Assessment of grinding power in silica and slag sands by using a laboratory disc mill: Influence of temperature

Abstract

In previous studies, we have shown that assessment of the grinding power in vibrating disc mills can be used to determine the specific energy and grindability of materials. We were able to demonstrate good compatibility with the standard procedure of the Zeisel test as well as high reproducibility of analytical results. In this study, we are investigating the influence of the grinding vessel temperature on the power when grinding silica sand and slag sand. A clear correlation was found for both materials, with higher temperatures resulting in lower grinding power. For example, a change in the grinding vessel temperature from 30 to 35°C led to a reduction in grinding power of approx. 3%. This result emphasizes that reproducible conditions such as temperature stability are essential for precise determination of grindability. Due to their automatic functions and high-precision temperature control, Herzog disc mills are ideally suited for reproducible comminution and grinding power assessment.

Key words

• **Grindability** • **Temperature** • **Vibrating disc mill** • **Slag sand** • **Silica Sand**

Introduction

In previous studies, we have shown that assessment of the grinding power in a vibrating disc mill can be used to investigate the grinding dynamics of a particular material (1, 2) and determine its grindability (3, 4). We have also demonstrated that the measurement of the grinding power of a specific sample can be performed with high precision, provided that all subsequent trials are carried out under reproducible conditions (5). Here, particular attention was paid to keeping a constant temperature within in the grinding vessel of the disc mill. It is a well-known phenomenon that the grindability of a material depends significantly on the temperature prevailing in the material to be ground or the temperature inside a mill. This has been demonstrated using different materials under laboratory (6) and production (7) conditions. As a rule of thumb, an increased temperature results in a reduction of the required grinding energy.

In this study, we therefore investigated the correlation between the grinding vessel temperature and the grinding power measured in a vibrating disc mill. For this purpose, we explored the temperature effect on two different materials, namely silica sand and slag sand, which is produced from blast furnace slag by wet granulation.

Methods

In this study, we ground (a) one type of silica sand and (b) four different types of slag sands from various steel plants. For all grinding trials we used the milling and pelletizing machine of the type HP-MP (Herzog, Germany). The HP-MP was equipped with the standard TCM module for the evaluation of grinding performance.

Each sample (30 g) was ground for 120 s at a rotation speed of 800 rpm. To determine the impact of the temperature on the grinding power, we varied the grinding vessel temperature in each of the test series. The exact grinding vessel temperature was measured using a pyrometer, which is an optional standard component of the HP-MP. Within each trial, we aimed to keep the target temperature constant. This was done using the integrated temperature control system of the HP-MP, involving the air-cooling unit for the grinding vessel.

In the experiments with silica sand, we first carried out a so-called internal warm-up of the grinding vessel to a target temperature of 25, 30, and 35°C, respectively. To do this, we ground 30 g of a clinker sample until the grinding vessel was warmed up to approx. 2 °C above the target temperature. After emptying the ground clinker from the grinding vessel, the grinding of the actual silica sand sample was automatically started when the exact target temperature was reached.

To ascertain that the effect on the grinding power was due to the temperature and not to other unknown factors, we carried out an external warm-up of the grinding vessel with a fan heater. The grinding vessel was heated to temperatures of 35, 55 and 65 °C. Because the warm-up was carried out from the outside and not from the inside by grinding clinker, higher target temperatures had to be chosen. Since the fan heater interfered with the internal pyrometer, the target temperature was verified using an external pyrometer and the grinding of the silica sand sample was started manually.

In the experiments with slag sands, we ground four different slag types after internal warming-up the grinding vessel to a temperature of 30 or 35°C. The process of internal warm-up was identical to the procedure for silica sand.

Each trial after internal or external warm-up of the grinding vessel was repeated three times. During each grinding trial, the grinding power of the HP-MP and the temperature of the internal pyrometer were continuously recorded at a sampling frequency of 100 Hz. Based on the grinding power of the three trials we calculated the moving average as well as the moving standard deviation of the grinding power and the grinding vessel temperature.

Results

Silica sand- Internal warm-up of the grinding vessel

For silica sand samples, we found a significant influence of the grinding vessel temperature on the grinding power of the HP-MP (Figure 1 A). The highest grinding power was found for a vessel temperature of 25 °C. The peak power around 25 s grinding time was approx. 0.184 kW. The lowest power was found at a grinding temperature of 35 °C with a peak power of approx. 0.164 kW. For a vessel temperature of 30 °C, the grinding power was between the two values with a peak power of around 0.170 kW. At all three temperatures, the variability of the power curve was low with a relative standard deviation of less than 1 % in all cases.

Simultaneously, we measured the temperature

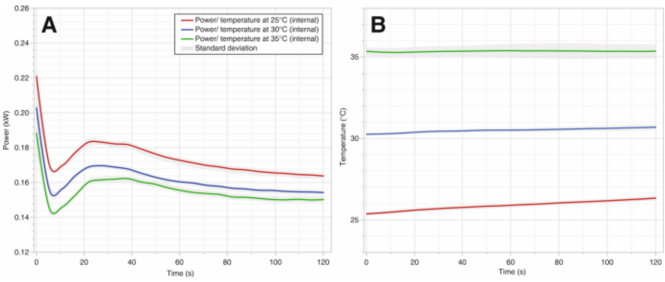

Figure 1: *Grinding power (A) and grinding vessel temperature (B) during grinding of silica sand.*

of the grinding vessel during the 120 s trials (Figure 1 B). When starting the trial at a temperature of 25°C, we found a mean increase in temperature of approx. 1°C. When starting at 30°C, the mean increase was approx. 0.5°C. At a temperature of 35°C we did not observe any increase in temperature.

<u>Silica sand- external warm-up of the grinding vessel</u>

External warm-up of the grinding vessel had the same qualitative effect on the grinding power as the internal warm-up (Figure 2). The lowest temperature of 35°C was associated with the highest grinding power peak at 0.188 kW around 30 s grinding time. For 65°C, the power curve was lowest with a peak value of approx. 0.164 kW. The temperature of 55°C led to an intermediate peak value of 0.172 kW. All values showed a low variability with a relative standard deviation below 1 %.

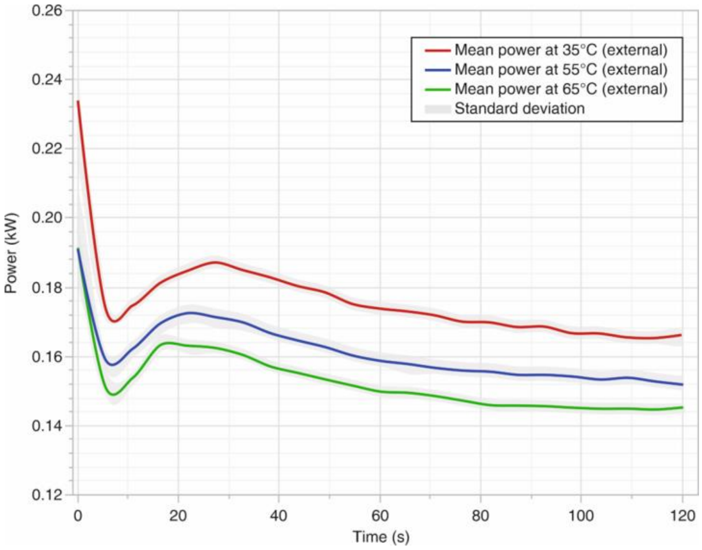

Figure 2: Power for grinding of silica sand after external warming-up of the grinding vessel.

<u>Slag sand- Internal warm-up of the grinding vessel</u>

In all four slag sands, the lower temperature of 30°C was associated with a higher grinding power compared to 35°C (Figure 3). The shape of the power curves as well as the peak power values differed between the various slag sand types. However, within one slag sand type both the 30°C and the 35°C curves were very reproducible. Accordingly, for 30°C, the relative standard deviation of the power curve was between 0.4 and 4.1 %. For 35°C, the relative standard deviation was between 0.3 and 2.7 %.

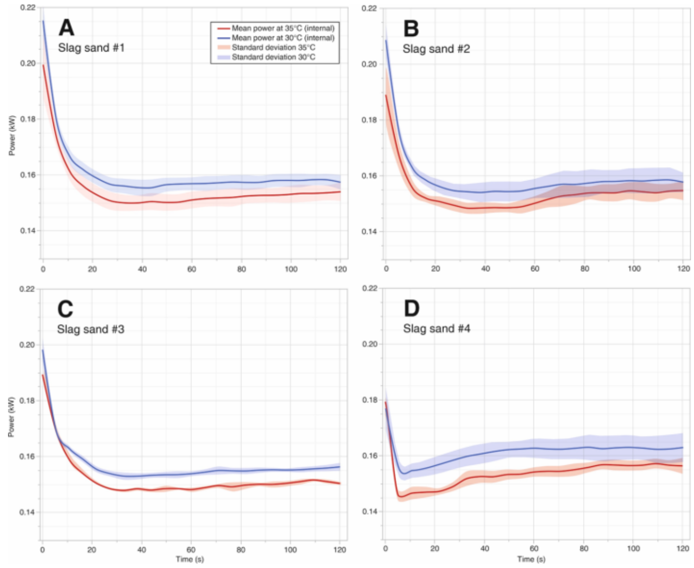

Figure 3: *Power during grinding of slag sand after internal warming-up of the vessel to 30 and 35°C.*

For all slag sands, the course of the grinding vessel temperatures at 30°C and 35°C was very stable (Figure 4). The largest average increase during the 120 s grinding trial was 0.3°C. The standard deviation of the temperature was somewhat higher for 35°C compared to 30°C.

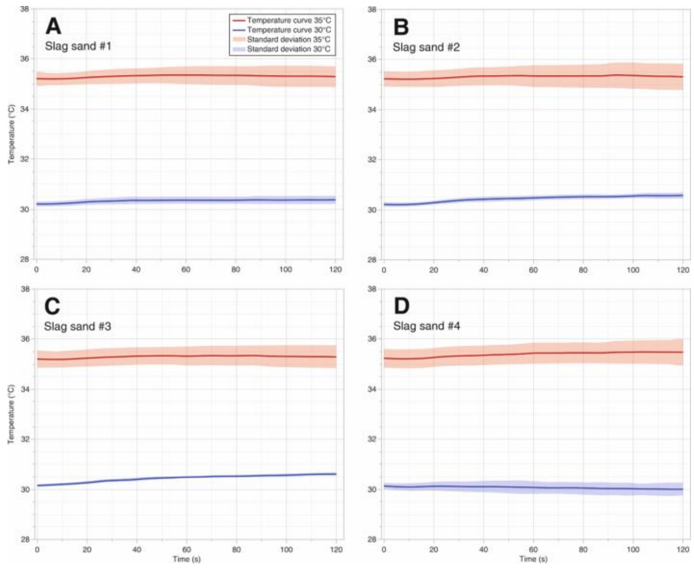

Figure 4: *Course of the grinding vessel temperature after internal warm-up to 30 and 35°C.*

Discussion

The results of this study confirm that the grinding power required to increase the surface of a material often depends on the temperature of the material itself or the temperature inside a mill. This was demonstrated on both silica sand

and slag sand samples. For both materials, an increase in the grinding vessel temperature by 5°C led to a reduction in the grinding power by approx. 3 %. In the case of silica sand, increasing the temperature by 10°C resulted in a power decrease by approx. 12%. Previous studies investigating the correlation between temperature and power consumption were mainly performed in ball mails (6, 7). It is a new finding that the temperature-dependent power consumption also applies to vibrating disc mills.

Our study clearly demonstrated that the direct temperature influence is the primary cause of change in grinding power as shown by warming-up the grinding vessel from the outside. Other causes are therefore very unlikely like, e.g., change in the surface properties of the grinding vessel by previous grinding with clinker.

Our results emphasize that for precise determination of grindability the grinding vessel temperature must be kept constant for all subsequent trials. This is easily possible with the temperature control system integrated in Herzog automatic disc mills. The process of internal heating with pre-grinding of, e.g., clinker ensures that the temperature is increased easily and quickly into the required temperature range. The grindability assessment then starts automatically when the exact target temperature is reached.

In this study we also verified that the target temperature is maintained over a period of at least 120 seconds. The maximum temperature increase for silica sand was only 1°C, and for slag sand only 0.3°C. Herzog disc mills such as the HP-MP therefore offer perfect conditions for reproducible grinding processes and high-precision assessment of grindability.

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