Beneficiation of Low Grade Chromite Ores from Sukinda

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Abstract

In order to produce directly marketable chrome ore for export and domestic industries, most of the chromite ore beneficiation plants in Sukinda region treat selected rich ores with rejection of huge quantities of low and sub-grade ore (10-38% Cr_20_3). Beneficiation is mostly limited to crushing, grinding, desliming and hydrosizing to produce a concentrate of about 50% Cr_20_3 with a yield of about 25-35%. By this also, a huge amount of sub grade fines of about 35-40% Cr_20_3 has been accumulating in the mines. Currently very little efforts are made to treat these low grade ores or recover values from waste dumps. Recently, a study was undertaken at NML. to explore the possibility of developing a flowsheet to produce chromite concentrate preferably with Cr_20_3 content of about 50% with SiO_2 about 2% from waste dumps analysing between 20 to 23% Cr_20_3, with a view to using these as additional source of feed stock. Detailed physical characterisation, mineralogical analysis, bench and pilot scale studies were undertaken on these samples. The beneficiation process essentially involved removal of ferruginous slime at stages by washing and hydrocycloning and enrichment of different size classified fractions by. simple gravity separation techniques like spiralling and tabling. It was observed that by adoption of the above operations, it was possible to upgrade these low grade ores to obtain concentrate having Cr_20_3 of desired grade with high recovery.

Based on the above findings, further investigations were carried out with some more samples of higher grade in order to get a complete picture to understand the economics on the basis of yield and grade. The results indicated that concentrates with grade of more than 50% Cr_20_3 with recovery of 50-80% could be achieved by using simply gravity techniques. The grade and recovery depended upon the nature of gangue minerals and their liberation. However, this study amply demonstrated and confirmed the beneficiability of the low grade ores and the dumps, which can definitely augment the export.

1. Introduction

Chromite with basic formula of FeO,Cr_2O_3; Fe being replaceable by Mg and Cr by Al & Fe, is the only economic source of chromium and India has fairly large resources mostly concentrated in Orissa in Boula-Nuasahi and Sukinda ultramafic belt with small occurrence near Bhalukasuni [1]. The total reserves of chromite in India is in the order of 114.3 million tonne and Orissa accounts for about 110.7 million tonne and the bulk of it are contained in Sukinda ultramafic belt [2]. Chromite has a wide range of application in metallurgical industry, refractory industry as bricks used in iron & steel, glass, cement and non-ferrous alloy industries, and chemical industries as chrome chemicals. A substantial portion of chromite produced is exported. Specifications for different uses are given below in Table 1[3].

Table 1 : Specification of chromite for industrial uses

Industry	**Cr_2O_3 (%), min**	**Cr:Fe Min**	**Al_2O_3 (%) max**	**Fe as FeO (%), max**	**SiO_2 (%) max**	**CaO (%) max**	**MgO (%) max**
Metallurgical							
Low Carbon Ferrochrome	48	3	13	15	5	5	14
High Carbon	48	2.8	13	16	8	5	16
Ferrochrome							14
Silico-chrome	48	3	13	15	10	5	
Chargechrome	44	1.6	10	18	12	5	12
Refractory	48-52			16-18	3-9		15
Chemical	44		14	20	7	3	14

Location of principal producers [4] of chromite in India is given below in Table 2

Table 2 : Principal producers of chromite

Agency	Location of Mine	State
FACOR	Dhenkanal, Jajpur, Keonjhar	Orissa
TISCO	Jajpur	Orissa
OMC	Dhenkanal, Jajpur	Orissa
Balasore Alloys	Jajpur	Orissa
Jindal Strips	Jajpur	Orissa

Chromite ore beneficiation plants in Sukinda region treat selected rich ores (≈38% Cr_2O_3) with a view to producing concentrate of about 50% Cr_2O_3 as directly marketable grade for export and domestic industries. This has resulted rejection and piling of huge quantities of low and sub-grade ore (10-38% Cr_2O_3). Beneficiation is mostly limited to size reduction, desliming and classification. The yield is low of about 25-35%. During beneficiation, sub grade intermediate products of about 35-40% Cr_2O_3 get generated which finds very little or no use and these have been accumulating in the mines. A schematic diagram of a beneficiation plant in Sukinda is given in Figure 1.

Developing a techno-economic scheme to upgrade the low grade ores and rejects & dumps to tap export market of fines may be a worth proposition which, apart from economic gains, will aim to reduce deterioration of the environment as well. With the above in view, recently, a study was undertaken at NML. to explore the possibility of developing a flowsheet to produce chromite concentrate preferably with Cr_2O_3 content of about 50% with SiO_2 about 2% from low grade ores/ waste dumps analysing between 20 to 35% Cr_2O_3, with a view to using these as additional source of feed stock for either expansion of the existing beneficiation plant or development of new plant exclusively to treat the rejects & dumps.

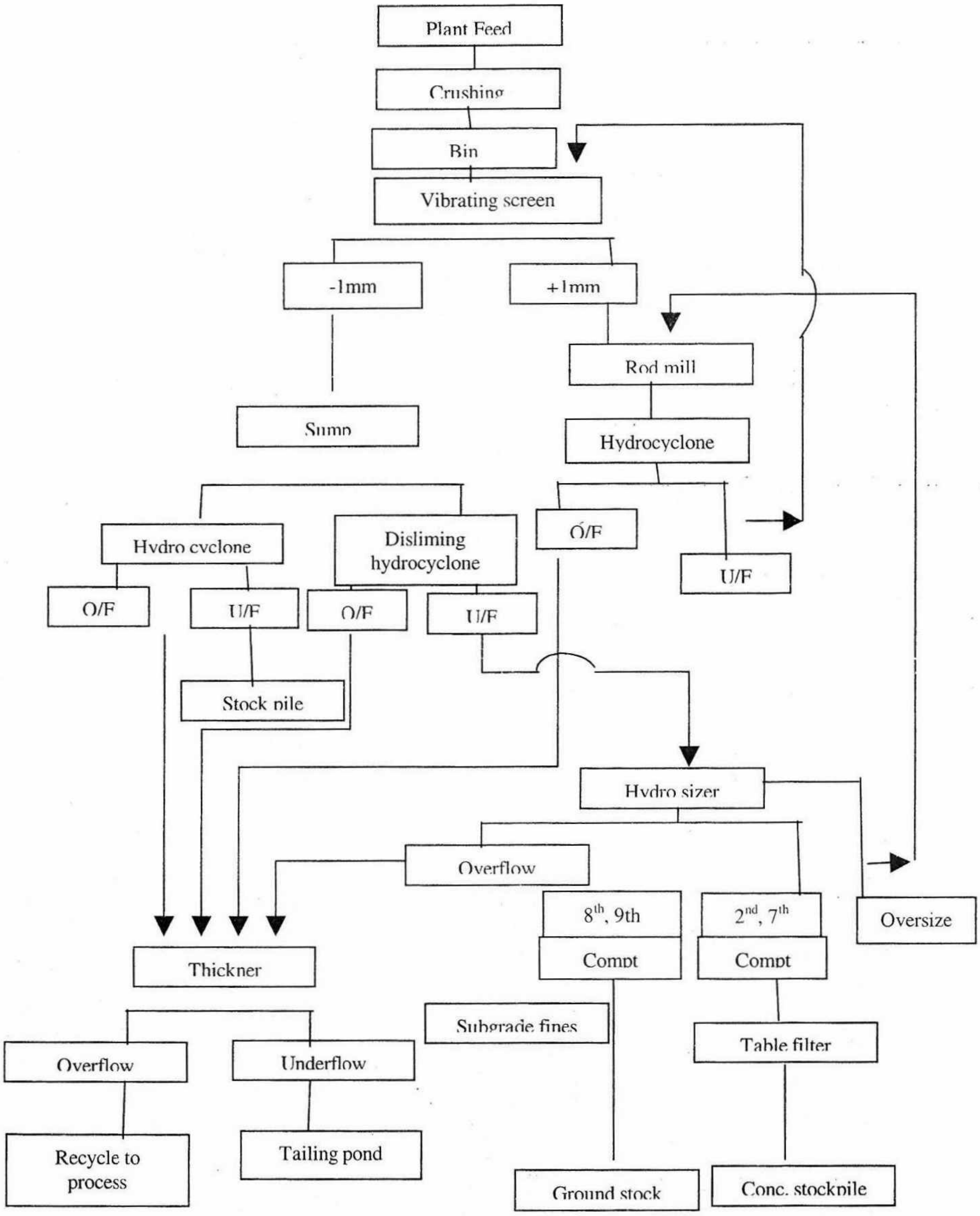


Fig 1. Flowsheet of a Chromite Ore Beneficiation Plant

2. Methodology

Six different samples from two mines of Sukinda area were received for developing a flowsheet for upgradation. Chemical analysis of the as-received samples are given in

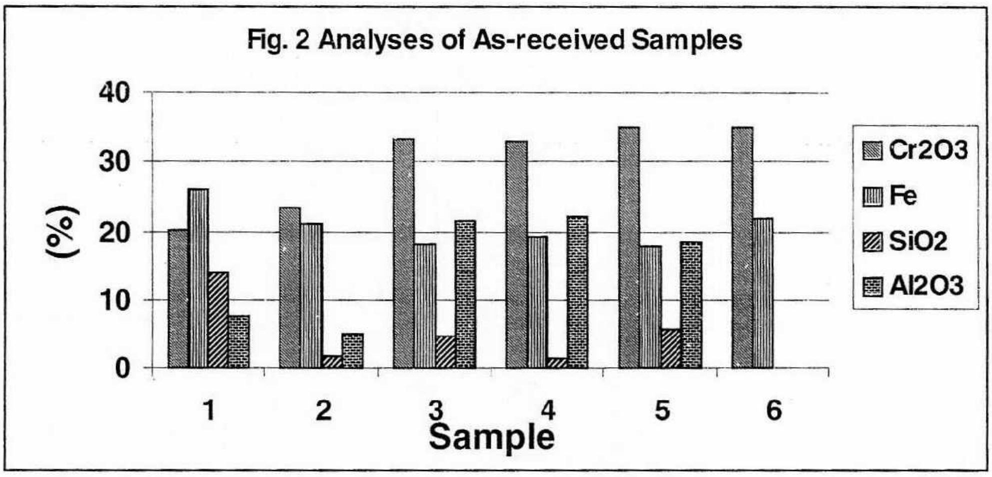


Figure 2. The as-received samples comprised lumps and fines. Megascopic and macroscopic observation of the samples indicated that samples from the first mines (Sample Nos. I, III & V) experienced extensive weatheing and alteration with the development of selective leaching, voids and limonitisation. Weathering is less for the samples from the second mines (Sample Nos. II, IV & VI) and lumps were harder than those of first mines with only few lumps brittle and brownish due to weathering and alteration. The thin sections and polished sections indicated that the samples were dominantly made up chromite, altered silicate (olivine) associated with quartz and ferruginous minerals (hematite, goethite, limonite, ilmenite) as minor to traces. Few microphotographs of the sample are given below (Figure 3 & 4). Locking and liberation study indicated a fair liberation below 250 micron and most of the grains were liberated below 150 μ.

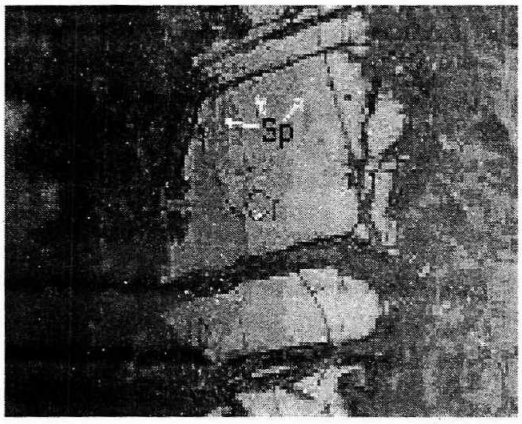


Fig 3: Subhedral grain of chromite (Cr) with development of spinel (Sp)

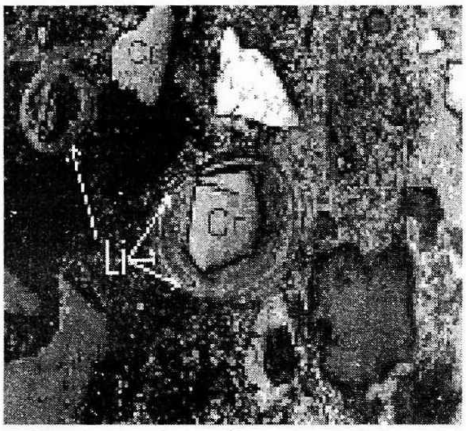


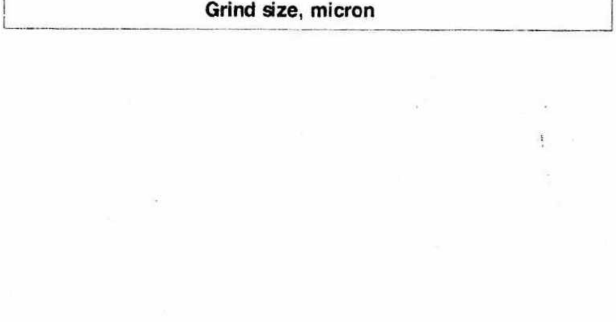
Fig 4: Locked chromite (Cr) within limpnitic oolite

Optimisation of process steps were carried out with Sample No. 1 first. The optimum grind size was to be established for proper liberation, keeping the overall size of the products as coarse as possible and at the same time making it suitable for rejection of ferruginous material present as surface coatings and inclusions to the extent possible. In the first circuit, scrubbing and wet screening at 1mm followed by first stage of rejection separation of ferruginous slime by screw classifier as overflow, from. -1mm material, were attempted. The second stage of rejection of ferruginous material was accomplished by grinding the +1mm washed material to just -1 mm, mixing with the -1 mm washed fines and subjecting the whole lot of -1mm material to hydrocycloning. The cyclone overflow was rejected while the cyclone underflow was subjected to size classifications with the help of CTS fabricated locally. In the subsequent circuits, the grinding size was reduced to 0.3 mm and 0.15 mm respectively and the ground pulp was similarly treated in hydrocyclone. The cyclone underflows were also classified into size fractions viz., -300+150 micron, -150+75 micron & -75 micron and -150+75 micron & -75 micron respectively. The -300+150 micron size fraction was subjected to spiraling and/or tabling, -150+75 micron fraction to tabling and -75 micron size fraction to Tabling/MGS.

3. Results & Discussion

Rejection of ferruginous material in the form of slime for different grind sizes are presented in Figure 5.

It could be seen that at finer sizes, rejection of slime was more with practically no change in the grade in slime which enabled the cyclone underflow to be upgraded to 27.06% Cr_2O_3 at -150 micron grind. Results of size classification of cyclone underflow in CTS are given in Figure 6. Analyses of classified fractions are given in Table 3.



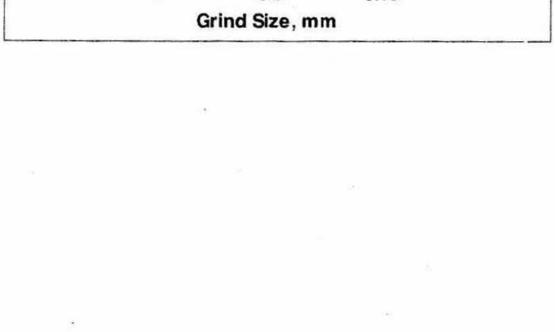


Table 3 : Chemical Analyses of classified size fractions

Grind	1 mm	0.3 mm	0.15 mm
Size Fraction	Cr_2O_3(%)		
+0.3 mm	22.03		
+0.15 mm	22.5	24.36	
+0.075 mm	27.2	27.01	28.74
-0.075 mm	21.15	21.15	26.02

The +0.15 mm fraction from 0.3 mm grinding was subjected to spiraling in a 5 turn 3 product Carpco Mineral Spiral and the Spiral middling was ground in a rod mill to -0.15 mm and subjected to tabling in a Carpco Wilfley Laboratory Fine Deck (13A)Table. In an alternate approach, the +0.15 mm fraction was subjected to tabling in a Carpco Wilfley Laboratory Coarse Deck (13A)Table and the middling from the same was ground to -0.15 mm and subjected to tabling in a Carpco Wilfley Laboratory Fine Deck (13A)Table.

The -0.15+0.075 mm fraction from 0.3 mm grinding was subjected to tabling and the middlings from the operation was ground to -0.075 mm and subjected to further tabling.

The -0.075 mm fraction was from 0.3 mm grinding was subjected to MGS. In addition to this, this was treated in a hydrocyclone for further rejection of slime and the cyclone underflow was subjected to both MGS and tabling.

The cyclone underflow (-0.15+0 mm) from 0.15 mm grinding was straightway subjected to MGS as well as tabling and also the classified products of cyclone underflow viz., -0.15+0.075 mm and -0.075 were subjected to both tabling and MGS. Salient results are presented in Table 4.

Table 4 : Yield and grade of concentrate for different operations and different grind

Grind Size (micron)	Fraction	Operation	Conc. Wt(%)	Grade, Cr_2O_3 (%)
300	-300+150μ	Spiralling	2.4	42.67
		Tabling of Spiral Middling after Grinding	3.4	41.58
	-150+75μ	Tabling *	10.7	43.59
	-75+0μ	Tabling	7.5	38.88
	Total	**Spiral+Tabling**	**24.0**	**41.75**
300	-300+150μ	Tabling	6.4	36.72
		Tabling of Table Middling of above after Grinding	2.5	40.61
	-150+75μ	Tabling *	10.7	43.59
	-75+0μ	Tabling	7.5	38.88
	Total	**Tabling**	**27.1**	**40.40**
150	-150+0μ	**Tabling***	**23.5**	**40.72**
		MGS	**25.4**	**39.97**
150	-150+75μ	Tabling*	04.3	46.05
	-75+0μ	Tabling	09.6	43.81
	Total	**Tabling**	**13.9**	**44.50**
150	-150+75μ	MGS	03.0	42.75
	-75+0μ	MGS	14.0	42.24
	Total	**MGS**	**17.0**	**42.55**

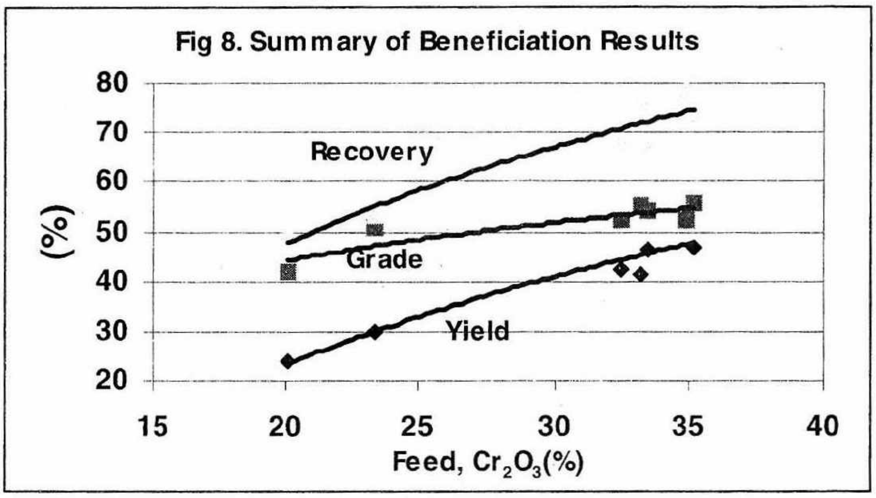
* without middlings

It was observed that reducing the grinding size, there was some improvement in the grade of concentrate but the loss of values were more in tailings and middlings and the yield got substantially reduced. The optimised flowsheet is presented in Figure 7.

Adopting the above flowsheet, all the remaining samples were treated, with optimisation of individual unit operations. The summarised results are presented below in Figure 8. [5].

Figure 7: Flowsheet for beneficiation of low grade chromite ore

- As received Sample (Crushed Ore)
  - Scrubbing, Wet Screening & Classification
    - Sand
      - Grinding to 0.3 mm)
        - Hydrocycloning
          - Underflow
            - Size Classification (CTS)
              - -300+150 μ
                - Spiraling
                  - Conc
                  - Middling
                    - Grinding
                      - Tabling
                        - Conc
                        - Tails (Reject)
                  - Tailing (Reject)
              - -150+75 μ
                - Tabling
                  - Conc
                  - Middling
                    - Grinding
                      - Tabling
                        - Conc
                        - Tails (Reject)
                  - Tails
              - -75 μ
                - Hydrocycloning
                  - Underflow
                    - Tabling
                      - Conc
                      - Middg.
                      - Tails (Reject)
                  - Overflow (Reject)
          - Overflow (Reject)
    - Classifier Overflow (Reject)



4. Conclusion

The above study amply demonstrated that by simple gravity techniques, low grade chromite ore/ waste dump samples could be enriched to a usable concentrate of more than 50% Cr_2O_3 with recovery of 50-80%.

5. Acknowledgement

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[3] Indian Mineral Year Book 2003, Indian Bureau of Mines, Dec 2003, p 23-9
[4] Indian Mineral Year Book 2003, Indian Bureau of Mines, Dec 2003, p 23-3
[5] NML Investigation Reports