Real-time monitoring of efficiency in quicklime grinding

Abstract

Quicklime is a challenging material to be ground in a laboratory disc mill. Due to blockage of the grinding set, the pulverizing process might become insufficient leading to an incomplete grain size reduction. In this application note, we show that real-time monitoring of the grinding vessel acceleration allows the easy identification of insufficient grinding trials. This smart industry approach is a valuable tool for improving reproducibility of sample preparation and analysis in quicklime applications.

Key words

• **Quicklime** • **Real time monitoring** • **Grinding** • **Disc mill** • **Wet slaking curve**

Introduction

We recently introduced a novel approach to measure the grinding efficiency in a disc mill by evaluation of the grinding vessel acceleration [1]. In this application note, we describe how this technology can be applied for pulverizing of quicklime.

Calcium oxide, also known as quicklime, is a ubiquitous chemical compound used for a wide range of applications like, e.g., desulphurization in basic oxygen steelmaking or production of mortar, plaster and desiccants. One of the main laboratory parameters for the process control of quicklime applications is the reaction rate of the conversion of lime with water (so-called quicklime reactivity as measured by the wet slaking curve). The reaction speed varies considerably depending on the physical properties of the quicklime. It is therefore mandatory that the quicklime used for the wet slake curve determination exhibits a reproducible grain size distribution within a narrow target range.

Typically, disc mills are used to comminute the quicklime to the required grain size. However, grinding of quicklime is complex due to the following two reasons: First, quicklime tends to form agglomerates very quickly. Chemical additives are usually not suitable for prevention of agglomerates as they may adulterate the analysis results. Therefore, the rotation speed of the disc mill has to be set as low as possible. Second, the grinding set (ring and stone)) is blocked easily between the sample material and the inner walls of the grinding vessel causing the interruption of the grinding process. The blockage is further supported by the low rotation speed and may lead to unpredictable grinding results with a significant bias in grain size distribution. Mechanical modification of the grinding set and vessel decreases the incidence of the blockage but does not eliminate it completely. Therefore, real-time monitoring of the grinding efficiency might be a valuable tool to reduce the uncertainty in grinding results and screen invalid trials.

Method

All trials were carried out on an automatic disc mill of the type HP-M 1500 with a 500 ccm chrome steel grinding vessel. The acceleration sensor used for monitoring of the grinding efficiency was mounted on the swinging aggregate and connected to the PLC of the HP-M 1500 for data acquisition. For analysis of the grinding vessel motion the root mean square (RMS) of the acceleration in the x- and y-direction was calculated and plotted over time for evaluation. All data were recorded and automatically evaluated using the HERZOG PrepMaster Analytics software.

In all trials, we used quicklime with a mean initial grain size of 71 % larger than 90 µm (Figure 1). We pulverized 350 g sample material for 20 s at a rotation speed of 600 rpm. The target grain size range was 80-90 % smaller than 90 µm.

Figure 1: *Photograph of unground quicklime (calcium oxide). In the sample used for the current trials, grain size distribution was relatively heterogenous with 71 % larger than 90 µm; the maximum grain size was approx. 3 mm. The Mohs hardness of the sample was between 3 and 4.*

Periods with efficient grinding and grinding blockage could be easily distinguished from one another by acceleration measurement. Efficient grinding was characterized by a mean RMS of 20.75 ± 1.05 m/s^2 (Figure 2, A). By contrast, during grinding blockage, the mean RMS (21.97 ± 0.53 m/s^2) was significantly higher with lower variability (Figure 2, B).

We performed eight grinding trials with above mentioned parameters. In each trial we evaluated the acceleration signal and analyzed the grain size distribution of the ground material by using a vibratory sieve shaker.

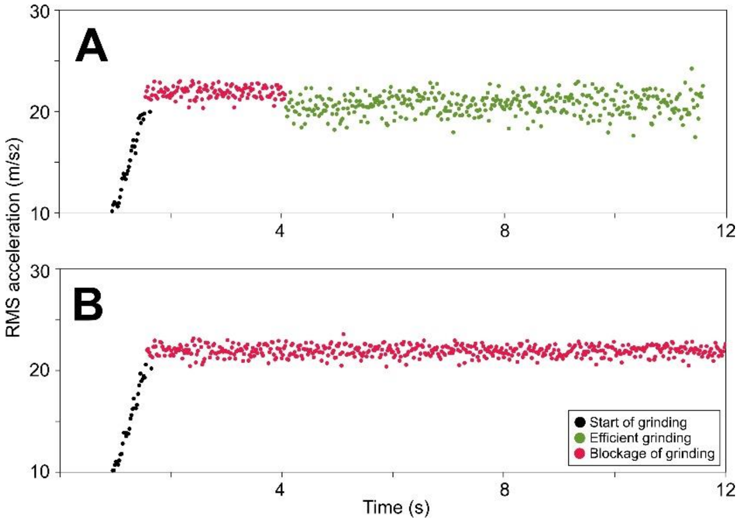

Figure 2: *Two examples of the RMS acceleration signal during quicklime grinding. A: The period of insufficient grinding (red dots) was followed by efficient grinding (green dots). B: In this trial, the grinding set was completely blocked without any efficient grinding.*

Results

In 6 out of 8 grinding trials, the efficient grinding time was between 17 and 18 s (Figure 3, A-F). In each trial, the start-up of the grinding process took approximately 2 s (black dots in Figure 3). In 3 trials, we identified short periods of approximately 1 s duration with a blockage of the grinding process (red dots in Figure 3, C, D, E). All blockage episodes took place at the beginning of the grinding process. The remaining part of the grinding process consisted of efficient grinding (green dots in Figure 3). The grain size fraction < 90 µm in these 6 trials (Figure 4, A- F) was between 82.6 % and 86.5% (mean 84.80 ± 1.29 %).

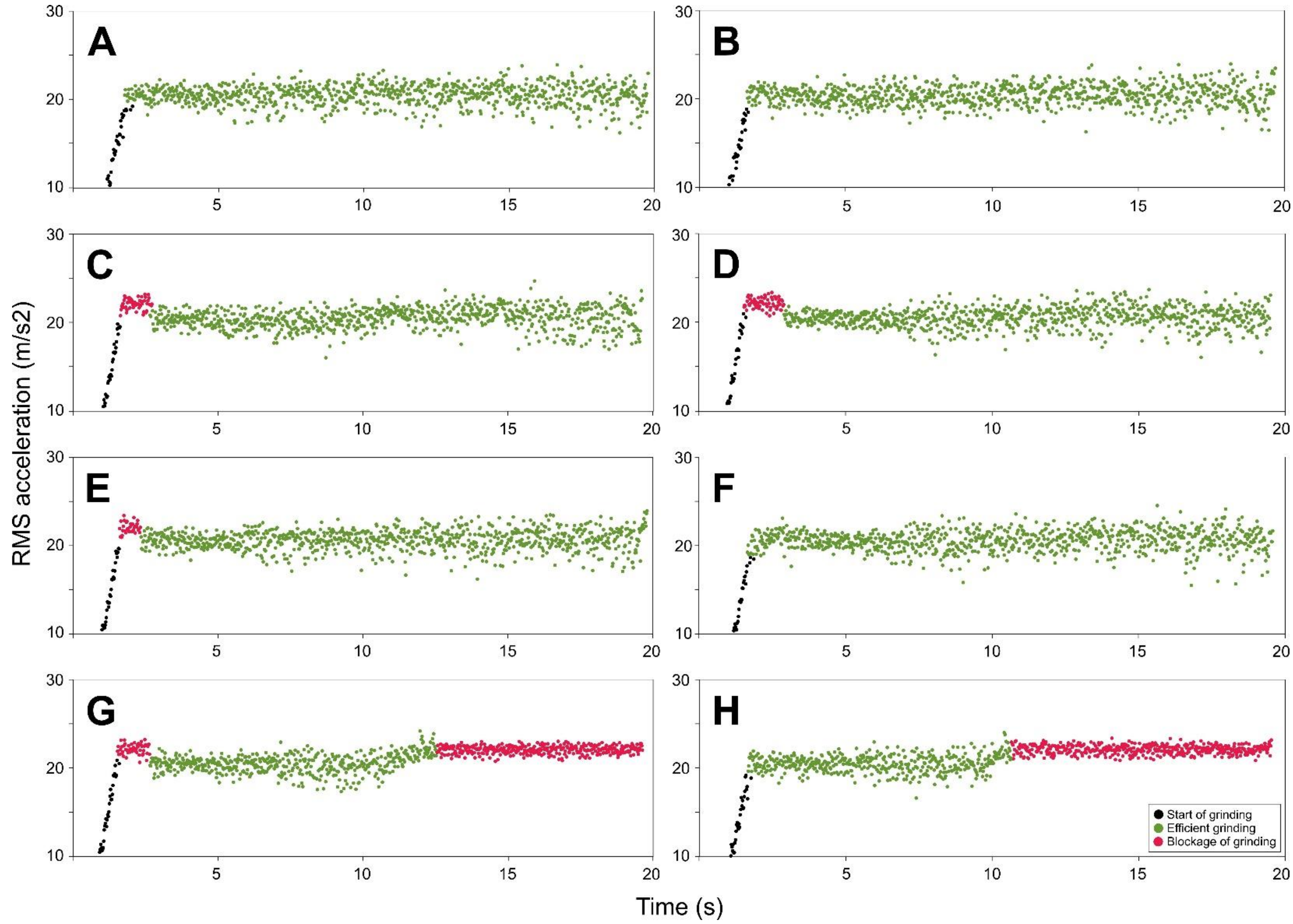

Figure 3: *RMS acceleration signal assessed during 20 s grinding of 350 g of quicklime in the HP-M 1500 disc mill. The trials A- F showed efficient grinding periods of at least 17 s duration (green dots). In C, D and E short periods of grinding blockage (red dots) were visible. The trials G and H consisted mainly of insufficient grinding due to blockage of the grinding set.*

In 2 out of 8 trials, the efficient grinding time was significantly shorter lasting only about 10 s. In both trials, the grinding process started with an efficient grinding period which ended after 12.5 s Figure 3, G) and 11 s (Figure 3, H). In both trials, the fraction < 90 µm was significantly smaller with 64.8 % and 64.7 %, respectively (Figure 4, G, H).

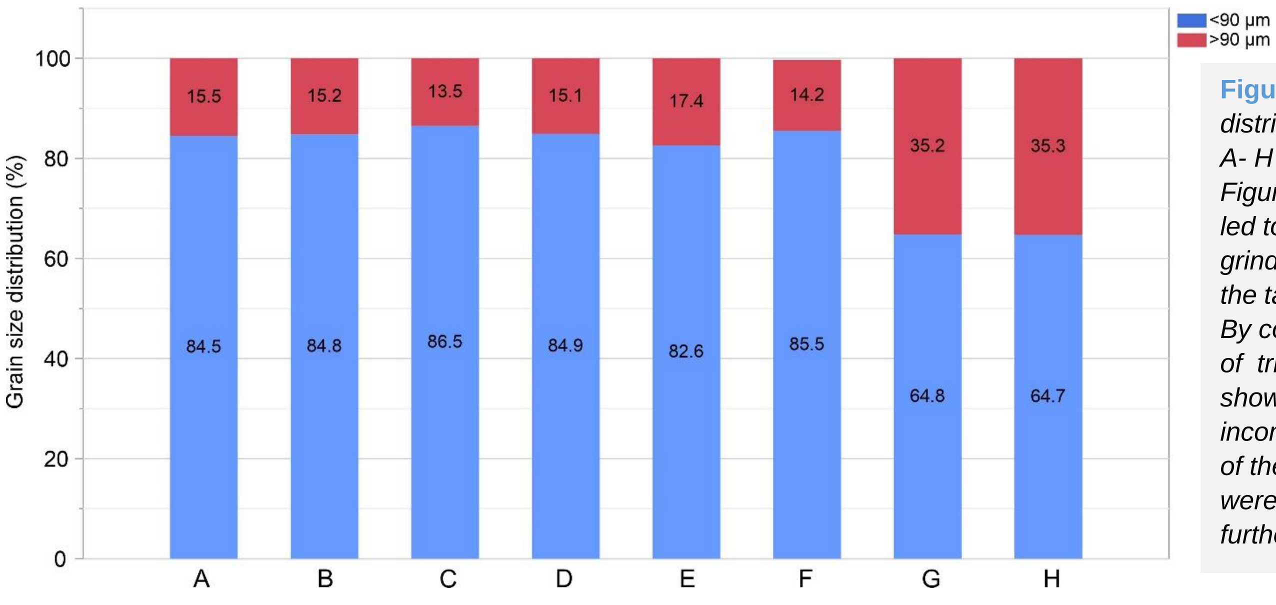

Figure 4: *Grain size distribution of the trials A- H as displayed in Figure 3. Trials A- F led to a sufficient grinding results within the target range. By contrast, samples of trials G and H showed only incomplete reduction of the grain size and were unsuitable for further analysis.*

Discussion

In this application note we demonstrate that the grinding process of quicklime can be exactly monitored by evaluation of the acceleration sensor signal. The method allows a definite distinction between efficient and insufficient grinding due to blockage of the grinding set. The efficient grinding of quicklime is characterized by decrease of the mean RMS acceleration value and increase of the signal variability. By contrast, blockage of the grinding set is associated with an immediate increase of the RMS value and decrease of the variability.

The signal pattern during efficient grinding strongly resembles the findings in previous studies of silica sand and iron ore [1]. This underlines the hypothesis that the decrease of the grain size during efficient grinding causes a higher viscosity of the sample material. This again impedes the movement of the grinding set through the material resulting in deceleration and higher variability of the grinding vessel motion. In case of complete blockage, the grinding set does not interfere with the grinding vessel motion resulting in an acceleration increase with very little variability.

The functional significance of these findings is reflected by the grain size analysis of the ground material. If the efficient grinding time was long enough (17- 18 s), the grain size was consistently reduced to the target range. If the efficient grinding time was significantly shortened (10 s), the grain size reduction was incomplete and the sample aliquot was not suitable for further tests.

This study opens up interesting possibilities for the sample preparation of quicklime and other materials difficult to grind. On the one hand, the real-time monitoring enables the operator to immediately detect insufficient grinding trials which then can be sorted out from further analysis. On the other hand, software systems like the PrepMaster Analytics might automatically identify periods of insufficient grinding and take appropriate measures like releasing the blockage by a sudden impulse. In any case, evaluation of the acceleration sensory signal improves the reproducibility of the sample preparation process and reduces the analytical bias.

References

[1] HERZOG Application note 30/2020: Real-time monitoring of grinding efficiency in disc mils by acceleration measurement

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