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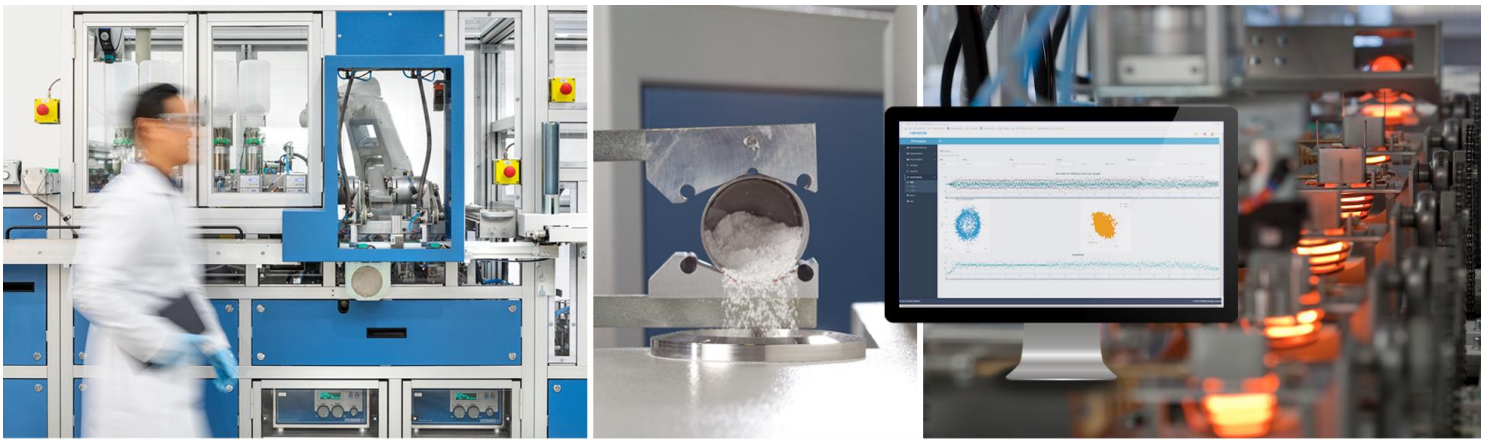

Acceleration Monitoring for Tool Condition in Large-Volume Vibratory Mills

Abstract

Vibratory disc mills rely on the precise circular motion of the grinding vessel, maintained by horizontal and vertical springs within the swing aggregate. This application note explores the impact of spring wear on the motion path of the HP-M 1500, a large-volume vibratory disc mill. Acceleration measurements under normal and worn spring conditions revealed that worn springs cause deviations in acceleration and variability. Vertical spring wear reduced acceleration and increased variability, while horizontal spring wear altered acceleration patterns without affecting variability. These results demonstrate the effectiveness of acceleration measurement for monitoring swing aggregate condition. HERZOG's PrepMaster Analytics software enables automated tool condition monitoring (TCM), ensuring consistent sample preparation, improved accuracy, and efficient maintenance.

Key words

• Vibratory disc mill • Acceleration • Tool condition monitoring • PrepMaster Analytics

Introduction

Vibratory disc mills are extensively used in laboratories for grinding granular sample materials of various types. These mills operate on the principle of eccentric motion, where a motor drives the grinding vessel in a circular path. Inside the vessel, a grinding set (ring and/or stone) comminutes the material.

The circular motion is achieved by mounting the grinding vessel on a "swing aggregate". Horizontal and vertical springs within the swing aggregate ensure precise circular motion, preventing undesirable lateral or vertical deviations. Any deviation from the optimal path negatively impacts grinding efficiency and reduces the reproducibility of the grain size distribution.

Previously [1], we analyzed the impact of worn horizontal and vertical springs on the motion of a 100 ccm grinding vessel in various mill types (HSM 100, HP-MA, HP-MP). We demonstrated that worn springs cause deviations in motion, detectable via an acceleration sensor. Specifically, wear in the horizontal springs reduced acceleration and increased variability in specific motion segments.

Figure 1: Photographs of the vibratory disc mill of the type HP-M 1500 with a 1500 ccm grinding vessel

In this application note, we focus on the HP-M 1500 (Figure 1), which has a elaborated swing aggregate to manage the heavier grinding vessel with a volume of 1500 ccm. The system employs 16 vertical springs, four upper horizontal tension springs, and four lower horizontal tension springs to maintain optimal motion (Figure 2, 3).

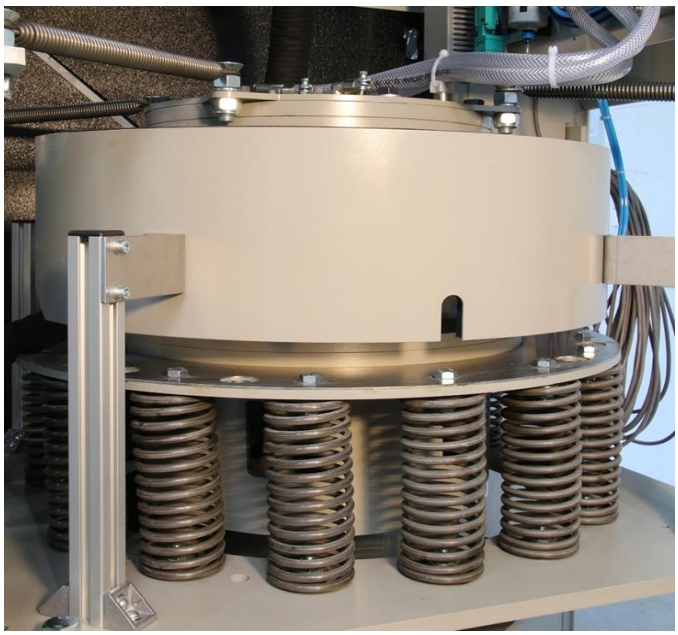

Figure 2: Photograph showing the swing aggregate of the HP-M 1500 vibrator disc mill.

We studied the effects of wear on these springs, evaluating changes in acceleration and variability.

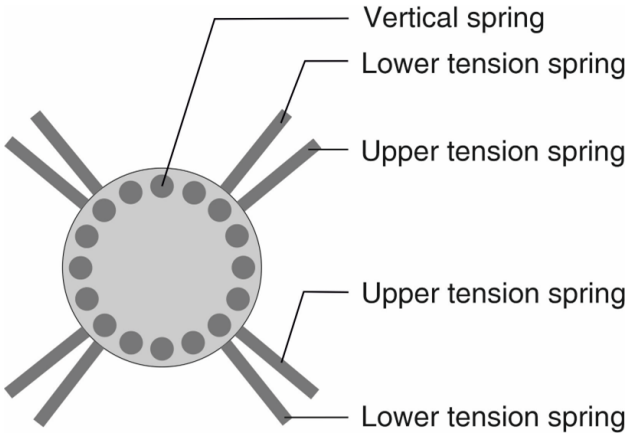

Figure 3: Schematic drawing of the swing aggregate showing the position of vertical and tension springs

Methods

The acceleration measurement method has been described previously [1, 2]. All experiments were conducted using the standard HP-M 1500 automatic vibratory disc mill. The acceleration sensor was mounted on the plate securing the vertical springs.

We measured acceleration under four different conditions: (1) Fully functional vertical and horizontal springs (normal conditions), (2) three worn vertical springs, (3) two worn lower horizontal tension springs, and (4) two worn upper horizontal tension springs.

Measurements were performed for 30 seconds with an empty grinding vessel at a speed of 800 rpm. Average acceleration and standard deviation were calculated for each circular segment, and the results were compared to those under normal conditions.

Results

Acceleration pattern under normal conditions

Acceleration values ranged between 52.5 and 53.5 m/s², with sinusoidal oscillations peaking at 140° and 320°. Standard deviation values ranged between 1.5 and 3.0 m/s², with a minimum at 80° and a maximum at 280° (Figure 4, A-C, blue graphs).

Acceleration pattern with worn vertical springs

Introducing three worn vertical springs caused a decrease in acceleration between 200° and 280°, accompanied by increased variability in the same segment (Figure 4, A1 and A2).

Acceleration pattern with worn lower tension springs

Using worn lower tension springs resulted in reduced acceleration between 200° and 280° (Figure 4, B1). Simultaneously, an increase in acceleration was observed in the opposite segments (80°–140°). Standard deviation remained unaffected (Figure 4, B2).

Acceleration pattern with worn upper tension springs

Worn upper tension springs also reduced acceleration between 200° and 280° and caused a secondary reduction in the opposite segments (Figure 4, C1). Standard deviation values were unchanged (Figure 4, C2).

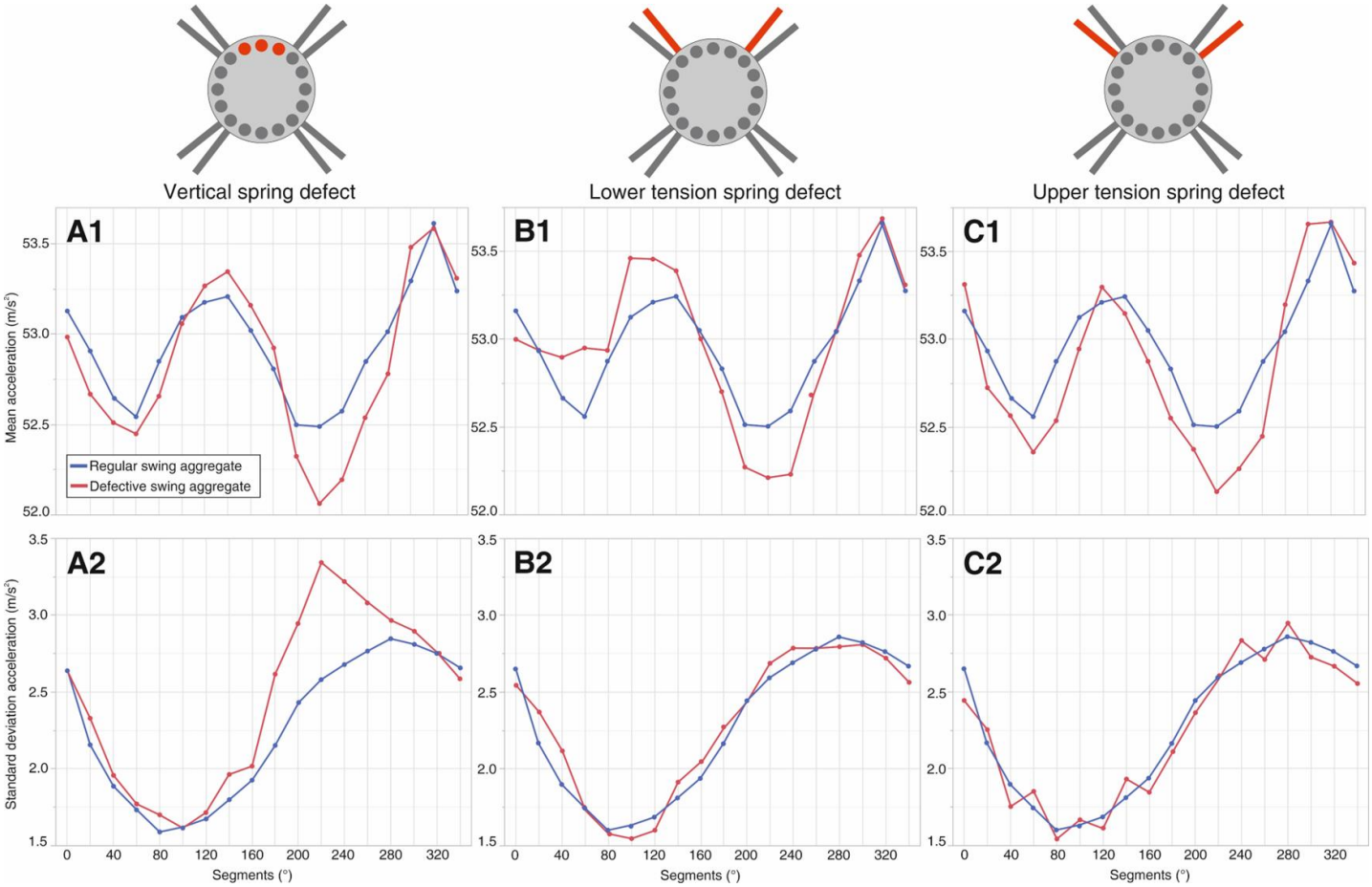

Figure 4: Graphs showing the mean average acceleration (upper row) and standard deviation (lower row) in the different motion path segments. The graphs for normal conditions are displayed in blue, for fault conditions in red.

Discussion

The findings of this study demonstrate that acceleration measurement is a highly effective method for monitoring the swing aggregate in vibratory disc mills, even for systems with large-volume grinding vessels like the HP-M 1500. Despite the more complex design of the HP-M 1500's vibratory unit, the principles of motion analysis proved adaptable, enabling reliable fault detection similar to smaller mills.

The data-acquisition system used in this study can detect minor deviations from the optimal circular motion path, making it a practical tool for tool condition monitoring (TCM). Faults in vertical springs lead to reduced acceleration and increased variability in specific segments, while faults in horizontal springs cause distinct changes in acceleration patterns without significantly affecting variability. These insights highlight the precision of acceleration-based monitoring for diagnosing specific issues in the swing aggregate.

Reproducible sample preparation is a cornerstone of accurate and precise analytical results. Variability in the motion path of the swing aggregate directly impacts the consistency of the grinding process, potentially introducing errors in downstream analysis. Acceleration monitoring therefore ensures that sample preparation remains consistent, enabling reliable and repeatable results in laboratory workflows.

HERZOG's PrepMaster Analytics software takes this capability a step further by automating the recording and evaluation of acceleration data. Based on statistical process control (SPC) mechanisms PrepMaster Analytics notify users of abnormalities potentially impacting the grinding performance of the mill. Our integrated solutions meet the evolving demands of modern high-precision laboratories for reliable performance and seamless preventative maintenance.

References

[1] HERZOG Application Note 25/2019: Tool condition monitoring of disc mills- Monitoring of the proper swing aggregate function

[2] HERZOG Application Note 26/2019: Tool condition monitoring of disc mills- Online monitoring of the wear of the grinding set

Germany

HERZOG Maschinenfabrik GmbH & Co. KG
Auf dem Gehren 1
49086 Osnabrück
Germany
+49 541 9332-0
+49 541 9332-33
info@herzog-maschinenfabrik.de

Subsidiaries

USA

HERZOG Automation Corp.

8245 Dow Circle
Strongsville, OH, 44136
USA

+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

+81 3 5907 1771
+81 3 5907 1770
info@herzog.co.jp
www.herzog.co.jp

China

HERZOG (Shanghai) Automation Equipment Co., Ltd.

No.473, West Fute 1st Road,
Waigaoqiao F.T.Z, Shanghai,
200131,
P.R. China

+86 21 50375915
+86 21 50375713
MP: +86 15 80 07 50 53 3
xc.zeng@herzog-automation.com.cn
www.herzog-automation.com.cn

India

HERZOG Automation India
Office No 416, 4th Floor,
Westport, Baner Gaon
Pune, Pune City,
Maharashtra, 411045
Indien

+49 541 9332 40
info@herzog-automation.in
www.herzog-automation.in

France

HERZOG FRANCE
8 rue Bis Gabriel Voisin
51100 REIMS
France

+33 (0)6 81 72 41 65
nolan.lopez-at-herzog-automation.fr
www.herzog-automation.fr