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THE PERFORMANCE OF A RESISTANCE-BASED FURNACE CONTROL SYSTEM ON A SUBMERGED-ARC FURNACE

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ABSTRACT

This paper describes the effect of a new furnace control system on the performance of a submerged-arc furnace. Operating data from three month-long periods are tabulated and discussed in detail.

Dramatic improvements in the furnace operation were realised, particularly in the consistency of the alloy quality.

Some details of the installation are also discussed briefly.

Keywords: Silicon-chrome, FeSiCr, electrode control, control and optimization

INTRODUCTION

Zimbabwe Alloys produce silicon-chrome in submerged-arc furnaces [1]. This is primarily for the ultimate purpose of producing low-carbon ferro-chrome.

In December 1992, a new controller (called Minstral [2]) for control of the electrodes based on resistance, and optimization of the power [3], was installed on the A3 Furnace at Zimbabwe Alloys. A study was then undertaken to determine the effects of this control system on the furnace performance. This paper summarizes the results of that study.

The Furnace

The A3 furnace is an open-topped unit with an electrical supply rated at 28 MVA. It is equipped with Söderberg electrodes with diameters of 1.275m. This furnace was installed in 1974, and a considerable amount of data and experience in the operation has been built up since then.

The power factor of the furnace is typically around 0.75, which means that the interaction effect [4] is large enough to cause noticeable problems if the furnace is run under current control. The furnace was generally difficult to operate and control prior to the installation of the new controller.

The feed to the furnace consists of a variety of lumpy ores, briquettes, quartz, coke, and occasionally coal. The briquettes consist of ore fines plus a small amount of binder. There is also a recycle of jigged material back to the furnace feed.

Previous Control System

The previous controllers were based on currents. They also had wide deadbands, which were not easily adjustable. This meant that the individual resistances varied over a wide range. Such a wide variation can be expected to have an adverse effect on the metallurgy of the smelting process.

INSTALLATION OF THE NEW CONTROL SYSTEM

Physically, the previous controllers formed part of the hydraulic system on the electrode hoists. To install the new Minstral controller, it was necessary to replace the old controllers with conventional hydraulic valves, which in turn were driven electrically by the Minstral. The Minstral was installed first, and then the hydraulics were changed over, so that the furnace did not have to operate for any extended period without control.

The new Minstral controller was located in the control room and the wiring was brought in under the floor of the control room. The wiring of the primary current and voltage signals into the Minstral required a downtime of a couple of hours. The transformer tap position required an extra transducer in the housing of the transformer tap changer, which was installed with virtually no interruption.

In early December 1992, the furnace was changed over to Minstral control, and has been running under it since then.

OPTIMISATION OF FURNACE OPERATION

After commissioning of the Minstral, the first three months were a period of learning. The resistance set point was varied from 1.0 to 1.4 mΩ using the same mix recipe as was used in the period prior to the Minstral. Power input was found to increase with resistance. However, at values higher than about 1.2 mΩ the electrode penetration became poor, and tapping became cold as the hot zone in the furnace moved upwards and became less intense.

The next phase was optimization of the mix recipe, especially with respect to the size distribution of the reductant, under the controlled electrical conditions provided by the Minstral system. It was found that as the burden resistivity increased, so the penetration improved, producing increased slipping of the electrodes and increased power input. With 20% of the total reductant fed to the furnace consisting of coke of 85% less than 12 mm, and with a resistance set point of 1.35 mΩ, a power input as high as 22 MW was achieved together with good tapping. This had never been achieved before.

TRENDS WITH MINSTRAL

Table 1 shows a comparison of the furnace operation before and after the installation of Minstral. The following three monthly periods are shown, as follows:

(i) December 1988 - best month for period prior to Minstral.

(ii) September 1993 - performance with Minstral, with normal reductant.

(iii) May 1994 - performance with Minstral, with small-sized coke as 20% of the reductant requirement.

The following trends are noticeable:

(a) Ore consumption

Ore consumption decreased by 4.6% after commissioning the Minstral, despite the fact that the grade of ore dropped from an average of 43.7% $Cr_2 0_3$ to an average of 42.0%.

The recycle of jig concentrates was lower both in tonnage and quality after installation of the Minstral, but due to good recoveries after the Minstral, greater efficiencies were realised.

(b) Consumables

As a reflection of ease of tapping which the Minstral has brought about due to better balance and proper electrode penetration, tapping bar consumption has improved by 35.5% for the period with the Minstral, and by 54% with the Minstral with small size coke.

Specific consumption for the cheaper gumpoles has gone up, as taps are free-running most of the time. This has resulted in a reduction in tapping costs. Tapping bars cost as much as Z$3200.00 per ton while gumpoles cost only 30 cents each, so it is more economic to use gumpoles than bars.

(c) Specific energy consumption

Since the Minstral was commissioned, the specific energy consumption (kWh/t) has improved by 5,5% with the normal size coke and by 9.8% with small size coke. Power input has also risen by 3,6% and 7,3%, and production has risen by 8,5% and 20,2% respectively for the two scenarios. In effect, production rises proportionately more than power input, resulting in a drop in the specific energy consumption. This is a significant saving.

TABLE 1: Metallurgical performance of furnace with and without Minstral control

Operating variables	**December 1988** Best month prior to Minstral	**September 1993** With Minstral, without small-sized reductant	**May 1994** With Minstral, with 20% small-sized reductant
Raw Materials			
Lumpy ore types	N/burn, Nehanda, Coop blend, Inyala	Inyala, Mwanza, Nehanda, Ngezi, Coop Blend, Manyame	Coop Blend, Dainstan
Briquettes	FSC,MF, recycle (note 1)	N/burn,slimes, recycle	MF,recycle (note 1)
Av. Cr_2O_3 in input	43.7%	42.0%	41.5%
Cr/Fe in ore	2.19	2.17	2.08
Jig conct.recyc.for month, t	326	315	209
Cr in jigs, %	28.3	27.5	27.7
Ore t/t (note 2)	1.273	1.214	1.256
Coke t/t (note 2)	0.662	0.587	0.718
Coal t/t (note 2)	-	0.106	-
Quartz t/t (note 2)	1.235	1.240	1.147
Performance			
kWh/t	7118	6730	6419
Power input (MW)	19.8	19.9	20.7
Tapping bars t/t (note 2)	0.031	0.020	0.017
Production			
(i) t/month	1955	2052	2351
(ii) t/day	63.07	68.4	75.8
Alloy analysis			
Cr, %	37.0	37.7	37.2
Si, %	42.0	41.6	42.1
C, %	0.028	0.024	0.030
COV of alloy analysis (note 3)			
Cr	4.0	3.16	2.73
Si	3.38	2.02	1.91
C	38.40	19.64	18.93

Notes:

1. FSC = Ore fines from Fe Si Cr ore, MF = Mixed fines
2. t refers to metric tons, t/t are tons of material per ton of metal tapped
3. COV = Coefficient of variation = (standard deviation/average)*100%

(d) **Product Quality**

Improvement in product quality brought about by the Minstral is shown by the decrease in variability of the product analysis, due to uniform electrode penetration (uniform bath). The coefficients of variation (COVs) of Cr, Si and C are shown to be lower and more consistent with the furnace under Minstral control.

DISCUSSION

It is obvious from the results that the furnace performance has improved with the introduction of the Minstral.

One of the effects of the improved electrode control is that it appears to keep the hot zone in the furnace more uniform and consistent. This is apparent from the reduced variation in the analyses of the metal (Table 1). Taps are more free-running, and there is more consistent tonnage from each tap-hole. The same is also true of the slag.

The Minstral controls the electrical aspects of furnace operation automatically, with minimal operator attention. This has freed the operator to concentrate more on other critical aspects of the furnace operation.

The availability of the information from the Minstral has enabled much better and more informed decisions to be made on the furnace operation.

The introduction of the small-sized coke brought about an improvement in power input and production. Development work on different size fractions of reductant is continuing, as this has been identified as an area for potential improvement in both operating costs and furnace control.

It has become clear that, in submerged-arc furnace operation, the electrical and metallurgical aspects are intimately interrelated. Even if the electrodes are well controlled, there will be little or no benefit if the metallurgy is wrong. Conversely, even the best metallurgy will be of little value if the electrical aspects are not kept in check. As this study shows, a combination of good electrode control with good metallurgy and systematic optimization can yield significant benefits.

CONCLUSION

It is evident that good control of the electrodes in a submerged-arc furnace can have significant and beneficial effects on the metallurgy, if the metallurgy is well controlled. When this is coupled with on-line optimization of the power fed to the furnace, the economic benefits can be considerable. The unit cost of production of silicon-chrome at Zimbabwe Alloys has improved by about 5% since commissioning of the Minstral.

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