BENCH SCALE BENEFICIATION STUDIES OF CHROMITES OF ZHOB VALLEY (BALUCHISTAN) AND MALAKAND (NWFP)

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Low grade chromites of Zhob Valley and Malakand, in the assay range of 30-35 % and 12-32 % Cr_2O_3, were upgraded to concentrates containing 48 % and 47 % Cr_2O_3 respectively. Gravity based processing of chromites was done by using spiral and table concentrators and the process variables were optimized. The overall recovery varied for 50-80 % depending upon the nature of the ore. The final concentrates produced met the grade specifications required for the chemical and metallurgical industries.

Key words: Table and spiral concentration; Recovery; Grade.

INTRODUCTION

Chromite bearing Alpine-type mafic and ultramafic complexes occur in the south western (Bela, Ras Koh, Muslimbagh) and northern (Harichaind, Jijal, Shangh, Dras) parts of Pakistan. The most extensive deposite of chromite exist around Muslimbagh in the Zhob Valley [1], which may be put into five groups according to their locations, namely, Khanozai, Jungtorgarh, Saplitorgarh, Nasai, and Fort Sandeman [2]. The host rocks are restricted to serpentinite and dunite, although chromite grains are also found in harzburgite, contact carbonate rocks and residual cherts [3]. Workable chromite deposits occur in the form of stringers, bands, pods, nodules and disseminations in the host rocks. The reserves have not been adequately estimated, however, a rough estimate is reported to be above 6 million tonnes [4]. Harichand ultramafic complex in Malakand area is divided into four blocks in which the cumulative reserves of chromite have been estimated to be 1.7 million tonnes [5]. However, no detail of reserves estimation on scientific basis is available.

The bulk of the chromite deposits of Zhob Valley and almost all of it in the Malakand area are of low grade. Besides, the current practice of selective mining of high grade ore, handsorting of the better grade chromite for export also results in the accumulation of low grade ore. Consequently, the high grade ore is dissipating fast leaving behind a big stock of low grade ore. The local chromite mining industry, therefore, will vanish with time, if the low grade ores are not beneficiated and utilized.

A number of studies have been conducted to beneficiate the Zhob Valley chromite ores [6-9] but a perusal of the resulting reports indicates that the work was limited in scope because the samples taken for test work were not sufficient and the tests conducted were limited in number to reach a definite conclusion. For the present study, representive samples were collected from important areas and a large number of processing tests by spiral and table concentrators were carried out. In the light of the results obtained by altering the necessary process parameters, some conclusions have been drawn.

Sample collection and chemical assays. The ore samples from Zohb Valley and Malakand, each weighing 50 kg, were collected with the help of Baluchistan Development Authority, Pakistan Mineral Development Corporation, Pakistan Chrome Mines and the Geological Survey of Pakistan. Mineralogical investigations and chemical assays were carried out prior to the systematic beneficiation tests. The description of the samples and the chemical assays are given in Tables 1 & 2 respectively.

Sample preparation. For the beneficiation test work, all the samples from Zhob Valley were mixed and the bulk sample was designated as Muslimbagh sample. This was done to facilitate the selection of an under consideration chromite concentrator to be set-up at Muslimbagh to handle the low grade ores of various mines in the Zhob Valley. Among Malakand ore samples, the Bajrokanri chromite was found to be different in physical appearnace, chemical analysis and mineralogical characteristics from those of Badasar and Heroshah. The Bajrokanri ore and the mixed sample of Badasar and Heroshah were, therefore, processed separately.

For the preparation of test feed, each sample (maximum lump size 250 mm) was passed through a jaw crusher set at 15 mm. The jaw product was taken to the rolls crussher set at 0.5 mm and operated in a closed circuit with a vibrating screen. The rolls products of Bajrokanri, Muslimbagh and Badasar ores were ground in a rod mill to prepare feeds of 30, 40 and 60 mesh respectively.

Beneficiation tests. Tests were carried out on 10 kg samples using Humphrey spiral (5 turns) and wilfley table (2.3 x 1.2 m deck). Attempts were made to initially upgrade all the samples by spiral concentrator but it was observed that only the Bajrokanri ore responded well to the concentration while the Muslimbagh and Badasar ores did not give encouraging results. So the spiral concentrate of the Bajrokanri ore and the other two ores were processed by the table concentrator.

RESULTS AND DISCUSSION

The test results are discussed under separate headings for each ore sample.

Bajrokanri ore. The disseminated chromite grains in dunite serpentine matrix were liberated at 30 mesh without generating too much fines. The material was, therefore, ideal for spiral treatment. Various parameters were worked out to optimize the spiral concentration. In Fig. 1, two process variables for spiral, namely, per cent solids in the feed and the pulp flow rate, have been plotted against the recovery. It may be seen in the plots that with a dry feed rate of 1.25 t/hr a recovery of 85 % was achieved at a flow rate of 100 liters per minute. But when at the fixed flow rate of 100 liters per minute the per cent solids in the slurry were changed a significant drop in recoveries of Cr_2O_3 in the concentrate was found. At 0.75 and 1 t/hr the recoveries dropped though the grade of the concentrate improved. Similarly, with the slurries of 1.5 and 1.75 t/hr sharp separation of concentrate and tailings could not be achieved. The rougher concentrate, therefore, was obtained with a pulp of 20 % solids and a flow rate of 100 liters per minute. The subsequent washings of the rougher concentrate were, however, done with pulps of 1.16 and 1 t/hr and at a flow rate of 80 liters per minute. This was done for recovering clean concentrates for subsequent treatment. The spiral concentrate (22.5 % Cr_2O_3) was ground in a rod mill to 100 % passing 60 mesh and was upgraded on the table concentrator. The results of the Tabling operation are given in Table. 3.

Table 1. Description of chromite samples

Area	Sample No.	Location	Mine No	Cr_2O_3 %	Description
Zhob valley	1	Nisai	551	27.30	Disseminated and massive
(Muslimbagh)	2	"	503	28.61	Cut-off-grade, disseminated
	3	"	636	32.50	Cut-off-grade, disseminated
	4	"	302	36.72	Fines generated during transportation
	5	"	618	42.80	Serpentinized banded ore
	6	"	604	49.42	Cut-off-grade, dunitic
	7	"	624	34.21	Fines generated during transportation
	8	Jangtorghar	166B	50.67	Hand sorted rejects
	9	Jangtorghar	135B	39.27	Hand sorted rejects
	10	Saplaitorghar	7ML	38.01	Hand sorted rejects
Malakand	11	Bajrokanri	–	38.01	Disseminated
	12	Badasar	–	31.65	Massive
	13	Hero Shah	–	31.02	Massive

Sample 1 to 10 were mixed to make a composite sample which is referred to in the text as Muslimbagh sample.

Table 2. Chemical composition of chromite samples

Constitutent	Muslimbagh	Bajrokanri	Badasar	Heroshah
Cr_2O_3	34.92	12.66	31.65	32.22
Fe_2O_3	15.95	12.80	14.00	13.11
SiO_2	17.30	31.00	19.24	21.00
Al_2O_3	13.00	2.60	17.50	16.41
MgO	11.20	34.86	15.57	15.59
L/I	7.00	6.00	2.96	3.12

Table 3. Results of tabling of the rougher concentrate from Bajrokanri ore

Product	Wt. %	Cr_2O_3 %	Recovery %
Concentrate	32.62	47.00	68.20
Middlings	6.29	20.60	5.75
Tailings	41.23	7.60	13.95
Slimes	19.86	13.70	12.10
			100.00

Results in Table. 3 indicate that by the scheme adopted for the Bajrokanri ore the concentrate of metallurgical grade (47 % Cr_2O_3) can be produced with a recovery of 68 %. It was not attempted to regrind the middlings and talings and return them to the table which would have resulted in an increased recovery.

It may be stated that the Cr : Fe ratio of the ore could not be improved. It is obvious that iron, being part of the structure, cannot be removed by physical methods. Howevr, insignificant improvement may be noticed due to the removal of iron containing gangue minerals.

Muslimbagh ore. The microscopic investigations revealed that the chromite grains could be liberated at 40 mesh. The ore, when ground to 40 mesh, resulted in about 20 % fines of minus 150 mesh size. In the presence of these fines, the idea of using spiral concentrator was dropped and the ore was proceesed by the wilfley table.

The important variables for the tabling process such as feed rate, deck inclination, wash-water flow rate and the stroke length were studied. In Fig. 2, the feed rate has been varied from 6 to 13 kg/min. at an arbitrarily fixed desk inclination of 4°, wash water flow rate of 12 liters/min and stroke length of 9 mn. Under these conditions, a feed rate of 10 kg/min was found to be optimum to give a sharp separation of concentrate with optimum recovery. The reocvery dropped with the increased feed rate due to non-

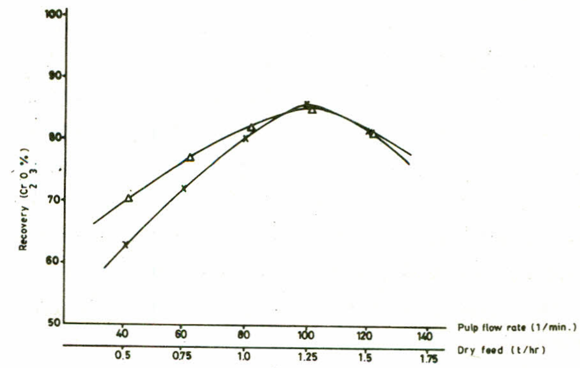

Fig. 1. Variation of percent recovery with pulp flow rate (△–△) and dry feed rate (x–x) in spiral operation on Bajrokanri chromite ore.

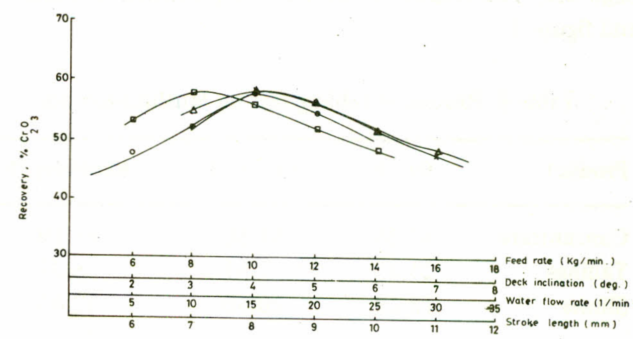

Fig. 2. Variation of percent recovery with feed rate (○–○), deck inclination (x–x), water flow rate (△–△) and stroke length (□–□) in the tabling of the Muslimbagh ore.

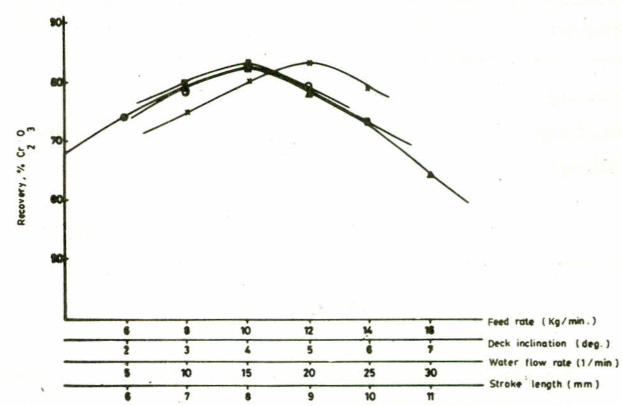

Fig. 3. Variation of percent recovery with feed rate (○–○), deck inclination (x–x), water flow rate (△–△) and Stroke length (□–□) in the tablign operation of the Badasar ore.

stratification of the feed over the deck and loss of the chomite grains in the middlings and tailings.

At a feed rate of 10 kg/min, water flow rate of 12 liters/min and a stroke length of 9 mm, the deck inclination was varied to get a sharp separation with optimum recovery (Fig. 2). At an angle of 4^o to the horizontal, the table gave better grade and recovery.

The effect of wash-water flow rate was studied at the fixed feed rate (10 kg/in), deck inclination (4^o) and stroke length of (9 mm). As is evident from Fig. 2, the water flow rate of 15 liters/min. was found to be an optimum. Under similar conditions, the stroke length of 8 mm was found to be suitable for a sharp separation and optimum recovery.

The results of the beneficiation test are given in Table 4.

Badasar ore. The mesh-of-libration for the ore, determined by microscopic studies, was found to be 60 mesh. The ore, ground at 60 mesh was, therefore, used to optimise variables like feed rate, deck inclination wash-water flow rate and stroke length as done earlier with the Muslimbagh ore. The results of the test are presented in Table 5 and figure 3.

Table 4. Results of tabling test on Muslimbagh ore

Product	Wt. %	Cr_2O_3 %	Recovery %
Concentrate	47.26	51.50	81.19
Tailings	25.45	7.51	6.37
Slimes	18.18	20.50	12.43
			99.99

Table 5. Results of tabling test on Badasar ore

Product	Wt. %	Cr_2O_3 %	Recovery %
Concentrate	52.0	47.0	78.62
Middlings	22.0	18.99	13.44
Tailings	4.50	4.50	7.94
			100.00

CONCLUSION

The gravity based processing tests done on low-grade chromite of Zhob Valley and Malakand indicate that chromite concentrates acceptable to the metallurgical and chemical industries can conveniently be produced. After the test work on pilot scale, commercial chromite beneficiation plants may be installed to meet the projected future demand of the country and to build a sound export potential.

In connection with the cost of processing, it may be stated that the laboratory scale test work was aimed at the optimization of various process parameters only. The cost of processing a tonne of ore has been estimated in a separate study conducted on pilot plant scale.

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