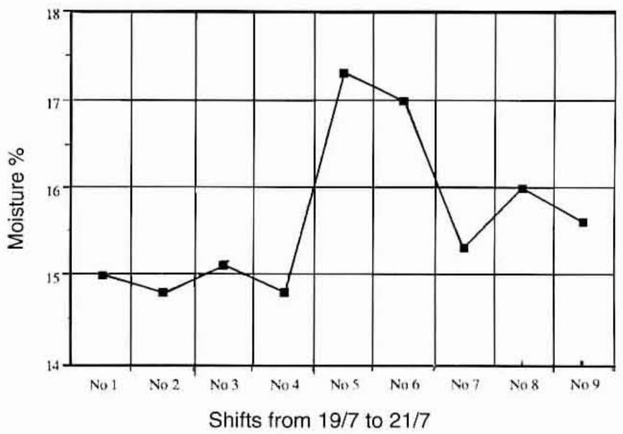


FIGURE 3. Variation of moisture in Chinese coke from 19/7–21/7

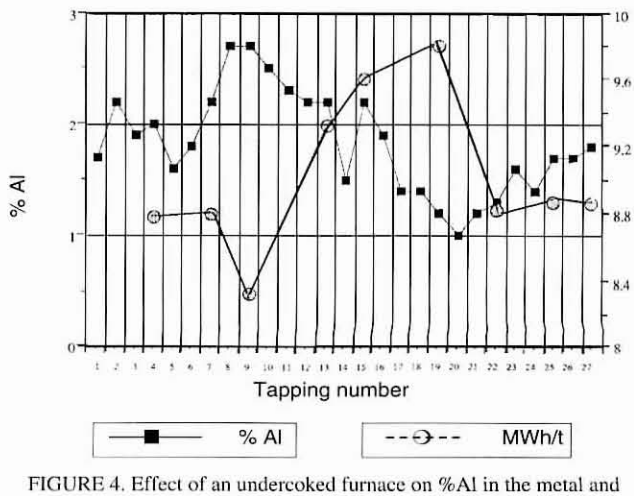


FIGURE 4. Effect of an undercoked furnace on %Al in the metal and furnace efficiency

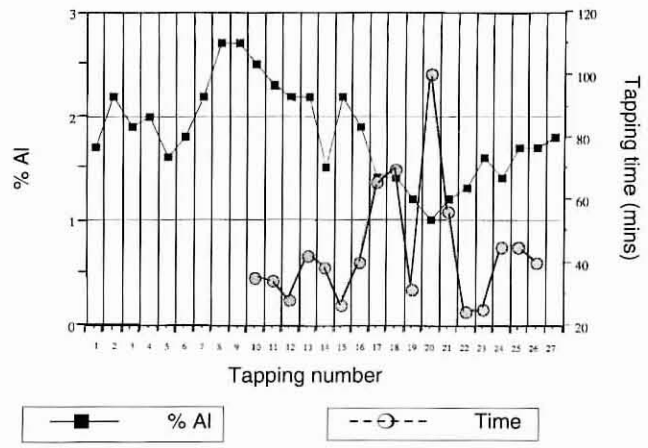


FIGURE 5. Effect of an undercoked furnace on tapping time

All these results are unacceptable both to the prospective customer and from an operational perspective.

Effect of Total Water Input

Figure 6 shows that there is a significant correlation between total water input to the furnace via the reductants and energy consumption. There are several possible explanations for these results.

Energy for drying

Simple theoretical calculations for the energy input for drying are shown below for 1 g of water heated from 20 to 390 °C:

20 °C to 100 °C $H_1 = 80$ cal ($Cp_1 = 1$ cal/g/°C)

At 100 °C $H_2 = 540$ cal ($L_5 = 540$ cal/g)

100 °C to 390 °C $H_3 = 290 \times 0{,}48$ ($Cp_2 = 0{,}48$ cal/g/°C)

$H_{required} = H_1 + H_2 + H_3 = 759{,}2$ cal/g or around 3180 J/g.

The metal production is $\dfrac{2{,}85}{3\ 600}$ t/s.

Therefore, a water input of 30 kg/t requires

$$30\ 000 \times \frac{2{,}85}{3\ 600} \times 3\ 180$$

$$= 75 \text{ kW}.$$

A water input of 90 kg/t requires

$$90\ 000 \times \frac{2{,}85}{3\ 600} \times 3\ 180$$

$$= 225 \text{ kW}.$$

This means that, theoretically, approximately 150 kWh of extra energy is required to give the maximum and minimum shown in Figure 6.

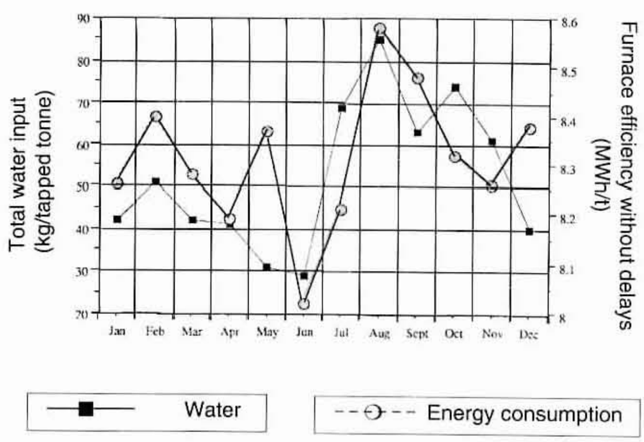
Effect on silicon recovery

From Figure 7, which shows the silicon recovery for the same 12-month period, it would appear that the moisture input via the reductants also affected the silicon recovery. This may have several mechanisms.

(1) The steam being generated may be a carrier for the silica fume.

(2) With the reaction $SiO + 2\ C = SiC + CO$, the steam being generated as the coke particles are dried through the burden may affect the SiO reaction as above. The steam given off may prevent the SiO gas from being deposited on the coke and forming silicon carbide (Figure 8).

(3) There may have been differences in the quality of the reductants being charged to the furnace. No measurements of fines in the coke and coal were taken during the study period. However, some recent figures have shown that very fine particles may adhere to the coarse fraction and not be removed during screening. This may have had an effect on the silicon recovery.



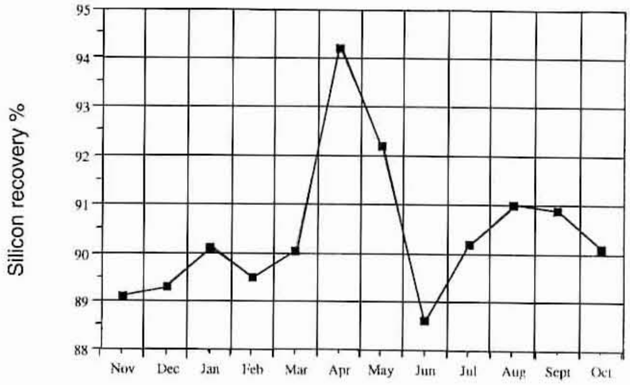


FIGURE 7. Silicon recovery from Nov. 87–Oct. 88

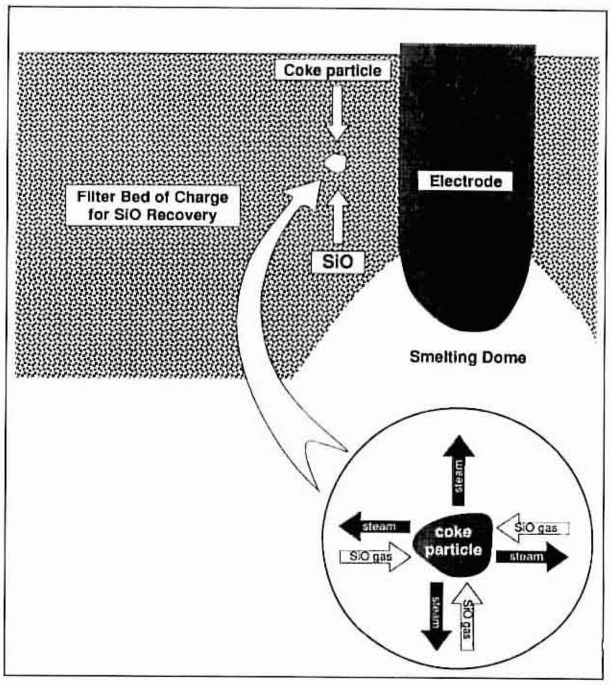


FIGURE 8. Reaction of SiO gas with carbon being retarded by steam generation

Conclusions and Recommendations

The analysis of the results has shown that rainfall of more than 10 mm can significantly affect the moisture content of porous reductants such as metallurgical coke. This variation, in turn, can be transposed to large variations in furnace performance, analysis trends, and tapping intervals.

It is becoming increasingly necessary to prevent variations in both raw materials and furnace operations in order to achieve improved furnace efficiencies. The storage of reductants under cover appears to be the simplest option, and is essential to reduce the effects of rainfall on furnace operations.

The correct storage of materials can ensure that the reductants of lower moisture content purchased can be kept at this low, stable value; for example, the coke used during the highest-efficiency months contained less than 1,5 per cent total moisture.

Another possible avenue being explored at present is the use of hot off-gas from the furnace for preheating the charge.

All operating plants need to consider the effects of variation on their process to ensure a more consistent product for their customers.

Addendum: Description of FES

This is an automatic system for the adjustment of carbon and iron. It uses both electrical parameters to control the fixed-carbon requirements, and tapping analyses to regulate the final silicon analysis.

The system was provided by Elkem Technology, USA branch, during their installation of the process-control computer (MODCOMP).