Technical and economical applicability study of centrifugal force gravity separator (MGS) to Kef chromite concentration plant

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The results of multigravity separator (MGS) upgrading tests on fine chromite gravity tailings using −100 and −100+150 μm fractions of the initial sample (−1 mm) with 24·7%Cr_2O_3 grade were presented. The metal screen analysis revealed that 20·66% of the total Cr_2O_3 content was present in the −106 μm size fraction. Under optimal operational conditions, a concentrate with 43·7%Cr_2O_3 content and 65·0% chromite yield for the size fraction of −100 μm and a concentrate with 30·5%Cr_2O_3 and 83·3% yield for the size fraction of −100+150 μm could be produced. Shaking table test results revealed that the coarse fraction of the tailings could not be enriched any further owing to the high concentration of interlocked particles. However, a saleable concentrate could be obtained by MGS when the coarse tailings were ground down to −100 μm and used as the feed. The results of the study suggested that multigravity separation of the Kef tailings was technically feasible and economically viable. The payback time of two alternatives suggested for the utilisation of MGS in Kef concentrator was calculated to be <7 months.

Keywords: Fine chromite tailings, Multigravity separator, Gravity separation

Introduction

Chromite is a strategic mineral used in metallurgical, chemical and refractory industries and Turkey is among the countries producing chromite ore, chromite concentrate and ferrochromium. The high grade chromite (30–48%Cr_2O_3) ore reserves of Turkey is ~31 000 000 tons[1] and the fine refuses of gravimetric chromite concentrators which contain 12–20% valuable Cr_2O_3 amounts to ~3 000 000 tons.[2] Turkey's chromite and chromite concentrate exports have reached over 1 500 000 tons in 1995.[3]

Chromite ores contain gangue minerals such as serpentine and olivine which must be separated from the ore by means of a beneficiation process. Although the methods such as heavy medium separation, magnetic separation and flotation are employed depending on the liberation particle size of the ore, they all give rise to significant amounts of fine chromite losses to the tailings.[4–8] On the other hand, conventional gravimetric equipment such as Humphrey spirals, Reichert cones and shaking tables which are widely used for chromite beneficiation in Turkey are of low efficiencies below 100 μm particle size especially in the plants where the process conditions are not optimised and/or the liberation size of the ore is relatively fine. Therefore remarkably high value of fine chromite in tailings has been reported by many researchers[4–7] and slime shaking tables have been used in some concentrators for scavenging purposes.

On the other hand, multigravity separator (MGS), a gravimetric concentrator utilising centrifugal forces to enhance the separation, invented and developed by Mozley Limited UK has been used successfully for upgrading fine cassiterite[9] as well as scavenging of precious metals or valuable minerals from fine tailings and preconcentrating heavy mineral sands, coal, etc.[9]

Furthermore, a number of research work have also been carried out to investigate the recovery of chromite fines from chromite beneficiation plants by MGS and the results were encouraging.[7,9]

Currently, two basic recovery processes seem to be promising for the beneficiation of fine gravity tailings of Turkish chromite ores, namely flotation and fine gravity separation using centrifugal force gravity separators. However, the flotation of fine chromite tailings is very difficult, costly and not applicable due to the gangue minerals containing olivine and serpentine showing electrochemical surface properties similar to chromite.[10] In a recent study, satisfactory results were gathered by flotation combined with wet high intensity magnetic separation and a pilot plant for processing fine chromite tailings has been installed and commissioned.[11,12] However, magnetic separation is in fact a costly technology that consumes a great deal of electrical energy and flotation raises environmental concerns due to use of chemical reagents. On the other hand, the results of semipilot scale tests conducted with a Mozley

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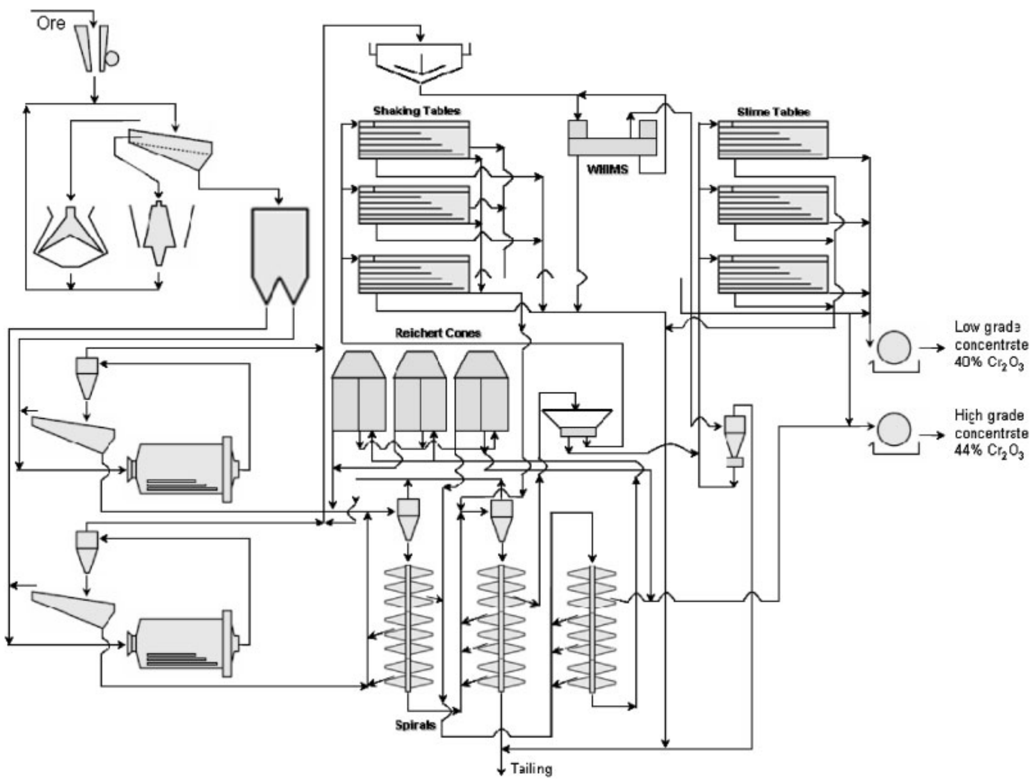


1 Principle flowsheet of Kef chromite ore concentrator

MGS on Turkish chromite tailings were quite promising.[13] In another study,[14] the beneficiation of Kef chromite ore by MGS was investigated by a series of batch tests and the optimum parameters were determined. In optimum working conditions, a concentrate with 52·14%Cr_2O_3 was obtained with 69·57% recovery. However, the metal screen analysis of the representative sample in order to determine the particle size fractions and Cr_2O_3 distributions were not conducted. Therefore, no information was given related to the amount of liberated and interlocked particles in their related particle size fractions. Instead, the whole sample was ground to 150 μm before MGS tests. This could indeed lead to excessive size reduction, increase the amount of ultra fine particles and increase the energy consumption for grinding. The investigation did not include a preliminary economical evaluation.

In this research work, the applicability of Mozley MGS to recover the chromite fines from the fine tailings of Turkish Kef chromite concentrator which was one of the most important chromite beneficiation plants operating in Turkey was investigated employing gravity methods. The Kef concentrator was shut down owing to the unprofitable chromite concentrate prizes at the time and high production costs due to low concentrate yield. The reason for the inefficiency of the plant was mainly the high losses in the fine concentrating stages. The wet high intensity magnetic separator (WHIMS) which was in operation to recover very fine chromite was inefficient and high energy consuming. The slime shaking table units were also working with high chromite losses. The present study was carried out just before the final shutdown of the plant with the purpose of developing a technically and economically feasible beneficiation procedure for the recovery of chromite fines from the tailings of Kef concentration plant. The most important aims of the process to be developed were as follows:

(i) to recover at least 60% of chromite fines from final tailings of the concentrator
(ii) to obtain a marketable quality concentrate that contains 42%Cr_2O_3 at the lowest
(iii) to develop a beneficiation procedure of which the capital costs are low and the payback time is short
(iv) to develop an environmentally friendly process for the recovery of valuable chromite fines from Kef plant tailings.

Experimental

Kef chromite ore concentrator

The flow sheet of Kef chromite ore concentrator is given in Fig. 1. Reichert cones, spirals, shaking tables and WHIMS were the main concentrating equipment of the plant. The concentrator was designed for the treatment of 84 tons h^{-1} chrome ore with about 28–32%Cr_2O_3 content. It was intended to produce two types of concentrate at the same time, namely high and low grade concentrate with 44 and 40%Cr_2O_3 content respectively. The maximum Cr_2O_3 content of the total tailings was targeted to be ~16·0%. However, during production periods, the Cr_2O_3 losses to the tailings were always higher than this value. For instance, the representative head sample for the present study contained 24·7%Cr_2O_3 which was considerably higher than the targeted value of 16·0%. Owing to high electrical energy consumption of WHIMS, this equipment was previously shut off and the thickener underflow was diverted directly to the slime shaking tables during the production campaign from which the head sample was taken for the present investigation. Therefore, in a way, a part of the unusual losses to the tailings can be explained by overloaded slime tables.

Material and experimental procedure

The sample collected for the present investigation represents the total tailings of the plant discarded during a production campaign in which the chromite ore with 30–32%Cr_2O_3 was enriched without having used the WHIMS.

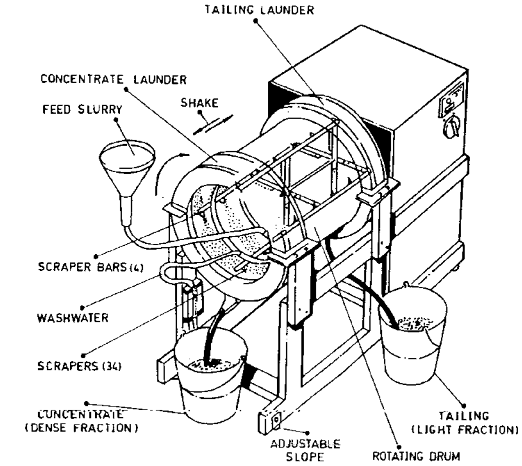
Metal screen analyses of head sample

The metal screen analysis of the head sample (tailings) assaying 24·7%Cr_2O_3 was carried out in order to determine the particle size and Cr_2O_3 distributions and the results are given in Table 1. The wet screening procedure was employed and the chemical analyses were performed in order to determine the Cr_2O_3 content of each individual particle size fraction as seen in Table 1. The Cr_2O_3 content of the tailings in the coarse particle size range (+300 μm) was higher (26·08–29·98%Cr_2O_3) than that of the fine particle size range. This can be attributed to the high amount of interlocked particles in the coarse particle size range rather than to the inefficiency of gravimetric concentrating machines in the plant because the investigations under stereo binocular microscope revealed that the majority (90%) of the particles were interlocked in the +300 μm size fraction. Furthermore, 80–90% of chromite particles were liberated only in the particle sizes smaller than 200 μm. On the other hand, it was also observed that the chromite and the gangue particles below 100 μm particle sizes were mostly liberated. Therefore, the excessive Cr_2O_3 content of the tailings can be attributed to very fine liberation degree of the ore which prevents the efficient operation of the plant equipment. Furthermore, 20·66 and 36·32% of the total chromite content of the head sample was presented in the −106 and −212 μm size fractions respectively (Table 1).

Sample preparation

The head sample collected for MGS and shaking table tests was screened with 100, 150 and 300 μm sieves using a laboratory size screen machine. Since MGS is designed for materials with fine particle size, −150+100 μm and the −100 μm size fractions of the head sample were used as the MGS feed. Shaking table upgrading tests were performed with −300+150 and +300 μm size fractions.

As mentioned above, the total chromite content of Kef concentrator tailings below 106 and 212 μm particle sizes was 20·66 and 36·32% respectively (Table 1). The Cr_2O_3 content of Kef tailings in the fine particle sizes is not very high compared to those in other chromite concentrator tailings. For instance, the Cr_2O_3 content of Karagedik concentrator (a concentrator in the western Turkey) tailings below 106 μm particle size is around 75–80% (Ref. 13). However, when the huge capacity of Kef concentrator (84 tons h^{-1}) is taken into consideration, 20·66%Cr_2O_3 in tailings is a remarkably high value for MGS which is very efficient for such fine particle sizes.



2 Mozley MGS

MGS tests

Multigravity separator

A laboratory/pilot size Mozley MGS of type C900 (Fig. 2) with a nominal capacity of 150 kg h^{-1} which consisted of an open ended conical drum with 500 mm in diameter and 600 mm in length was used for the tests. The drum rapidly rotated in a clockwise direction between 100 and 280 rev min^{-1} and was shaken sinusoidally in the axial direction. The scraper assembly of the drum rotated in the same direction but at a slightly higher speed. The feed in slurry form was introduced continuously onto the internal surface of the drum via a perforated ring. Wash water was added via a similar ring positioned near the open end of the drum. The drum could be tilted between 0 and 8°. During operation the dense particles migrated by means of the high centrifugal forces and the sheering effect of the sinusoidal shakes against the wall of the drum forming a semisolid layer. The scrapers conveyed this dense layer towards the concentrate launder located at the open end of the drum. The light particles were carried by the flow of wash water into the tailing launder at the rear end of the drum. The parameters affecting the separation efficiency of the MGS are the drum speed (100–280 rev min^{-1}), drum slope (0–8°), shaking amplitude

Table 1 Metal screen analyses of head sample

Screen fraction, μm	Weight, %	Cr_2O_3 content, %	Cr_2O_3 distribution, %
+1000	8·8	26·62	9·48
−1000+850	4·1	29·98	4·97
−850+500	20·4	29·04	23·96
−500+300	15·1	26·08	15·93
−300+212	10·8	21·41	9·35
−212+106	18·9	20·48	15·66
−106+75	7·5	22·08	6·70
−75+63	2·5	22·81	2·31
−63+45	5·6	21·27	4·82
−45+38	2·1	24·59	2·09
−38	4·2	27·92	4·74
Total	100·0	24·72	100·00

Table 2 Conditions and results of MGS tests

Test no.	Feed particle size fraction, μm	Drum slope, °	Drum speed, rev min^{-1}	Feedrate of flow, L min^{-1}	Feed Cr_2O_3, %	Conc. Cr_2O_3, %	Tailing Cr_2O_3, %	Conc. weight, %	Yield Cr_2O_3, %
1	−100	6	140	3	22·2	43·7	11·6	33·0	65·0
2	−100	6	150	2	22·2	40·1	9·3	41·9	75·7
3	−100	6	160	2	22·2	37·8	8·2	47·3	80·5
4	−100	6	165	2	22·2	32·5	6·1	61·0	89·3
5	−100	6	175	2	22·2	31·2	5·7	64·7	90·9
6	−100	6	185	2	22·2	29·1	5·1	71·3	93·5
7	−150+100	6	135	2	21·5	38·4	18·8	13·8	24·7
8	−150+100	6	140	2	21·5	38·6	16·8	21·6	38·8
9	−150+100	6	150	2	21·5	30·5	8·5	59·1	83·3
10	−150+100	6	160	2	21·5	28·2	9·2	64·7	84·9
11	−150+100	6	165	2	21·5	30·4	7·3	61·5	87·0
12	−150+100	6	175	2	21·5	27·2	7·3	71·4	90·3
13	−150+100	6	185	2	21·5	25·8	6·5	77·7	93·2

(10–15–20 mm), shaking frequency (4–4·8–5·7 cycles s^{-1}), the amount of washwater (0–10 L min^{-1}) and feed pulp density (10–50% solids by weight).[7,9]

Test procedure

The operation of MGS is very simple since all operational parameters can be adjusted precisely and no middlings are taken. In the present investigation, some parameters affecting the separation efficiency of the MGS such as shaking frequency (4·8 cycle s^{-1}) and shaking amplitude (10 mm) and the amount of wash water (5 L min^{-1}) were kept constant while the others such as drum speed, drum slope, flowrate of feed were changed according to the results obtained. The MGS tests were carried out as continuous tests and the minimum 5 kg of feed in slurry (with 25% solid ratio) form was fed with the aid of a peristaltic pump into the drum. After ~3 min of feeding, the small quantities taken from the concentrate and the tailings in 10 s intervals until the end of the test were mixed together to form the base for the final samples which were analysed for their Cr_2O_3 content. The weight and chromite recoveries were calculated using the grades of feed, concentrate and tailings.

Experimental results and discussions

Results of MGS tests

The test conditions and the results of the tests conducted with the −100 and the −150+100 μm size fractions of Kef tailings sample are summarised in Table 2. As seen in Table 2, the −100 μm size fraction of Kef concentrator tailings contains 22·2%Cr_2O_3. In MGS tests, high Cr_2O_3 yields were achieved at high drum speeds. For instance, at the drum speed of 185 rev min^{-1}, the Cr_2O_3 yield was 93·5% for the −100 μm size fraction but the Cr_2O_3 grade of the concentrate obtained was only 29·1%. The concentrate grade increased as the drum speed decreased followed by a decrease in the Cr_2O_3 yield. According to the test results (Table 2), it can be concluded that the optimum operational parameters of MGS are the drum speeds of 140–150 rev min^{-1} and the drum slope of 6° for the −100 μm size fraction. It is clear that the drum speed has to be <140 rev min^{-1} in order to obtain a concentrate with a grade higher than 43·7%Cr_2O_3. But in this case, a sharp decrease in the Cr_2O_3 yield should be expected.

As seen from Table 2, a saleable product could be obtained from −100 μm size fraction only at a drum speed below 150 rev min^{-1}. Higher drum speeds gave better chromite yields but lower concentrate grades. Based on the test results, it can be concluded that a concentrate with 40·1–43·7%Cr_2O_3 content can be produced with 65·0–75·7% chromite yields at the drum speeds of 140 and 150 rev min^{-1} respectively (Table 2).

It was found out that to obtain a high grade concentrate from −150+100 μm size fraction was impossible even at very low drum speeds. At a drum speed of 135 rev min^{-1}, a concentrate with 38·4%Cr_2O_3 content could be produced with the chromite yield of only 24·7%. The poor Cr_2O_3 yield achieved can be attributed to the relatively poor liberation degree of the chromite particles in the −150+100 μm size fraction and therefore this size fraction must not be used as MGS feed which will affect the Cr_2O_3 concentration process adversely.

Results of shaking table tests

In order to check the performance of the gravity equipment of Kef plant, the shaking table tests were performed with −300+150 μm and −1000+300 μm size fractions of the head sample using a laboratory scale Wilfley type shaking table. The results are summarised in Table 3.

The shaking table test results clearly revealed that the gravimetric equipment of the plant showed a low performance in the −300+150 μm size fraction since a concentrate with 39·02%Cr_2O_3 content could be

Table 3 Results of shaking table tests carried out for tailings of Kef concentrator

Sieve size, μm		Feed	Concentrate	Middling	Tailing
−1000+300	Weight, %	100·0	11·20	49·70	39·10
	Cr_2O_3, %	27·52	37·42	30·9	20·41
	Cr_2O_3 yield, %	100·00	15·22		
−300+150	Weight, %	100·00	20·17	36·03	43·80
	Cr_2O_3, %	22·70	39·02	27·23	11·50
	Cr_2O_3 yield, %		34·67		

obtained with 20·17% weight and 34·67% chromite recoveries. On the other hand, again a low quality concentrate with only 37·42%Cr_2O_3 content with a very low weight recovery of 11·20% and with the chromite yield of 15·22% could be obtained from the coarser size fraction of −1000+300 μm. Thus it can be easily said that, in both size fractions mentioned above, it is not possible to obtain a marketable concentrate with high Cr_2O_3 recoveries. Although the recoverable liberated Cr_2O_3 losses are low in both fractions, they can easily reach to significant amounts in the long term when 84 tons h^{-1} capacity of Kef concentrator is taken into account. However, it must be pointed out that these poor results should not be linked to the plant equipment that does not work under optimum operational conditions. The unusually high chromite losses to the plant tailings can be explained, to a great extent, with poor liberation degree of the chromite particles above 100 μm particle size.

MGS tests with ground sample

The experiments carried out with Kef tailings using MGS and shaking table showed that it was possible to obtain a saleable quality concentrate with sufficient Cr_2O_3 yield from −100 size fraction. The Cr_2O_3 losses in the coarser fractions of the tailings which are not suitable for MGS can be reduced to a certain extent by optimising the process parameters of the equipment installed in the plant. The tailings of Kef concentrator are very rich in chromite due to high amount of interlocked particles as mentioned above. The shaking table tests indicated that the reason of unusually high amount of chromite losses was mainly a result of poor degree of liberation of the ore in the particle size range of +100 μm. Therefore, the total recovery of chromite from coarse particle size range can be improved only by further size reduction down to −100 μm and by the beneficiation treatment using MGS. Such a treatment could be economically beneficial for Kef ores which become liberated in very fine particle sizes. In order to investigate the feasibility of such a process, −1000+100 μm fraction of the Kef tailings was ground to −100 μm in a closed circuit using a laboratory vibrating ball mill. The ground material obtained with a particle size of −100 μm was used as the feed material in MGS tests. The conditions and the results of these tests are given in Table 4.

As seen from Table 4, it was possible to produce a saleable product with 42·80%Cr_2O_3 content and 57·01% chromite yield from the ground tailing of Kef concentrator. In other words, Table 4 shows that it is possible to obtain a marketable concentrate from Kef plant tailings by size reduction down to −100 μm following the MGS stage. However, the Cr_2O_3 yield from the tailings ground to −100 μm was lower than those obtained by classification with the same particle size fraction of −100 μm. The chromite yield remained below 60%. The low chromite yield achieved from ground tailings can be attributed to the relatively high ultra fine fraction content (<5–10 μm) of the sample formed due to dry grinding carried out under laboratory conditions. Nevertheless, by means of proper closed circuit industrial scale wet grinding, the circulating load can be increased and the amount of ultra fine particles can be minimised which will in fact maximise the MGS performance.

Process alternatives suggested for Kef concentrator and preliminary economical evaluation

Kef concentrator was designed to produce two types of concentrate with 44 and 40%Cr_2O_3 content (42% grade in average) from 32% grade chromite ore with a capacity of 84 tons h^{-1}. The maximum Cr_2O_3 content of the tailings was targeted to be ~16–17%. However, the head sample of the tailings collected has shown that the actual Cr_2O_3 content of tailings was much higher (24·7%) than the targeted values. In the preliminary economical evaluations, in order to be able to evaluate the results of the present investigation, the Cr_2O_3 content of tailings was suggested to be 24·7%. The Cr_2O_3 content of the total concentrate and the run of mine were assumed to be 42 and 32% respectively. Two alternatives were suggested for the beneficiation of Kef tailings by MGS:

(i) alternative 1: to separate the −100 μm size fraction of Kef tailings from the rough tailings by using hydrocyclones and to enrich it by MGS. The mass/metal balance of this alternative is given in Fig. 3

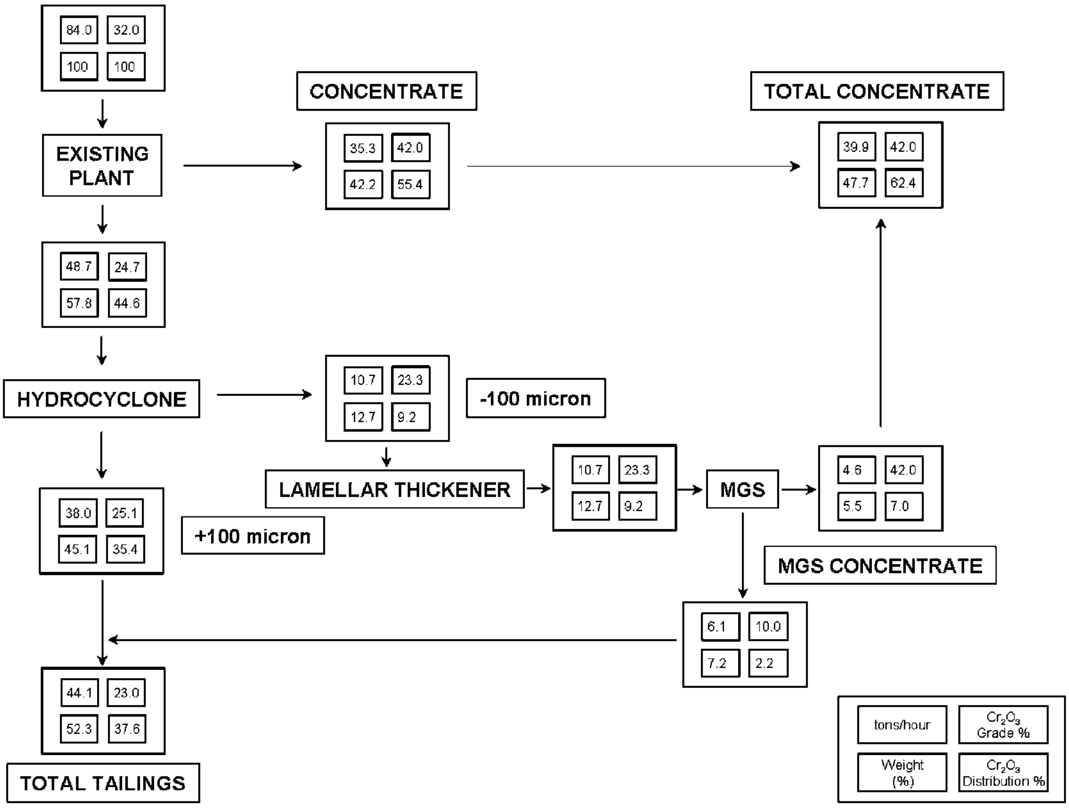
(ii) alternative 2: to separate the −100 μm size fraction of Kef tailings from the coarse size fraction by using hydrocyclones and to grind the course fraction down to −100 μm particle size by a ball mill in a closed circuit with cyclones and to enrich it by MGS (Fig. 4).

The equipment needed for these two alternatives mentioned above and a preliminary economical evaluation was presented in Table 5. According to this evaluation, the amount of the additional concentrate which will be produced in the designed capacity would be 23 000 tons $year^{-1}$ and the yearly profit would be $2 150 000. On the other hand, the amount of the additional concentrate which will be produced in the second alternative would be >67 000 tons $year^{-1}$ with a yearly profit of >$6 200 000.

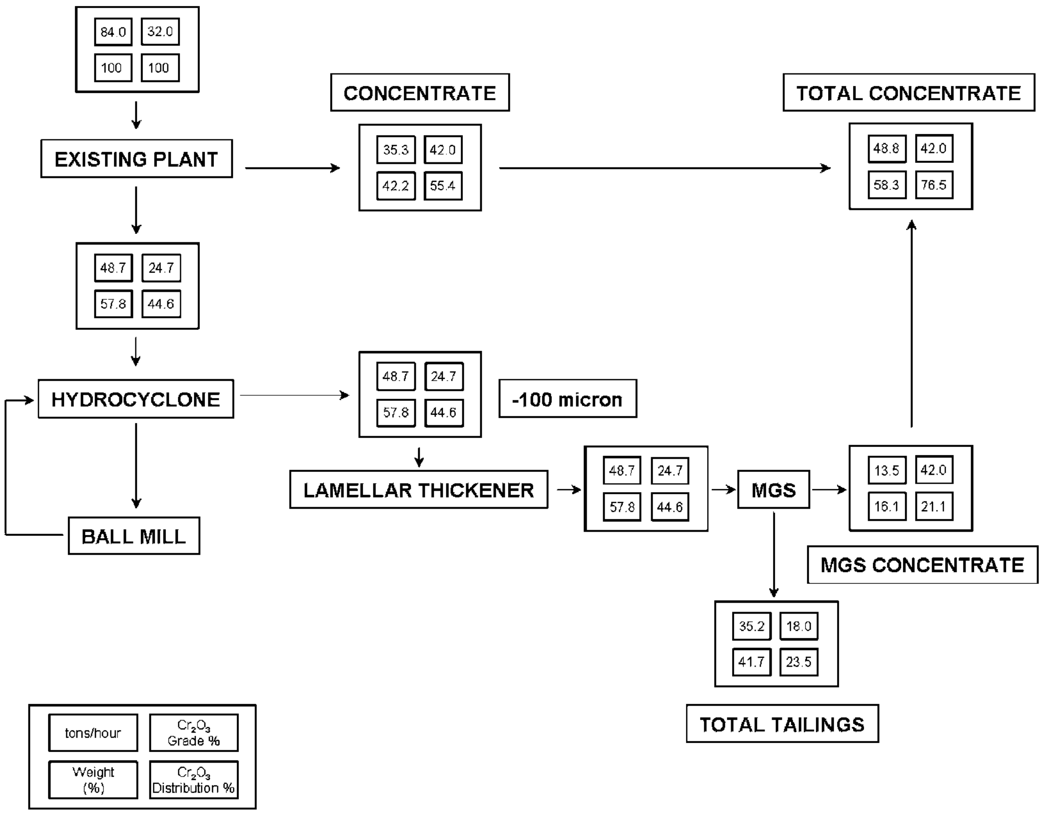
As seen from the preliminary economical evaluation (Table 5), while all the suggested alternatives are rather economical, their capital costs can be paid back in a period of <7 months. The alternative which does not include grinding circuit can be easily fit into the plant and put into operation in a short period of time. The investment for the grinding circuit can be actualised after the first alternative is implemented. The

Table 4 Results of MGS tests carried out with tailings milled below 100 μm

Test no.	Feed, μm	Drum slope, °	Drum speed, rev min^{-1}	Feedrate of flow, L min^{-1}	Feed Cr_2O_3, %	Conc. Cr_2O_3, %	Tailing Cr_2O_3, %	Conc. weight, %	Cr_2O_3 yield, %
Kef									
1	−100	6	140	2	26·23	48·47	19·27	23·84	44·05
2	−100	6	150	2	26·23	42·80	17·33	34·94	57·01



3 Mass/metal balance and flowsheet for alternative 1



4 mass/metal balance and flowsheet for alternative 2

Table 5 Preliminary economical evaluation of two alternatives suggested for beneficiation of tailings of Kef concentrator by MGS

Alternatives	Unit	Kef 1	Kef 2
Plant capacity	tons h^{-1}	84	84
Total operational time	h $year^{-1}$	5000	5000
Tailings to be processed	tons h^{-1}	48·7	48·7
Tailings to be processed	tons $year^{-1}$	243 500	243 500
Additional concentrate to be obtained	tons $year^{-1}$	23 000	67 500
Concentrate value	\$ ton^{-1}	100	100
Capital costs (required equipment)			
MGS 20–25 tons h^{-1}	Unit	1	2
Hydrocylone	Unit	4	8
Ballmill	Unit	–	1
Pump	Unit	1	2
Lamellar thickener	Unit	1	1
Cost of equipment			
MGS (Megasep) 20 tons h^{-1}	\$	750 000	1 500 000
Hydrocyclone	\$	40 000	80 000
Ballmill	\$	–	800 000
Pump	\$	50 000	140 000
Lamellar thickener	\$	100 000	150 000
Others	\$	100 000	200 000
Installation cost	\$	200 000	500 000
Total costs	\$	1 240 000	3 370 000
Expenditure			
Concentrator expenditure (energy, water, grinding media, lining and others)	\$ $year^{-1}$	50 000	250 000
Overhaul and maintenance costs	\$ $year^{-1}$	50 000	150 000
Personnel costs	\$ $year^{-1}$	50 000	100 000
Total expenditure		150 000	550 000
Concentrate sales	\$ $year^{-1}$	2 300 000	6 750 000
Profit	\$ $year^{-1}$	2 150 000	6 200 000
Investment pay back time	Months	7	6·5

characteristics and the approximate costs of suggested equipment in the process alternatives presented above are given in Table 6.

Conclusions

In this laboratory work the technical and the economical feasibility of the recovery of valuable chromite losses from the gravity tailings of Kef concentrator employing MGS was investigated through upgrading tests. The results of the study were as follows.

1. According to the metal screen analysis, the Cr_2O_3 content of the tailings in the coarse particle size range (+300 μm) was higher (26·08–29·98 %Cr_2O_3) than that of the fine particle size range.
2. The head sample with 20·66 and 36·32% of the total chromite content was presented in the −106 and −212 μm size fractions respectively.
3. The investigations under stereo binocular microscope revealed that 90% of the particles were interlocked in the +300 μm size fraction, 80–90% of the chromite particles were liberated only in the particle sizes smaller than 200 μm and finally the chromite and the gangue particles below 100 μm particle sizes were mostly liberated.
4. The MGS concentrate grade increased as the drum speed decreased followed by a decrease in the Cr_2O_3 yield.
5. The optimal operational parameters for MGS were determined to be the drum speeds of 140–150 rev min^{-1} and the drum slope of 6° for the −100 μm size fraction.
6. A concentrate from the −100 μm size fraction with 40·1–43·7%Cr_2O_3 content could be produced with 65·0–75·7% chromite yields at the drum speeds of 140 and 150 rev min^{-1} respectively.
7. To obtain a high grade MGS concentrate from −150+100 μm size fraction was impossible even at very low drum speeds owing to the poor liberation degree of the chromite particles.
8. The shaking table test results clearly showed that to obtain a saleable concentrate was impossible both in the −300+150 μm and −1000+300 μm size fractions due to the high ratio of interlocked particles.
9. The recovery of Cr_2O_3 by MGS from the −100 μm size fraction of the gravity plant tailings was technically and economically applicable (alternative 1).

Table 6 Characteristics and approximate costs of equipment to be used

Equipment	Characteristics	Approximate cost, \$/unit
MGS (Megasep)	20 tons h^{-1} capacity	750 000
Ball mill	Diameter: 3·5 m, length: 5·0 m, engine: 600 kW	800 000
Hydrocyclone	Diameter: 15 inch, rubber lining	10 000
Pump	10×8 inch, engine: 60 kW, adjustable speed+pump tank	70 000
Pump	8×6 inch, engine: 30 kW, adjustable speed+pump tank	50 000
Lamellar thickener	300 m^3 h^{-1}	150 000
Lamellar thickener	100 m^3 h^{-1}	100 000

10. The recovery of Cr_2O_3 from tailings coarser than 100 μm particle sizes was possible by grinding the material down to −-100 μm and by employing the MGS. In this way, the total Cr_2O_3 yield will also be maximised (alternative 2).

11. The Cr_2O_3 yield of the concentrate (wt-%) for alternatives 1 and 2 can be increased by 13 and 38% respectively.

12. The actual Cr_2O_3 yield of the concentrate which is 55·4% by weight can be elevated up to 62·4 and 76·5% by the alternatives 1 and 2 respectively which indicates the recovery of significant amount of valuable Cr_2O_3 from Kef chromite concentrator tailings by the utilisation of MGS.

13. As an added advantage, the use of MGS as suggested in alternatives 1 and 2 eliminates the need for the existing WHIMS which was put out of operation due to its high electrical energy consumption.

14. The preliminary economical evaluation shows that all the suggested alternatives are rather economical and their capital costs can be paid back in a period of <7 months. The alternative 1 which does not include grinding circuit can be easily fit into the plant and put into operation in a short period of time. The investment for the grinding circuit can be actualised after the alternative 1 is implemented.

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