JME

Journal of Mining & Environment,
Vol.8, No.4, 2017, 567-571.
DOI: 10.22044/jme.2017.932

Prediction of effect of fine particle removal on efficiency of a spiral circuit by size-by-size partition curves

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Received 14 April 2017; received in revised form 18 May 2017; accepted 24 May 2017
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Abstract
Partition curves are widely used to determine the spiral separator efficiency. In this work, the partition curves were used in order to investigate the particle transportation to concentrate and tailing streams. Simulation of fine particle removal using the size-by-size partition curves showed that the recovery of gangue particles to concentrate can decrease 8.7%. It also showed that the recovery of valuable particles would increase by 6.5% and reaches 90%. Therefore, pilot-scale tests were conducted to verify the simulations. After removal of fine particles from the feed of spiral separator and treating the removed materials with high-intensity magnetic separator, total mass recovery, iron recovery, and iron grade increased from 71%, 85%, and 54% to 80%, 91%, and 56%, respectively.

Keywords: *Spiral Separator, Gravity Separator, Size-by-Size Partition Curve, Simulation, Separation Efficiency.*

1. Introduction

Spiral separators that have considerable advantages such as low installation cost per ton and low energy cost are commonly used in the processing of heavy minerals and coal [1-3]. Partition curves are widely used to determine the spiral separator efficiency by defining the particle separation efficiency as the probability of particle recovery to one of the output streams based upon size or density of the particles. Partition curves of classifiers and gravity separators are often measured as a function of particle size and density, respectively [4-6].

Various research works have been conducted on partition curves of gravity separators, describing the effects of the operational and geometrical parameters involved such as particle size, feed rate, wash water, and spiral length on the partition curve [7-11]. However, very few research works can be found on simulation of the separation process based on the size-by-size partition curves. In this work, we applied the measured size-by-size partition curves to simulate the effect of fine particle removal on the spiral separators of DTP (Dry Tailing Processing) line of Hematite Recovery and Desulphurization Plant of Golgohar mine. The circuit consists of roughing, cleaning, and scavenging spirals (Figure 1). The results of the particle removal simulation using partition curves measured from the samples of the circuit of the spiral separators are compared with the data measured from the experiments executed in the pilot scale. Classifying the materials by size and treating them with different methods are suggested in this paper since feeding in an optimum range of particle size (reducing the production of fine particles) is not possible, considering the nature of the circuit feed, which is the old deposited tailings of another plant.

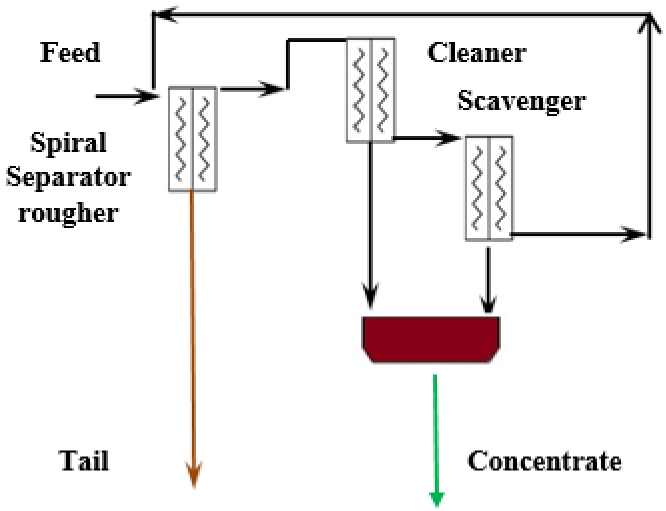


Figure 1. Flow sheet of spiral circuit of DTP line of Golgohar.

2. Methods and materials

2.1. Sampling and sink-float analysis

The samples were collected from the tailing and concentrate streams of rougher, cleaner and scavenger spirals of DTP line and pilot-plant spiral. The pilot spiral was the same as the industrial one, a SC-20 Multotec spiral. The sink-float analysis was performed on the collected samples. Each sample was classified into 4 density classes of +3.3, 3-3.3, 2.8-3, and -2.6 g/cm^3. Then the size distribution of each class was determined.

2.2. Partition curve

The size-by-size partition curves were determined by combining the sink-float analysis and the size distribution data. Particles were classified into 3 size classes: coarse (710-2500 µm), medium (250-710 µm), and fine (35-250 µm) particles; and Eq. (1) was employed to obtain the size-by-size partition curves. The recovery in the concentrate stream of the density class of i within the size interval j is noted as $R_{i,j}$ [10]:

$$R_{ij} = \frac{Cc_i x_{cij}}{Ff_i x_{fij}} \quad (1)$$

where F and C indicate the solid flow rate of the feed and the concentrate streams, respectively. c_i and f_i stand for the weight retained in the ith density class of concentrate and feed, respectively, while x_{cij} and x_{fij} are used for the concentrate and feed material content in size class j of density class i, respectively. The circuit partition curve was obtained by combining the partition curves of three separation stages.

2.3. Simulation of fine particle removal

The size-by-size partition curves of spiral separators obtained through Eq. (1) were coded in MATLAB and used for predicting the effect of fine particle removal in the spiral circuit. Considering the circuit configuration (Figure 1), the circuit feed, which was the subtraction of rougher separator feed and scavenging recirculation stream, was obtained through Eq. (2) by the linear circuit analysis method:

$$F_{i,j} = F_{Ri,j} * (P_R P_C - P_R + P_R P_S - P_R P_C P_S + 1) \quad (2)$$

where $F_{i,j}$ and $F_{Ri,j}$ are the flow rates of the circuit and rougher feed in the ith density class and jth size interval, respectively. P_R, P_C and P_S are the roughing, cleaning, and scavenging size-by-size partition curves, respectively.

2.4. Validation of simulation of fine particle removal

One industrial spiral was moved from the plant to the pilot and installed in a closed continuous system (Figure 2). The validation tests were conducted in pilot scale on two samples taken from the circuit feed. For one sample, it was tried to remove the particles finer than 250 µm by screening; however, due to the non-ideal screening process, some fine materials still existed in the sample.

Figure 2. Pilot-plant spiral installed in a closed continuous system.

2.5. HIMS test on removed fine particles

Considering the abundance and high iron content of fine particles and the decrease in total recovery due to the elimination of fine particles, an HIMS (High-Intensity Magnetic Separator) test was conducted on these particles to show the possibility of treatment of fines by the HIMS device of the DTP circuit after the spirals. A laboratory HIMS with a magnetic field intensity of 8000 Gauss was used and the iron contents of the concentrate and tailing streams were measured.

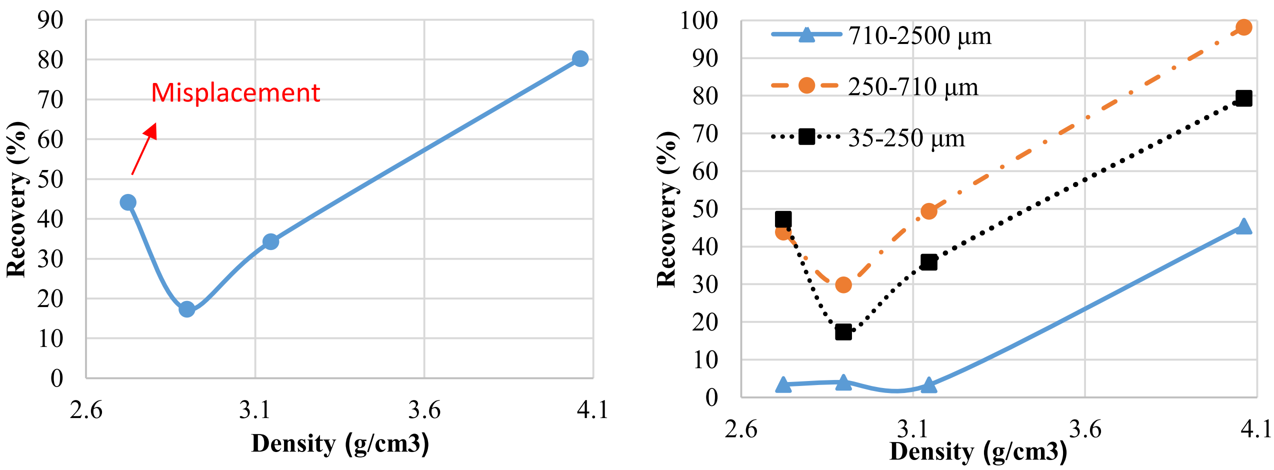
3. Results and discussion

3.1. Sampling and circuit partition curve

The circuit partition curve (Figure 3a) obtained by combining the rougher, cleaner, and scavenger partition curves showed that approximately 45% of gangue (light, mostly Silica) particles was deported to concentrate, resulting in a reduction of quality of the product. Thus reducing the effect of particle entrapment and misplacement could be the key to increase the quality of the final product.

3.2. Size-by-size partition curve

The size-by-size partition curve of the DTP spiral circuit (Figure 3b) shows that the circuit has the best gangue separation performance in the size range of 710-2500 µm, where entrapment and entrainment are inconsiderable. Recovery increases to 50% as the particle size decreases from coarse size range (2500-710 µm) to fine size range (250-35 µm). Thus the decrease in quality of the final product could be associated with the incorrect separation of gangue in the size range of 35-710 µm.



(a) (b)

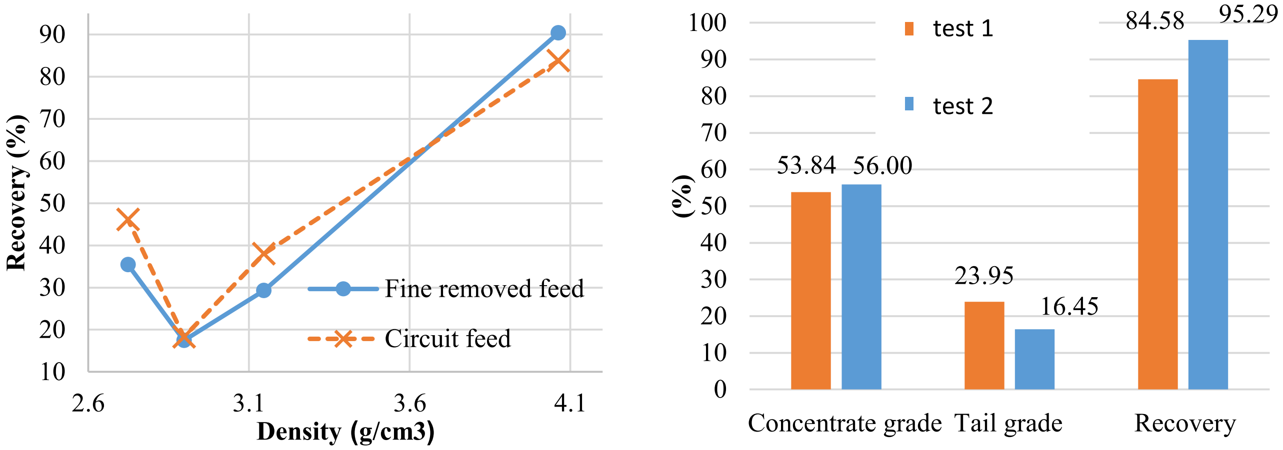
Figure 3. (a) Partition curve of DTP spiral circuit. (b) Size-by-size partition curve of DTP spiral circuit.

3.3. Simulation of fine particle removal

Results of simulation of fine particle removal are illustrated in **Error! Reference source not found.**, showing that by removing the particles finer than 250 µm from the feed, recovery of gangue particles of light particles (-2.6 and 2.6-3 g/cm^3) decreases by 9.65%, approximately (8.7% and 10.6%, respectively). Also recovery of valuable particles increases by 6.5% and reaches 90%. Thus removal of fine particles of the feed before introducing them to the circuit increases the recovery and final product quality.

3.4. Validation of simulation of fine particle removal

Error! Reference source not found. presents a graphical comparison of the results of iron recovery and grade of two tests conducted on the circuit feed sample and the de-slimed feed sample (fines removed) using pilot-scale spiral. According to the results obtained, it can be specified that the spiral separator performance of test 2 in which the fine particles have been removed from the feed improved, which confirms the simulation results. The recovery and concentrate iron grade increased by 10.7% and 2.2%, respectively, and tailing iron grade decreased by 7.5%. Although it should be noted that the removed portion of the feed containing fine particles is not considered in the calculation of the recovery and if they are disposed of, the circuit total recovery decreases to 76.6%, eventually. The HIMS test was done on the fine particles to show the possibility to recover the Hematite from the removed fine particles to increase the total recovery.



(a) (b)

Figure 4. (a) Simulation of fine particle removal effect on DTP spiral circuit partition curve. (b) Iron recovery and grade of two pilot-scale tests (test 1: original sample, test 2: fines removed from sample).

3.5. HIMS test on removed fine particles

Thec results of Davis tube test showed that the FeO content of the removed fine particles is scant, and therefore, the fines can directly go to HIMS. According to the results obtained, after removing the fine particles from the feed of spiral separator and treating the removed materials with HIMS total mass recovery, iron recovery and iron grade increased by 10%, 6%, and 2%, respectively. Comparison of the results is depicted in Table 1.

Table 1. Comparison of results of separation by HIMS and spiral with different feeds.

Test	Iron recovery %	Mass recovery %	Concentrate iron grade %
Test with circuit feed (Test 1)	84.58	70.47	53.84
Test with de-slimed feed (Test 2)	95.29	90.07	56.00
HIMS test	39.70	25.00	55.20
Combination of Test 2 & HIMS	90.76	80.31	55.96

4. Conclusions

The results of size-by-size partition curves show that mis-transportation of the fine particles to the undesired places (the innermost region of the trough) has the most important effect on the spiral performance of DTP line of Hematite Recovery and Desulphurization plant of Golgohar. Removal of fine particles was simulated using the partition curves obtained by the sink-float tests on the samples gathered from the circuit and from the pilot. The results obtained show that it is possible to increase the recovery of heavy valuable particles up to 90%, while decreasing the recovery of gangue light particles to 38%. Pilot-scale tests were conducted to validate the simulations; these results also showed that the concentrate iron grade increased by 2.2% and the tailing iron grade decreased by 7.5%. The decrease in the total recovery of the circuit due to removal of fine particles from the feed can be solved by treating them with HIMS. This subject was examined by a laboratory HIMS, and the results obtained show that it is possible to reach the total recovery and grade of 90.76 and 55.96 percent, respectively, which are 12.76 and 1.56 percent above the current values of the circuit.

Acknowledgments
The authors acknowledge the helps of Golgohar Iron ore and Steel Research Institute in conducting the sampling campaigns, pilot tests, and financial supports.

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پیش‌بینی اثر حذف ذرات ریز بر کارایی یک مدار جداکننده مارپیچی با استفاده از منحنی‌های جدایش اندازه به اندازه

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ارسال ۲۰۱۷/۴/۱۴، پذیرش ۲۰۱۷/۵/۲۴

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چکیده:

منحنی‌های جدایش به صورت گسترده‌ای برای تعیین کارایی جداکننده‌های مارپیچ استفاده می‌شوند. در این پژوهش، از منحنی جدایش برای بررسی انتقال ذرات به جریان‌های کنسانتره و باطله استفاده شد. شبیه‌سازی حذف ذرات ریز با استفاده از منحنی‌های جدایش اندازه به اندازه نشان داد که بازیابی ذرات گانگ به کنسانتره می‌تواند ۸/۷٪ کاهش یابد. همچنین، نشان داده شد که بازیابی ذرات با ارزش نیز می‌تواند با ۶/۵٪ افزایش به ۹۰٪ برسد. در نتیجه، آزمایش‌های نیمه‌صنعتی برای اعتبارسنجی نتایج شبیه‌سازی انجام شد. پس از حذف ذرات ریز از خوراک جداکننده مارپیچ و فرآوری ذرات حذف‌شده با جداکننده مغناطیسی شدت بالا، بازیابی کل، بازیابی آهن و عیار آهن به ترتیب از ۷۱٪، ۸۵٪ و ۵۴٪ به ۸۰٪، ۹۱٪ و ۵۶٪ افزایش یافت.

کلمات کلیدی: جداکننده مارپیچ، جداکننده ثقلی، منحنی جدایش اندازه به اندازه، شبیه‌سازی، کارایی جدایش.