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EFFECTS OF RE-ROUTING OF CONCENTRATE STREAMS IN THE INDUSTRIAL SCALE FROTH FLOTATION OF LOWER GROUP 6 PGM ORE

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Abstract

The Lower Group 6 (LG6) platinum group of metals (PGM) ore was subjected to batch and continuous industrial froth flotation with and without concentrate streams re-routing. The batch test indicated that the ore has a recovery of about 69%.However, the average PGM recovery before and after rougher stage re-routing during plant scale tests were 41.5 and 64.5%, respectively. The re-routing of roughers 4 to 6 streams thus successfully improved recovery by 23%.Similar results were also obtained for both PGM and PGM 4E recoveries in both cleaner and re-cleaner stages re-routing. The results obtained thus strongly suggest that the circuit PGM recovery was optimized by the re-routing. It was however further observed that the PGM grade decreased significantly while the chromium content of oxide origin increased in the concentrates after re-routing. The optimum grade and recovery combination for each metal value will thus have to be determined by the plant based on the Net Smelter Return (NSR) analyses that incorporate both grade and recovery results.

Keywords: PGM ore, Batch, Continuous flotation, Re-routing, Recovery, Grade.

1. Introduction

The three ore layers in the Bushveld Complex each have their own distinctive associated mineralogy. The Merensky reef contains the platinum group metals (PGMs) that occur in conjunction with the base metal sulphides, while the UG2 (chromite layer) has a high chromite content together with relatively low quantities of base metal sulphides. The Plat reef has greater quantity of base metal sulphides in it.

Industrial scale mineral flotation processes consist of several units that are grouped into banks and inter-connected in a pre-defined manner in order to process the feed into concentrate and tailing. The behaviour of these processes depends on the configuration of the circuit and the physical and chemical nature of the slurry treated. Many of the complex circuits used in the mineral processing industry are the results of attempts to find more efficient methods for treating minerals so that mineral value recovery is maintained at a maximum while the dilution of the concentrate by gangue is maintained at a minimum. The design of these processing circuits is carried out based on the experience of the designer, with the help of laboratory tests and simulations [1, 2].

Flotation is a physico-chemical separation process that utilizes the difference in the surface properties of the valuable minerals and the un-wanted gangue minerals. True flotation exploits the differences in physico-chemical surface properties of particles of the various minerals contained in an ore. After treatment with reagents, the differences in surface properties between the minerals within the flotation pulp become apparent and flotation takes place. An air bubble must be able to attach itself to a particle and lift it to the water surface. The agitator provides enough turbulence in the pulp phase to promote collision of particles and bubbles which results in the attachment of valuable mineral particles to bubbles and their transport into the froth phase for recovery. The process can only be applied to relatively fine particles, because if the particles are too large; adhesion between the particle and the bubble will be less than the particle weight and the bubble will therefore drop its load [3, 4].

Grind refers to the size distribution of the mill product. Plants operate to a target grind, usually defined as the % passing 75 μm in the mill circuit product (MCP). Mills are required to produce about 80% -75 μm discharge from the ore feeds. The smaller the size of the particles produced by milling, the more liberated are the mineral values. It has been observed that froth flotation of PGMs is most efficient while treating ground feeds at particle sizes ranging from 38 to 106 μm. In order to optimise the grinding circuit of its UG-2 concentrator, Impala SA converted its primary mills to attrition and selective grinding units operating in fully autogenous mode such that the finer chromite and coarser silicate components in the mill discharge are separated by screening and processed in dedicated circuits and thus averting the expense of large capital on primary grinding capacity increase. Laboratory flotation tests provide the basis for the design of commercial plants. Commercial plant flotation is a continuous process consisting of cells arranged in series to form a bank [4 - 7]. The contents of PGM values in ores and concentrates are usually determined by fire assay analysis [8].

In this research, the re-routing of the concentrate streams of an industrial scale mineral flotation plant that treats the PGMs bearing LG6 ore was carrired out to study the effects on the recovery and grade of the concentrates obtained.

2. Materials and Methods

2.1. Materials

The material used was the Lower Group 6 (LG6) PGM ore. Tons of the ore was used in the flotation plant.

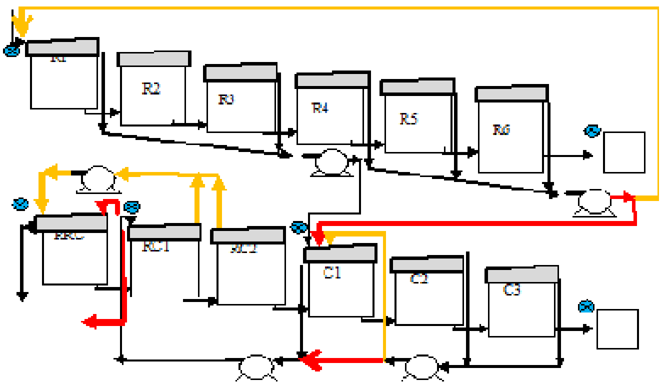
2.2. Methods

2.2.1. Batch flotation

The rougher batch flotation test was carried out in a 5 litre flotation cell using 1 kg of feed at a feed specific gravity of 1.28 with 200 g/t dosage of sodium Iso-butyl Xanthate (SIBX) as the collector, 30g/t of Senfroth 38 as frother and 80g/t of Sendep 30D as depressant.The concentrates and tailings were collected inthree timed increments at 5, 10 and 15 minutes. The samples were analysed for the 4 elements-platinum, palladium, rhodium and gold and Cr_2O_3. The 4E Prill split (Pt, Pd, Rh and Au) were determined by Fire Assay with ICP-OES finish, while the Cr_2O_3 and SiO_2 were determined by borate fusion X-ray fluorescence spectrometry [8].

2.2.2. Plant flotation trial

The plant trial consisted of three re-routing stages as shown in Fig. 1. In the rougher circuit, rougher 4 to 6 streams were re-routed to cleaner 1, while the cleaners 2 to 3 were re-routed to re-cleaner 1 (RC1). In the third stage, the cleaner 1 was re-routed to re-re-cleaner 1 (RRC). The reagents spot check was done every two hours. Rougher feed density ranged between 1.26 and 1.28 t/m³ and the check was done in two hours interval. In addition, sampling was also done in two hours interval. The rougher tail volumetric flow rate was calculated to determine the mass pull of the cells.



Previous concentrate flow

Proposed concentrate stream

Sampling point

R – Rougher, C-Cleaner, RC-Re-cleaner, RRC-Re-re-cleaner

Fig. 1. Processing plant layout.

3. Results and Discussion

Figures 2 and 3 show the grades and recoveries obtainable from the batch flotation of LG6 ore samples. The rougher rate kinetics show that recovery increased with time such that at 5, 10, 15 and 30 minutes the recovery obtained were 29, 54, 65, and 69%, respectively for the batch flotation treatment. The maximum recovery obtainable for the LG6 ore in batch flotation was thus 69%. The grade-recovery curve shows that as recovery increases, the grade decreased as obtained in ore processing. At recoveries of 29, 54, 65, and 69%, the grades decreased from 54 to 45, 35 and 20, respectively [4].

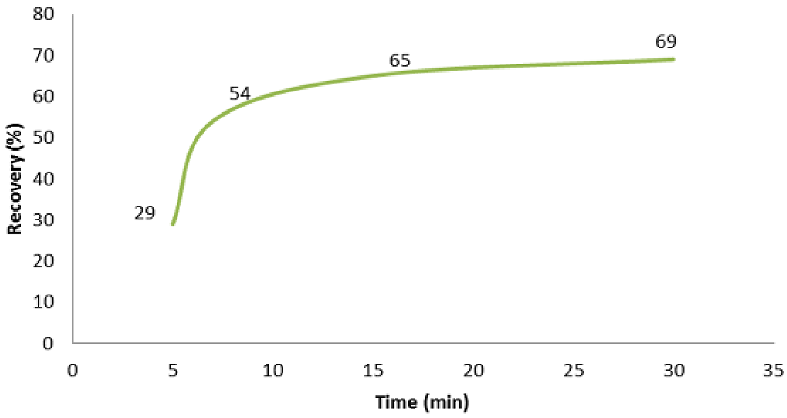


Fig. 2. Rougher rate kinetics.

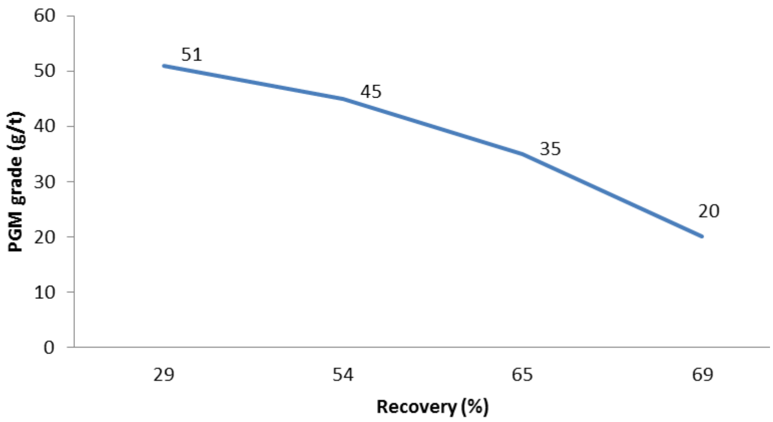


Fig. 3. Rougher PGM grade vs. recovery.

Figures 4 and 5 indicate the relationship between rougher PGM recovery before and after re-routing roughers 4-6 to cleaner 1. The graph indicated that the PGM recovery before re-routing was much lower than the recovery after re-routing. On average, the PGM recovery before and after were 41.5 and 64.5%, respectively. Re-routing the roughers 4-6 thus improved recovery by 23% on average. The results obtained thus strongly suggest that the re-routing caused higher mass pull to the concentrate from the pulp feed. It was also observed that the industrial scale froth flotation was about 4.5% lower in recovery efficiency in comparison with batch based laboratory scale study as expected.

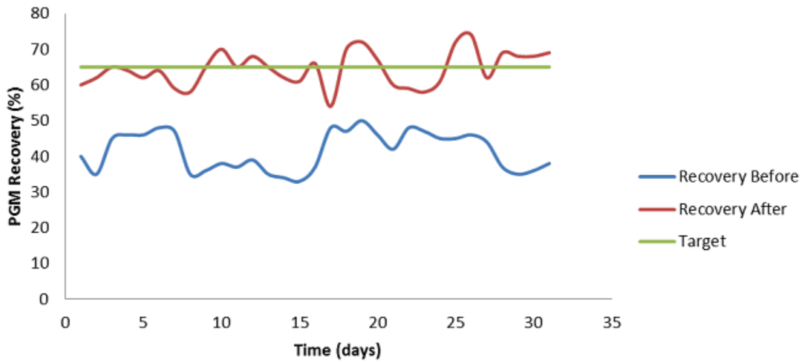


Fig. 4. Rougher PGM recovery before and after re-routing rougher 4-6 to cleaner 1.

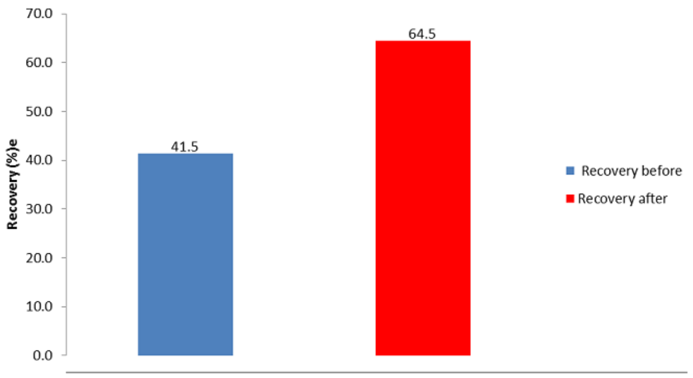


Fig. 5. Rougher average PGM recovery before and after re-routing rougher 4-6 to cleaner 1.

Figures 6 and 7 indicate the relationship between the rougher PGM grade before and after re-routing roughers 4-6 to cleaner 1. The results show that the PGM grade decreased from 46.9 to 36.8 g/t. The chromium content in the rougher concentrate however increased from 13.9 to 15.8%.The results thus suggest that the higher PGM recovery was obtained at the expense of the grade of the concentrate. The opposite marginal increase in the chromium content instead of a decrease as that of PGM grade may be because chromium is found as an oxide in chromite while PGMs mostly occur as sulphides with oxides and sulphides exhibiting different behaviour in the presence of flotation reagents. It has been reported [9] that a PGM industrial froth flotation concentration circuit was modified by including a chrome extraction plant in its middle thus reducing chromium contamination of the PGM concentrate and increasing PGM recovery to 80%.The optimum grade and recovery combination in a plant's flotation programme will have to be determined by the plant based on the Net Smelter Return analyses that incorporate both grade and recovery results [4].

Figures 8 and 9 show that the average PGM 4E grade at the cleaners before roughers 4-6 were introduced to cleaner 1 was high at 137 g/t, while the grade after was 130 g/t. However, the chromium content increased from 10.4 to 12.3% respectively. The re-cleaners' average PGM grade before and after re-routing cleaners 2 and 3 were 232 and 218 g/t with the grades obtained after re-routing for the 30 days trial tests being generally lower than that before re-routing. The results obtained on grades of PGM and PGM 4E in the cleaner and re-cleaner concentrates are thus similar to those of PGM in rougher concentrates with the known trend of decrease in grade with increase in metal value recovery, except for chromium with oxide origin.

Table 1 and Figu. 10 show that the chromium contents in the concentrate before and after re-routing cleaner 1 to re-re-cleaner 1were 3.9 and 5.6%. The PGM 4E grade before and after re-routing cleaner 1 to re-re-cleaner 1 decreased from 341 to 317 g/t.

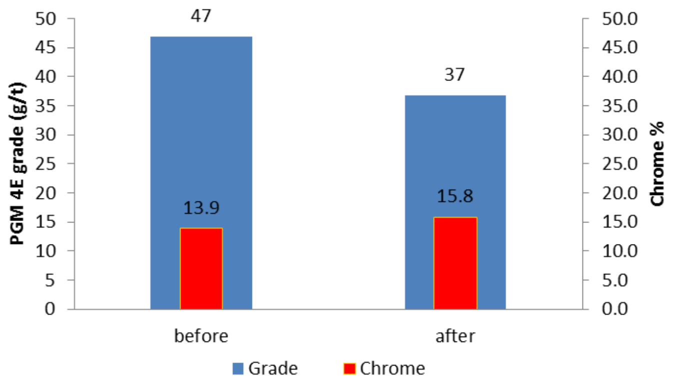


Fig. 6. Rougher concentrate average PGM grade before and after re-routing rougher 4-6 to cleaner 1.

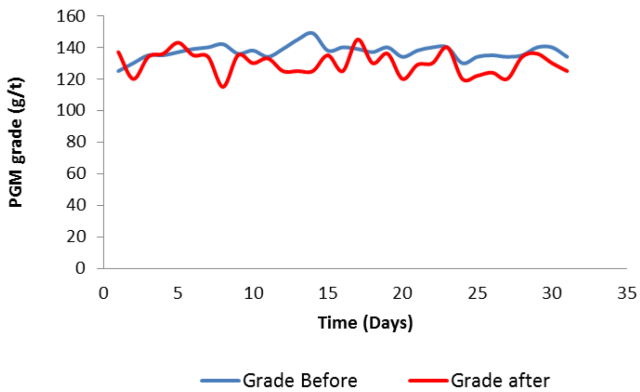


Fig. 7. Cleaners 2 and 3 concentrate PGM grade before and after re-routing roughers 4-6.

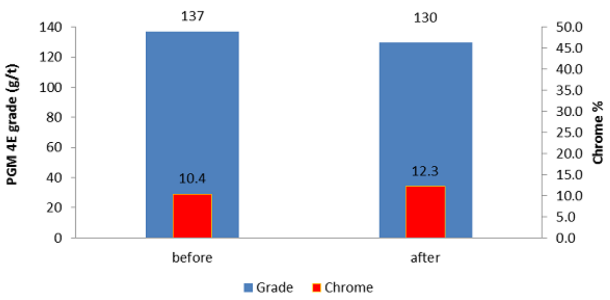


Fig. 8. Cleaners 2-3 concentrate average PGM grade before and after rerouting roughers 4-6 to cleaner 1.

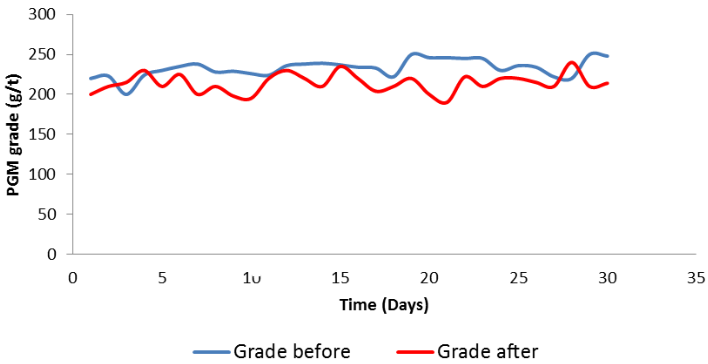


Fig. 9. Re-cleaner PGM grade before and after re-routing cleaners 2 and 3 to re-cleaner 1.

Table 1. Re-cleaner concentrate PGM grade before and after re-routing cleaner 1 to re-re-cleaner 1.

		Grade	
S/N	**Parameters**	**g/t**	**Weight%**
1	**PGM 4E grade before re-routing**	341	
2	**PGM 4E grade after re-routing**	317	
3	**Cr content before re-routing**		3.9
4	**Cr content after re-routing**		5.6

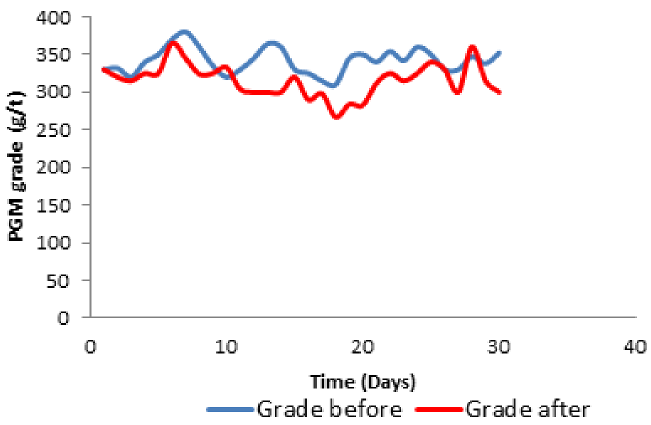


Fig. 10. Re-recleaner concentrate PGM grade before and after re-routing cleaner 1 to re-re-cleaner 1.

4. Conclusions

An investigation has been made of the effects of re-routing on the continuous industrial froth flotation of PGM. The investigation comprised of a preliminary batch flotation and subsequent re-routing tests. Some concluding observations from the investigation are given below.

- The results obtained in the preliminary batch flotation rate kinetics study showed that PGM value recovery generally increases with scraping time yielding a maximum of 69% at a low grade of 20 g/t since grade correspondingly decreases with recovery.
- The re-routing of roughers 4-6 to cleaner 1 during the continuous plant trial was observed to cause a 23% increase in PGM recovery from 41.5 to 64.5%, but with a decrease of 10 g/t in PGM grade and an increase of 2% in chromium grade.The results obtained on grades of PGM and PGM 4E in the cleaner and re-cleaner concentrates are also similar to those of PGM in rougher concentrates with the known trend of decrease in grade with increase in metal value recovery, except for chromium with oxide origin.
- The optimum grade and recovery combination for each metal value will thus have to be determined by the plant based on the Net Smelter Return (NSR) analyses that incorporate both grade and recovery results.

References

1. Yingling, J.C. (1993). Parameter and configuration optimization of flotation circuits: Part I. A review of prior work. *International Journal of Mineral Processing*, 38(1-2), 21-40.
2. Williams, S.R.; Ounpuu, M.O.; and Sarbutt, K.W. (2002). *Bench and flotation pilot plant programs for flotation circuit design*. SGS Mineral Services, Technical Bulletin 2002-04.

3. Margery van den Berg (2004). Basic metallurgical tool kit. *Technical paper*. Impala Platinum.Marshalltown.
4. Wills, B.A.(1997). *Mineral processing technology*. Butterworth-Heinemann Oxford.
5. Singh, A.; Louw, J.J.; and Hubert, D.G. (2003). Flotation stabilization and optimization,*South African Institute of Mining and Metallurgy*, November Edition, 581-588.
6. Matis, K.A. (1991). Foam/Froth flotation. Retrieved June 8, 2015, from http: //www.researchgate.net/...Foamfroth flotation/- - -.
7. Nel, E.; Theron, J.; Martin, C.; and Raabe, H. (2012). PGM ore processing at Impala's UG-2 concentrator in Rustenburg, South Africa.*Technical Paper* 2004-02.SGS Mineral Services.
8. Cooley, E.F.; Curry, K.J.; and Carlson, R.R. (1976). Analysis for the platinum group metals by fire-assay emission spectroscopy. *Applied Spectroscopy*, 30(1), 52-56.
9. Afolabi; A.S.; Nkobane, P.; Abdulkareem, A.S. (2012). Development of PGMs and chromite extraction circuit for UG-2 ore.*Proceedings of the World Congress on Engineering*, Vol. III, London, UK, 1-5. Retrieved August 09, 2015, from http://www.google.com.ng/?gws_rd=ssl#q=Afolabi%- -