Application note No. 56 | 2024

Assessment of grindability in slag sands by using a laboratory disc mill: Determination of analytical precision

Abstract

In previous application notes we have shown that the grindability of materials can be determined quickly and easily using a Herzog vibratory disc mill. For assessment of grindability, the grinding power of the disc mill is recorded using the PrepMaster Analytics software and correlated with the specific surface area determined by laser granulometry. In the current study, we evaluate the repeatability (using relative standard deviation) of the grinding power and specific surface area by measuring four different slag sands. In this way, we aim at estimating the analytical precision of the method and the expected measurement uncertainty. On average, the relative standard deviation was 1.5 % for determining the grinding power and 1.7 % for the specific surface area. These values indicate a high precision in determining grindability by using a vibratory disc mill.

Key words

• **Grindability** • **Slag sand** • **Vibrating disc mill** • **Precision** • **Measurement Uncertainty**

Introduction

We have previously shown that the grinding power measured in a vibrating disc mill can be used to determine the specific energy for comminution of slag sands [1]. The correlation of the specific energy with the specific surface area measured in the laser granulometry yields the grindability. The comparison of the measurement results obtained in the vibrating disc mill with the standard procedure of the Zeisel test revealed that both methods lead to comparable results. Both the disc mill measurement and the Zeisel test were capable of revealing significant differences in grindability between the four slag sands analyzed.

The present application note aims at evaluating the repeatability of the two independent variables (grinding power and specific surface) which specify grindability in a vibrating disc mill. For this purpose, the grinding tests were repeated several times with four different slag sands. Subsequently, the standard deviation of both the grinding power and the specific surface area were determined. The resulting variability of both factors thus provides an initial indication of the measurement uncertainty to be expected when determining grindability using a vibrating disc mill.

Methods

We ground four different slag sands from various steel plants using 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.

For each slag sand, we carried out six trials each with a grinding time of 30, 60, 90, 120 s, respectively. Each sample was ground at the same rotation speed of 800 rpm and a constant grinding vessel temperature of 35 °C. For the test we used pre-dried sample material without any grinding aid. During each grinding trial, the grinding power of the HP-MP was automatically recorded at a sampling frequency of 100 Hz. Based on the grinding energy of the six trials we calculated the moving average and the moving standard deviation of the grinding energy for the grinding times of 30, 60, 90 and 120 s. Finally, we summarized the mean relative standard deviation calculated from the different grinding times in Table 1.

After each trial the ground sample was discharged into a cup and the specific surface was determined by granulometry (Mastersizer 3000, Malvern, UK). Several (up to six) determinations of the specific surface area were carried out for each grinding trial. Based on this, the so-called intra-trial mean and intra-trial standard deviation were calculated. In addition, we calculated the so-called inter-atrial mean and inter-atrial standard deviation of the six subsequent grinding trials. For each of the four slag sands, we calculated the cumulative relative standard deviation (intra-trial and inter-trial) shown in Table 1.

Results

<u>Standard deviation of the grinding power</u>

Figure 1 shows an example of the grinding power of six consecutive grinding trials (grey lines) with slag sand #4 at a grinding time of 120 seconds. The resulting average value was calculated from the six trials and displayed as a black line.

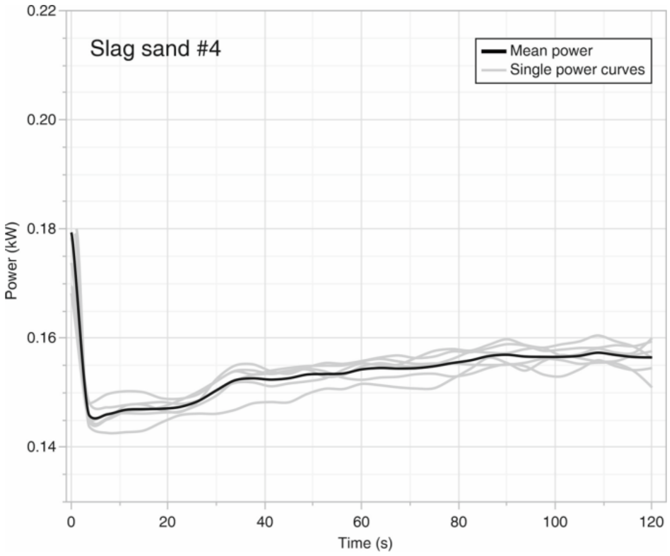

Figure 1: *Course of the grinding power of six subsequent 120 s grinding trials (grey) of slag sand #4 and the calculated mean power (black).*

In the example shown in Figure 1, almost all curves show a very similar course and similar power values. Only the lowest of the curves stands out due to a different curve shape.

Figure 2 displays the mean average curve of the grinding power together with the corresponding standard deviation for all four slag sands at a grinding time of 120 s. The visual impression indicates that the standard deviation is highest for slag sand #1, followed by slag sands #2 and #4. The lowest standard deviation is found for slag sand #3.

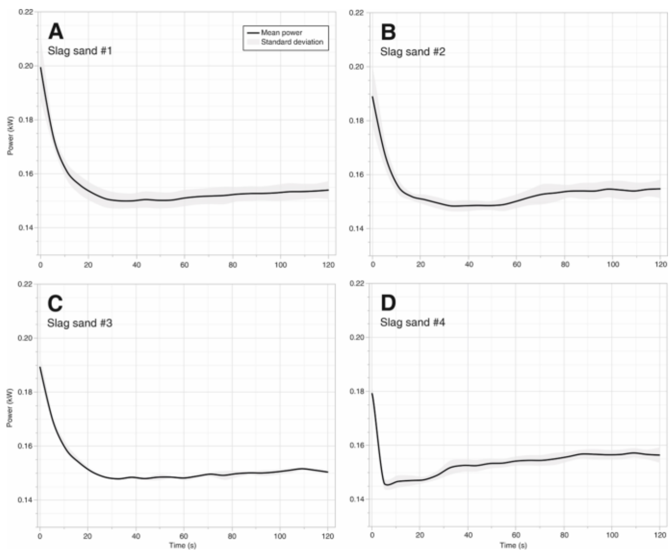

Figure 2: *Mean grinding power and standard deviation of six subsequent 120s grinding trials for all four slag samples analyzed in this study.*

This visual impression is confirmed by the numerical analysis of the cumulative relative standard deviations in Table 1, which shows a value of 2.19 % for slag sands #1, 1.85 % for #2 and 1.33 % for #4. The lowest relative standard deviation is found for slag sand #3 at 0.53 %.

Standard deviation of the specific surface

Figure 3 shows exemplarily the intra-trial mean and standard deviation of the specific surface for each slag sand separately for 30, 60, 90 and 120 s grinding time. The cumulative relative intra-trial standard deviation was between 1.26 % and 3.08 % (Table 1).

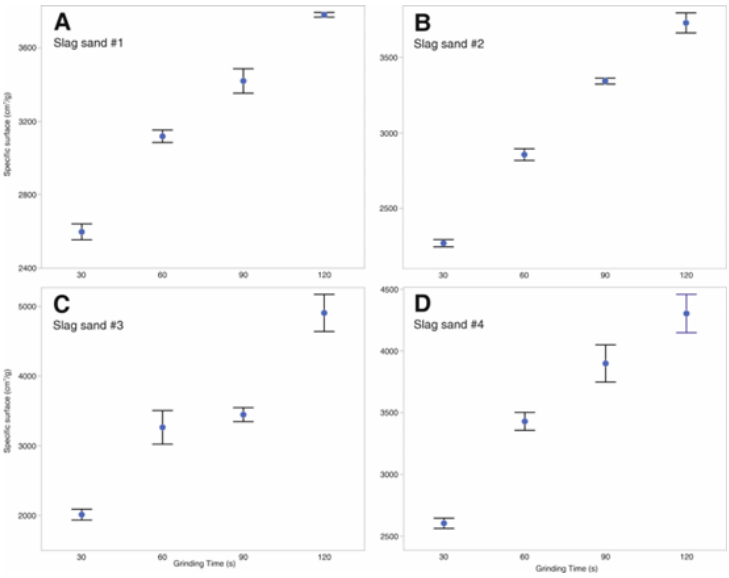

Figure 3: Exemplarily *plot showing the intra-trial mean specific surface and standard deviation.*

Additionally, we calculated the standard deviation of the specific surface obtained in the consecutive grinding trials (inter-atrial standard deviation). Here, the relative standard deviation was between 0.97 % and 2.31 % (Table 1).

Discussion

In general, grindability is defined as the change in dispersity of a material in relation to the specific energy input required. In grinding processes, the dispersity is usually expressed by the specific surface area, which can be read, e.g., directly from granulometers. In our approach, the specific energy is obtained directly by computing the integral of the grinding power of the vibrating disc mill.

In this series of tests, we specified the standard deviation of these two measurement variables that are used to determine the grindability of sample material. This makes it possible to estimate the repeatability and, in part, the measurement uncertainty when using a vibratory disc mill for specifying the grindability of a certain sample material.

In summary, we found a high repeatability of both parameters. Regarding grinding power, the average relative standard deviation in the four materials was approx. 1.5 %. A slightly higher relative standard deviation of 2.19 % was only observed for slag sand #1. For the specific surface area, the relative standard deviation (intra- and inter-trial) was approx. 1.7 %. Here, too, there was a small outlier in the intra-trial standard deviation of 3.08 % for slag sand #4.

It can therefore be concluded that determination of grindability by means of a vibrating disc mill is possible with high precision and low measurement uncertainty, at least for slag sands. A similarly good repeatability as in these tests has already been observed for other materials such as clinker [2], so that the method can be considered as precise in general.

Material	rSD Grinding power	rSD specific surface (intra-trial)	rSD specific surface (inter-trial)
Slag sand #1	2.19 %	1.26 %	1.69 %
Slag sand #2	1.85 %	1.43 %	1.63 %
Slag sand #3	0.53 %	1.28 %	2.31 %
Slag sand #4	1.33 %	3.08 %	0.97 %

Table 1: *Overview of the relative standard deviation (rSD) of the mean grinding power and intra-trial and inter-trial specific surface area. The rSD values given here are cumulative, i.e., the values for the 30, 60, 90 and 120 grinding trials were aggregated into one value.*

All tests were carried out at a grinding vessel temperature of exactly 30°C. The temperature was set so accurately because preliminary tests had already shown a significant impact of temperature on the grinding power and consequently test repeatability. In the following Application Note 57/2024, we will present the influence of temperature on grinding power in more detail.

References

[1] Herzog Application Note 55/2024: Assessment of grindability in slag sands by using a laboratory disc mill: Comparison to the Zeisel test

[2] Herzog Application Note 51/2023: A novel an easy approach to determine the specific energy demand of clinker grinding

Germany

HERZOG Maschinenfabrik
GmbH & Co.KG
Auf dem Gehren 1
49086 Osnabrück
Germany
Phone +49 541 93320
info@herzog-maschinenfarbik.de
www.herzog-maschinenfabrik.de

USA

HERZOG Automation Corp.
16600 Sprague Road, Suite 400
Cleveland, Ohio 44130
USA
Phone +1 440 891 9777
info@herzogautomation.com
www.herzogautomation.com

Japan

HERZOG Japan Co., Ltd.
3-7, Komagome 2-chome
Toshima-ku
Tokio 170-0003
Japan
Phone +81 3 5907 1771
info@herzog.co.jp
www.herzog.co.jp

China

HERZOG (Shanghai) Automation
Equipment Co., Ltd.
Section A2, 2/F, Building 6
No. 473, West Fute 1st Road,
Waigaoqiao F.T.Z., Shagnhai,
200131
P.R.China
Phone +86 21 50375915
info@herzog-automation.com.cn
www.herzog-automation.com.cn