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Relining efficiency and liner design for improved plant performance

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ABSTRACT

Liners in grinding mills not only protect the mill shell from the aggressive environment inside the mill, but they also play a significant role in the efficiency of grinding. The design of mill liners dictates the charge trajectory and hence the grinding efficiency. The common approach in designing liners is designing for a longer life. However, this approach does not necessarily consider optimum performance over the liner life. It has been observed in many operations that mills under-perform over a significant portion of the liner life (10–25% of the liner life at the beginning and often 5–10% at the end). This paper extends the method proposed by Toor (2013) and Toor et al. (2013) to design liners for performance through investigating the effect of relining efficiency using such an approach in an industrial case.

As indicated in the Toor et al. (2013) study, relining efficiency affects the benefits that can be realised by designing liners for efficiency. Russell Mineral Equipment's Mill Reline Director (MRD) analyses the relining process and provides an accurate estimation of relining time for a given scenario. In this study, five different relining scenarios were simulated and compared against the reference reline (i.e. current liner design) to accurately estimate the time required for relining. This is the first study to demonstrate that incorporating relining constraints in the liner design can be used to inform liner design characteristics of a proper design that meets the requirements of an efficient relining practice.

JKSimMet simulation for the industrial case predicts a liner which has same lifter face angle as the current liner design with reduced lifter height from 300 mm to 210 mm, could increase the plant throughput by 8% on average while producing a product with same P80 as the current liner. Considering relining time predictions by MRD for the proposed liner, this study predicts a 3.7% increase on average in throughput per annum. Although the proposed strategy will increase the cost of liners plus relining by 31.5% (i.e. A$ 548,000), the increase in plant throughput is estimated to yield A$ 20.1 M of additional revenue based on data for 12 months to 30 June 2014 from the plant quarterly report.

1. Introduction

The primary function of liners is to protect the mill shell from the aggressive milling environment and to deliver the input power to the charge by providing lift. The aggressive milling environment limits liner life, requiring regular replacement at a considerable cost of liners, labour and lost production during the shut-down.

The challenging aspect is that, as the liners wear, the shape of the lifters changes, which consequently alters the motion of mill charge and the energy transfer characteristics and the grinding efficiency changes significantly. The dual functions of the liners tend to be in conflict as designing the liner profile to maximise liner life inevitably reduces the grinding rate in the mill. It is therefore necessary to develop a balance between the liner life and milling performance.

1.1. Designing liners for performance

The Julius Kruttschnitt Mineral Research Centre (JKMRC) has developed a methodology to assess the impact of liner design on grinding performance over the life of the liner (Bird et al., 2011; Toor, 2013; Toor et al., 2011; Weerasekara et al., 2011). Studies have shown that accurate estimation of the efficiency of relining and its associated costs is a key factor in identifying optimum liner design when liners are designed for performance rather than life (Powell et al., 2012).

Plant operating data for the 32 ft semi-autogenous grinding (SAG) mill at Concentrator Two at Cadia Valley Operations (CVO) indicates that mill throughput decreases more than 10% after

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replacing shell liners and grates. As evident from Fig. 1, the specific energy decreases between 8% and 12% over the liner life.

Reviewing the performance of mill throughout over two liner life cycles indicates that designing liners with a profile similar to that of current design half-worn liners could increase the mill throughput via optimising the SAG mill breakage rates.

The idea of designing liners for performance was investigated by Toor et al. (2013) based on the hypothesis proposed by John Russell that designing liners for performance, despite requirement for more frequent relining, will enhance the mill throughput (Russell, 2006).

A novel technique was implemented to quantify the effect of liner design on mill performance by surveying the mill before and after reline (i.e. fully worn and new liners). This enabled the effect of changes in feed characteristics and mill operation on the mill performance to be minimised and allowed the research team to model the effect of liner profile on breakage rates. Analysis indicated that although a design with the profile of half-worn liners could increase the throughput, relining time affects the viability of such an approach. As illustrated in Fig. 2, by improving the relining efficiency (reducing the reline time) the position of the peak of total ore milled over a 6 month cycle moves from 2 to 4 relines per 6 months. A more efficient relining process favours a more frequent relining schedule, and a higher overall throughput is achieved at any relining frequency (Toor et al., 2013).

Improving the liner design and material could also improve the grinding efficiency while enhancing the life of the liners. As illustrated by the dashed line in Fig. 2, the optimum throughput could correspond to less frequent relining (e.g. 2 relines per 6 months) which will introduce additional benefits.

Lacking both the data and tools for determining the efficiency of relining for the shell and grates, Toor et al. (2013) used an average relining time for both the current and the proposed liner designs. With the advent of new tools, this simplification can be eliminated to obtain more accurate predictions in performance increases.

1.2. Simulating efficiency of relining

Russell Mineral Equipment (RME) has developed the Mill Reline Director (MRD) as a tool to analyse and review the effectiveness of relining activities (O'Shannassy and Russell, 2014; Rubie, 2011; Russell, 2014). This tool uses discrete event simulation to identify opportunities for performance improvement in relining procedures.

MRD implements discrete event analysis principles to program the movement of each element of the relining process according to a set of attributes or properties. This allows simulating relining activities and their interaction with other elements as they would be in a real world scenario (O'Shannassy and Russell, 2014). Application of MRD requires the duration of each relining activities to be known. This data can be collected either through recording video of every aspect of a mill reline or from existing data from a similar mill. Other information such as physical dimensions, mill bolt patterns, liner arrangement, forklift travel routes, relining crew members per shift, mill relining machine capacity, number of THUNDERBOLT hammers, T-MAGS, O-ZONE Worn Liner Lifting Tools, number of feed chute transporters, and forklifts are also required (Russell, 2014).

Specialist operators then analyse videos recorded from relining activities to determine the duration of each event. Thereafter the duration data is converted to a discrete frequency distribution of five logical time intervals. In Fig. 3, examples of time required for retrieval of the liner (a) and liner cart return (b) are presented for a relining practice. This approach, rather than using an overall average time, provides an estimate of relining time which is more realistic. In this example, using the average time the relining machine never waits for the liner cart to return and pick up the liner. However, from distribution data it is evident that the relining machine can wait up to 220 s for the liner cart. Therefore, total relining time depends on interactions between events. Time assigned to an event will be randomly selected from its frequency distribution data. Thereafter, based on the order in which activities are combined, total relining time will be simulated. Because of the random nature of the duration of activities, each scenario could be simulated thousands of times to provide an accurate distribution of relining time results (Rubie, 2011).

Analytical interpretation of reline with MRD is conducted by looking into the duration database to model total relining time for any given scenario. It is also possible to use a library of relining for benchmarking the efficiency of relining in the site of interest. Relining tools can be compared with MRD simulations through applying a theoretical relative effectiveness index. Principles of MRD and its capabilities and applications has been explained extensively in Rubie (2011), Russell (2014) and O'Shannassy and Russell (2014).

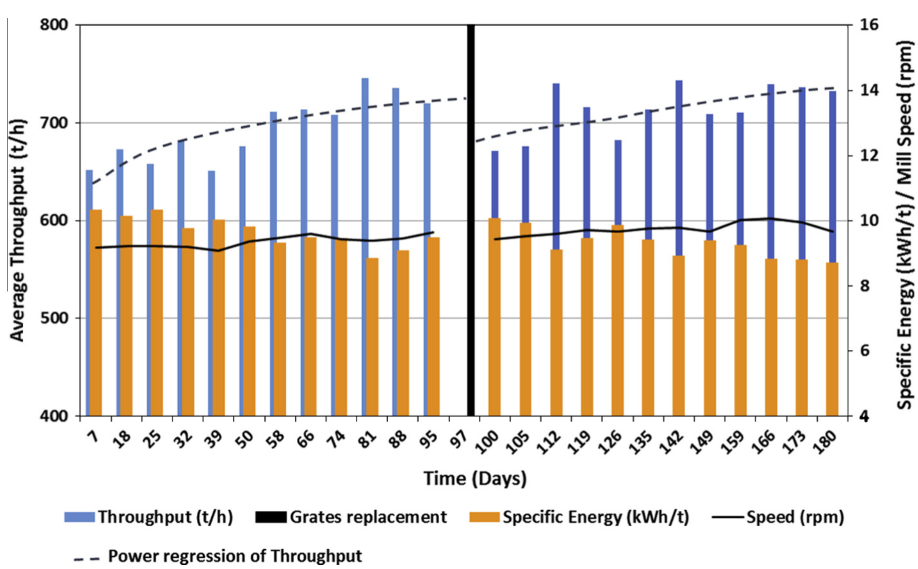

Fig. 1. Comparison of SAG mill throughput and specific energy over liner lifer (modified after Toor, 2013).