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Tool condition monitoring of disc mills- Monitoring of the proper swing aggregate function

Abstract

Disc mills are used to comminute sample material for analysis by XRF, XRD or other methods. Here we present a method for online tool condition monitoring (TCM) of the proper swing aggregate function by means of acceleration measurement (patent pending). We show that this TCM approach is capable to detect even minimal deviations in the motion of grinding vessel due to, e.g., wear of the horizontal springs. The use of a TCM system for disc mills will have a significant impact of the reproducibility of the sample preparation process.

Key words

• **Disc mill** • **Tool Condition Monitoring** • **Swing Aggregate** • **Acceleration Measurement**

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 being ground. Basic principles of particle size reduction are shearing, impacting and compression of the material between ring, stone and the wall of the grinding vessel.

In order to guarantee an efficient grinding process it is essential that ring and stone make a circular motion along the wall of the grinding vessel.

The circular motion is achieved by mounting of the grinding vessel on the so called swing aggregate of the disc mill (Figure 1). Horizontal and vertical springs within the swing aggregate guide the vessel into a precise circular motion and prevent it from swinging sideward or upward. Deviations of the grinding vessel from the optimal circular path have an adverse effect on the grinding efficiency resulting in a decreased reproducibility of the grain size distribution. Eventually, this may lead to an increased bias of the analytical results using X-ray spectroscopy or diffraction analysis.

In this application note, we present a method for online monitoring of the proper swing aggregate function (patent pending). The movement of the swing aggregate is tracked in three space dimensions over time using a capacitive acceleration sensor. Based on these data values, it is possible to identify patterns that are typical for functional variation of the swing aggregate due to wear of the springs.

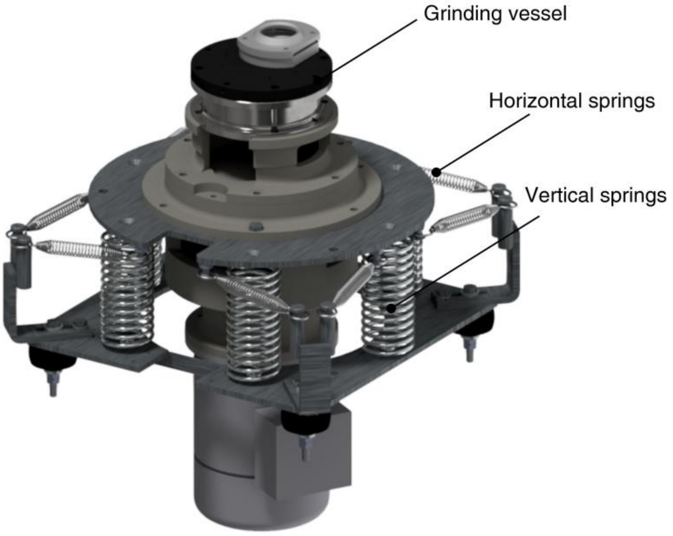

Figure 1: *Swing aggregate of a vibratory disc mill with horizontal and vertical springs guiding the motion of the grinding vessel*

Method

The 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 is calculated for each point of time. Due to the circular movement of the vessel the 2D vector points form a circular scatter plot (Figure 2) which is divided in 18 segments (each covering 20°) for further analysis.

Acceleration vectors in each segment were evaluated using statistical characteristics including mean and standard deviation. Data collection, display and analysis were performed by the TCM module of the PrepMaster Analytics software.

The functionality of the swing aggregate 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 monitoring and detection of condition change in each segment we applied methods of statistical process control (SPC).

The tests were carried out in swing aggregates of both manual and automatic mills including the model HSM 100, HP-MA, HP-MP and others. We aimed at simulating the wear process of the horizontal springs of the swing aggregate. Therefore, we used worn springs (operation time approx. 15 months) from another mill to replace the new springs of the test aggregate. As the spring wear is usually irregular we did not exchange all springs at once but two adjacent springs in the corner of the swing aggregate.

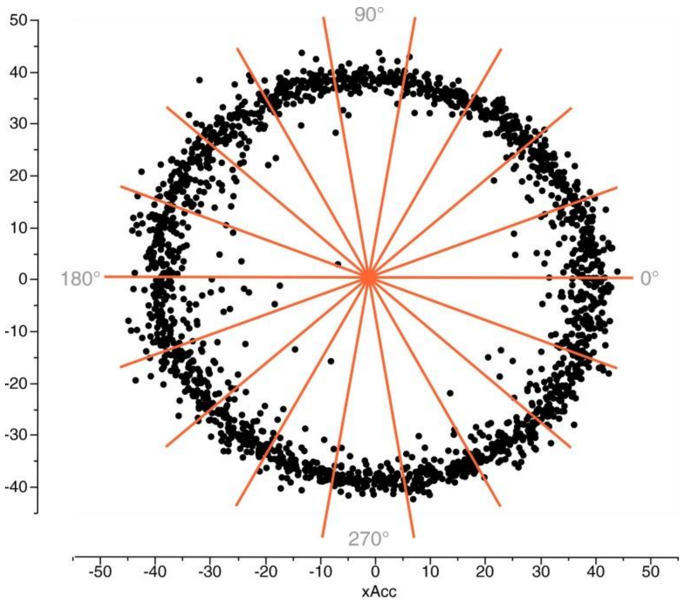

Figure 2: *Circular distribution of the vectors calculated from x- and y-acceleration during motion of the empty grinding vessel. In each of the 20° sectors the mean average and standard deviation of the acceleration vectors are determined.*

Results

The swing aggregate with new springs showed a characteristic acceleration pattern with a harmonic wavelike profile across the segments. In each segment, the acceleration vectors were of similar size resulting in a small standard deviation (Figure 3, A). By contrast, the swing aggregate with worn springs revealed an acceleration decline in the affected segments of the spring aggregates. Figure 3 (B) shows a decrease of acceleration in the segments 100° to 160° corresponding to the section of the swing aggregate where the springs were exchanged. Furthermore, in the affected segments the standard deviation of the acceleration was significantly increased reflecting a less reproducible acceleration of the grinding vessel in this section.

Correspondingly, the difference between the values of the reference runs and the test runs disclosed a decrease of acceleration in the affected segments and a small compensatory increase in the other segments (Figure 3, C). The values for standard deviation showed a significant increase in the affected segments and a small increase in the remaining sectors (Figure 3, D).

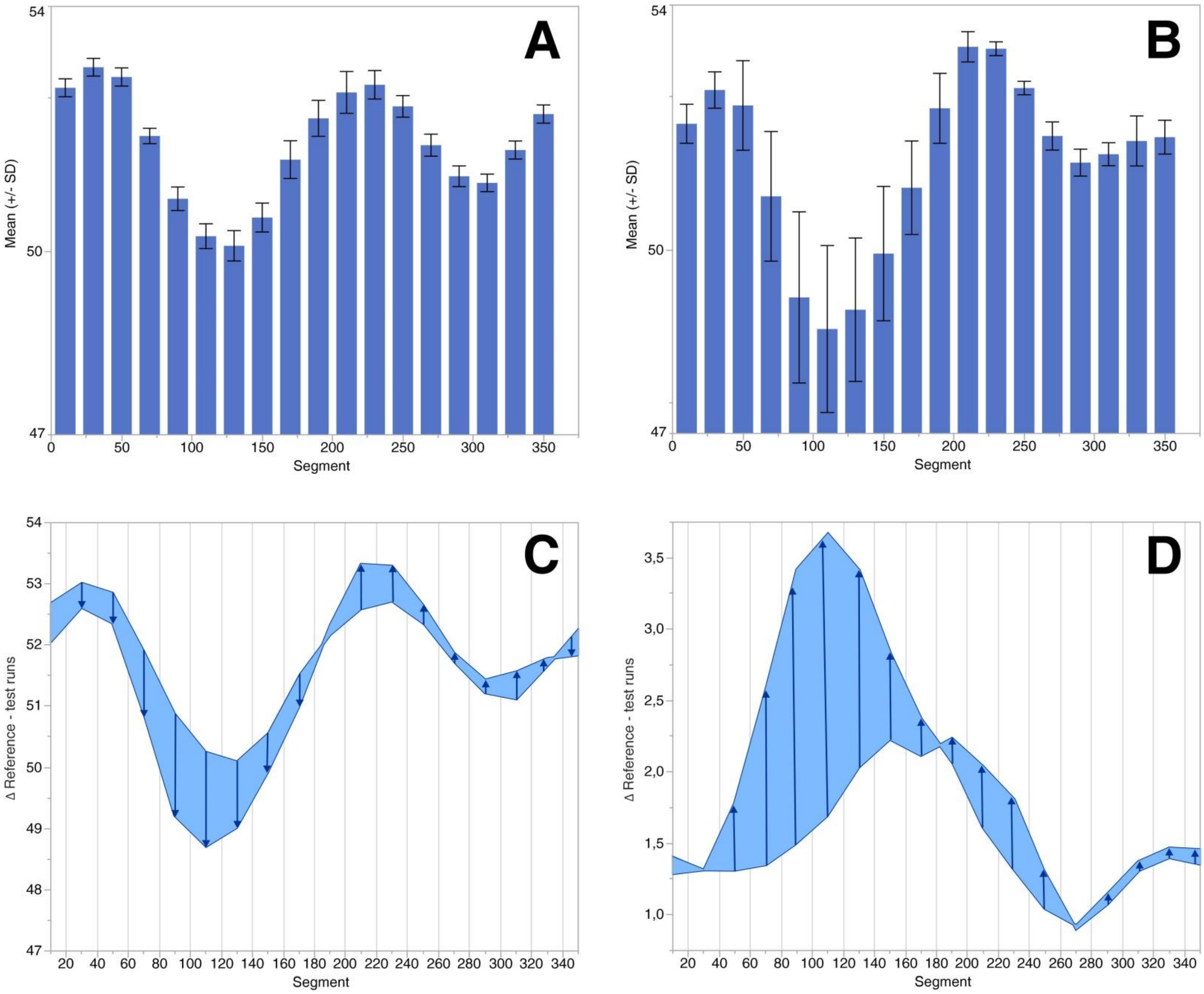

Figure 3: *A, B: Mean average and standard deviation of the acceleration measured in a swing aggregate with intact (A) and worn (B) horizontal springs. C, D: The difference between reference runs with intact springs and test runs with worn springs shows an decrease of acceleration (C) and increase of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

Discussion

This study demonstrates that acceleration measurement is an appropriate approach for online monitoring of the swing aggregate. The method is reliable and easy to implement in all Herzog swing aggregates used for manual, semi-automatic and fully-automatic pulverizing mills.

The special design of the spring-mounted swing aggregate allows a highly-precise tracking of the motion of the grinding vessel. Even small deviations from the optimal path can be detected and used for, e.g., tool condition monitoring (TCM) of the swing aggregate. The wear of the horizontal springs leads to a characteristic pattern with a decrease of the acceleration vector and increase of the standard deviation in the affected segment. The swing aggregate performance is displayed using the mill monitoring module of the PrepMaster Analytics (Figure 4, 5). Abnormalities and deviations from the regular condition are detected and categorized using methods of statistical process control (SPC). This data processing provides the operator with a quick and easy overview about the proper sample preparation in the disc grinding mill.

Incorrect and inappropriate sample preparation accounts for approximately 30% of the total analytical error in quality control laboratories.

Therefore, each step in the sample preparation process has to be as reproducible as possible to reduce the uncertainty and bias in measurement. Deviations in the movement of the grinding vessel can result in an increased variability of the grain size distribution from sample to sample. This may have direct impact on the analysis result in x-ray fluorescence spectroscopy or diffractometry.

The TCM of the swing aggregate is a powerful tool to guarantee a high degree of reproducibility in the sample preparation process. An error can be detected and rectified before it has a negative effect on the analysis result. In case of a worn horizontal spring the exchange of the spring is very simple and cheap.

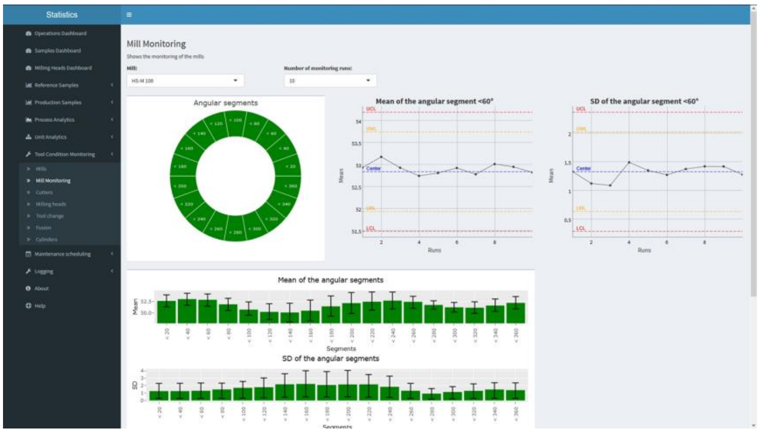

Figure 4: *Dashboard of the PrepMaster Analytics used for TCM of the swing aggregate. For detection of deviations methods of statistical process control (SPC) are applied.*

Figure 5: *Dashboard of the PrepMaster Analytics showing the typical pattern of worn horizontal springs.*

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