Tool condition monitoring of disc mills- Online monitoring of the wear of the grinding set

Abstract

Disc mills are used to comminute sample material for analysis by XRF, XRD or other methods. Here we present a new approach for online tool condition monitoring (TCM) of the wear of the grinding set by means of acceleration measurement (patent pending). We show that that the wear of the grinding set leads to a characteristic pattern that can easily be detected in the PrepMaster Analytics software. The TCM of disc mills is an important component to ensure a high degree of reproducibility in the sample preparation process.

Key words

• **Disc mill** • **Tool Condition Monitoring** • **Grinding set** • **Disc** • **Stone** • **Acceleration**

Introduction

Disc grinding mills are standard equipment in many laboratories specializing in sample preparation and analysis of non-organic material. The operation principle of disc mills is that a motor puts the grinding vessel into an eccentric motion. This causes a ring and/or stone (so called grinding set) to move inside the vessel leading to comminution of the material inside. Basic principles of particle size reduction are shearing, impacting and compression of the material between ring, stone and the wall of the grinding vessel.

Proper and reproducible material grinding depends on the integrity of the grinding set. The ring and stone are subject to wear due to the mechanical stress inside the grinding vessels. This leads to a progressive decrease of the weight and loss of material especially at the chamfers of ring and stone. As a matter of course, the lifetime of the grinding set is strongly correlated with the total grinding time and the type of material to be ground. Usually, pulverizing of hard and brittle samples results in a faster wear than pulverizing soft material. If the wear exceeds a certain limit this might have negative impact on the grinding results leading to an increased bias in the grain size distribution. The best option to monitor the condition of the grinding set is visual inspection by the experienced operator. However, especially in automatic mills it might be cumbersome and time-consuming to open the grinding vessel at regular intervals for inspection. Furthermore, not every user might have the sufficient qualification and experience to assess the state of the grinding set.

In this application note, we present an approach for online monitoring of the grinding set wear. The tool condition monitoring (TCM) is based on sensory data obtained through an acceleration sensor fixed on the swing aggregate of the disc mill. The sensor allows the three-dimensional tracking of the movement of the grinding vessel mounted on the swing aggregate. Based on these data values, it is possible to identify patterns that are typical for a significant wear of the grinding set.

Method

An acceleration sensor is mounted on the lower half of the swinging aggregate and connected to the PLC of the grinding mill for data acquisition. The sampling frequency of the sensor is 100 Hz. For analysis of the grinding vessel motion, the vector from acceleration in x- and y-direction was calculated for each point of time. For TCM of the grinding set the length of the combined x-/ and y-vector was evaluated by calculation of the root mean square (RMS).

Additionally, we performed a topological analysis by scatter plotting the 2D vector points. Due to the circular movement of the grinding vessel the vector points form a circle which was divided in 18 segments à 20 degree. For each segment, the mean and standard deviation of acceleration were calculated and evaluated by the TCM module of the PrepMaster (PM) Analytics software.

The functionality of the grinding set was monitored by regular 20 seconds test runs with an empty grinding vessel. These test runs were compared to a set of reference values recorded while the mill was in a new and proper condition. For detection of significant changes in mean and standard deviation of the RMS and the vector points in each segment we applied methods of statistical process control (SPC) implemented in the PM Analytics.

The tests were carried out in swing aggregates of both manual and automatic mills including the model HSM 100, HP-MA and HP-MP. We aimed at simulating the wear process of the ring and stone. Therefore, we used a worn ring and stone made from tungsten carbide (weight loss of ring and stone approx. 9%, Figure 1, B) from another mill to replace the new grinding set of the vessel.

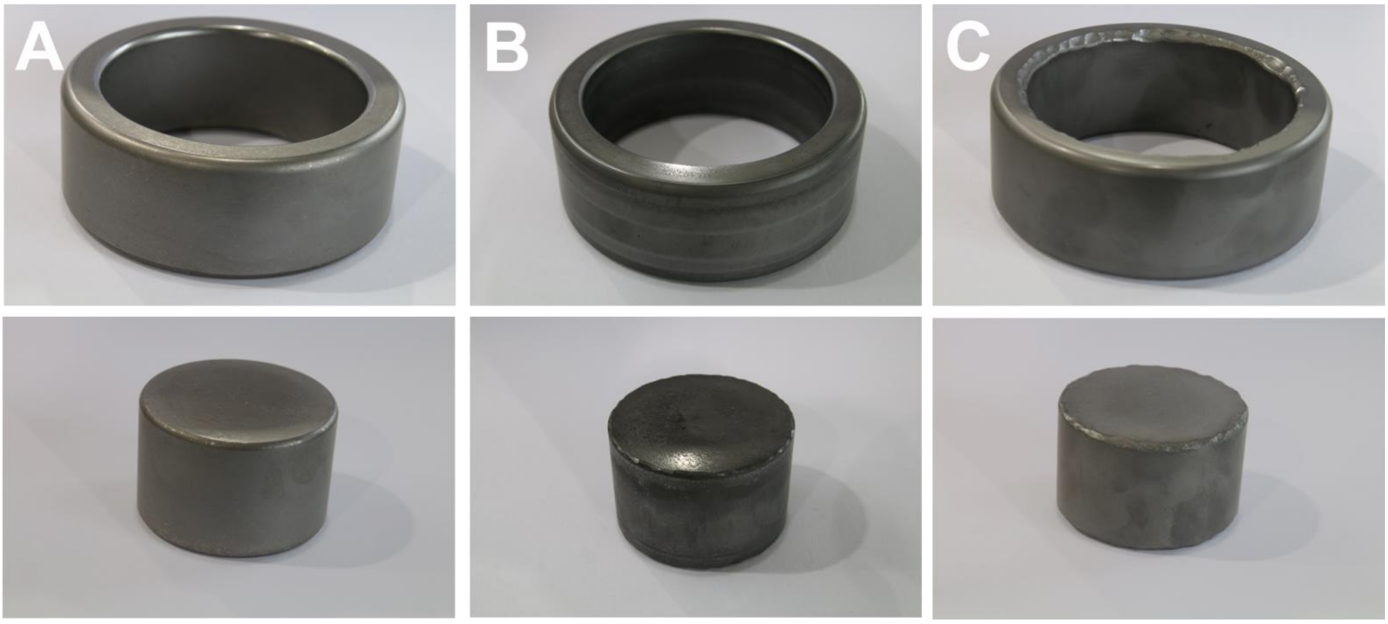

Figure 1: *Examples of a grinding set with ring and stone made from tungsten carbide in different stages of wear. (A) shows a new grinding set. (B) displays a grinding set with a weight loss of approx. 9%. Usually, in this stage of wear an exchange is recommended. (C) shows a grinding set with heavy wear. Usually, at this stage, predictable grinding results can hardly be achieved.*

Results

The calculation of the RMS of the x-/y acceleration vectors revealed a significant increase of the standard deviation using a worn grinding set. Figure 2 exemplarily shows the RMS of a worn grinding set during a 20 s test rung (B) compared to values of a new grinding set obtained during a reference run (A).

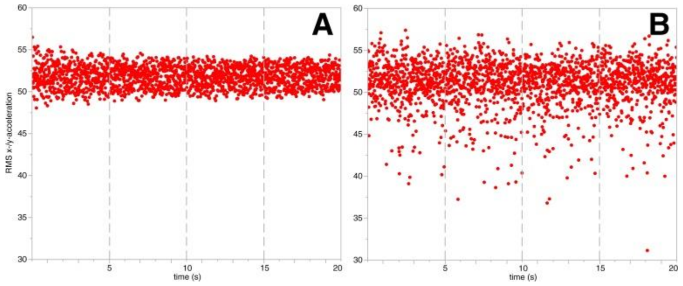

Figure 2: *Examples of a reference run with new (A) and worn (B) grinding set. The wear leads to an increase of RMS standard deviation.*

We performed a statistical analysis of 30 test runs compared to 20 reference runs (Figure 3). In each of the four time periods of the 20 s test run, we found an increase of the mean average of the standard deviation compared to the reference values. Furthermore, the wear of the grinding set was associated with an increased variability between single runs leading to a wider interquartile range (IQR).

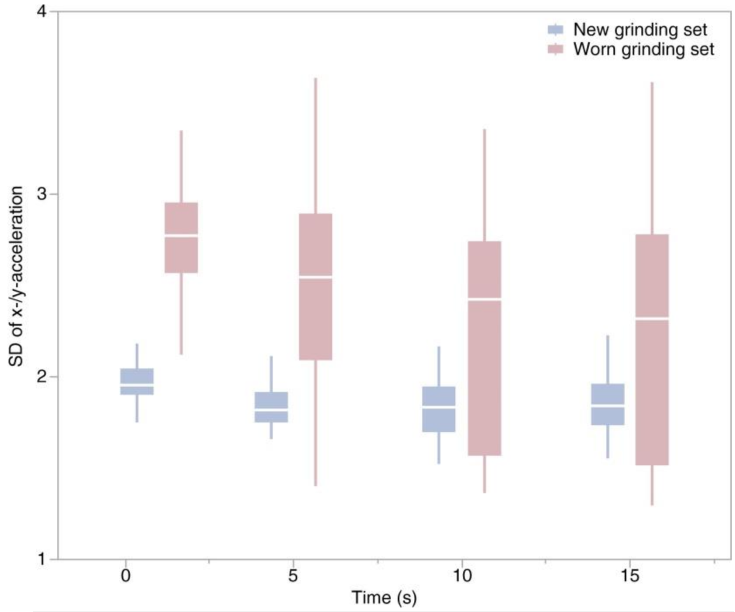

Figure 3: *Comparison of reference runs with new grinding set (n= 20, blue boxes) and test runs with worn grinding set (n=30, red boxes). The wear of the grinding set leads to an increased standard deviation of the acceleration RMS. The increase of the IQR reflects the higher variability between test runs.*

In the topological assessment, the wear of the grinding set resulted in an equal acceleration reduction in all 18 segments (Figure 3, A). Simultaneously, standard deviation was uniformly increased in all segments (Figure 3, B).

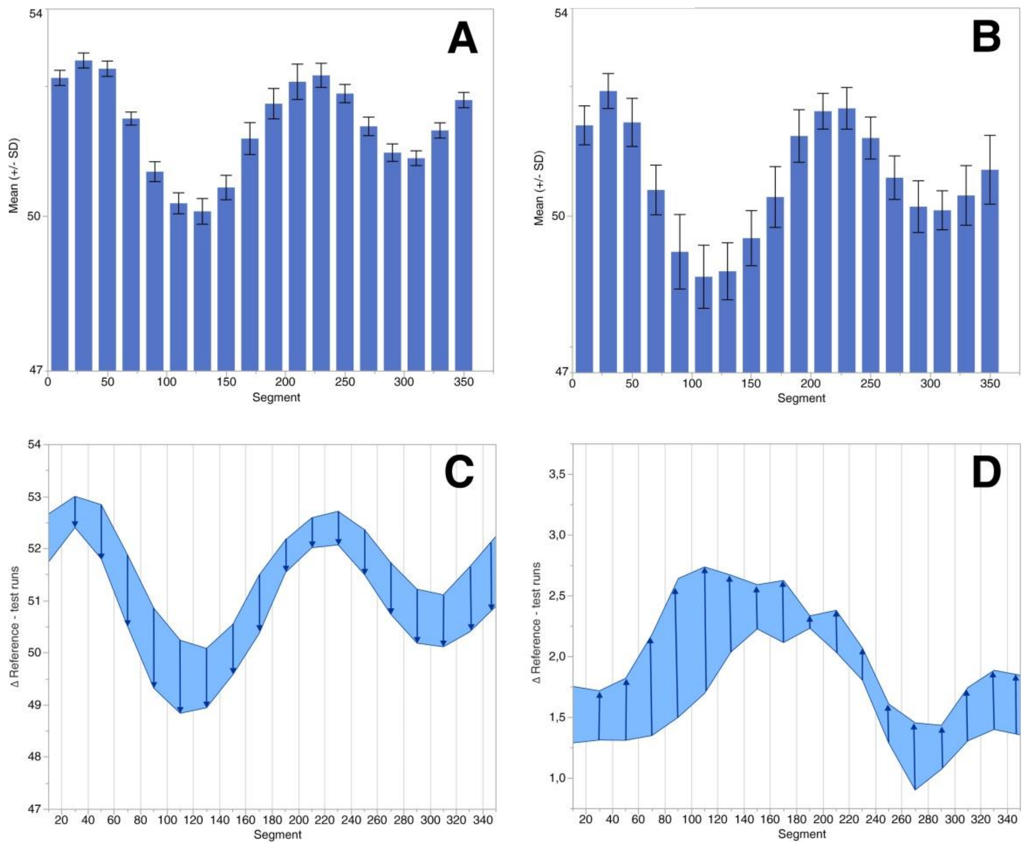

Figure 3: *A, B: Mean average and standard deviation of the acceleration measured in a swing aggregate with new (A) and worn (B) grinding set. C, D: The difference between reference runs with new grinding set and test runs with worn grinding set shows an decrease of acceleration (C) and increase of standard deviation in all segments.*

Discussion

In this application note, we present a simple method for online monitoring of the grinding set condition. The characteristic pattern of a worn grinding set consists of an increased standard deviation of the acceleration RMS and a decrease of acceleration in all segments. The trials showed that a single test run with a worn grinding may reveal values within the normal range. However, the deviating pattern can be clearly recognized over the course of time by using methods of SPC.

We recommend performing short test runs of 20 s once or twice daily to have a comprehensive overview about the state of the grinding set. In automatic systems, the test runs can be automatically initiated by the PrepMaster Core or Entry. These test runs are carried out only in time intervals when no samples are in the system in order to not disturb the performance of the system. The evaluation of the test data is done fully automatically by the TCM module of the PM Analytics (Figure 4, 5).

As incorrect and inappropriate sample preparation accounts for approximately 30% of the total analytical error it is of prime importance that all conditions of the preparation steps are highly reproducible. If machines used for sample preparation deviate from the optimal state this may lead to an increased rate of uncertainty in measurement that is very difficult to recognize and disclose.

TCM is increasingly used as integral part of smart industry solution for process management and optimization. The Herzog TCM system for disc mills using acceleration measurement allows the control of essential key performance indicators of the grinding process like, e.g., motion of the swing aggregate and wear of the grinding set. Therefore, TCM turns out to be an important component to guarantee reproducible preparation conditions. The automatic analysis by the PM Analytics makes it easy even for the unexperienced operator to take the appropriate action.

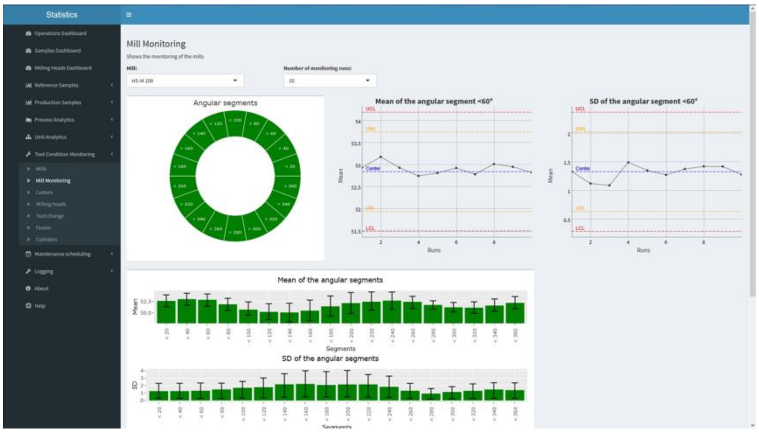

Figure 4: *Dashboard of the PM Analytics used for TCM of the swing aggregate. For detection of deviations methods of statistical process control (SPC) are applied.*

Figure 5: *Example of a dashboard showing the typical pattern of a worn grinding set.*

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