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Systematic Separation Studies on Finely Dispersed Raw Magnesite by Using Triboelectrostatic Belt Separation

Sabrina Gehringer, Christoph Luckeneder, and Helmut Flachberger

Chair of Mineral Processing, Department Mineral Resources Engineering, Montanuniversität Leoben, Leoben, Austria

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Abstract: In the course of this study, systematic test series were examined to analyse and optimise the sortability of raw magnesite by using triboelectrostatic belt separation. The objective of the study was to find a dry sorting process for the separation of raw magnesite from accompanying components such as other carbonates and silicates. The aim of this test series was to develop knowledge about the optimal operating parameters for the triboelectrostatic separation of raw magnesite. All sorting tests were carried out with a triboelectrostatic belt separator type "ST X2" in an air-conditioned room at the Chair of Mineral Processing, Montanuniversität Leoben, Austria.

Keywords: Electrostatic separation, Mineral processing, Raw magnesite, Dry processing methods

Systematische aufbereitungstechnische Untersuchungen an feindispersem Rohmagnesit mittels triboelektrostatischer Bandscheidung

Zusammenfassung: Im Rahmen dieser Studie wurden systematische Versuchsreihen durchgeführt, um die Sortierbarkeit von Rohmagnesit unter Verwendung der triboelektrostatischen Bandscheidung zu analysieren und in weiterer Folge zu optimieren. Ziel der Studie ist es, ein trockenes Sortierverfahren zu finden, um die Begleitkomponenten des Rohmagnesits – wie andere Karbonate und Silikate – möglichst vollständig abzutrennen. Ziel dieser Versuchsreihen war es, Erkenntnisse über die optimalen Betriebsbedingungen für die Sortierung von Rohmagnesit zu gewinnen. Alle Sortierversuche wurden mit einem triboelektrostatischen Bandabscheider der Type „ST X2" in einem klimatisierten Raum im Aufbereitungstechnikum des Lehrstuhls für Aufbereitung und Veredlung durchgeführt.

Schlüsselwörter: Elektrostatische Sortierung, Mineralaufbereitung, Rohmagnesit, Trocken-Sortierverfahren

Dipl.-Ing. S. Gehringer (✉)
Chair of Mineral Processing, Department Mineral Resources Engineering,
Montanuniversität Leoben,
Franz-Josef-Str. 18,
8700 Leoben, Austria
sabrina.gehringer@unileoben.ac.at

1. Introduction and Motivation

Raw magnesite is found in most deposits along with limestone, dolomite, ferruginous minerals, quartz and other silicates. The most important quality criteria for magnesite concentrates are the contents of MgO, CaO, SiO_2 and for some applications also Fe_2O_3. These components lower the melting point, which negatively affects the processing of the magnesite concentrate. In the coarse fractions the concentration of magnesite is often achieved by utilising selective extraction and crushing, manual and sensor-based sorting, density sorting and dry magnetic separation. For achieving a separation effect in the fractions smaller than one millimetre wet processing technologies such as wet magnetic separation and flotation are applied. Especially for the fraction smaller than 200 μm flotation is to some extend irreplaceable.

Due to natural breakage characteristics of crude ores fractions smaller than 200 μm will always be resulting from mining, crushing and milling activities. Dumping those fractions contradicts economic pressure nowadays. The maximization of recovery of minerals in the mined ore is necessary for a successful mining operation. The responsibility towards future generations of the minimization of wasting natural resources leads to the same direction.

Nevertheless, a sustainable and future-orientated usage of a deposit makes the processing of the fractions smaller than 200 μm necessary. Due to the increasing demand for high-grade concentrates, the importance of a separation technology for fractions smaller than 200 μm will increase in the future. In situations and areas where access to water for processing is limited or not available, a water-free

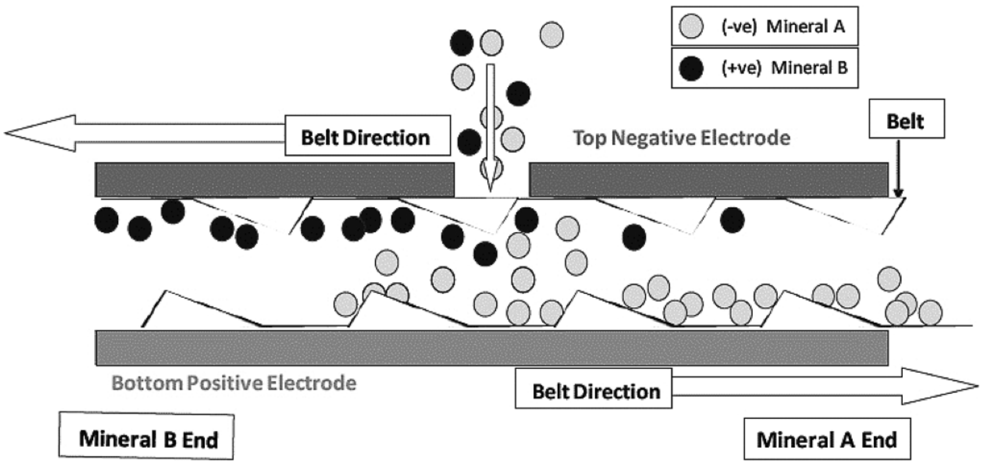

Fig. 1: Operation principle of a triboelectrostatic belt separator [7]

processing technology will be an essential alternative [1, 2].

The company "Styromag Steirische Magnesitindustrie GmbH" provided the raw magnesite for the separation tests. The philosophy of this company is strongly geared to sustainability and pursues the goal of sensible and sustainable use of natural resources. This corporate policy and readiness for sustainable raw material production offers an optimal basis for carrying out joint research in the field of dry mineral processing [3].

2. Electrostatic Separation

The separation in the electrostatic field offers an alternative for the well-developed and widely used flotation technology. In contrast to flotation the separation in an electrostatic field is a dry separation technology.

The separation features in the field of electrostatic separation are the different sizes of the charge or opposite charge of the particle surfaces.

An electrostatic separation process is a two-step process. It is necessary to distinguish between the charging of the surfaces of the particles and the separation of the charged particles in the electrostatic field. The charging of the particle surfaces is based on differences in the surface properties of the mineral phases. Electrostatic separation is sub-divided into two different challenges: the separation of conductors versus non-conductors and the separation of non-conductors versus non-conductors.

The separation of conductors versus non-conductors is based on the surface conductivity of the mineral phases. The charging of the particle surfaces is done by induction or with a corona electrode. For the separation of conductors versus non-conductors mostly drum separators are in use.

The processing of mixtures of non-conductors is based on differences in the surface work function. The generation of the charge differences of the particle surfaces is called tribo polarization. In case the difference in surface work function is high enough, one particle is charged positively and the other one negatively when getting into contact. The separation is done by utilising free-fall separators and belt separators.

Within this paper, the separation tests were conducted using an electrostatic belt separator including the charging of the particles by utilising a triboelectrostatic effect. In the case of the triboelectrostatic belt separator the particles are charged through particle to particle, particle to electrode and particle to belt collisions. The intensity of this electron transfer depends on the size of the contact surface as well as the contact duration, frequency and strength. Often collision effects inside upstream units such as vibro feeders, fluidised bed dryers and cyclones have a charging effect, too [4–6].

The operation principle of a triboelectrostatic belt separator is shown in Fig. 1; [7].

3. Characterization of the Raw Magnesite Sample

To obtain a first impression of the raw magnesite sample, the chemical composition and a particle size distribution were determined. The results of the chemical analysis are summarised in Table 1, the particle size distribution in the logarithmic grid is shown in Fig. 2. According to supplier information, the sample consists of the minerals magnesite, calcite, dolomite, quartz and talc.

TABLE 1
Chemical composition of the raw magnesite sample

MgO	CaO	SiO_2	R_2O_3	Acid insoluble components	Loss in ignition
[%]	[%]	[%]	[%]	[%]	[%]
36.1	2.5	13.0	2.1	19.5	40.9

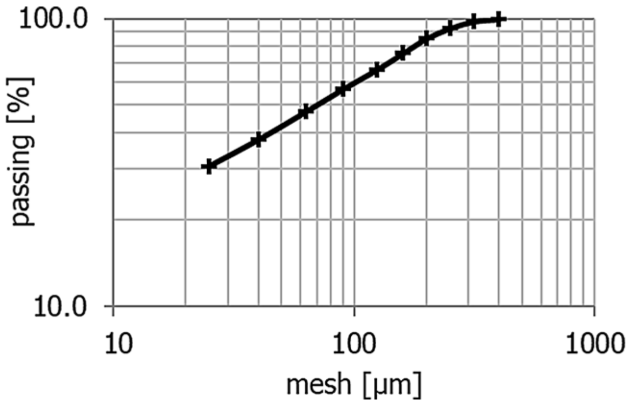

Fig. 2: Particle size distribution of the raw magnesite sample in the logarithmic grid

4. Experimentation

4.1 Experimental Setup

The separation tests were carried out at the "ST X2" triboelectrostatic belt separator. The operational principle has already been shown in Fig. 1. The feed sample passes from above via a vibrating unit into the electrostatic field, which is generated via electrodes arranged one above the other. In the gap between the electrodes a belt, which is basically a large mesh, is running towards itself in a continuous loop. The belt takes care of intensive feed material charging. The charged particles are dragged to the electrodes with the opposite polarisation and are then transported by the belt in the respective direction. The polarity of the electrodes can be reversed on both sides. Product discharge takes place on the left and right side of the machine after leaving the electrostatic field. The two products are collected in bags [8].

4.2 Experimental Design

The experimental design is based on the statistical design of experiments, which is a further development of traditional experimental design methods. Through detailed planning and targeted change of influencing factors, the efficiency of the experimental setup can be increased [8, 9].

4.3 Machine Settings for the Separation of Raw Magnesite

The triboelectrostatic belt separator enables the variation of numerous parameters. In order to gain knowledge about the influence of these parameters on the separation efficiency of the raw magnesite sample, these and their interactions with each other were analysed in detail. For the execution of the separation tests, a fractional factorial test design of type "2^{5-1}" was chosen [8, 9]. The separation success was assessed by determining the chemical composition by means of XRF in combination with the acid insoluble residue and the loss on ignition.

For the determination of the machine settings for the separation of raw magnesite the following machine parameters were changed on the lab scale belt separator: [8]

a) applied voltage
b) electrode distance
c) belt speed
d) polarity of the top electrode
e) feed rate

Ad a) The voltage applied to the electrodes can be infinitely adjusted from 0 to 6 kV. For the tests, the levels for the applied voltage were set at 3 and 6 kV [8].

Ad b) The electrode distance is limited by the geometric conditions. For the maximum distance a value of 14 mm was determined, for the minimum it was 9 mm. These two extremes were taken as a level in the experimental design plan [8].

Ad c) A belt speed of 35.2 fps (10.9 m/s) was defined as the upper level in the design plan. For the lower level 17 fps (5.2 m/s) was selected [8].

Ad d) The polarity of the top and bottom electrode can be set positive or negative. For the generation of an electrostatic field, one electrode must always be positive and one negative. For the experiments, both variants were implemented. Further information on the polarity always refers to the head electrode [8].

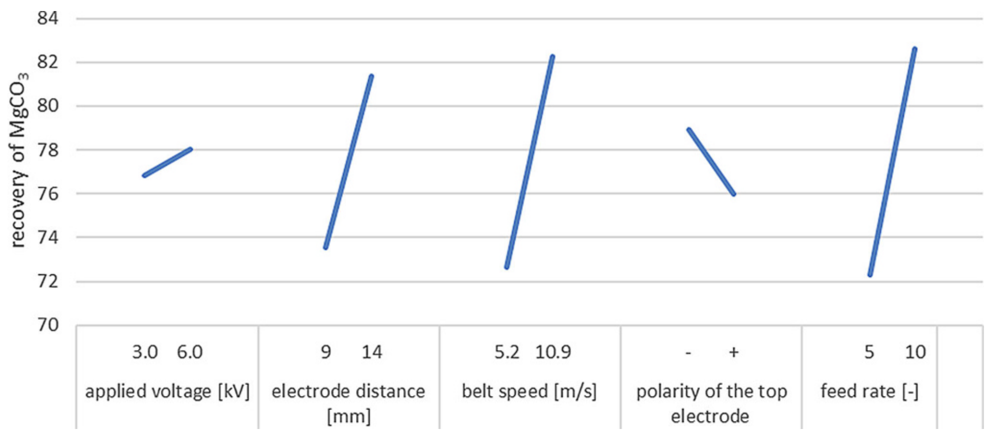

Fig. 3: Effect diagram for the applied test program

TABLE 2
Partial factorial test plan of type "2^{5-1}"

Test number	Belt speed [fps]	Gap between the electrodes [mm]	Applied voltage [kV]	Polarity of the top electrode (+/–)	Feed rate (1–10)
1	17.0	9	3	(–)	10
2	17.0	9	6	(–)	5
3	35.2	9	3	(–)	5
4	35.2	9	6	(–)	10
5	17.0	14	3	(–)	5
6	17.0	14	6	(–)	10
7	35.2	14	3	(–)	10
8	35.2	14	6	(–)	5
9	17.0	9	3	(+)	5
10	17.0	9	6	(+)	10
11	35.2	9	3	(+)	10
12	35.2	9	6	(+)	5
13	17.0	14	3	(+)	10
14	17.0	14	6	(+)	5
15	35.2	14	3	(+)	5
16	35.2	14	6	(+)	10

TABLE 3
Balance sheet of the most successful separation test

	Yield [%]	Grade—$MgCO_3$ [%]	Recovery—$MgCO_3$ [%]
Concentrate	78.9	97.9	90.7
Tailings	21.1	33.7	9.3
Feed	100.0	76.5	100.0

Ad e) The feed rate of the vibro feeder can be adjusted from 1 to 10. The values 5 (about 120 g/min) and 10 (about 250 g/min) were defined as levels [8].

The levels of the parameters a) to e) given here were taken over into a fractional factorial test design of the type "2^{5-1}" which is illustrated in Table 2.

During the execution of the tests, the machine settings were changed as previously defined in the design plan in Table 2. The environmental influences of the system were kept constant as far as possible. The room temperature during all tests was about 25 °C, the relative humidity about 30%.

5. Results and Discussion

The assessment of the machine settings for the separation of raw magnesite was carried out by the average values of the $MgCO_3$ grade and recovery in the concentrate at the 16 different setting combinations (according to Table 2).

The average values were calculated from the results obtained at the different levels, from the two mean values at setting (maximum) and (minimum) the difference between these two values was also formed, which describes the intensity of the influence of the factor [8].

The effect diagram for the applied test program (Fig. 3) indicates the influence of the factors on the separation result. Electrode distance, belt speed and feed rate had a big influence on the separation result. Increasing the level resulted in increasing $MgCO_3$ recovery. Increasing applied voltage increased the $MgCO_3$ recovery as well, but the impact on the separation result was quite low. A negatively charged top electrode resulted in a higher $MgCO_3$ recovery than a positively charged top electrode.

The balance sheet of the most successful separation test is shown in Table 3. The $MgCO_3$ grade was increased from 76.5% in the feed to 87.9% in the concentrate with a yield of 78.9%. 90.7% of the $MgCO_3$ was reported to the concentrate, just 9.3% of the $MgCO_3$ was lost to the tailings product.

Fig. 4 presents a comparison of the recoveries of $MgCO_3$ versus $CaCO_3$ in the products. The recoveries of $MgCO_3$ and $CaCO_3$ correlate to a greater extent. The fact that there are no intergrown particles to be expected in the test feed proves that magnesite, dolomite and calcite were transported to the same product. There was not one single test resulting in magnesite, dolomite and calcite being recovered in different products.

The position of the minerals in the triboelectric series also defines this trend [10].

The associated machine settings for the separation of raw magnesite are summarised in Table 4.

TABLE 4
Machine settings for the separation of raw magnesite

Belt speed	Gap between the electrodes	Applied voltage	Polarity of the top electrode	Feed rate
[fps]	[mm]	[kV]	(+/–)	(1–10)
35.2	14	6	(+)	10

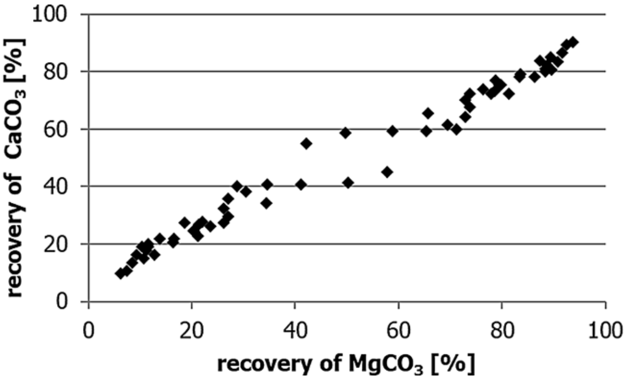

Fig. 4: Recovery of $CaCO_3$ versus recovery of $MgCO_3$

6. Conclusion

In course of the presented study the sortability of raw magnesite with the "ST X2" triboelectrostatic belt separator was confirmed. For an efficient separation, the optimum machine parameters for this raw material (Table 4) must be set.

The presented separation test series showed an impressive separation performance between carbonates and silicates. High mass and $MgCO_3$ recovery in the concentrate combined with a significant increase of the $MgCO_3$ grade in the concentrate prove the applicability of the technology for the tested raw material.

The comparison of the recoveries of $MgCO_3$ and $CaCO_3$ indicate that the carbonates in the feed sample resulted in the same separation behaviour. A separation effect regarding the containing carbonates was not achieved. All tests resulted in a concentrate consisting of a mixture of the carbonates.

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