FROTH FLOTATION TO REPLACE ELECTRIC FURNACE FOR NICKEL LOSS REDUCTION IN THE FLASH FURNACE SLAG

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Introduction

A Southern African metallurgical plant is monthly fed with 257400 tonnes of ore per month with a grade of 0.69%Ni, 0.05%Co and 0.70%Cu[1]. 63000 tonnes per month concentrate with 3.20%Ni, 4%Cu and 0.18%Co is produced therefrom through froth flotation and is fed into a Niro dryer at 75%-78% solids, producing a dry concentrate with less than 0.2% humidity. The dry concentrate is the feed to an Outokumpu flash-smelting furnace, which produces a low-grade matte and high-grade slag. While the high-grade slag from the flash furnace is further treated in the two electric furnaces to further recover the matte, the low grade matte from the flash furnace is fed to three Pierce-Smith converters for further upgrading (Figure 1a). The matte from the electric furnaces is allowed to settle in the slag and tapped at the bottom. Slag from the converters is further treated in the Converter Slag Cleaning Vessel for further cobalt recovery. The final product from the converters, usually refined in Norway, contains high-grade matte which runs at 74% or 92% nickel plus copper (and 20% and 6% sulphur contents) according to customer specification[2]. Presently around 120 tonnes per hour of concentrate feed the Flash Furnace. The flash furnace slag, fed into two 2.5 MW electric furnaces in series, is cleaned from 0.6% Ni to around 0.24% Ni using lump coal[2]. Although most of the Ni in the slag still occurs as sulphides, the slag is quite oxidised with a higher amount of magnetite; thus affecting the settling of entrained metal particles in the matte. It is then required to recover the entrapped Ni in the slag. Suggestions made include: increase the electric power in the furnace, increase the residence time, use of an appropriate reductant (type and ratio), dissolution into appropriate lixiviant, gravity concentration or froth flotation. It is the aim of this paper to discuss results of the froth flotation recovery of nickel entrapped in the flash furnace slag.Materials and Methods

Slag material sampled from the flash furnace was crushed in the rolls crusher with a product top size of 12 mm, which was then further crushed in the cone crusher for product top size of 5 mm. The bulk slag was thoroughly mixed and split using a Jones riffle sample splitter. From the resulting material of top size 5 mm the sample was further split in the rotary splitter and the six aliquots, each weighing 1 kg, were collected for laboratory grind curve determination. The samples were then wet ground in a 170 mm X 200 mm (length X diameter) laboratory rod mill for 10, 20, 30, 40, 50, and 60 minute periods respectively at a slurry density of 65% solids w/w. The ground

ore from each run was wet screened through a 75 µm test sieve. In this way, a curve illustrating % -75 µm versus time was plotted. A grind of 60% passing 75 µm was targeted for the float runs.

The chemical composition of the slag was determined using XRF. Base metals bearing minerals contained in the slag were concentrated using froth flotation with different flotation reagents suites as shown in Table 1. As most of the metals in the slag were finely dispersed in the iron oxide, only 74 µm passing particles were selected for the flotation. The slurry density was adjusted to 36-37% solids w/w and a 24 minute float test was carried out in a 2.2 litre Wemco laboratory cell with the rotor set at 1200 rpm. The pH was measured before flotation and adjusted to approximately 9.5-10 with $Ca(OH)_2$. Concentrates were collected at two minute intervals for conc. 1, conc. 2 and four minute intervals for conc. 3, conc. 4 and six minutes interval for conc. 5 and conc. 6 respectively. These concentrates were dried, weighed and assayed along with the tails from each run. From the analysis and sample weights a reconstituted feed was calculated along with mass pull and recovery for each run.

Table 1: Flotation reagents used

	Reagent types	Dosage
Collectors	Potassium Normal Butyl Xanthate (PNBX) Sodium Normal Propyl Xanthate (SNPX) Polypropylene Glycol Methyl Ether. Contains: Fatty acids, Tall oil reaction products with diethylene triamine, Methane carboxylic acid and Unsaturated alkyl derivatives (CUJ 6)	70 g/t, 100 g/t 50 g/t, 75 g/t, 100 g/t 60 g/t, 90 g/t, 120 g/t
Frother	Polypropylene Glycol Methyl Ether. (FUJ 6) Polypropylene Glycol Methyl Ether. (FUJ 8) unknown but is believed to be a mixture of higher alcohols. (TFB 285)	20 g/t 20 g/t 20 g/t
Dowfroth 200		20 g/t
Depressant	Sulphonated Sodium Naphthalene Condensate. (DUJ 16)	120 g/t

Results and Discussion

Grind curve of the slag material of the composition tabulated in Table 2, shows that 64% -of materials passing 75 µm could be produced after milling for 40 minutes. The acidic characteristics of the slag is confirmed by a higher SiO_2/Al_2O_3 fraction of 4.63. Relatively higher amount of sulphur (2.6%) in a slag hints the presence of sulphide bearing minerals in the slag.

Table 2: Chemical composition of the flash furnace slag used (%)

Ni	Cu	S	SiO_2	Fe	Co	Fe_3O_4	MgO	CaO	Al_2O_3
0.99	0.87	2.60	26.1	43.21	0.14	7.42	1.91	2.44	5.63

The longer one mills, the more the finer particles are produced. As expected[3], this comes with an increased energy consumption. Used as flotation feed, about 64% particles are passing 75 µm. It was observed that the FUJ 6 and FUJ 8 frothers formed small stable bubbles, which produced a very good froth during the flotation process and once the froth had left the cell surface it broke down quickly which was good for easy pumping during transportation at the plant. Additionally, these frothers were found easily soluble in aqueous medium, which improved their good dispersion in the medium. The TFB 285 frother produced bigger bubbles, very brittle, breaking quickly and letting nickel, copper and cobalt bearing minerals to fall back into the pulp with the risk of being lost to the tailings. The same was observed when Dowfroth 200 frother was used. The flotation process was fast (less than 20 minutes) for all tests runs1. Targeted grade of 3.5% nickel and recovery of between 81% and 85% were easily achieved at 60 g/t CUJ 6 & FUJ 6 and also at dosage of 90 g/t CUJ6 & FUJ 6. Most of the other test works were also fast but with lower values than the targeted grade and recovery. Despite a low sulphur content (of around 2.60%) in the slag a flotation recovery of greater than 50% nickel bearing minerals was achieved in most cases. Poor metallurgical results[4] were observed at both dosages of SNPX & DOWFROTH 200, while 70 g/t PNBX & TFB 285 showed good Ni grade and recoveries compared to the 100 g/t PNBX & TFB 285. In contrast, higher recoveries of above 60% Ni recovery were observed in the first two minutes for 90 g/t CUJ 6 & FUJ 6 and also for 120 g/t CUJ 6 & FUJ 6, but it was interesting to notice that at least after eight minutes four of the test works (90 g/t CUJ 6& FUJ 6, 60 g/t CUJ 6 & FUJ 6, 120 g/t CUJ 6 & FUJ 6, 120 g/t CUJ 6 & FUJ 8) showed Ni % recoveries of above 80% despite the test work carried out for 24 minutes. After 12 minutes, all the test work showed recoveries above 50%.

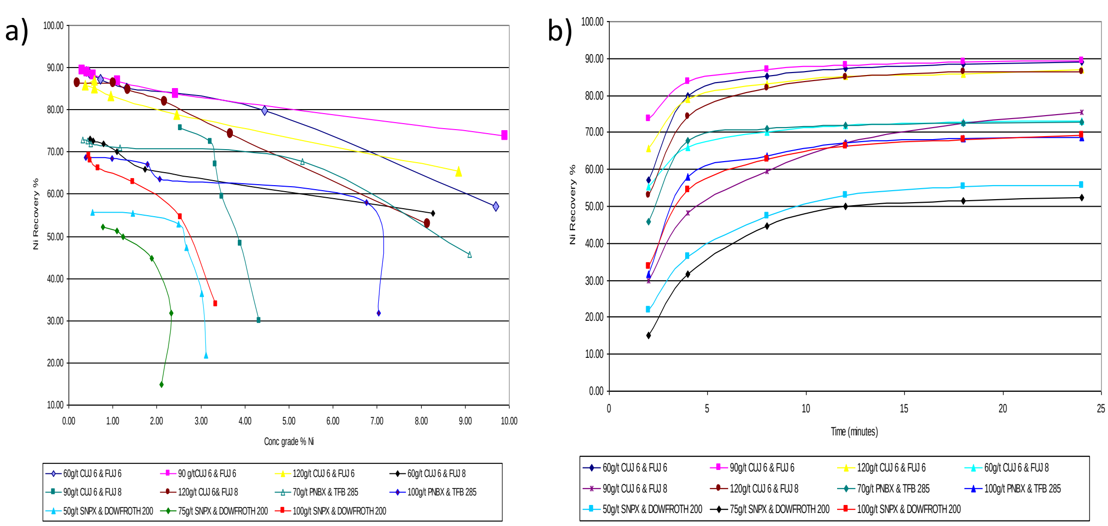

Figure 1: a) The higher the Ni recovery the lower the Ni grade; b) Ni minerals flotation recovery increases with time

Economics

The average Ni price for the year, \$6.91/lb, is marginally higher than \$6.76/lb the previous year's average. Cu was about \$2.25/lb. At the time the tests works were conducted, the BWP/ US \$ exchange rate was 5.05 compared to 4.33 the previous year[5]. The cash flow analysis was carried out in constant money terms *i.e.* with no inflation or escalation factors applied to revenue, cost or capex forecast. The operating cost forecasts for current production was based on monthly data for the previous past seven months, per the BCL Mining and Smelting cost book. The analysis of the economics was done based on the Ni metal content after treatment of the slag tonnage from the Flash furnace. Matte grade of 17%Ni at normal electric furnace nickel recovery of 21% was used and nickel mass of 1814 tonnes was achieved at a production cost of US \$705.42 per matte tonne produced. It was assumed that after flotation, the concentrate grading 3.5% Ni was directly fed to the flash furnace at a feed rate of 207982 tonnes to produce a matte grade of 15% Ni grade at recovery of 37% nickel. It will produce about 2684 tonnes of nickel metal at a matte production cost of US \$454.28 per tonne. Froth flotation followed by flash smelting showed good economic values for the final contained value of US \$40.8 million at 15% Ni grade. While the direct reduction of slag in the electric furnace produces contained value of US \$27.6 million at 17% Ni grade.

Conclusions

Despite a low sulphur content of 2.60% in the slag, a flotation recovery of above 50% nickel was achieved. Laboratory flotation results indicated that better grade and recovery were obtained for 90 g/t CUJ 6 & FUJ 8 and 60 g/t CUJ 6 & FUJ 6; and good grade of 3.5%Ni and recoveries of 81% and 85% Ni were achieved. Froth flotation followed by flash smelting showed good economic values of final Ni contained value of US \$40.8 million at 15% Ni grade. While the direct reduction of slag in the electric furnace produces contained value of US \$27.6 million at 17% Ni grade.

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