INVESTIGATION OF CHARGE SHAPE AND MILL SPEED EFFECTS ON POWER DRAW IN TUMBLING MILLS

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Abstract: Power draw estimation plays a vital role in sizing, control and optimization of grinding mills. As a result, power draw is considered to be one of the key control parameters in grinding circuits. Most of the equations presented to determine the power draw make use of the torque created by the charge inside the mill. In this research, effect of filling, mill speed, and liner shape on power draw were studied using a 1-m diameter laboratory mill, considering the amount of free flight materials with varying torque arm. The amount of inflight material and mill charge were calculated by image analysis of pictures taken from the transparent end of the mill during operation. The center of mass and the length of torque arm were calculated using Solidworks© software. Results indicated that for 45% filling, due to a reduction in the amount of materials in contact with mill shell, the maximum inflight material was obtained at speed of 100% (relative to the critical speed); whereas, for 15% filling this occurred at speed of 85%. Furthermore, the maximum torque arm for 15% filling was observed when mill speed was 45%; in case of 45% filling, the same obtained at a speed close to 80%. The power draw for a new and a worn liner (5184 h of operation) in Sarcheshmeh copper concentrator were compared. It was observed that at all mill speeds, the mill power draws for worn liners were higher than that of the new liners. For example, for 25% filling and 70% mill speed, the power draw of the worn liner was 10% higher than the new liner.

Keywords: Mill, torque arm, power draw, charge shape.

INTRODUCTION

In mineral processing plants, the power draw of tumbling mills is an important design and operating variable. The power draw of a tumbling mill refers to the energy expended per unit time in causing motion of the contents, or charge. The power draw quantity is determined as a product of the torque exerted by charge on external shell and specified mill rotational speed. Many methods have been proposed to predict the power draw of tumbling mills. In recent years, an advance in measurement and computational tools has enabled more detailed studies of the mechanisms that govern charge motion behavior. This has provided the opportunity to develop appropriate models which describe the power draw in terms of variables that influence charge motion. Different manufacturers usually specify different sizes and operating conditions for an identical ore test data.

The availability of large-scale cost-effective computing power in recent years has allowed the development of Discrete Element Modelling (DEM) computer programs that model charge flow in mills. DEM helps to understand charge motion in tumbling mills for given liner designs and lifters, ball and rock properties and, mill operating conditions. Based on success of 2-D models of tumbling mills, 3-D models in DEM were developed. These model could help to study charge motion and power draw more accurately and also could provide information regarding the effect of operational variables and liner design on charge motion and power draft.

In recent years, a combination of analytical and physical studies was used to study the effects of a wide range of mill and particle properties on charge shape and power draw of tumbling mills to understand the effects of operational, liner and feed variations on the performance of industrial mills. In this research, the effect of operational conditions, such as filling and mill speed, and liners properties on power draw were studied by considering the amount of free flight material and variation of torque arm using a 1-m diameter laboratory mill.

METHODS

In order to determine ball trajectories in different operating conditions and liner profiles, a 100 cm×11 cm mill was used. A 2.5 kW motor with a variable speed drive was used to provide sufficient flexibility to test various operating speed conditions. The transparent end of the mill made accurate trajectory determination possible with taking photographs. In order to exactly copy the plant liner arrangements in the mill, three types of polyurethane rings, which were scaled-down versions of the liners, were accurately machined to be used in the model mill. The three liners types were: new and worn (after 5184 h of operation) liners of SAG mill in Sarcheshmeh copper complex, and new (i.e. proposed) liner of AG mills in Gol-E-Gohar iron ore company.

Experiments were performed for each type of liners at 30 - 100% of critical speed and mill filling of 15-45% by volume. For any experiment, the amount of inflight material and mill charge were calculated by the image analysis of pictures taken from the transparent end of the mill during operation. An image analysis software called "ImageJ" was used to determine the percentage of load on the flight. The center of mass and the length of torque arm were calculated using Solidworks© software.

FINDINGS AND ARGUMENT

Equations indicated that power draw depends on torque size and mill speed, and the torque is related to the filling percent and distance between center of mass and mill center. Results showed, by increasing mill filling, the torque increases because of increased mill weight. Also, with increasing mill speed, amount of torque reaches a maximum value and then begins to drop as speed increases. As the mill speed increases, percentage of inflight material increases for each filling and continues to a point that loads centrifuges. In this study, in addition to determining the amount of flight material, change in the mass center of gravity was also studied. Results indicated that for 45% filling, due to a reduction in the amount of material in contact with the mill shell, the maximum inflight material was obtained at speed of 100% (relative to the critical speed); whereas, for 15% filling this occurred at speed of 85%. Furthermore, maximum torque arm for 15% filling was observed when mill speed was 45%; in case of 45% filling, the same obtained at a speed close to 80%.

The torque change trends were also investigated in different operational conditions for new and worn liners. The power draw for a new and a worn liner (5184 h of operation) in Sarcheshmeh copper concentrator were compared. It was observed that at all mill speeds, the mill power draws for worn liners were higher than that of the new liners. For example, for 25% filling and a mill speed of 70%, the power draw of the worn liner was 10% higher than the new liners.

CONCLUSIONS

It was found that as the mill filling increases, percentage of inflight material decreases in comparison to low mill filling. For example, for Gol-e-Gohar new liner, for 15% of mill filling and 85% of mill speed, percentage of inflight material was 68%; whereas for 45% mill filling it was 45%.

Results showed that by increasing the mill filling, the load thickness increases, the length of torque arm decreases, and the maximum torque arm occurs at higher speeds.

Results also indicated that for 45% filling, due to a reduction in the amount of material in contact with the mill shell, maximum inflight material was obtained at speed of 100%; whereas, for 15% filling this occurred at speed of 85%.

The trend of torque change was also investigated for both new and worn liners. The power draw for a new and a worn liner (5184 h of operation) in Sarcheshmeh copper concentrator was compared.

It was observed that at all mill speeds, the mill power draws for worn liners were higher than that of the new liners. For example, for 25% filling and 70% mill speed, the power draw of the worn liner was 10% higher than the new liner.

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