Applicability of Electrostatic Separation on Talc-Containing Mineral Samples for Production of a High-Grade Talc Concentrate in Comparison to Flotation

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Abstract: In the course of this study, the applicability of electrostatic separation and flotation for processing a mineral sample rich in talc was examined. The aim was a comparison of those two separation processes and the concentrates obtained. Furthermore the separation behaviour of the silicates and carbonates was a goal of the examination. The electrostatic separation test work was conducted with a triboelectric belt separator. The feed, an artificially prepared mineral sample, was composed of four components: talc, quartz, dolomite, and magnesite. The lab scale test work was done exclusively at the Chair of Mineral Processing, Montanuniversitaet Leoben, Austria.

Keywords: Electrostatic separation, Mineral processing, Flotation, Talc, Magnesite, Quartz, Dry processing

Anwendbarkeit der elektrostatischen Sortierung auf ein talkreiches mineralisches Rohgut für die Herstellung eines hochangereicherten Talkkoncentrates im Vergleich zur Floation

Zusammenfassung: Im Zuge dieser Studie wurde die Anwendbarkeit der Sortierung im elektrostatischen Feld und – vergleichend dazu – in der Floation für die Aufbereitung eines talkreichen Rohgutes untersucht. Übergeordnete Ziele waren der Vergleich der Sortierprozesse und der resultierenden Konzentratqualitäten wie auch die An- und Abreicherungseffekte der enthaltenen Silikate und Karbonate in den Sortierprodukten. Der Versuch zur Sortierung im elektrostatischen Feld wurde auf einem triboelektrischen Bandscheiben durchgeführt. Das Aufgaberothgut bestand aus Talk, Quarz, Dolomit und Magnesit. Die Versuche im Labormaßstab wurden am Lehrstuhl für Aufbereitung und Veredlung an der Montanuniversität Leoben durchgeführt.

Schlüsselwörter: Elektrostatische Sortierung, Mineralaufbereitung, Floation, Talk, Magnesit, Quarz, Trockensortierverfahren

1. Introduction

Talc is an industrial mineral with numerous applications in the paper industry, plastics, ceramics, cosmetics, and pharmaceuticals. The global market for talc reached about 7.6Mt in 2020. The industry demands high-quality talc concentrates. At the moment the People’s Republic of China is the most important producer of high-quality talc products. Rising production costs in China may cause a general increase in prices for high-quality talc products. The use of alternative sorting processes, including dry sorting, for effective and efficient processing is therefore of particular importance [1–3].

The production of marketable, high-grade talc products demands a separation of talc from other minerals, which are present in the run-of-mine material. Most talc deposits are based on Mg-rich ultramafic rocks or on carbonates. Talc is formed by hydrothermal addition of silica and hydroxide ions to those two types of host rock. Chlorite, serpentinite, mica, sulfides, quartz, and carbonates, such as magnesite, dolomite, and calcite, are common gangue minerals [3, 4].

The separation by optical properties and flotation are the established technologies for the sorting of talc. Hand or sensor-based sorting can be applied on feed material with a minimum particle size of 50mm (by hand) or 10 to 20mm (sensor-based). The losses of talc in the fine fractions contradict the principles of running a processing plant
efficiently as well as the sustainable usage of natural resources [3, 5].

Concentrating talc by flotation is suitable for almost every talc ore. The high amounts of water required for the process and the necessity of drying the products results in high energy demand. The process water and the tailings slurries cause additional costs for a treatment [6].

2. Project Idea

The applicability of electrostatic separation under the precondition of triboelectric charging for the separation of talc and magnesite was indicated in literature. Fraas [7] separated talc from magnesite by triboelectric charging and the utilization of a free-fall separator. Bittner et al. [8] published the successful separation of talc and magnesite with a triboelectrostatic belt separator. Both, Fraas and Bittner, obtained concentrates with a content of talc of 95% [7, 8].

Gehringer et al. [9] used a feed material consisting of magnesite, dolomite, calcite, quartz, and talc. The test work aimed for the production of a concentrate consisting mainly from magnesite. As a result the separation of the carbonates and the silicates worked out very well, but the separation of the different carbonates for obtaining a magnesite concentrate was not successful. All tests resulted in a product rich in carbonates and a product rich in silicates. There was no indication in the study that talc and quartz ever took separate ways during a test run [9].

The charging of mineral surfaces by utilization of a triboelectrostatic effect is influenced by many factors. Until today the effects are not fully understood and a matter of intense research. The effect is predictable quite well by the surface work function of the participating minerals. The material with a higher surface work function is charged negatively, the surface of the material with the lower surface work function is charged positively. Arranging materials in a series based on the fact of the polarity acquired when being in contact results in a triboelectric series. The triboelectric series by Ferguson [10] indicates the processability of a run-of-mine material consisting of talc, various silicates, and carbonates due to the fact that in this triboelectric series various silicates such as quartz or feldspar and the carbonates are on opposite ends of the series. The fact the silicates and the carbonates are on the opposite ends of this triboelectric series and therefore are charging each other easily matches the results of Fraas [7], Bittner [8], and Gehringer [9] [7–10].

On the contrary, the separation of minerals, which are located at the same end of the triboelectric series, is possible and applicable. On the triboelectric series by Ferguson [10], quartz is on the negative end, feldspar is just one step further towards the positive end of the series. The separation of those two minerals in industrial scale was documented in literature [10, 11].

The basic idea of the test work presented within this contribution is the comparison of electrostatic separation including triboelectric charging and flotation in laboratory scale with a well-defined test feed. Hand-picked mineral samples were mixed together serving as an artificial run-of-mine material. Mineral samples rich in talc, magnesite, quartz, and dolomite were prepared for this purpose. This combination of minerals was chosen for two reasons. First, the test work should provide knowledge about the separability of talc against carbonates and a silicate at the same time. Second, the mineral mixture represented a probable combination of minerals being present together in a talc deposit and, at the same time, allowing the attribution of the observed effects during the test work to the minerals being present.

The test work aimed for a comparison of the obtained concentrates in matters of purity of the concentrate and recovery of talc. Furthermore the test work aimed for gaining knowledge about the behaviour of talc and quartz in the triboelectric belt separator. One of the basic questions of the presented test work was: Will the talc and the quartz be separable by usage of the belt separator or will talc and quartz just be separated from the carbonates?

3. Experimentation

3.1 Raw Material Characterization

The artificial run-of-mine material was obtained by a defined mixing of three separate mineral samples. The samples were provided by industrial partners of the Chair of Mineral Processing. The samples were received as hand-picked lumps.

The three samples were analysed with regard to density, loss-on-ignition (LOI), and carbon grade prior to preparation of the test work. The results of the analysis of the three samples are presented in Table 1.

The analysis of the talc sample resulted in a LOI of 9.4% and a carbon grade of 1.4%. The sample consists of talc and a considerable amount of magnesite. About 10% of the talc sample was actually magnesite. Due to the results of the analysis, the samples of dolomite and quartz were considered of high purity.

3.2 Test Feed Preparation

The test feed consisted of 31.5% of the talc sample, 50% of the dolomite sample, 15% of the quartz sample, and 3.5% of the magnesite sample. The analysis of the test feed resulted in a LOI of 26.8% and a carbon grade of 7.2%. The composition of the test feed is presented in Table 2.

| Mineral | Density g/cm³ | Loss-on-ignition % | Carbon % |
|---------|---------------|---------------------|----------|
| Talc    | 2.78          | 9.4                 | 1.4      |
| Dolomite| 2.84          | 46.6                | 13.5     |
| Quartz  | 2.64          | 0.4                 | 0.0      |
| Test feed | 2.79       | 26.8                | 7.2      |
The test feed was prepared for the separation test work by crushing with a laboratory jaw crusher and milling with a laboratory rod mill. The product from the jaw crusher was 100% smaller than 1.0 mm. The intermediate fraction was then fed to a laboratory rod mill in batch-wise mode and milled with a circulating load of 100% for obtaining a test feed smaller than 200 µm.

The particle size distribution of the test feed is presented in Fig. 1. The 125 µm screen was passed by 90.7% of the feed material. About 50% of the test feed was smaller than 35 µm.

3.3 Electrostatic Separation Test

The test work concerning electrostatic separation was carried out with a triboelectrostatic belt separator of type “STET X2.5” in laboratory scale. At the belt separator, five machine parameters can be changed to influence the triboelectrostatic charging behaviour of the feed as well as the separation process: applied voltage, electrode distance, belt speed, polarity of the top electrode, and feed rate [9].

Based on the experience with triboelectrostatic belt separation in the field of silicates and carbonates, the machine settings presented in Table 3 were chosen [9].

For keeping the environmental influences of the system constant as far as possible, the electrostatic separation test was carried out in the climate chamber of the Chair of Mineral Processing. During the test runs the ambient temperature was about 25.0°C, the relative humidity was about 30.0%.

The test was run batch-wise. A rougher and a cleaner stage were conducted. The silicates product (negatively charged product) from the rougher stage was fed a second time to the belt separator for the simulation of a cleaner stage.

3.4 Flotation Test

The flotation test work was carried out in a laboratory flotation cell of type “Denver D12”. A flow sheet for a batch test including a rougher stage and two cleaner stages was chosen. The rougher stage and the first cleaner stage were done by using a flotation cell with a volume of 2000 cm³. A flotation cell with a volume of 1280 cm³ was utilized for the second cleaner. The froth concentrates of the flotation stages were the feed for the next stage. This batch-wise mode of operation resulted in one tailings product, two intermediate products and one concentrate.

The volume concentration of solids in the feed of the rougher stage was 20%. The initial pH-value of the rougher feed was 8.27. Tap water was used for the flotation test work. The rotor was running with 950 rpm. The values for run time of the test, the cell volume, the solids concentration, and the volume of air are listed in Table 4.

3.5 Test Evaluation

After the test runs, all products were weighed. The evaluation of the test results was done by analysis of the loss-on-ignition and the carbon grade.

For determination of the loss-on-ignition the sample was put into a muffle furnace at a temperature of 1050°C for two hours. A combustion analyzer provided the carbon grade. All samples were prepared with a planetary micro mill for the measurements.
4. Results

4.1 Electrostatic Separation Test

The results for the electrostatic separation test are presented in Table 5. Due to the nature of the test setup, the losses on solids through dust and material remaining in the separation zone, the mass recovery was calculated via n-product formula.

The mass recovery in the concentrate amounts to 16.9%. The LOI was determined to be 9.1% (starting from 26.8%), the carbon grade was considerably reduced from 7.4 to 1.8%. The balance sheet clearly shows that a significant separation effect was achieved.

**Table 5**

| Mass recovery  | Loss-on-ignition | Carbon |
|----------------|------------------|--------|
| Rougher tail   | 75.0             | 31.1   | 8.7   |
| Cleaner tail   | 8.1              | 24.4   | 6.8   |
| Concentrate    | 16.9             | 9.1    | 1.8   |
| Test feed      | 100.0            | 26.8   | 7.4   |

4.2 Flotation Test

The results for the flotation test are presented in Table 6. The mass recovery of the concentrate was 8.9%. The flotation concentrate resulted in a LOI of 6.3% (again starting from 26.8%) and the carbon grade was significantly reduced from 7.2 to 0.4%.

**Table 6**

| Mass recovery  | Loss-on-ignition | Carbon |
|----------------|------------------|--------|
| Rougher tail   | 65.7             | 33.1   | 9.4   |
| Cl. 1 tail     | 17.7             | 21.1   | 5.3   |
| Cl. 2 tail     | 7.7              | 10.0   | 1.6   |
| Concentrate    | 8.9              | 6.3    | 0.4   |
| Test feed      | 100.0            | 26.8   | 7.2   |

4.3 Concentrates

Based on the test results, the distribution of the minerals in the concentrate products was calculated. The results are presented in Table 7. The electrostatic separation test resulted in a concentrate consisting of 57.6% of talc, 29.2% of quartz and 13.3% of carbonates. During the flotation test, a concentrate consisting of 96.5% of talc and 3.5% of carbonates was obtained.

5. Discussion

Although the composition of the test feed for the two different separation tests was predominantly the same, the two test results differ considerably in terms of sorting efficiency as well as product quality. The flotation test resulted in a concentrate with a talc grade of 96.5%, while the talc grade of the concentrate resulting from the electrostatic separation tests was only 57.6%.

In the electrostatic separation test, the recovery of talc in the concentrate was 30.8%, the recovery of quartz was 32.8%. This indicates that talc and quartz were subjected to the same separation effects. In comparison to the flotation concentrate containing no quartz, the concentrate resulting from the electrostatic separation test was a silicates concentrate with weak separation effect between talc and quartz. The reduction of the share of carbonates worked out well though.

The differences in the results of the concentrates can be traced back to the characteristics of the two separation processes. In the presented case, the flotation process is based on the natural hydrophobicity of the talc. The result was a concentrate rich in talc.

In the triboelectric belt separator, the minerals charge each other by a triboelectric effect before moving towards the electrode with the opposite charge and being dragged out of the separation zone by the belt. Silicates such as talc and quartz have a similar charging behaviour. The surfaces of the two mineral phases were both charged negatively. The separation between silicates and carbonates worked out. The reduction of the LOI and the content of carbon were significant. The concentrate obtained was not a talc concentrate but a silicates concentrate. As mentioned above this observation fits the results of Gehring [9] quite well. Gehring obtained a concentrate of carbonates in course of the test work and not the desired concentrate of magnesite [9].

The flotation tests proved the applicability of the process for obtaining a high-quality talc concentrate. The recovery of talc in the concentrate reached a level of 27.1% and was in the same dimension as the recovery of talc during the electrostatic separation test, resulting in a recovery of 30.8%.

The low recoveries resulted from the fact that the test work was conducted in a batch-wise setup. For obtaining results for the recovery of talc for a counter-current cascade, a locked-cycle test would have been necessary [12].

A recovery of talc of 30.8% in the concentrate leads to 69.2% of talc losses. In the present case, the feed for the tests was 50% smaller than 35µm. The electrostatic separa-
tion tests of Gehringer [9] resulted in a recovery of MgCO₃ of 90.7% in the concentrate. In this case the test feed was significantly coarser. About 50% of the feed was smaller than 70 µm. Resulting from those numbers, the particle size distribution has to be taken into account for being responsible for high losses [9].

6. Conclusion

The separation of silicates and carbonates is working out quite well utilizing the triboelectric belt separator. The reduction of the share of carbonates in the concentrate in comparison to the feed material was proven.

The concentration of a single silicate from other silicates and carbonates in the feed did not work out. A concentrate rich in silicates was obtained. The ratio between the talc and the quartz was basically the same in the test feed and in the concentrate.

The particle size distribution of the test feed is an important influence factor on the separation result and has to be examined in detail in future tests.

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