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Corresponding author:

Sabrina Gehringer (MU Leoben - Chair of Mineral Processing), sabrina.gehringer@unileoben.ac.at

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Controlled charging of mineral surfaces for a successful separation in the electrostatic field

Sabrina Gehringer¹, Helmut Flachberger¹

¹ Chair of Mineral Processing, Department Mineral Resources Engineering, Montanuniversität Leoben, Austria
sabrina.gehringer@unileoben.ac.at

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Abstract

In course of this project, the charging behavior of industrial minerals is analyzed to allow a successful separation in the electrostatic field. The experimental design is based on the statistical design of experiments.

The first part is the development of basic knowledge about the triboelectrostatic charging behavior and the sortability of industrial mineral samples.

The second part of the project is the design of a triboelectrostatic charging unit, aiming to produce a clearly delimited system in which the triboelectrostatic charging is carried out, recorded by measurement and thus controllable.

The project background is to make a scientific contribution for expanding the area of the application of electrostatic separation in the processing in the challenging field of industrial minerals.

Introduction

The global demand for high-quality industrial minerals is continuously increasing. [1]

Minerals of this group offer a wide range of applications in modern industry due to their specific physical properties. Areas of application include without any claim of completeness the pharmaceutical, paper, paint and plastics industry. Depending on the field of application, concentrates must fulfill very different quality criteria with respect to color, purity, grain size, etc.

As high quality deposits are running low, future deposits will have lower grades and / or less favorable growth conditions. Due to the increasingly fine intergrowth, mineral processing in the fine grain size ranges (<100 µm) is becoming increasingly important.

Currently for fine particle sizes, predominantly wet treatment processes (e.g. flotation and wet operated magnetic separation) are used. Due to the limited availability of water and restrictive environmental regulations, dry operated fine grain processing is becoming essential. Electrostatic separation is one such processing method in dry operation.

Depending on the mineral phases involved, the separation takes place according to differences in conductivity or surface charge. [2], [3]

Due to the fact, that industrial minerals are largely non-conductors, research in the field of sorting due to differences in surface charge, the so-called triboelectrostatic separation, is in the foreground.

Situation in Austria

Despite the fact, that Austria is "*the promised land of water*", the careful use of this valuable resource is becoming increasingly important. A first marker for this tendency is that the average water consumption in Austria is steadily decreasing. Industry is more economical with process water than before, primarily for cost reasons. Circulation systems and water treatment plants are often used.

Nevertheless, 56 % of the total amount of water in Austria is still used by industry (Figure 1). [4]

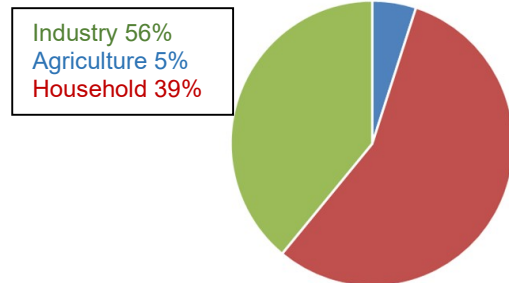


Figure 1: Average water consumption in Austria [4]

By establishing a dry treatment method, such as triboelectrostatic separation, for the processing of industrial minerals, the proportion of water consumption could be significantly reduced.

However, in the field of triboelectrostatic separation, especially in the targeted charging of mineral phase surfaces, intensive research work is still required.

Research question

During the project "*Controlled charging of mineral surfaces for a successful separation in the electrostatic field*", the charging behavior of mineral surfaces is investigated in order to enable a successful separation in the electrostatic field and to expand the knowledge in the area of triboelectrostatic charging of (industrial) mineral phases.

Based on systematic parameter studies, triboelectrostatic charging mechanisms are examined in detail in order to gain a better knowledge of charging behavior and to be able to carry out the separation process in a controlled manner.

This is intended to make a scientific contribution for expanding the area of the application of electrostatic separation in dry processing of high-quality filler products, especially in the challenging field of industrial minerals.

State of research

The beginning of electrostatics goes back to the Greek philosophers. In ancient Greece, Thales von Milet is said to have recognized that the rubbing of amber on a cat's fur attracted small dust particles.

The observation of this triboelectrostatic charging effect was ultimately the basis for today's electricity. [5]

The use of electrostatics for the separation of mineral raw materials started at the beginning of the 20th century. With the advent of flotation and the fact that high voltage was insufficiently manageable, electrostatic separation, with the exception of niche applications, was pushed out of mineral processing for decades.

At the beginning of research activities in this area, the focus was on the separation of electrically conductive from nonconductive mineral phases (e.g. separation of ore from gangue).

The first successful separation tests on different

nonconductors were carried out in the 1950s with salt minerals. Since the 1970s, electrostatic separation has been a standard process in the treatment of potassium salts, which competes with flotation. [6] [7]

Research activities at the Chair of Mineral Processing on the topic of "electrostatic separation of industrial minerals" started about 15 years ago. In course of this project this research activities are continued in order to gain a better understanding of the triboelectrostatic charging behavior of mineral phases and their influencing factors and to subsequently expand the possible uses of electrostatic separation of industrial minerals in the fine grain range (< 100 μm).

Methodological approach

The first target of the project is the development of basic knowledge about the triboelectrostatic charging behavior and the sortability of selected industrial mineral samples. This is realized by use of triboelectrostatic belt separation.

The second target of the project is the design of a triboelectrostatic charging unit, aiming to produce a clearly delimited system in which the triboelectrostatic charging is carried out, recorded by measurement and thus controllable.

Triboelectrostatic belt separation

The experiments for the first project part are carried out at a "ST X2" triboelectrostatic belt separator in laboratory scale, provided by ST Equipment and Technology LLC.

The operational principle of this lab scale separator is shown in figure 2.

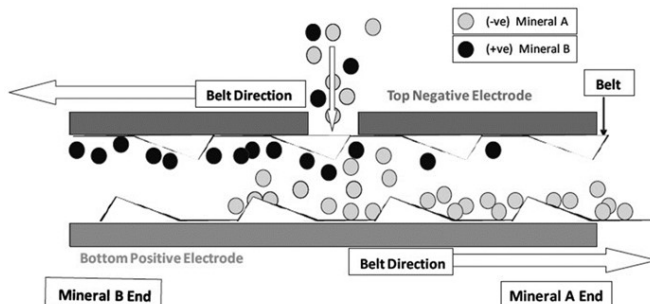


Figure 2: Operation principle of a triboelectrostatic belt separator [8]

The sample passes from above through a vibro-feeder and a downspout into the separation area. The separation area is delimited with two electrodes, called top and bottom electrode. The polarity of top and bottom electrodes can be reversed. The sample is triboelectrostatic charged and transported with a fast circulating plastic belt.

Depending on the charge the mineral phases are deflected to the top or bottom electrode. The discharge of the products takes place on the left and right side after leaving the separation chamber.

The two produced products are collected in bags for further tests and analysis. [9]

The following machine parameters can be changed on the lab scale belt separator:

- applied voltage
- electrode distance
- belt speed
- polarity of the top electrode
- feed rate

The five machine parameters (a-e), ambient and raw

material conditions (humidity and temperature) are checked and varied in a targeted manner in order to examine their influence on the charging behavior of the raw material samples and subsequently to increase or suppress the triboelectrostatic charging effect.

The procedure for varying the parameters 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. [10]

Triboelectrostatic charging unit

The triboelectrostatic charging unit is designed for the generation of a clearly delimited system in which the triboelectrostatic charging is carried out and recorded by measurement. This system is intended to offer further parameters for influencing charging behavior. These parameters should be able to be precisely defined and monitored during charging process so that the process can be better understood and subsequently influenced.

A 3D illustration of the triboelectrostatic charging unit is shown in figure 3.



Figure 3: 3D illustration of the triboelectrostatic charging unit

At the beginning of the dimensioning work, the conditions of the in-house compressed air network determined the maximum available compressed air volume flow rate and the maximum available volume flow rate and operating pressure for the charging unit.

Taking into account the simultaneous operation of other smaller compressed air consumers, the maximum volume flow rate for the charging unit was set at 160 Nm^3/h at an operating pressure of 6 bar. The relative humidity of the air supply is about 20 %.

The grain size range and density for analyzed raw material samples were then defined.

In order to fluidize as many different industrial minerals as possible, density between 2 and 4 g/cm^3 was assumed.

The desired grain size range lies between 40 µm and 1 mm, a possible discharge of the fine fraction (<20 µm) in the filter system is accepted, since this fraction often has a negative impact on the selectivity in the electrostatic separation process anyway.

The fluidized bed consists of three chambers, which are connected to each other by detachable flange connections.

The feed weight is about 1.5 kg, the inside diameter is about 14 cm. Operation is possible at different air temperatures ranging from 20 to 150 °C.

In order to measure the charging success of the raw material samples under consideration, a possibility for sampling and in the following measuring the surface charge is integrated into the triboelectrostatic charging unit. The charge measurement is carried out with an electroscopes and faraday cup. This measurement is discontinuous and enables simple and quick measurement. [11]

The gas for fluidization is supplied by de-oiled compressed air (max. 6 bar) from the laboratory own compressed air network. Furthermore, the possibility of supplying different gases (e.g. nitrogen, argon) should be provided via changeable gas bottles.

The gas flow is subjected to a flow measurement at the beginning in order to adapt it to the fluidized raw material.

The gas is then passed through an electrical flow heater to set the desired temperature for the triboelectrostatic charging process. The flow heater offers the possibility to heat up the gas to a maximum temperature of 150 °C.

The gas is then fed directly into the fluidization chamber where it can optionally be mixed with chemicals in order to specifically influence the charging behavior of the fluidized mineral phases.

In table 1 technical data of the triboelectrostatic charging unit are summarized.

nominal voltage	400 V
air pressure	6 bar
volume flow rate	1 - 160 Nm ³ /h
max. volume flow rate (lab facility)	10 Nm ³ /h
air heating	150 °C
dimensions fluidized bed ground	14 cm
dimensions fluidized bed chamber	87 cm
maximum feed mass	1.5 kg

Table 1: Technical data of the triboelectrostatic charging unit.

Sampling unit

For understanding the charging mechanism, it is necessary to detect the total charge of the fluidized samples. For this reason, a sampling unit is integrated into the process chamber of the charging unit.

This allows to take samples during the fluidization process to check the charge growth over the time.

In the figures 4 and 5 the principle of the sampling unit is shown in a 3D model.

In figure 4 the sampling unit is positioned in the fluidization chamber, where the sample is collected in the sampling bag.

In figure 5 the sample is extracted from the fluidization and afterwards transferred into the faraday cup (figure 6: Principle of charge measurement with faraday cup and electroscopes).

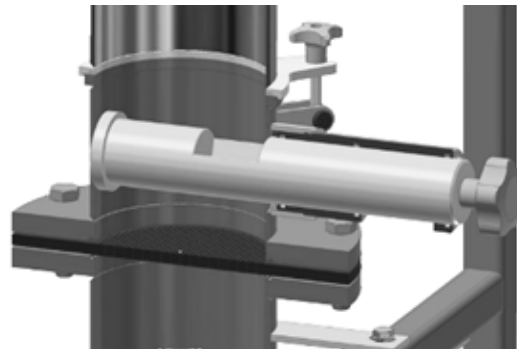


Figure 4: 3D model of the sampling unit

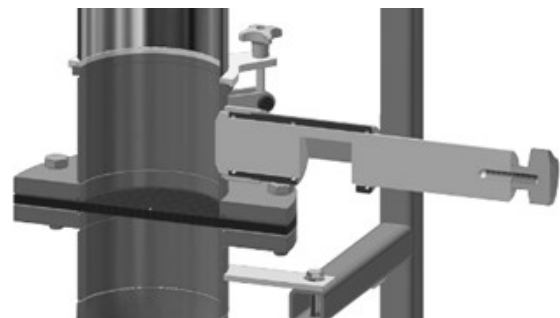


Figure 5: 3D model of the sampling unit

Charge measurement

To measure the efficiency of the triboelectrostatic charging during the fluidization tests, a faraday cup was positioned below the sampling unit of the triboelectrostatic charging unit.

The faraday cup consists of two concentrically arranged metal cylinders well insulated from each other. The two cylinders are fixed by polyethylene foam. The outer cylinder is used for shielding from external interference.

The via tribopolarization charged grains are transferred by use of the sampling unit into the inner cylinder of the faraday cup.

The principle of the charge measurement with faraday cup and electroscopes is shown in figure 6.

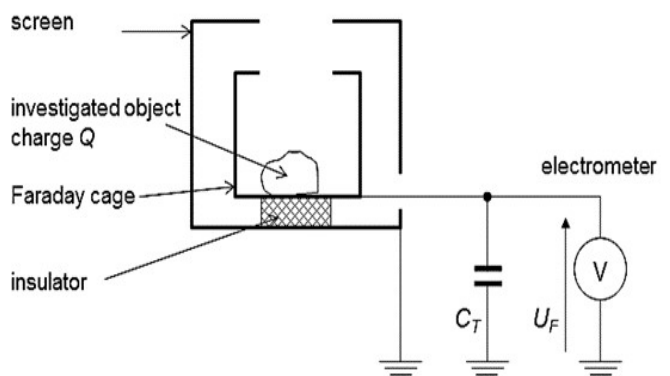


Figure 6: Principle of charge measurement with faraday cup and electroscopes [14]

After fluidization in the triboelectrostatic charging unit the grains generate an electrical charge on the surface of the inner cylinder according to the principle of influential charge an electrical charge on the surface of the inner cylinder.

The inner cylinder is connected to a Coulomb meter of

type "Monroe 284".

The connection to the Coulomb meter is realized via a BNC connector. The total charge of the sample is shown with the correct sign on the display of the Coulomb meter. After the total charge has been measured, the collected sample in the Faraday cup is weighed and the mass specific surface charge is calculated. [12], [13]

The equation for the calculation of the mass specific surface charge is given below:

$$q_m = Q / m$$

q_m [nC/g] ... mass specific surface charge

Q [nC] ... total charge

m [g] ... sample mass

Charging behavior of mineral phases

For the detection of the triboelectrostatic charging behavior of mineral phases high quality products are used in the first step. This serves the purpose of generating basic knowledge about the charging behavior of a special pure mineral phase. Furthermore, a very narrow grain size distribution was chosen for these tests in order to eliminate any effects caused by grain size and grain size distribution.

The samples are fluidized for 60 minutes at the triboelectrostatic charging unit. Samples are taken every 15 minutes and measured immediately in the faraday cup to check the mass specific surface charge over time.

The result of these tests is the time course of the surface charge, the so-called basic charging curve of pure minerals.

This curve could be used to predict how long the charging process will take and from which other minerals the phase can be separated.

For illustration, such a curve (that of quartz) is shown in Figure 7. Therefore a high quality quartz product was used, that was not processed using chemicals.

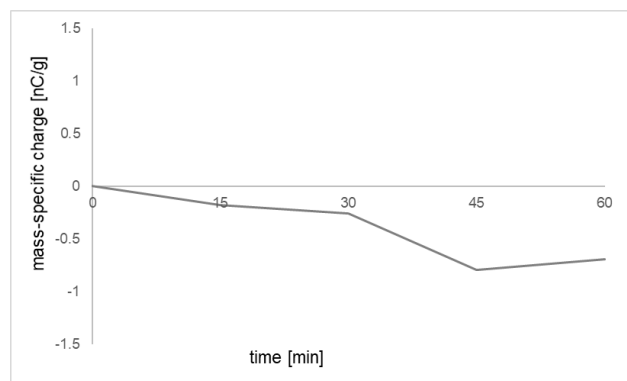


Figure 7: Basic charging curve of pure quartz

If the charging tests are repeated with the addition of reagents, this could generate assumptions about how the chemical used influences the charging behavior of the mineral sample. These tests are a first step towards controlled charging of mineral surfaces.

Summary

From the results of systematic sorting tests of various industrial minerals at the triboelectrostatic belt separator, it can be concluded that there is a specific optimal setting of machine, ambient and raw material parameters for each feed type.

These settings need to be determined for each raw material to ensure the right conditions for the successful separation at the triboelectrostatic belt separator.

With the aid of the triboelectrostatic charging unit, charging processes and the influencing factors mentioned can be tracked over time.

Thereby, advantageous conditions for sorting at the belt separator and the basic charging curves of minerals can be predicted. Furthermore, the influence of chemical surface conditioning can be determined which could subsequently support the targeted influencing of the surface charge of minerals phases.

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Figure 7: Basic charging curve of pure quartz

Table 1: Technical data of the triboelectrostatic charging unit

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