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BENEFICIATION OF ELAZIĞ-KEFDAĞ CHROMITES BY MULTI GRAVITY SEPARATOR

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ABSTRACT: *In this study, the possibility of beneficiation of Elazığ-Kefdağ region's chromite by Multi-Gravity Separator was investigated. Petrological and mineralogical analyses of the samples have shown that major constituents were chromite, olivine and pyroxene. The results of beneficiation studies showed that, the concentrate to be sold containing 52.14% Cr_2O_3 was obtainable with 69.57% recovery. The optimum operation parameters determined for concentration of chromite ores are as follows; washwater flowrate of 3 l/min, shake amplitude of 15mm, shake frequency of 4.8 cps, tilt angle of 4^o and drum speed of 220 rpm.*

KEYWORDS: *Multi-Gravity Separator, chromite*

ELAZIĞ-KEFDAĞ KROMİTLERİNİN MULTİ GRAVİTE SEPARATÖR İLE ZENGİNLEŞTİRİLMESİ

ÖZET: *Bu çalışmada, Elazığ-Kefdağ yöresi kromitlerinin Multi Gravite Separatör ile zenginleştirilebilme olanakları araştırılmıştır. Petrografik ve mineralojik incelemeler başlıca bileşenlerinin kromit, olivin ve piroksen olduğunu ortaya koymuştur. Zenginleştirme çalışmalarının sonuçları % 52.14 Cr_2O_3 içeren satılabilir konsantrenin % 69.57 verimle elde edilebileceğini göstermektedir. Optimum deney koşulları; yıkama suyu: 3 l/dk, genlik: 15mm, çalkalama hızı: 4.8 cps, açı: 4^0 ve tambur hızı: 220 rpm olarak belirlenmiştir.*

ANAHTAR KELİMELER: *Multi Gravite Separatör, kromit*

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I. INTRODUCTION

Chromite is an important mineral used in the metallurgy, chemistry and refractory industries. It is also an important strategic element. Chromite ore contains variety of gangue minerals such as serpentine and olivine. Therefore some kind of ore beneficiation is mandatory. The most commonly used beneficiation methods for chromite ores are the gravity methods such as shaking table, jig, spiral and Reichert cone. Beneficiation with heavy medium is also utilised for pre-concentration purposes. In addition, magnetic separation may be preferable depending on the ore characteristics. Flotation is also used for the beneficiation of finely grained ores. Using these conventional methods depending on the liberation particle size of the ore, remarkable amount of fine chromite is lost to the tailings. Because of this reason, all of these methods are partly successful in the fine particle size range [1-7].

The Multi Gravity Separator (MGS) is able to separate two minerals from each other, provided that there is a reasonable difference in specific gravity. The MGS is suitable for the treatment of fines with a maximum particle size of approximately 0.5 mm. Typical applications include the scavenging of precious metals or valuable minerals from tailings; pre-concentrating heavy mineral sands or industrial minerals such as chromite, barytes, anatase, coal etc [8-10].

In this study, the possibilities of beneficiation of Elazığ-Kefdağ chromites is investigated by using a laboratory/pilot scale MGS.

II. EXPERIMENTAL STUDIES

II.1. Sample, Equipment and Method

The chromite sample used for MGS studies was taken from Elazığ-Kefdağ Chromite plant. Petrological and mineralogical analyses of the samples have shown that major constituents were chromite, olivine and pyroxene. The sample was ground to minus 0.150 mm before MGS tests. The analysis of the raw chromite sample is given in Table 1. The sieve analysis and the content of Cr_2O_3 and Fe_2O_3 along with the distribution of Cr_2O_3 are given in Table 2.

Table 1. Complete analysis of raw chromite sample

Content (%)					
Cr_2O_3	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO
38.33	18.00	12.83	9.38	0.40	21.06

Table 2. Sieve analysis and Cr_2O_3, Fe_2O_3 content of sample

Particle Size (mm)	Weight (%)	ASSAYS (%)		Distribution of Cr_2O_3 (%)
		Cr_2O_3	Fe_2O_3	
-0.150+0.105	65.95	39.41	19.64	67.81
-0.105+0.074	14.22	36.94	15.81	13.70
-0.074+0.053	13.36	35.56	14.51	12.40
-0.053	6.47	36.10	13.35	6.09
TOTAL	100.00	38.33	18.00	100.00

A series of batch test were run in order to obtain the optimum operational parameters for the maximum concentrate grade and chromite recovery. The laboratory/pilot MGS of type C900 is used for the tests. The MGS consists of a slightly tapered open-ended drum that rotates in a clockwise direction and is shaken sinusoidal in an axial direction. The parameters affecting the efficiency of separation on MGS are the drum speed (100 to 300 rpm), tilt angle (0^0 to 9^0), shake amplitude (10/15/20 mm), shake frequency (4.0/4.8/5.7 cps), washwater amount (0 to 10 liters per minute) and feed pulp density (10% to 50% solids w/w) [7,11-15].

Feed slurry is introduced continuously midway onto the internal surface of the drum via a perforated ring. Washwater is added via a similar ring positioned near the open end of the drum.

During the experiment the dense particles migrate through the slurry film to form a semisolid layer against the wall of the drum as a result of the high centrifugal forces and the added shearing effect of the shake. The scrapers towards the open end of the drum convey this dense layer where it discharges into the concentrate launder. The less dense particles are carried by the flow of washwater into the tailing launder at the rear end of the drum.

The shake amplitude and frequency drum speed, tilt angle and washwater amount was adjusted, and the MGS, was operated.

A sample bucket was placed under the tailing discharge pipe, another under the concentrate discharge pipe and the other one under the center spillage discharge pipe. 500 grams of dry sample was mixed with one liter of water giving a feed density of 33% solids concentration w/w. The solids were kept in suspension during the test by manual stirring. The feed pulp was poured into the MGS feed vessel at a steady rate of 1.2 liters/minute giving a feedrate of 40 kg/h of dry sample whilst stirring continuously.

In all tests, the total feeding time was 45 seconds. At the end of the feed period, the separator was kept running until the material flow was finished and the washwater was allowed to run for a further 2 or 3 minutes, and the washwater turned off and the MGS was stopped.

Scraper or conveyed product, which collected via the front launder during the feed and the wash period were referred to as concentrate, another product which collected during the feed period was referred to as Tailing 1 and the other one which collected during the wash period was slightly higher in grade and was referred to as Tailing 2.

These samples were dried at 105 ^{0}C, weighed and analysed in order to determine grades and chromite recovery. Throughout the tests, washings and Tailing 2 were combined with concentrate and Tailing 1 respectively.

III. RESULTS AND DISCUSSION

A series of batch tests were run in order to upgrade the ore to over 48.0% Cr_2O_3 with maximum chromite recovery. In order to determine the effects of machine operating parameters, several variables were tested. The operational variables are the washwater flowrate, rotational speed of the drum, the shake amplitude, the shake frequency and tilt angle of the drum. The effects of the operational variables are summarised as follows:

III.1. Washwater Flowrate

The effect of washwater flowrate was examined under the following conditions:

Drum speed	: 240 rpm.	Shake frequency	: 4.0 cps
Tilt angle	: 4^0	Shake amplitude	: 10 mm

Washwater is added close to the concentrate discharge end of the drum. It carries the light particles released by the ploughing action of the scrapers. As it can be seen from Table 3, with increasing washwater flowrate the grade of the concentrate increases whereas the recovery of the concentrate decreases. The experiments indicated that the best results were obtained at washwater flowrate of 3 l/min, and Cr_2O_3 grade was increased to 41.47% with 72.46% recovery.

III.2. Shake Amplitude

A series of MGS experiments were carried out to determine the effect of the shake amplitude on the separation, and the shake amplitude was varied between 10 mm and 20 mm. The variables of MGS were kept constant as given above but washwater flowrate was set as 3 l/min. In practice small amplitude is usually used with a higher shake frequency. The results, given in Table 4, showed that 15 mm shake amplitude produced the best results. The grade of

Cr_2O_3 in concentrate was 44.26%. Increasig the shake amplitude leads to higher concentrate grade but lower recovery.

Table 3. The effect of washwater flowrate

Washwater (l/min)	PRODUCTS	WEIGHT %	ASSAY Cr_2O_3 (%)	RECOVERY Cr_2O_3 (%)
2	Concentrate	74.02	36.20	69.91
	Tailing	25.98	44.40	30.09
3	Concentrate	66.97	41.47	72.46
	Tailing	33.03	31.96	27.54
4	Concentrate	59.78	41.64	64.94
	Tailing	40.22	33.41	35.06
5	Concentrate	55.20	41.98	60.46
	Tailing	44.80	33.83	39.54
6	Concentrate	49.47	42.01	54.22
	Tailing	50.53	34.73	45.78
	TOTAL	100.00	38.33	100.00

Table 4. The effect of shake amplitude

Shake amplitude (mm)	PRODUCTS	WEIGHT %	ASSAY Cr_2O_3 (%)	RECOVERY Cr_2O_3 (%)
10	Concentrate	66.97	41.47	72.46
	Tailing	33.03	31.96	27.54
15	Concentrate	61.13	44.26	70.59
	Tailing	38.87	29.00	29.41
20	Concentrate	53.25	44.60	61.96
	Tailing	46.75	31.19	38.04
	TOTAL	100.00	38.33	100.00

III.3. Shake Frequency

Shake frequency is adjustable and the following options which are 4.0-4.8 and 5.7 cps are available. A higher shake frequency is used with small amplitude, whereas lower frequencies are necessary for larger shake amplitudes. The shake frequency was varied between 4.0 cps and 5.7 cps while other conditions kept constant, but shake amplitude was set as 15 mm. Table 5 shows the effect on Cr_2O_3 grade and recovery, as the shake frequency is varied. An increase in the shake frequency results in a decrease in recovery and an increase in grade. The results indicated that the best results were obtained at a shake frequency of 4.8 cps.

Table 5. The effect of shake frequency

Shake frequency (cps)	PRODUCTS	WEIGHT %	ASSAY Cr_2O_3 (%)	RECOVERY Cr_2O_3 (%)
4.0	Concentrate	61.13	44.26	70.59
	Tailing	38.87	29.00	29.41
4.8	Concentrate	60.25	45.97	72.26
	Tailing	39.75	26.75	27.74
5.7	Concentrate	56.94	46.05	68.41
	Tailing	43.06	28.12	31.59
	TOTAL	100.00	38.33	100.00

III.4. Tilt Angle

The angle of tilt can be adjusted between 0 and 9 degrees. Fine and/or low-density minerals will require a smaller tilt angle; coarse and/or high-density minerals will require a larger tilt angle, that is, the angle used will depend on the nature of the material treated. The angle of tilt was varied between 4 and 8 degrees while other conditions kept constant, but shake frequency was set as 4.8 cps. As it can be seen from Table 6, with increasing tilt angle the grade of concentrate increases whereas the recovery of the concentrate decreases. The experiments showed that the best results obtained at a tilt angle of 4^0, and Cr_2O_3 grade was increased to 45.97% with 72.26% recovery.

III.5. Drum Speed

The rotational speed of the drum is the most dominant operational parameter. Depending on the nature of the material treated, drum speeds of between 160 rpm and 300 rpm, giving "g" forces at the drum surface of 6.5 to 24 g, are required. In the experiments, drum speed was varied between 180 rpm and 240 rpm with other conditions kept constant. The tilt angle was set as 4^0. The results given in Table 7 showed that 220 rpm drum speed produced the best results. The grade of Cr_2O_3 in concentrate was 54.99%. A significant increase in the recovery of concentrate and a decrease in the grade was obtained with increasing the rotational speed of the drum.

Table 6. The effect of tilt angle

Tilt angle (^{0})	PRODUCTS	WEIGHT %	ASSAY Cr_2O_3 (%)	RECOVERY Cr_2O_3 (%)
4	Concentrate	60.25	45.97	72.26
	Tailing	39.75	26.75	27.74
6	Concentrate	56.24	46.12	67.67
	Tailing	43.76	28.13	32.33
8	Concentrate	50.07	46.25	60.42
	Tailing	49.93	30.39	39.58
	TOTAL	100.00	38.33	100.00

Table 7. The effect of rotational speed of the drum

Drum speed (rpm)	PRODUCTS	WEIGHT %	ASSAY Cr_2O_3 (%)	RECOVERY Cr_2O_3 (%)
180	Concentrate	10.56	53.84	14.83
	Washings	21.18	44.10	24.37
	Tailing	68.26	34.14	60.80
200	Concentrate	29.48	54.99	42.29
	Washings	23.84	41.09	25.56
	Tailing	46.68	26.40	32.15
220	Concentrate	43.95	52.14	59.79
	Washings	13.18	39.30	13.51
	Tailing	42.87	23.87	26.70
240	Concentrate	38.87	46.27	46.92
	Washings	23.84	34.41	21.40
	Tailing	37.29	32.56	31.68
	TOTAL	100.00	38.33	100.00

Table 8. The results after washings have been apportioned to concentrate and tailing

Drum speed (rpm)	PRODUCT	WEIGHT %	ASSAY Cr_2O_3 (%)	RECOVERY Cr_2O_3 (%)
180	Concentrate	21.27	53.84	29.88
	Tailing	78.73	34.14	70.12
200	Concentrate	41.73	54.99	59.87
	Tailing	58.27	26.40	40.13
220	Concentrate	51.14	52.14	69.57
	Tailing	48.86	23.87	30.43
240	Concentrate	42.09	46.27	50.81
	Tailing	57.91	32.56	49.19
	TOTAL	100.00	38.33	100.00

IV. CONCLUSIONS

1. Concentration of fine sized chromite ores by Multi Gravity Separator is possible.
2. The optimum operation parameters determined for concentration of chromite ores are as follows;

Washwater flowrate	: 3 l/min	Drum speed	: 220 rpm
Shake amplitude	: 15 mm	Feed density	: 33% w/w
Shake frequency	: 4.8 cps	Feed rate	: 40 kg/h
Tilt angle	: 4^0		

3. As a result of the procedures followed to determine the optimum working conditions, the concentrate to be sold containing 52.14 % Cr_2O_3 was obtainable with 69.57 % recovery (Table 8).

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