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Beneficiation Studies on the Low-Grade Chromite of Muslim Bagh, Balochistan, Pakistan

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Abstract. Low-grade chromite of Muslim Bagh, Balochistan, Pakisktan was beneficiated to produce chromite concentrate by cationic flotation using disodium *n*-octadecyl sulfosuccinamate as collector. Effect of various parameters such as grind size, pulp density, pH, and conditioning time on the overall grade and recovery of chromite was also investigated. Particle liberation studies during this investigation revealed that grinding of the ore upto -80 # liberated over 89% of chromite. However, presence of excessive amounts of fines inhibited the flotation. The ore, initially containing 38% Cr_2O_3, was upgraded to concentrates assaying Cr_2O_3 upto 60% with an overall Cr_2O_3 recovery of 82%.

Keywords: beneficiation, cationic flotation, disodium *n*-octadecyl sulfosuccinamate, chromite ore, Pakistan chromite, low-grade chromite

Introduction

Chromite is the only commercial source of chromium, which is used in metallurgical, refractory and chemical industries. The most extensive deposits of chromite in Pakistan exist around Muslim Bagh in the Zhob Valley (Ahmed, 1975). These deposits may be placed in five different groups according to their locations, namely, Khanozai, Jungtogarh, Saplitogarh, Nasai, and Fort Sandeman (Ahmed, 1969; Bilgrami, 1964). The host rocks are restricted to serpentine and dunite, although chromite grains are also found in harzburgite, contact carbonate rocks, and residual cherts (Bilgrami, 1968). Chromite deposits occur in the form of stringers, bands, pods, nodules, and as disseminations in the host rocks. These deposits are quite variable in size and grade. No concrete data on the quantity of chromite reserves is available. However, total reserves in the Zhob-Muslim Bagh area are estimated to be of the order of millions of tonnes. Chromite of Muslim Bagh is being mined since 1903, and until now over 1.5 million tonnes of the ore has been mined (Kazmi and Abbas, 2001). Selective mining of exportable higher grades of chromite has resulted in such deposits being close to exhaustion. The present scenario requires utilization of the indigenous low-grade chromite for the production of value-added chromium-based chemicals to replace their imports (R & D-PCSIR, 1988).

The gravity concentration of low-grade chromite ore is uneconomical and technologically complex (Fillip and Junaka, 1956), whereas froth flotation technique is considered to be an adequate method for upgrading low-grade chromite ore. Using this technique, minerals can be separated based on their surface properties. The valuable minerals are made aerophilic and the gangue minerals aerophobic by adjusting the pulp properties with the help of suitable flotation reagents (Wills, 1977). The present investigation deals with the beneficiation of low-grade chromite ore from deposits, which at present have little or no commercial value.

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Materials and Methods

Sample preparation. Ore sample (about 10 tonnes) procured from Muslim Bagh, Balochistan, Pakistan was crushed by using a jaw crusher and a roll crusher. The representative samples were then prepared by coning-quartering and riffling the roll product. Five samples were drawn from the representative lot and analysed for their chemical composition using gravimetric and spectrophotometric techniques. The average chemical analysis of the ore is presented in Table 1. The size analysis of the ore, after intermediate crushing, was carried out using an Octagon 200 sieving apparatus, which is given in Fig. 1.

Table 1. Average chemical analysis of the Muslim Bagh, Balochistan, Pakistan low-grade chromite ore

Constituents	Percentage
Cr_2O_3	38.06
Fe_2O_3	13.80
SiO_2	20.02
Al_2O_3	10.50
MgO	14.40
LOI	3.20

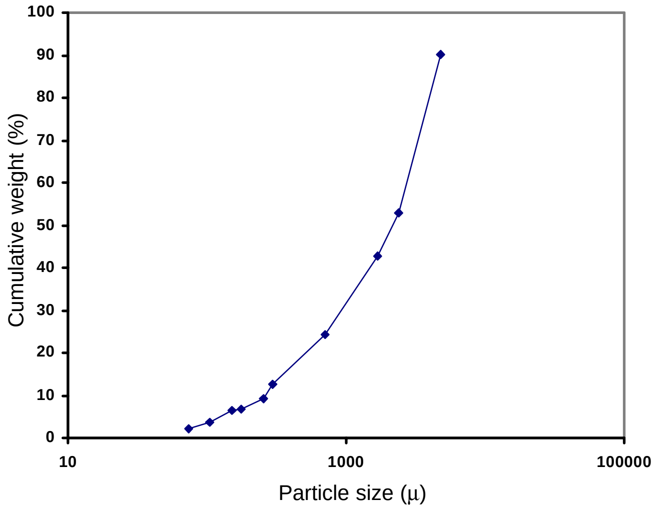

Fig. 1. Cumulative weight (%) as a function of particle size (μ), after intermediate crushing of chromite ore.

Particle liberation studies. The fractions obtained from roll product were analysed for liberation of chromite grains. The optical microscopic examination revealed that the ore required grinding upto -80 # for adequate liberation of the chromite grains. Data showing liberation of chromite at various size fractions is presented in Table 2. The percentage chromite liberation was calculated using the following relationship (Hafeez *et al.*, 1989; Sullian and Workentine, 1964):

$$\text{Chromite liberation (\%)} = \frac{\text{Free chromite (\%) x 100}}{\text{Free chromite + Locked chromite (\%)}}$$

Table 2. Liberation of the chromite ore at different particle size fractions

Particle size (mesh #)	Free chromite grains (%)	Compound grains (%)	Free gangue (%)	Chromite liberation (%)
-8+10	15.38	58.91	25.70	20.68
-10+25	30.4	34.16	35.43	47.00
-25+50	39.2	22.38	38.41	63.65
-50+60	49.0	10.23	40.71	82.72
-60+80	50.1	9.0	40.8	84.71
-80	52.2	6.4	41.3	89.08

Experimental reagents. In the present investigation, disodium octadecyl sulfosuccinamate (American Cyanamide Company) was used as the cationic collector for chromite flotation. The other reagents included hydrofluoric acid (Merck), which acted as an activator. In order to stabilize the froth, small quantity of polypropylene glycol was used. In addition, tannic acid and sulfuric acid were used to act as depressant and pH regulator, respectively.

Beneficiation studies. Flotation tests were carried out in a Denver flotation machine (Model D-12) at a speed of 1000 rpm for the recovery of chromite. The ore for flotation feed was prepared by grinding the roll product in laboratory ball mill for 5 min to obtain a product of 100% passing mesh size -80 #. Due to the brittle nature of the ore, crushing and grinding produced considerable quantity of chromite fines. The sieve analysis of the material so prepared along with Cr_2O_3 contents of different size fractions is given in Table 3.

Table 3. Sieve analysis of the chromite ore ground in ball mill for 5 min

Mesh size #	Weight (%)	Cr_2O_3 (%)
-80+100	7.34	41.3
-100+150	31.00	45.4
-150+200	14.23	43.3
-200+325	17.46	40.0
-325+400	12.97	31.5
-400	17.00	20.7

Results and Discussion

Presence of slime in the flotation feed is known to adversely affect the flotation process. The detrimental effect of slimes was thought to be two-folds: firstly, slimes consumed reagents because of high specific surface, and secondly, the factor of interference of slime particles with the air-mineral contact (Iwasaki, 1983). The ore was, therefore, thoroughly deslimed prior to flotation.

The flotation of chromite, using a cationic collector, can be improved by the addition of adequate amount of a suitable activator (Abido, 1971). It was observed during the present investigations that the chromite ore floated in an acidic environment, after activation by fluoride ions, in the form of HF. The pH required to activate the chromite ore was in the vicinity of 3.0.

An extensive investigation on chromite of Heroshah (NWFP, Pakistan) has been done previously (Hafeez *et al.*, 1999). These authors were able to upgrade the chromite ore containing 31-32% Cr_2O_3 to 43-44 % Cr_2O_3 with 90% recovery using oleic acid as collector. Fatty acids, such as oleic acid, have been successfully used in the anionic flotation by a host of researchers (Hussain and Hafeez, 1989; Hafeez *et al.*, 1988). However, in the present studies, ore was beneficiated by using a cationic collector, namely, disodium *n*-octadecyl sulfo-succinamate. This collector is an amine derivative and relatively more expensive. However, the fact that disodium *n*-octadecyl sulfosuccinamate was required in much lower quantity yielding better grades with higher recoveries, made the whole process very competitive.

The particle size was optimized at -80 # after carrying out a series of tests. Size, coarser than -80 #, had adverse effects on the overall recovery and grade, whereas feed size finer than -80 # generated excessive quantities of slime which inhibited the flotation process. Pulp density is another vital parameter in any flotation process. Present investigations revealed that the ore under investigation can be effectively floated at the pulp density of 35%, with the conditioning time ranging from 12-15 min.

Tannic acid (300 g/tonne) was used to effectively depress the gangue minerals in the ore. Any increase in the quantity of depressant resulted in lower yield and grade of the concentrate. The optimum quantity of the collector (disodium-*n*-octadecyl sulfosuccinamate) was determined to be 400 g/tonne, along with 300 g/tonne HF, which acted as an activator.

The flotation parameters, as optimized during present research, are summarized in Table 4 and the beneficiation process flowsheet is presented in Fig. 2.

The flotation process yielded concentrate assaying 60.1% Cr_2O_3, corresponding to chromite recovery of 82.65%. The metallurgical balance of the flotation process is presented in Table 5.

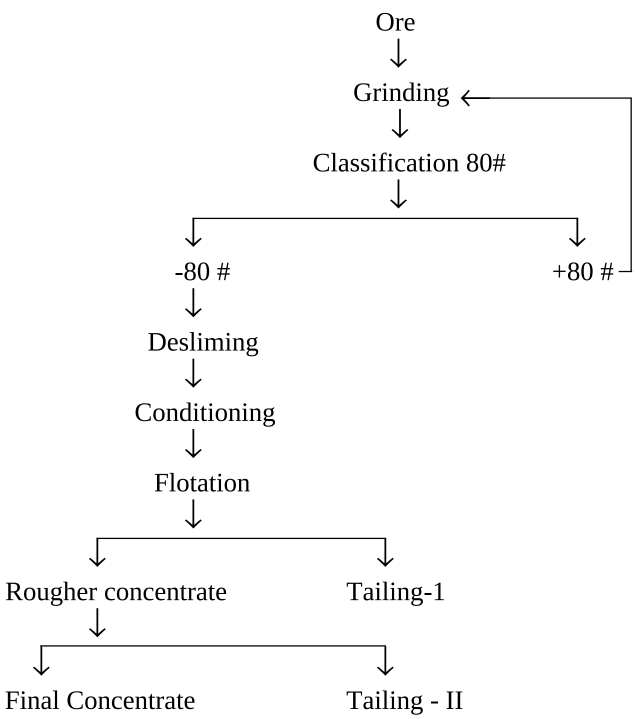

Fig. 2. Flow-sheet for the processing of Muslim Bagh, Balochistan, Pakistan low-grade chromite ore.

Table 4. Optimum parameters for flotation of chromite ore

Parameters	Conditions	
	Rougher	Cleaner
Grind size	-80 + 200 #	-80 + 200 #
Pulp density	35% solids	20% solids
pH	~3	~3
Activator	200 g/tonne HF	100 g/tonne HF
Conditioning time	15 min	10 min
Fuel oil	120 g/tonne	50 g/tonne
Depressant	200 g/tonne tannic acid	100 g /tonne tannic acid
Frother	150 g/tonne polypropylene glycol	50 g/tonne polypropylene glycol
Collector	300 g/tonne disodium *n*-octadecyl sulfosuccinamate	100 g/tonne disodium *n*-octadecyl sulfosuccinamate

Table 5. Metallurgical balance of feed size -80 # of chromite ore

Product	Weight (%)	Grade (%)	Recovery (%)
Cleaner concentrate	52.35	60.0	82.65
Cleaner tail	4.3	17.8	2.01
Rougher tail	17.64	6.06	2.81
Slimes	25.7	18.5	12.51
Calculated heads	99.99	38.0	99.98

Conclusion

The results of these investigations indicated that it is beneficial to upgrade the Muslim Bagh low-grade chromite ore by the flotation technique to produce chromite concentrate assaying 60.1% Cr_2O_3 with a recovery of 82.65% using disodium *n*-octadecyl sulfosuccinamate as the collector. However, upgradation through floatation technique required desliming of the feed without which no significant grade or recovery was obtained. Moreover, when the feed containd finer particles, the loss of material to the slimes increased, which ultimately decreased the recovery of the concentrate. It is concluded that the concentrate so produced can be gainfully utilized in the metallurgical, chemical and refractory making industries.

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