THE FLOTATION OF SOUTH AFRICAN CHROMITE ORES IN ACIDIC MEDIA

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Abstract

Chromite is an important strategic mineral usually associated with other gangue minerals, mainly silicates. The selective flotation of chromite minerals of any chromite ore have some difficulties due to dissolved cations from gangue minerals. By this work, selective flotation of various chromite ores were studied to determine some of the features of flotation. Different chromite ores from South Africa were made flotation using the anionic collector, A825 (petroleum sulfonate), after conditioning with H_2SO_4 at low pH values in the range of 1 and 3. Chromite was separated as concentrate from the gangue successfully by using anionic collector at low pH values. Higher recovery ratios and higher separation index values were obtained at lower pH values. Longer conditioning time has positive effect on the recovery ratio of chromite in the concentrates and of silica in the tailings.

Keywords: Flotation, chromite ore, pH, anionic collector, separation index

1. INTRODUCTION

Chromite is an iron chromium oxide ($FeCr_2O_4$) mineral belonging to the spinel group [1]. The only ore of chromium is chromite ore which ferrochromium and metallic chromium are produced from it by extracting processes.

South Africa is the largest producer of chromite ores, where over 70 % of world chromite ore reserves are believed to be located. Today, South Africa supplies approximately 50 % of world's supplies of chromite ores. So, it is the leading producer of chromite ore and concentrate globally and a major supplier of ferrochrome. Other countries playing a significant role in the supply of chromite ores are Kazakhstan and India [2].

Chromite is an important strategic mineral usually associated with other gangue minerals, mainly silicates. A good knowledge of the flotation behavior of chromite and the establishment of conditions for its selective separation from the gangue minerals might help the future exploitation of chromite deposits [3].

As early as the 1930's many attempts were made to solve the problem of selective flotation of chromite ores. In early attempts mainly anionic collectors such as fatty acids were used [4, 5]. Morawitz studied the effect of pH regulators on pure chromite minerals [6]. He found that all amines with HCl and NaOH gave satisfactory results in the range of pH 6.5 and to pH 11, respectively. The pH range was down to 5 for H_2SO_4 and 3 for H_3PO_4. After so much researches on chromite flotation it was generally concluded almost by all researchers [7-9] that it was impossible to predict the response of any chromite ore due to dissolved cations from gangue minerals causing difficulties on the selective flotation of chromite minerals.

The scope of this research was to investigate the effect of reagents, pH value and conditioning time on recovery ratio of chromite and silica in the concentrates and tailings during selective flotation of different chromite ores of South Africa.

2. EXPERIMENTAL

Experiments were done by Erdogan Yigit when he was working in NIM (now MINTEK) in South Africa but results have been rearranged, discussed and presented by all authors.

Chromite ores obtained from different regions of South Africa, Maandagshoek UG-2, Pandora UG-2, Grasvally, Winterveld, and Steelpoort, were ground in a laboratory scale rod mill that 90 % of all amount were less than 75 micron. The flotation tests were conducted in a laboratory type flotation cell (Denver type). Flotation tests were carried out in presence of H_2SO_4 using test procedure of **Fig. 1** and of **Table 1**.

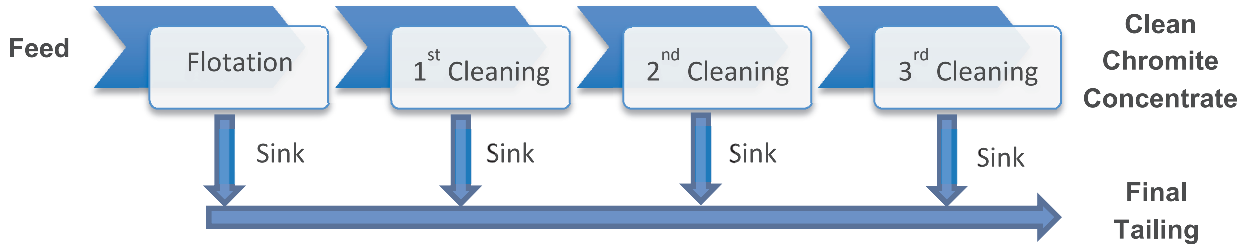

Fig. 1 The flotation test procedure

Experiments consisted of chromite flotation and after that 3 cleaning steps. Chemicals used in experiments were A825 (Cynamid Pertroleum Sulphonate) as collectors, DF250 as frother and sulfuric acid (H_2SO_4) to ensure pH value desired. Pulps were conditioned 5 min and 1 hour at pH value of 1, 2 and 3. Time used in the cleaning period was 1 min for all steps. Chemical analysis of chromite concentrates and final tailings were carried out by XRF method. Head grade of all samples were calculated from the grades of concentrates and tailings and given below all the Tables.

Table 1 Operation parameters of flotation tests

Stages	**Reagents, g/t**		**Acid**	**Time**		**pH**
	Collector, A825	Frother DF 250		Conditioning	Flotation	
Flotation 3 Cleanings	600 300	30 -	to pH to pH	5 min., 1 hr 5 min.	20 min. 15 min.	1, 2, 3 1, 2, 3
Conditions:	Mass of the sample: 1 kg, grinding sample: 90 % <75 µm Rotation: 1000 rpm, cell size: 2300 ml for roughing and cleanings					

3. RESULTS AND DISCUSSIONS

Flotation test results of chromite ores are given in **Table 2**. In these flotation tests, chromite minerals were floated and separated from gangue minerals in presence of H_2SO_4 very effectively. The results in the **Table 2** show that higher recovery ratio of chromite with lower recovery ratio of silica has been obtained at low pH values for almost all chromite ores.

Table 2 Flotation test results of different chromite ores when an anionic collector, A825, used with H_2SO_4

Test No	Conditioning time	pH	Chromite Concentrates					Final Tailings			
			Cr_2O_3 (%)	Rec. (%)	S.I.	SiO_2 (%)	Rec. (%)	Cr_2O_3 (%)	Rec. (%)	SiO_2 (%)	Rec. (%)
Maandagshoek UG-2 chromite ore											
1	5 min	1	39.95	84.08	33.6	2.10	9.30	12.90	15.92	34.90	90.70
2	1 hr	1	40.35	92.22	37.2	1.35	4.06	7.50	7.78	41.20	95.94
3	1 hr	2	39.05	83.00	33.1	2.60	12.1	13.80	17.00	32.60	87.90
4	1 hr	3	38.30	85.73	32.8	3.70	6.89	15.10	14.27	31.40	83.11
Calculated average head grade: 30.54 % Cr_2O_3, 13.70 % SiO_2											
Pandora UG-2 chromite ore											
1	5 min	1	42.50	75.56	32.1	0.20	0.67	15.43	24.44	33.05	99.93
2	1 hr	1	42.50	82.00	34.9	0.28	1.04	12.75	18.00	36.28	98.90
3	1 hr	2	42.30	87.61	37.1	0.42	1.72	9.80	12.39	39.36	98.20
Calculated average head grade: 29.88 % Cr_2O_3, 15.45 % SiO_2											
Grasvally chromite ore											
1	5 min	1	43.55	90.70	39.5	2.40	25.2	18.90	9.30	30.06	79.72
2	1 hr	1	44.00	91.64	40.3	2.00	21.1	17.40	8.36	32.25	78.86
3	1 hr	2	43.90	93.51	41.1	2.20	23.7	15.00	6.49	34.70	76.21
Calculated average head grade: 38.96 % Cr_2O_3, 17.69 % SiO_2											
Winterveld chromite ore											
1	5 min	1	44.20	95.40	42.2	1.34	4.96	11.80	4.86	39.80	85.04
2	1 hr	1	44.95	94.95	42.7	0.93	10.3	12.40	5.15	41.10	89.69
3	1 hr	2	44.66	92.93	41.5	1.30	14.6	15.80	7.67	35.55	85.37
Calculated average head grade: 39.37 % Cr_2O_3, 7.49 % SiO_2											
Steelpoort chromite ore											
1	5 min	1	44.50	94.56	42.1	2.85	24.3	11.40	5.44	39.46	75.63
2	1 hr	1	45.70	99.58	45.6	1.85	14.6	16.90	10.42	34.20	85.33
3	1 hr	2	46.10	92.54	42.7	1.40	11.1	12.85	7.46	38.60	88.86
Calculated average head grade: 36.63 % Cr_2O_3, 9.63 % SiO_2											

The concentrates of about 40 % Cr_2O_3 and 2 % SiO_2 content were produced from calculated head grade of 30.54 % Cr_2O_3 and 13.70 % SiO_2 from the flotation of Maandagshoek UG-2 chromite ore. The grade of chromite concentrates was affected by conditioning time at low pH value. When conditioning time was increased from 5 min to 1 hour, recovery ratio of chromite increased from 84.08 % to 92.22 % at pH = 1. But higher pH values longer conditioning time is needed to reach almost the same recovery ratio at pH = 1 for conditioning time of 5 min. Longer conditioning time has positive effect on recovery ratios of all samples both at low and high pH values. The highest recovery ratio of chromite was obtained as 92.22 % at pH = 1 for 1 hour conditioning time.

Flotation tests of Pandora UG-2 chromite ore using A 825 in presence of H_2SO_4 were carried out and the concentrates of about 42.5 % Cr_2O_3 were obtained from calculated average head grade of 29.88 % Cr_2O_3, 15.45 % SiO_2. Recovery ratio of chromite increased with increasing pH value and conditioning time. Similar situation is also valid for SiO_2 content of the tailing. The highest recovery ratio of chromite was obtained as 87.61 % at pH = 2 for 1 hour conditioning time.

The concentrates obtained from Grasvally chromite ore contain average 44 % Cr_2O_3 with average 2.2 % SiO_2. Calculated average head grade for these products is 39.96 % Cr_2O_3 and 7.69 % SiO_2. Similar to Pandora UG-2 chromite ore, recovery ratio of chromite in the concentrate and silica in the tailing increased with increasing pH and conditioning time but SiO_2 content of the concentrate did not change with these parameters.

It can be accepted approximately that flotation tests conducted with Winterveld chromite ore and Steelpoort chromite ore gave similar results with Maandagshoek UG-2 chromite ore; low pH value and longer conditioning time gave higher recovery ratios of chromite. But recovery ratio of Winterveld chromite concentrate decreased with increasing conditioning time at pH = 1. The highest Cr_2O_3 content in chromite concentrate has been obtained by Steelpoort chromite ore as 46.10 % using A825 and H_2SO_4 at pH 2 with conditioning time of 1 hour. But the highest recovery ratio has been attained by the same type ore as 99.58 % with the same chemicals at pH = 1 with conditioning time of 1 hour.

The effects of pH value and conditioning time on recovery ratios of chromite and silica in the flotation tests were almost similar for various chromite ores of South Africa. Flotation test results were also evaluated by term of separation index (S.I.) that is given in **Table 2**. Separation index is a new concept [10-12] for the evaluation of a separation process such as flotation practice. It is well known fact in a separation process that the grades and recoveries of the concentrates are inversely proportional to each other. In other words, if the grade of a concentrate raises, the recovery of this concentrate drops or vice versa. In **Table 2**, separation index values (Separation index = Grade x Recovery) were obtained by multiplying Cr_2O_3 grades by the recovery values.

When flotation test results of all chromite ores were evaluated by separation index (S.I.) term, effect of conditioning time and pH value can be seen clearly. Namely, separation index values of chromite concentrates at conditioning time of 5 min. are 33.6, 32.1, 39.5, 42.2 and 42.1 for Maandagshoek UG-2, Pandora UG-2, Grasvally, Winterveld, and Steelpoort chromite ores respectively. However, separation index values of chromite concentrates at 1 hour conditioning time are 37.2, 34.9, 40.3, 42.7 and 45.6 for Maandagshoek UG-2, Pandora UG-2, Grasvally, Winterveld, and Steelpoort chromite ores respectively. For all chromite ores the separation index values increase by raising conditioning time. So, different case in Winterveld chromite ore which recovery ratio decreased with increasing conditioning time has been eliminated by using separation index term.

CONCLUSION

The anionic collector, A825 (petroleum sulphanate), separated chromite minerals from the gangue successfully with high recovery ratio at acidic pH values. The pH value of conditioning media is very important and has increasing intensity effect on recovery ratio of chromite concentrate at lower value. The highest recovery ratio of chromite can be obtained at pH = 1. Besides, conditioning time is also affect chromite content and recovery ratio of concentrates. Longer conditioning time give higher recovery ratio of chromite and this situation is valid for all different chromite ores. In order to obtain high recovery ratio with the same level of pH = at higher pH conditioning media, it is needed much longer conditioning time.

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