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Recovery of Cobalt and Copper from Nchanga Mines Slag using Ferrosilicon

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ABSTRACT

Nchanga Smelter treats slag that contains appreciable amounts of copper and cobalt oxides by reducing with coke as a reductant in arc Electric Furnaces using electricity as a source of heat energy. However, the recovery of Cobalt from the time the plant was commissioned has remained around 57% which is significantly below the design capacity of 80%. The aim of this study was, therefore, to investigate the use of an alternative reductant (Ferro-silicon) in the reduction of copper and cobalt oxide to metallic copper and cobalt as a way of improving recovery. Charge blends starting from stoichiometry ratio and increasing the reductants in the respective reactions from 5-10.5% were fused in an induction furnace. The results showed that the copper and cobalt recoveries were high in ferrosilicon based reactions than in coke based reaction.

Keywords*:* *Reductants, Ferro-Silicon, Coke, Slag-Smelting, Pyrometallurgy*

1. INTRODUCTION

Copper smelting slag is the solid waste generated during pyrometallurgical production of copper from copper containing ores. Depending on the nature of the copper ore and the limitations of the smelting technology employed, most of the copper smelting slag contains certain amount of copper, cobalt, iron, aluminium and silica [1]. These metal losses to slag occur as a result of mechanical entrapment of the particles or floating of unstable droplets of matte as well as the physical-chemical solubility of the metals in slag in the oxide and sulphide forms [2, 3]. In practice, the reduction recovery of the metal oxides from slag is achieved using a variety of reducing agents such carbon or coke [4 - 6], aluminum, Silicon and hydrogen. Ferrosilicon can also be used in the treatment of slag to recover valuable metals [7,8].

At Nchanga mines, the slag obtained from the flash smelting furnace (FSF) is treated in an arc furnace called slag cleaning furnace (SCF) to produce blister copper. The blister copper produced in this process is also laundered to an anode furnace for further refining and casted into anodes. The SCF slag is processed for copper-cobalt recovery to produce a copper-cobalt-iron alloy in the cobalt recovery furnace (CRF). The CRF process aims to obtain a final slag of approximately 0.4% copper and 0.2% cobalt which is normally discarded. The reductant used in these two processes is coke. The CRF process is intended to maximize the recovery of copper and cobalt metallic alloy through strict process control to leave minimum amounts of copper and cobalt in slag. However, the plant process data indicates that cobalt recovery, since the plant was commissioned, stands at approximately 57 % on average against the design capacity recovery of about 80% [9]. The problem is to find a reductant with the right physical and chemical properties that can improve the reduction melting of cobalt oxide in order to improve its recovery. This work was therefore, aimed at investigating the use of ferrosilicon as an alternative reductant in the reduction recovery of cobalt from Nchanga mines slag.

2. EXPERIMENTAL

2.1. Materials and Equipment

The slag used in this study was obtained from Konkola Copper Mines (KCM) Nchanga smelter in Zambia. The slag samples obtained were crushed, pulverized into powder form and analyzed for elemental composition (Table 1). The percentage excess of reductants used in this study ranged between 5 and 10.5%. Prior to mixing the reductant and the slag to form a charge, the slag samples were mixed with dry composite concentrate assaying as shown in Table 2. The charge formed was then treated in an induction furnace at KCM Nkana laboratory.

Table 1: Chemical composition of the Nchanga smelter slag sample

Element	Cu	Fe	SiO_2	CaO	MgO	Co	S	Al_2O_3	Fe_3O_4
% Composition	7.34	20.44	33.28	5.30	3.27	1.54	0.27	7.13	17.25

Table 2: Chemical composition of the composite concentrate sample

Element	Cu	Fe	SiO_2	CaO	MgO	Co	S	Al_2O_3	K_2O
% Composition	28.22	14.25	17.70	1.47	2.06	2.30	20.86	4.81	1.64

2.2. Experimental procedure and sample analysis

The induction furnace of 45KW power rating was switched on and the temperature was raised to 1050ºC. Upon reaching this temperature, silica crucibles containing the blend charge were placed in an induction furnace. The temperature of the furnace was adjusted up wards until it reached 1200ºC. The furnace temperature was then held at 1200ºC with crucibles inside for one (1) hour. Thereafter, the crucibles were removed and left to cool. The crucibles were then cut to separate the matte phase and slag phase. Slag and button from each smelted samples were then analyzed using ICP-OES for Co, Cu, Fe and S though only Co and Cu recoveries were calculated using the following expression:

$$\%\boldsymbol{Metal\ Recovery} = \frac{\%\ \boldsymbol{Metal\ total\ input} - \%\ \boldsymbol{Metal\ Slag\ Output}}{\%\boldsymbol{Metal\ total\ input}} \times \mathbf{100} \qquad \textbf{(1)}$$

3. RESULTS AND DISCUSSION

3.1. Composition of the fused samples

The chemical analysis of the mate and slag obtained from the fused CRF slag and composite concentrate sample using ferrosilicon and coke as reductants are presented in Error! Reference source not found.. It is evident from this table that the matte generated after fusing the sample at 1200ºC for one hour were characterised by the predominance of copper. The data also indicated that ferrosilicon produced a matte with higher copper content in comparison to that produced using coke. Mattes containing approximately 65.4% Cu and 83.3% Cu were obtained using coke and ferrosilicon, respectively. In addition, the slag generated when ferrosilicon was used produced a slag with significantly lower cobalt content than that obtained using coke although both were below the plant's minimum design value. It was also observed that ferrosilicon generated a matte with relatively higher iron content although in general the reducing agent dosage increase also increased iron recovery. Thus for the benefit of metal value recovery, where the application of processes such as hydrometallurgy are intended, a low iron recovery should be preferred.

Table 3: Composition of the matte and slag obtained from the coke and ferrosilicon fused sample

Reductant	Chemical species	% Composition (Matte)	% Composition (Slag)
Coke	Cu	65.4	2.3
	Co	5.96	0.35
	Fe	7.68	16.16
	S	-	-
FeSi	Cu	83.3	1.9
	Co	3.89	0.12
	Fe	11.55	15.3
	S	-	-

3.2. Influence reductant type on Cu and Co recovery

The effect of reductant type on the recovery of copper and cobalt from Nchanga mines slag was investigated using coke and ferrosilicon as reductants. The percentage recovery results calculated using equation 1 where plotted against the percentage excess ferrosilicon and coke dosages as shown in Figure 1 and Figure 2, respectively. According to Figure 1, the per cent recovery of copper and cobalt generally increased with increasing reagent dosage. The highest recovery of about 88% Cu and 87% Co were achieved using approximately 10% excess ferrosilicon dosage. These results indicate that ferrosilicon has the potential to increase the plant recovery of cobalt and copper from the CRF slag and consequently reduce on the amount of valuable metals currently being discarded in form of slag. Referring to Figure 2, it can also be seen that an increase in coke dosage generally resulted in increased copper and cobalt recovery although the overall recoveries were significantly lower than those achieved using ferrosilicon. According to this figure, the highest recoveries for Cu and Co were obtained when about 9 % and 10% excess coke was used, respectively. The corresponding recoveries values were approximately 68% Cu and 47% Co. Thus compared to coke, ferrosilicon could potentially help improve the cobalt recovery and reduce on the quantity of the cobalt lost in the slag as was shown in Table 3.

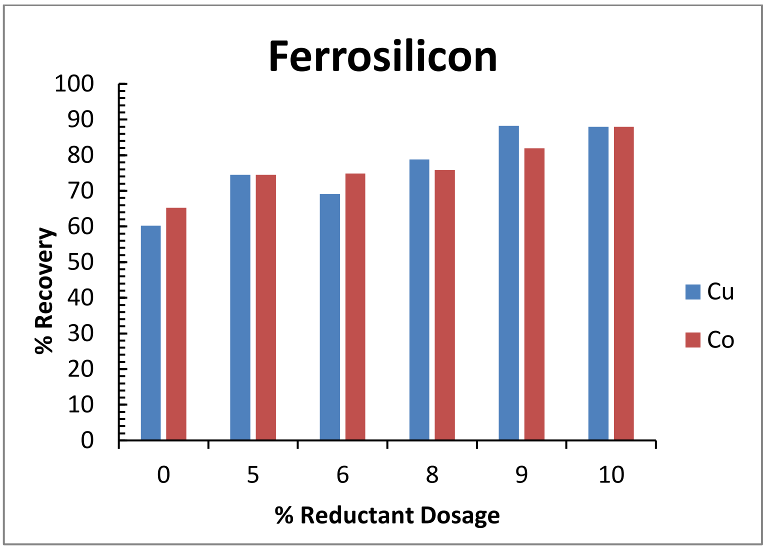

Figure 1: Influence of ferrosilicon on % recovery of Cu and Co from Nchanga slag

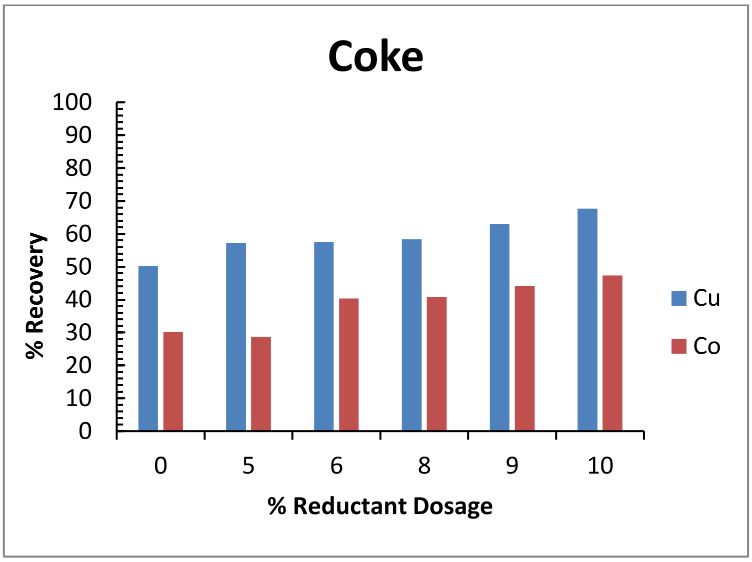

Figure 2: Influence of coke on % recovery of Cu and Co from Nchanga slag

4. CONCLUSIONS

The effect of reductant type and dosage on the recovery of cobalt and copper from Nchanga smelter slag was investigated in this study using ferrosilicon and coke at 1200ºC for a duration of 1 hour. Under these conditions, it was concluded that ferrosilicon had better potential to improve Cu and Co recovery and consequently reduce the loss of these metals in the slag. At these conditions, as high 88% Cu and 87% Co recoveries can be achieved using ferrosilicon.

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