Pakistan J. Sci. Ind. Res., Vol. 31, No. 8, August 1988

BENEFICIATION OF LANDI RAUD (MALAKAND, NWFP) CHROMITE ORE

A. Hafeez, Saqib Ahmad and K. Hussain

PCSIR Laboratories, Lahore-54600

(Received May 29, 1988; revised September 7, 1988)

Low grade chromite ore from Landhi Raud in the assay range of 27-28 % Cr_2O_3 has been upgraded by gravity based processing methods to a concentrate containing 43-44 % Cr_2O_3 with a recovery of 65 %.

Recovery of chromite from the fines generated during the crushing and grinding of the ore has been attempted by the flotation technique. An overall recovery of 81 % with a concentrate grade of 43.4 % Cr_2O_3 has been achieved.

Key words: Beneficiation, Desliming, Flotation.

INTRODUCTION

In Pakistan, the chromite deposits in the Landhi Raud area of Malakand Division (NWFP) are believed to be the second largest after the Zhob Valley (Baluchistan). A figure of 1.7 [1] million tons for four main chromite occurrences in Malakand (Landhi Raud, Heru Shah, Bajrokanri and Badasar) was reported, taking into consideration the total proved and probable reserves.

The chromite mining in Pakistan has mainly been export oriented. With the depletion of high grade ore the chromite production has appreciably dwindled during the last few years. The production of chromite in Pakistan during the years [2] 1975-1985 has been given in Table 1.

Table 1. Chromite production in Pakistan.

Year	Tonnes
1975-76	12,360
1976-77	10,015
1977-78	9,845
1978-79	4,885
1979-80	3,835
1980-81	1,108
1981-82	3,028
1982-83	4,487
1983-84	4,180
1984-85	3,090

The continuously falling trend in the high grade chromite ore production and the substantial amount of foreign exchange spending on the import of chromite based products, demands the exploitation of low grade chromite reserves on a commercial scale.

Keeping in view this situation of the chromite industry, the PCSIR carried out studies on laboratory and pilot plant scales on chromite ores from different areas [3-5]. The present study was undertaken on a bulk sample of about 10 tonnes of chromite ore from Landi Raud deposit of the Malakand Division (NWFP).

Mineralogy of the ore. The Landhi Raud chromite ore is fine to medium grained and has nodular, disseminated, orbicular and porphyritic nodular characters. In addition, the ore also shows some massive uniformly disseminated occluded silicate and chromite net textures. The chromite grains at places show intense veining and fracture. The matrix minerals consist of magnesium silicate minerals and belong generally to the serpentine group of minerals. These minerals occur in so small crystals that discrete forms may not be observed without electron microscope. Traces of talc and magnesite are also observed as veinlets.

Photographs of the various thin sections have been shown in Figs. 1-6.

Mesh of liberation. The mesh of liberation stuides were undertaken by grinding the ore to below 20 mesh size. The screen analysis and particle counting of the sieved products were undertaken to show the liberation behaviour of the ore and have been given in Table 2.

From Table 2(b), the mesh of liberation for this ore may safely be taken as below 40 mesh (0.37 mm).

Processing of the ore

(a) *Sample preparation.* The ore as received (about 10 tonnes) was crushed, ground and classified through a jaw crusher, a roll crusher and a double deck vibrating screen to obtain a product 100 percent passing 0.5 and 0.25 mm respectively. For pilot plant tests the ore was prepared by using a rod mill instead of the double deck screen. The average chemical analysis of the ore and the sieve analysis

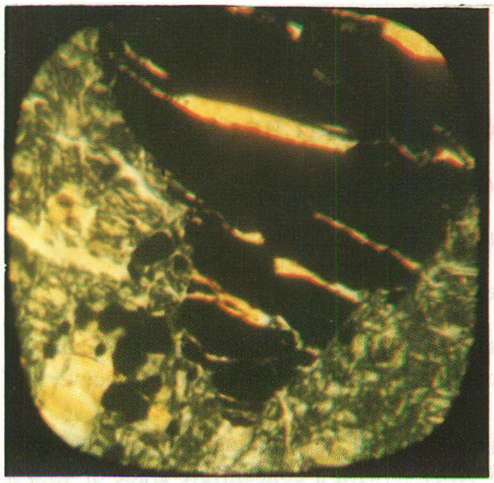

Fig. 1. Chromite in Landi Raud ore showing both coarse grain with pull apart, speckled texture and fine grained disseminated and modular texture. Thin Section, X120.

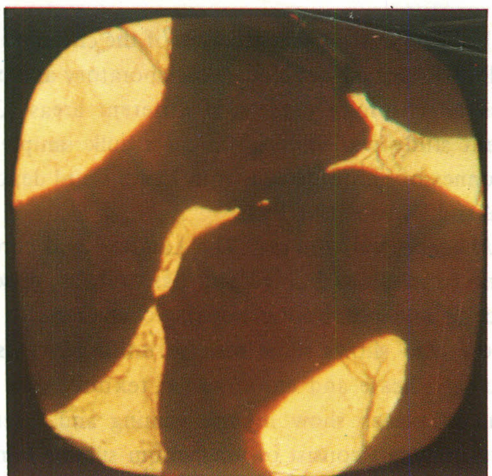

Fig. 2. Unzoned modules in Landi Raud chromite in the form of spherical, elliptical or subrounded crystal as mettled texture. One grain shows orbicular texture with coarse grained gangue as inclusions. Thin Section, X120.

Fig. 3. landi Raud chromite with inclusion of veins, speckled areas and a coarse grained gangue inclusion. Two types of gangue formed as a result of solution activity and replacement characters at the margin. Polished Section, Mag. 1cm-50 microns.

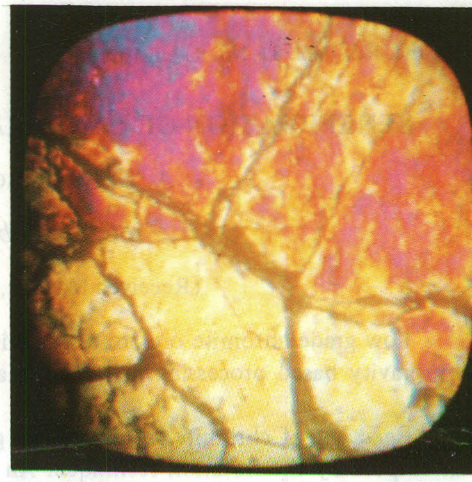

Fig. 4. Dunitic gangue showing coarse euhedral olivine crystals under cross polarization with characteristic birefringent colours in Landi Raud area. Thin Section, X120.

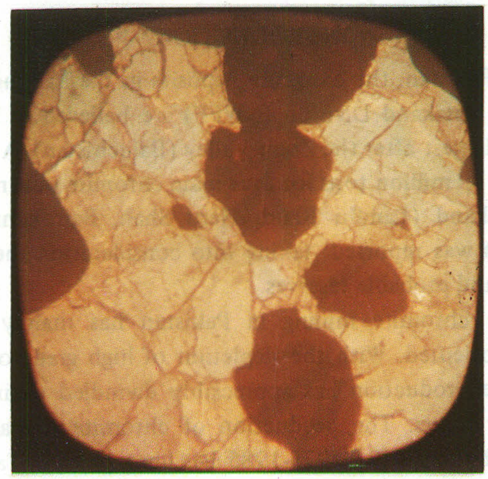

Fig. 5. Partially replaced relict olivine by serpentine as matrix. Magnesite and talc in a vein in Landi Raud Area. Thin Section, X120.

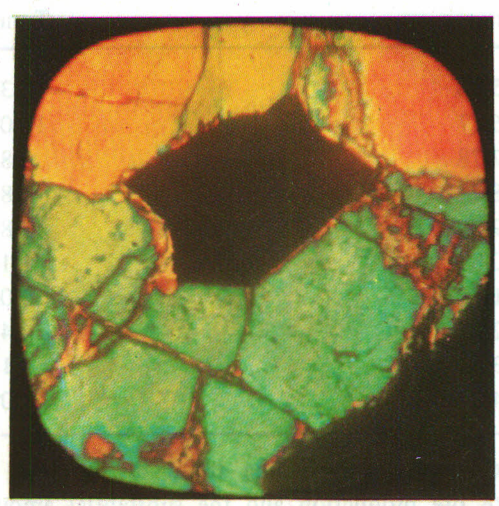

Fig. 6. 0.2 mm size chromite grain set in a matrix of enhedral olivine crystals. Interspaces are filled with chlorite and serpentine in Landi Raud area. Thin Section, X120.

of the minus 0.5 and 0.25 mm comminuted products are given in Tables 3 and 4a. b respectively.

Table 2. (a) Dry Sieve analysis.

Mesh (B.S.S.)	Weight (gms)	Percentage	Cumulative weight (%)
+ 30	155	25.96	25.96
+ 40	70	11.73	37.69
+ 60	150	19.26	59.95
+ 80	85	14.24	71.19
+ 100	25	4.18	75.37
+ 150	35	5.86	81.23
– 150	112	18.76	99.99

Table 2.(b). Percentage grain counting.

Mesh (B.S.S.)	Chromite	Dominant Chromite	Mixed	Dominant gangue	Gangue
– 20+30	18	52	12	14	4
– 30+40	31	35	14	12	8
– 40+60	36	31	3	8	20
– 60+80	43	11	2	5	39
– 80+100	37	6	1	2	54

Table 3. Chemical analysis of the ore.

Constituents	Percentage
Cr_2O_3	28.49
SiO_2	18.66
Fe_2O_3	16.82
Al_2O_3	11.51
MgO	21.40
L/I	2.92
Cr/Fe	1.65

Table 4(a). Sieve analysis of the minus 0.5 mm product.

Mesh Size	Percentage
– 30+40	7.80
– 40+60	13.80
– 60+80	13.20
– 80+100	19.60
– 100+150	8.00
– 150	37.60

(b) *Beneficiation.* A number of experiments were carried out to optimise the conditions for producing a suitable concentrate by processing the ore on Wilfley table and Humphrey spiral concentrators. Since the ore is friable and generates fines on crushing and grinding, an appreciable loss of chromite grains was observed during the processing of the ore. This loss increased when the ore was processed on the Humphrey's spiral. So the use of the spiral concentrator was discontinued.

The various parameters involved in the tabling operation (deck inclination, water flow rate, stroke length, etc.). were optimised on two sizes of the ore for a comparative study, viz. 100 % passing 0.5 and 0.25 mm respectively and beneficiation was carried out on the table concentrator. The optimization of the tabling variables on the two sizes of the ore resulted in the production of concentrates assaying 41.23 % Cr_2O_3 at a recovery of 66.66 % and 44 % Cr_2O_3 at a recovery of 65 % respectively. The optimum results obtained for two feed sizes have been presented in the form of Metallurgical balance Tables 5-6 and the processing sequence has been given in the form of flow sheet (Fig. 7).

Table 4(b). Sieve analysis of the minus 0.25 mm product.

Mesh Size	Percentage
– 60+80	16.50
– 80+100	18.50
– 100+150	18.00
– 150+200	13.50
– 200	33.50

Table 5. Metallurgical balance of bench scale result of Landi raud ore feed 100% passing 0.5 mm (Cf. Fig. 7).

Product	Weight %	Cr_2O_3 %	Recovery %
Concentrate	49	41.23	66.66
Middling	21	21.00	14.54
Slimes & tails	30	19.00	18.80
Calculated heads	100	30.31	100.00

Table 6. Metallurgical balance of bench scale result of Landi raud ore feed 100% passing 0.25 mm (Cf. Fig. 8).

Product	Weight %	Cr_2O_3 %	Recovery %
Concentrate	45.40	44.0	65.0
Middling	12.00	23.0	9.0
Slimes & tails	42.60	19.00	26.0
Calculated heads	100.00	30.9	100.0

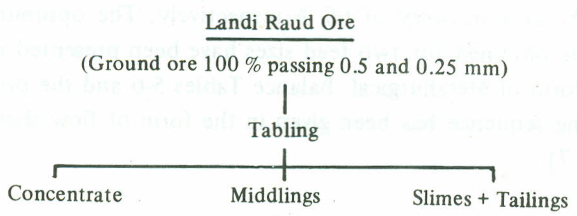

Fig. 7. Processing flowsheet for Landi Raud Ore at 0.5 and 0.25 m.m sizes.

As in the case of the spiral concentrator, loss of material in the tailings and fines fraction was noticed in the tabling operation as well. In the case of the 0.5 mm feed, the loss of chromite into the tailings and fines fraction was 30 % at a grade of 19 % Cr_2O_3 equivalent to a recovery loss of 18.8 %. In the case of 0.25 mm feed, the loss was noted to be 42.6 % at a grade of 19 % Cr_2O_3 equivalent to a recovery loss of 26 %.

In order to improve the overall recovery, chromite gravity tailings and fines were collected for processing by flotation. Flotation experiments were carried out to optimise such variables as pulp density, pH of the slurry and nature of activator, conditioner and frother. The sieve analysis of gravity tailings and slimes and their Cr_2O_3 contents have been given in Table 8. The flotation test work resulted in the production of a concentrate assaying 41 % Cr_2O_3 with a recovery of 56 %. The optimum results of the flotation tests and the operating conditions have been given separately in Table 9 and the flotation sequence has been presented in the form of a flow sheet (Fig. 8). When the results of the gravity and flotation concentration were combined, a recovery of 81 % at an average grade of 43.42 % Cr_2O_3 was obtained. Table 7 indicates the metallurgical balance of the combined gravity and flotation procesing methods. The chemical analysis of the combined chromite concentrate is given in Table 10.

Table 7. Metallurgical balance of the combined gravity and flotation chromite processing circuit.

Products	Weight %	Cr_2O_3 %	Recovery %
Gravity concentrate	45.33	44.00	66.54
Middling	12.00	23.40	9.37
Flotation concentrate	10.67	41.00	14.59
Flotation Slimes	32.00	8.90	9.50
Calculated heads	100.00	29.98	100.00

Table 8. Sieve analysis of tailings and slimes with Cr_2O_3 contents.

Mesh Size	Weight Percentage	Cr_2O_3 %
+ 85	2.40	13.29
– 85+100	1.60	9.50
– 100+150	6.96	8.86
– 150+200	4.52	10.13
– 200+240	4.43	12.66
– 240	80.11	19.62

Table 9. Flotation test results. (a) Flotation conditions (deslimed feed).

Parameters	Conditions
Rougher pulp density	25% solid
Rougher pH	4.5-5 (H_2SO_4)
Dispersant	1000 gm/t (Sodium silicate)
Rougher activator	200 g/t (HF)
Rougher conditioning time	10 minutes
Rougher collector/frother	70 g/t(Oleic Acid)
Rougher flotation time	20 minutes
Cleaner pulp density	12% Solid
Cleaner pH	3.5-4 (H_2SO_4)
Cleaner activator	100 g/t (HF)
Cleaner flotation time (2 cleanings)	10-15 minutes

Table 9.(b). Metallurgical balance.

Products	Weight %	Cr_2O_3 %	Recovery %
Cl.Concentrate	25.00	41.00	56.38
Cl.Tail	13.00	7.45	5.33
R.Conc.	(38.00)	(29.59)	(61.71)
R. Tail	22.00	6.33	7.64
Slimes	40.00	13.93	30.64
Calculated heads	100.00	18.18	99.99

Table 10. Chemical analysis of concentrate.

Constituents	Percentage
Cr_2O_3	44.00
Fe_2O3	17.44
Al_2O_3	14.52
SiO_2	6.70
MgO	15.72
L/I	1.50
Cr/Fe	2.46

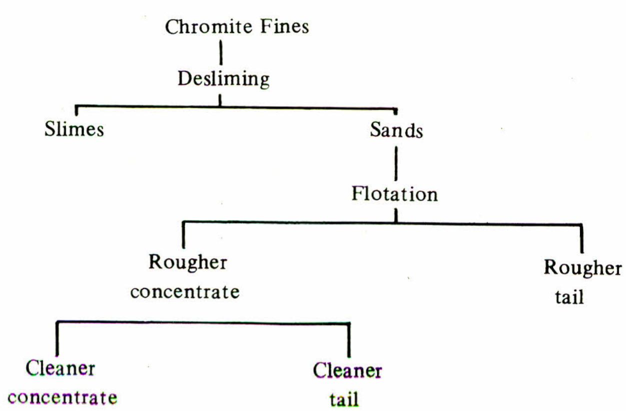

Fig. 8. Flotation sequence for the recovery of chromite fines.

CONCLUSION

The results of the beneficiation study showed that a chromite concentrate assying 43-44 % Cr_2O_3 can conveniently be produced from the low grade chromite ore. This concentrate may be used for the production of chrome chemicals by conventional known process and ferrochrome using the AOD process.

A comparison of the results obtained on the processing of the two sizes i.e. 0.5 and 0.25 mm, reveals that the grade improves while the recovery falls slightly by treating the ore at finer sizes. It may, however, be pointed out that as the feed size decreases, the loss in the fines will increase. It is obvious from Tables 4 and 5 that the weight loss at 0.5 mm is around 30 % and at 0.25 mm it is around 40 %. The loss in terms of Cr_2O_3 contents amounts to 18.8 and 26.0 percent at the two sizes respectively. In order to improve the recovery by a few percentage points, it may not be justified to increase the cost of processing by grinding the ore beyond 0.25 mm and also losing the fine material.

The fines generated during comminution of the ore may be recovered to some extent by flotation. The flotation requires desliming of the feed without which no significant grade or recovery was obtained. In the commercial production of chromite concentrate from this ore, a combined gravity and flotation approach appears to be more logical.

An examination of the metallurgical balance sheets brings out the fact that 21 weight percent of ore with a grade of 21 % Cr_2O_3 was reporting in the middling in the case of 0.5 mm feed while for 0.25 mm feed the weight percent reporting into the middlings was 12 at a grade of 23 % Cr_2O_3. This chromite could be recovered to some extent by grinding the middlings and processing them by tabling or by grinding them to below 100-150 mesh and subjecting to flotation. In both cases grinding of the middlings is involved which, in case of tabling, may not improve the recovery significantly due to losses in fines. In the case of flotation better recoveries may be expected; and this requires an independent study. It was, therefore, not attempted to process the middlings in the present study.

The cost [6] of producing one tonne of chromite concentrate from the present ore based on gravity processing only comes out to be Rs. 341/- and a combined gravity and flotation processing cost is estimated to be Rs. 400/-. It is assumed in the cost calculations that the processing will be carried out at the mine site and the mined ore will cost Rs. 200 per tonne.

REFERENCES

1. S.S. Mehdi, Geology and Economic Aspects of Malakand Crhomite Deposits, P.M.D.C. Report, Peshawar, (1979), p.130.
2. Pakistan Statistical Year Book 1986, Federal Bureau of Statistics, Govt. of Pakistan, p. 150.
3. A Report on Beneficiation and Utilization of Chromite Resources of Pakistan, Ore Dressing and Metallurgy

Division, PCSIR Laboratories, Lahore, June 1973).
4. Beneficiation Studies on Chromites of Zhob Valley (Baluchistan) and Malakand (NWFP), Ore Processing and Metallurgy Division, PCSIR Laboratories, Lahore (1979).
5. K. Hussain, A. Hafeez, and N. Sheikh, Pakistan J. Sci. Ind. Res., **30**, (1987).
6. Substitution of Imported Minerals and Mineral Based Products, Phase-II, Part 2, Minerals and Metallurgy Division, PCSIR Laboratories, Lahore (1987), p. 131.