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Effective Processing of Low Grade Chromite Ore by Heavy Medium Separation Process

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Abstract: The main objective of this study to investigate the effectiveness of the gravity concentration technique for beneficiation of the low-grade chromite ore materials after the high-grade lumps are sorted out by hand picking from the run of mine ore. They are low-grade type of ore containing a high amount of fine serpentine as gangue materials, and an average chromium oxide content of about 21.56 % Cr_2O_3. Based on the fact that there are significant differences in specific gravity between the desired chromite mineral and the gangue minerals, therefore it was suggested that gravity separation methods may be able to concentrate this type of ore .This technique was attempted to process Ingassana waste materials within mine dumps. The chromite mineral of this sample could be liberated at around 500um. Such material size would be successfully dressed by gravity processes. Hence, these materials were subjected to treatment by heavy media system .The heavy medium separation has produced from the treated materials concentrate of about46.5 %Cr_2O_3 and a recovery of about 85.48%Cr_2O_3 are achieved.

Keywords: *Ingassana*; *Low Grade Chromite; Chromite Ores; Processing*; *Heavy Medium Separation.*

1. INTRODUCTION

Chromite ore deposits in Sudan occur mainly in the Ingassana Hills in the Blue Nile State. The chromite deposits are found in many places in the serpentine rocks or in the associated talc-carbonate rocks. They usually occur either as lenticular or banded bodies of irregular shapes and variable size as well as veins or disseminated ores. The chromite ore bodies are mainly massive, compact, medium and coarse subhedral to anhedral in texture. The ores are either compact, hard, high grade and lumpy with Cr_2O_3 content varying from 48% to more than 50% and Cr/Fe ratio above 3, or medium grade spotted ores or medium-grade combined lumpy and spotted varieties. The chemical composition of the ore changes from compact massive ores to sparsely disseminated ores. The Cr_2O_3 content decreases successively, and the Cr/Fe ratio, while the Al_2O_3 content to increases with ore bodies which are mainly composed of fine to medium euhedral to subhedral grains and are generally of medium to low grade quality, the Cr_2O_3 content is less than 35 and Cr/Fe ratio below 3[1].

Most chromite ores currently mined in the Ingassana area are of high grade (more than 46% Cr_2O_3. These ores are marketed without any concentration other than hand picking sorting. The disseminated and banded chromite ores are not mined because they are of a low grade quality. Low-grade deposit ores and that fines resulting during mining operations can't be exported, since they are unmarketable. Therefore, beneficiation of these low grade and fine grain disseminated ores is becoming more important in recent years due to the shortage of high grade ores reserves. The practice at Ingassana mines, the run-of mine ore being piled and rich the chromite dumps are picked from these stockpiles, leaving behind coarse waste and all fines material less than about 25.4mm size. The total measured potential of low grade ores in dumps of IHMC amounts are appox.200, 000 tons with average chromite oxide content of about 22.6%.The concentration of these low grade chromite ores may lead to market them, which would achieve revenues in foreign currency and create job opportunities in this area [2-3].

Hence the main objective of the present work is to investigate the amenability of the remained chromite ores after high-grade lumps have been removed by hand picking to be concentrated by gravity methods, utilizing the relatively difference in the specific gravity of the main constituting minerals of chromite. More intensive beneficiation methods now being used in the area of mineral ores processing include sink and float, shaking table, spirals, hydrocyclones, electromagnetic and electrostatic separation and flotation .All these methods could separate chromite ores from silicate gangue which leave chromium mineral , iron and minerals such as aluminium oxides and magnesium carbonate associated together .However there are several chemical based methods could enrich the chromite in Cr2O3 by reducing the iron content, hence the Cr/Fe ratio is increased which has been an important consideration for metallurgical purposes. Gravity concentration such as heavy medium separation is applicable to any ore in which, after suitable degree of liberation by grinding, there is enough difference in specific gravity between mineral and gangue material particles .The process is most widely applied when the density difference occurs at a coarse particle size, as separation efficiency decreases with decreasing the size due to the slower rate of settling of the particles. Particles should preferably be larger than about 3 mm in diameter, in which case separation can be effective on a difference in specific gravity of 0.1 or less. Separation down to 500 microns and less, in size can, however, be made by the use of centrifugal separators. Providing a density difference exists, there is no upper size limit except that determined by the ability of the plant to handle the material [4].

Ferrosilicon which having specific gravity of ranges from 6.7 to 6.9 is an alloy of iron and silicon which should contain not less than 82% Fe and 15-16% Si. If the silicon content is less than 15% ; the alloy will tend to corrode, while if it is more than 16% the magnetic susceptibility will be greatly reduced resulting losses of ferrosilicon fines from the heavy mineral circuit which vary widely, from as little as 0.1 to more than 2.5 Kg / ton of ore treated. Corrosion usually accounts for relatively small losses, and can be effectively prevented by maintaining the ferrosilicon in its passive state. This is normally achieved by atmospheric oxygen diffusing into the medium, or by addition of small quantities of sodium nitrite [5]. At 15% Si the density of ferrosilicon is 6.8 and a medium density of 3.2 can be prepared from this alloy. Various size grades are produced from 95%-150µm to 95%-40µm, the finer material being employed for treatment of finer ore. Ferrosilicon consists of rounded particles which produced lower apparent, atomized viscosities and can be used to produce density up to 3 to 4 [6].

Liquids covering a range of densities in incremental steps are prepared, and the representative sample of coarse ground ore is introduced into the liquid of highest density. The floats product is removed and washed and placed in the liquid of next lower density, whose float product is then transferred to the next lower density and so on. The sinks product is finally drained, washed and dried, and then weighed, together with the final floats product, to give the density distribution of the sample by weight. After assaying the fraction for metal content the distribution of material and metal in the various den sites fractions of the sample can be tabulated. The difficulty or ease of separation is thus dependent on the amount of material present of specific gravity approaching that of the medium. Conversely, the efficiency of a particular, separation process depends on its ability to separate material of specific gravity close to that of the medium [4]. It has excellent potential for processing waste materials–mine dumps, slag, and municipal and other solid wastes.

Heavy media separation was attempted to concentrate the Seial Lake chromite ore at feed size fraction+100 mesh {+150um} materials. Considerable amount of coarse gangue minerals was rejected and a sink product assaying 35.0%Cr_2O_3 and a recovery of 86% was obtained. Concentrating the Elazig –Kefdag chromite ore in Turkey using a Multi-gravity Separators, MGS, was reported by gence in 1999.The obtained concentrate assayed 52.1%Cr2O3 and a recovery of 69.6% at the optimum operating conditions [7].

2. MATERIALS AND METHODS

2.1. Chromite Ore

Low grade chromite samples each of about 150 kg was collected from the rest of the ore left after high-grade lumps have been sorted out by hand sorting. The samples were collected from different pits in the dump mine area to represent, to some extent, the actual dumps, at the Ingassana Hills Blue Nile State.

The sizes greater than 3.35mm were crushed to minus 3.35mm. These minus 3.35mm sizes materials were divided to four portions to be used in beneficiation experiments. This fraction was deslimed using a hydrocyclone at a cut size of 100µm, which made the feed fraction to be -3.350mm +100 µm .The major associated gangue mineral was serpentine density 2.6g/cm³ together with few olivines mineral 3.2g/cm³. The density of the chromite mineral is about 4.6g/cm³. This significant difference in specific gravities between the constituting minerals gives a concentration criterion of more than 2.2 and it suggests the use of the gravity separation techniques for upgrading the chromite ore sample.

2.2. Heavy Media Material

Ferrosilicon alloy was used to make the media solutions having different specific gravities, 3.6, 3.3, 3.0, and 2.7. Ferrosilicon alloy of Sp.Gr. 6.8 is an alloy of iron and silicon which contains 82%Fe and 15%Si was used throughout this study. The mount of ferrosilicon which makes the heavy media with water is treated by magnetic separation to separate the ferrosilicon particles from the employed medium in order to be re-circulated again to the process.

2.3. Characterization of the Ore

2.3.1 Microscopic Examination

Under the optical microscope it was observed that the broken crystals in chromite tailings which are derived from the main ore body. The assemblage is produced by minerals mostly associated with serpentine and olivine. The gangue part of the remaining high-grade ore is exist as fine ore of size ranges from (-2 inch to + 1.5 inch), which have been recovered, in photomicrograph, (see Fig. 1).
Photomicrograph in Fig. 1 showed the brown crystals (partly black crystal) are chromite .The ground mass consists of serpentine, talc and olivine.

2.3.2 Chemical Analyses

Table 1,below, gives the chemical analysis of the chromite ore sample used in this research work .It is obvious that the chromite content is relatively low, less than 21.56%Cr2O3 and the major gangue material is serpentine.

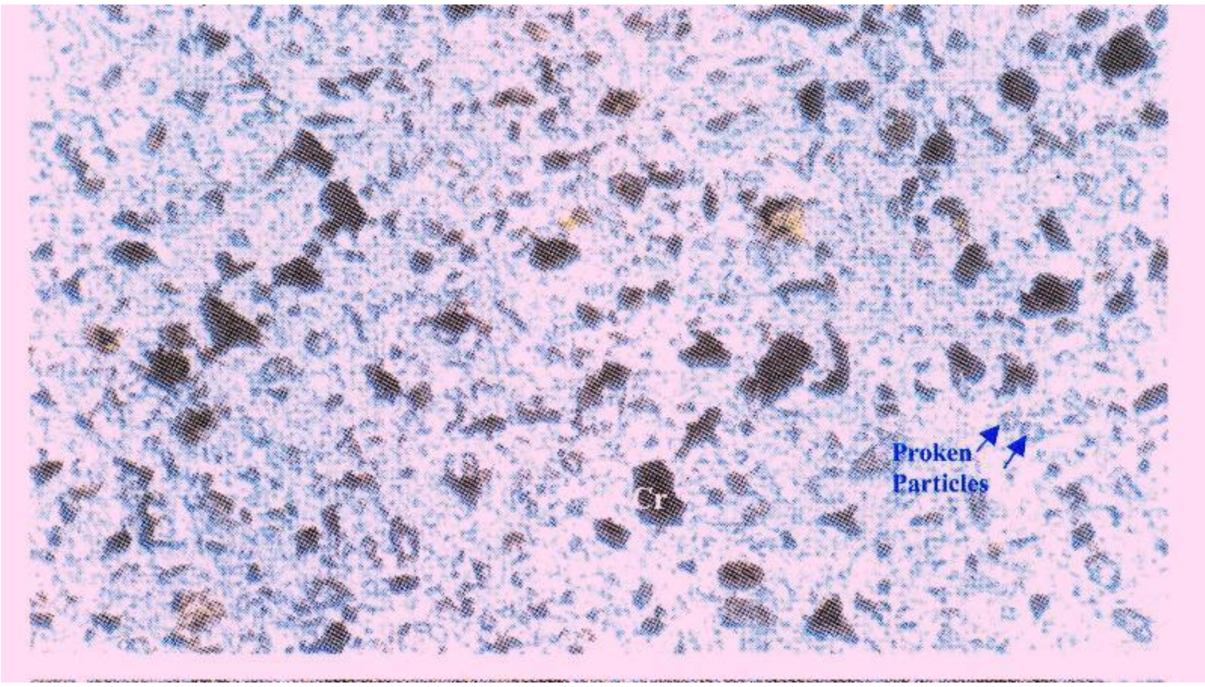

Fig.1. Thin section results

Table 1. Chemical analysis of a chromite ore sample

Constituent	% Cr_2O_3	% FeO	%Al_2O_3	% MgO	%SiO_2	Cr/Fe	CaO
Percent	21.56	7.79	6.11	20.33	22.65	2.42	0.31

Desliming of the ore sample fraction -3.35mm product was carried out using a hydrocyclone to remove the minus 100um particles. Table2 shows the results of desliming tests. The slimes fraction range is 6.95% by weight with rejected amount of 4.16% Cr_2O_3.Table2 also shows the results of a screen analysis performed on tailings dumps chromite for preliminary evaluation of suitability for treatment. The screen analysis results show that less of the chromite 10.67% is present in the -0.5mm fraction, which constitutes only 13.68% of the total bulk of the material. This indicates that these materials could be easily processed.

2.2 Procedure

The representative sample of coarse ground ore is introduced into a liquid of high density. The floats product is removed and washed and placed in a next liquid having lower density, whose float product is then transferred to the next lower density and so on. The sink product is finally drained, washed and dried, and then weighed, together with the final floats product, to give the density distribution of the sample by weight. In this process it is very necessary, for the viscosity of media should be constant during the operation.

Table 2. Classification of the feed fractions

Size range (mm)	%Weight	Cum %W	Assay %Cr_2O_3	Cr_2O_3 Units	CumCr_2O_3 Units	%FeO	Distribution % Cr_2O_3	Cum Distribution % Cr_2O_3
-3.3+1.18	59.1	59.1	18.87	11.15	11.15	7.21	51.73	51.73
-1.18+0.5	27.22	86.32	29.78	8.11	19.26	9.51	37.6	89.33
-0.5+0.1	6.73	93.05	20.85	1.40	20.66	7.9	6.51	95.84
-0.1	6.95	100	12.91	0.9	21.56	5.89	4.16	100.00
Feed	100.00		21.56	21.56		7.79	100.00	

3. RESULTS AND DISCUSSION

3.1 Gravity Separation Tests

Two series of separation experiments were carried out; one for different specific gravities 3.6, 3.3, 3.0, and 2.7, and the other for different particles size ranges of the feed.

Table 3 summarizes the effect of the different specific gravities to the HMS on the assay and metal distribution of the concentrate. It could be seen that the material being heavier than specific gravity fraction 3.3 was 42.61% and only 5.35% of Cr2O3 would be lost for this fraction, similarly 94.65 % of Cr2O3 would be recovered into the sink product. Which its yield accounts for 38.06 % of the original total feed weight.

3.2 Effect of Feed Size Fraction

To study the effect of feed size fraction on the grade and recovery of the chromite, two alternatives were attempted. Table 4 shows the effect of the whole feed size fraction of the deslimed materials -3.35+0,5mm on the heavy media separation performance to concentrate of chromite ore .The specific gravities of the medium were 3.6 and 3.3.

The chromite ore (-3.35mm +0.5 mm) was used as the heavy media feed and the size fraction -0.5 mm was excluded. The results of this alternative were shown in Table 4.The grade and recovery of the concentrate was 46.5 %Cr2O3 and 85.48%Cr2O3, respectively.

Table5 shows effect of feed size fraction of the deslimed ore on the heavy media separation performance for concentrating of the chromite ore. The specific gravity of the medium is 3.6 and 3.3 g/Cm³. In this alternative, an attempt was made to split the feed into three fractions-3,35+1.18, -1.18 +0.5 and -0.5 +0.1 mm .Table 3 presents the results obtained in this series of experiments. The Combined concentrate assay is 45.86 %Cr2O3 at a recovery of 83.93%Cr2O3.

Table 3. Effect of different specific gravities of feed size fraction range -3.35 +0.5mm

Specific gravity of heavy media.	Sink Product %W	Cum Sink Product.	Assay % Cr2O3	Cr2O3 Units	Cum Cr2O3 Units	% Cr_2O_3 Recovery	Cum %Cr_2O_3 Recoveries
3.6	38.20	38.20	47.0	17.95	17.95	86.90	86.90
3.3	4.41	42.61	36.3	1.60	19.55	7.75	94.65
3.0	15.30	57.91	4,50	0.69	20.24	3.33	97.98
2.7	42.09	100.00	0.99	0.42	20.66	2.02	100.00

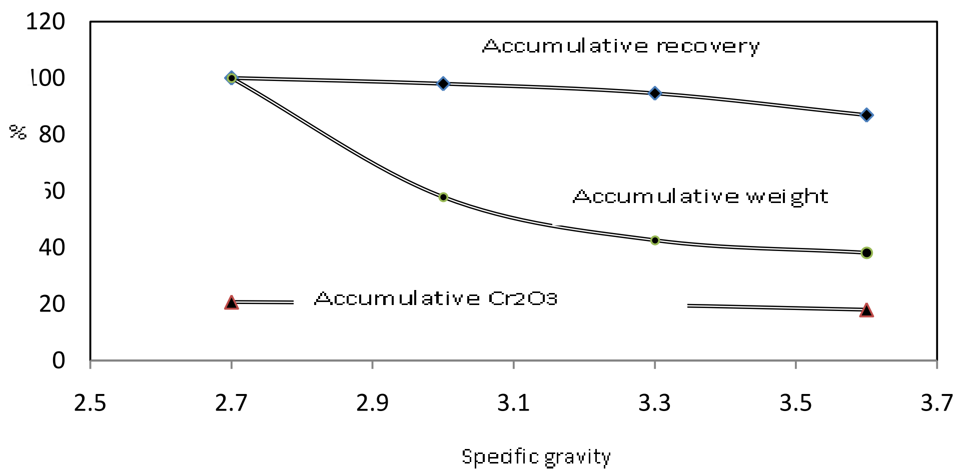

Fig. 2. Relation between specific gravity and accumulative recovery, accumulative weight and accumulative Cr_2O3 content

Table 4. Effect of the whole feed size fraction of the deslimed material

Size fraction (mm)	Product	Product %W	Assay %Cr2O3	Cr/ Fe	Metal Distribution	Metal Distribution relative to original weight %
-3.35+0.5	Sink at 3.6	38.1	47.70		87.97	78.6
	Sink at 3.3	4.41	36.10		7.70	6.88
	Total Sink	42.51	46.45	3.52	95.67	85.48
	Float at 3.3	57.49	1.56		4.33	3.87
	Total	100.00	20,66		100.00	89.35

Table 5. Effect of feed size fraction of the deslimed ore on the heavy media

Size fraction (mm)	Product	Product %W	Assay %Cr2O3	Cr/ Fe	Metal Distribution	Metal Distribution relative to original weight %
-3.35+1.18	Sink at 3.6	17.73	49.70		42.65	
	Sink at 3.3	5.12	30.74		7.62	
	Total Sink (1)	22.85	45.45	3.3	50.27	48.18
	Float at 3.3	36.25	2.14		3.75	
	Total	50.10	20,66		54.02	
-1.18 +0.5	Sink at 3.6	11.89	50.70		24.18	
	Sink at 3.3	4.90	34.50		8.18	
	Total Sink (2)	16.79	45.97	3.45	37.36	35.80
	Float at 3.3	10.43	3.70		1.87	
	Total	27.22	20,66		39.23	
-0.5 +0.1	Sink at 3.6	2.53	30.40		3.70	
	Sink at 3.3	0.50	27.60		0.67	
	Total Sink(3)	3.05	29.60	2.69	4.37	4.15
	Float at 3.3	3.70	11.50		2.06	
	Total	6.73	20,66		6.79	
Combined total sink (1+2)		39.64	45.86	3.44	87.63	83.93

4. CONCLUSIONS

The following conclusions were reached from this study:

- Most chromite ores currently mined in the Ingassana area are of high grade (more than 46% Cr_2O_3).The high grade ores are marketed without concentration except hand picking sorting, leaving behind coarse waste and all fines less than about 25.4mm in size.
- In Optical microscope examination, it was observed that the broken crystal of chromite tailings derived from the main ore body. The assemblage is produced by minerals mostly associated with serpentine, olivine and talc.
- It is found that the screen analysis results less than 10.67% Cr_2O_3 which is present in the -0.5mm fraction that constitutes only 13.68% of the total bulk of the material, which indicates that these materials can be easily processed by heavy media separation.
- It is evident that the concentrate obtained from dumps, has a remarkable value at specific gravity (3.3, 3.6), and the feed in size fraction (-3.35mm +0.5 mm) was used as the heavy media feed and the size fraction -0.5 mm was excluded. Assayed 46.45 %Cr_2O_3, Cr/Fe more than 3 at a recovery of 85.48%, which can be sold as metallurgical product.

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