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Performance assessment of river sand versus ceramic grinding media on the Fimiston Ultra-Fine Grinding application

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Introduction

The Kalgoorlie Consolidated Gold Mines (KCGM) operations are an equally shared joint venture between Barrick Gold Corporation (Barrick) and Newmont Mining Corporation (Newmont). The operations include the Fimiston open pit (colloquially referred to as the ‘Superpit’), the Mount Charlotte underground, the Fimiston mineral processing plant and the Gidji Roaster.

The KCGM Fimiston plant utilises an Ultra-Fine Grinding (UFG) M3000 IsaMill® (Figure 1) to grind a portion of its refractory flotation concentrate as an alternative to roasting. Ultra-Fine Grinding increases the amenability of the refractory concentrate to direct cyanide leaching. IsaMills have historically been able to use low cost media such as silica river sand to obtain very fine product grind sizes, however the sand media is quite angular and is often supplied with a broad size distribution. Media shape, grain size, and specific gravity greatly influence the energy efficiency and maximum feed size to the IsaMill.

It is generally accepted that the use of a ceramic grinding media will result in a finer product size or allow an increase in the mill throughput. This is believed to be a direct result of the ceramic media’s higher sphericity, narrow and uniform media size distribution and higher specific gravity. The use of small diameter media results in significantly more surface area per volume of media, and hence significantly increases the probability of media – ore particle collision. The capacity of a mill is known to increase with decreasing grinding media diameter. It is also well understood that grinding media consumption and mill wear can be decreased with the use of spherical media particles. Energy loss in grinding due to friction is minimised, improving the efficiency of grinding.

A decision was made to purchase an initial quantity of 22 tonnes of Magotteaux Keramax-MTX® Ceramic grinding media for a plant trial at the KCGM Fimiston plant in 2011. A nominal ceramic media size of 2.5 mm was chosen due to the $P_{80}$ of the feed ore. The chosen ceramic is a zirconia toughened alumina which is chemically inert and hard wearing. It is highly spherical, has low porosity and a narrow size distribution. The specific gravity of the ceramic media is 3.5 kg/cm³ compared with the river sand at 2.7 kg/cm³, allowing a lower media filling for a similar power draw.

The aim of the trial was to assess the performance of the ceramic media in terms of:

- any increase in the new feed throughput (t/h) achieved, whilst ensuring that the circuit’s product specifications remained within limits
- any effect on the energy efficiency of the IsaMill (kWh/t)
- any effect on the wear rates of the IsaMill’s internal rubber components and its impact on the duration between scheduled maintenance shutdowns
- a comparison of the grinding media consumption rates between ceramic and sand media, measured in tonnes of media per day, and in kilograms of media per tonne of concentrate milled and
- a comparison of the total costs per tonne of concentrate milled.

Fimiston Ultra-Fine Grinding IsaMill circuit configuration

The new feed to the UFG circuit originates from the overflow (COF) from a set of Cavex 150 mm feed preparation cyclones. The feed preparation COF has a $P_{80}$ between 30 and 50 microns.

The IsaMill is configured in a ‘reverse feed closed circuit’ arrangement where the new feed is pumped to a discharge hopper where it is combined with the IsaMill discharge (Figure 2). This combined slurry is then classified by a set of Cavex 100 mm UFG cyclones. The UFG COF is monitored to ensure it has a $P_{80}$ less than 12 microns and is pumped to a thickener before being sent to a carbon in leach (CIL) circuit. The UFG cyclone underflow (CUF) is gravity fed to a feed hopper. Grinding media is added via a screw-feeder to the feed hopper. The slurry in the feed hopper feeds the IsaMill.

In normal operating conditions when using river sand media, the new feed throughput is about 10-10.5 t/h. The IsaMill operates with a power draw set point of 950 kilowatts (kW). Generally eight to ten UFG cyclone pods are open (16 to 20 individual cyclones).

Trial

Slurry samples were collected from around the circuit every four hours throughout the 57 days of the trial to produce a complete mass balance and both size distribution and percentage solids were measured.
Initial data were collected during a campaign using river sand to assess the performance of the IsaMill.

At the next scheduled maintenance shutdown the river sand grinding media was dumped to the bunds and removed from all media bins, hoppers and bunds by vacuum-truck. Normal scheduled maintenance was carried out and any worn IsaMill internal components were replaced.

An initial size-graduated charge of ceramic grinding media was added to the IsaMill feed hopper using a rapid fill pump. The graduated charge consisted of two tonnes of 1.5 mm ceramic, two tonnes of 2.0 mm ceramic and two tonnes of 2.5 mm ceramic. The remaining 16 tonnes of 2.5 mm ceramic media were added via the screw-feeder as required thereafter to maintain the required power draw set point of 950 kW. Sampling was continued for the duration of the trial.

Figure 2. Ultra-Fine Grinding and IsaMill flowsheet at Fimiston.

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The set-point (SV) for the new feed throughput (t/h) of the UFG circuit was slowly increased during both the sand and ceramic grinding media campaigns, whilst monitoring and ensuring that the above mentioned key performance indicators were not exceeded.

During the trial the maximum new feed throughput, whilst using sand grinding media, was found to be close to 10.5 t/h of concentrate. When using Keramax-MTX ceramic, a new feed throughput of 13.2 t/h was achieved. This represents an increase of 26 per cent.

**Mill specific power and energy saving**

Analysis of the trial data identified a linear relationship between the mill specific power (kWh/t) and the product grind size (UFG COF $P_{80}$), for both media types: the product size decreased as the mill specific power was increased (Figure 3). This was to be expected, as a higher energy input into the grinding process should result in a finer product.

There is a significant improvement when using ceramic media compared to river sand.

The relationship between mill specific power and the IsaMill discharge $P_{80}$ was also plotted and gives a similar but somewhat more scattered result. However, it can be clearly seen in the graph below that the ceramic media continues to perform better than the sand media when looking at the mill discharge particle size (Figure 4).

The mill specific power levels were determined to be approximately 89.6 kWh/t with a throughput of 10.5 t/h using sand grinding media and were reduced to approximately 72.4 kWh/t with a throughput of 13.2 t/h, using ceramic grinding media.

The use of ceramic media allowed an energy saving of 17.2 kWh/t or an increase in energy efficiency of 20 per cent.

**Sampling surveys**

Slurry samples were collected every four hours for size distribution analysis and percentage solids determination, from the following points (Figure 1):

- New feed – concentrate collected post tank F3STK62 (at F3SPCP65)
- IsaMill discharge – concentrate collected prior to screening (F34SC01)
- UFG cyclone feed – concentrate collected post the discharge hopper (at F34PP02)
- UFG cyclone underflow – concentrate collected prior to the feed hopper
- UFG IsaMill feed – concentrate collected post the feed hopper (at F34PP01) and
- UFG cyclone overflow – the final product.

The size distribution analyses were conducted using a Malvern Hydro 2000MU laser sizer. The pulp density (per cent solids) checks were determined by wet and dry sample weights.

All plant operating conditions were collected using Pi Historian software.

**Results**

**New feed throughput**

Two of the main key performance indicators for the UFG circuit are the product grind size, ($P_{80}$), the UFG cyclone overflow $P_{80}$, and the power draw (kW). The target UFG COF $P_{80}$ was constrained to 12 microns or less, and the power draw was to be maintained at around 950 kW.
Ultra-Fine Grinding IsaMill internal component wear and maintenance

Wear rates on the UFG IsaMill internal components (shell liner and discs) were found to decrease when ceramic grinding media was used compared with when river sand was used (Figure 5). This allowed the duration between future maintenance shutdowns to be increased from two to three weeks.

Media consumption rate

As a result of the low porosity, increased hardness, and mechanical integrity of the ceramic grinding media, compared to silica river sand, the grinding media consumption was expected to greatly decrease. The consumption rate of sand was determined to be 15.9 kg/t of concentrate milled compared to just 2.3 kg/t with ceramic media. This is a reduction of 85 per cent in the consumption of grinding media.

Figure 5. IsaMill internals at Fimiston.

Conclusion

The grinding media trial in the IsaMill at Fimiston has been successful. The data indicate that using Magotteaux Keramax-MTX:

- enabled throughput to be increased by over 26 per cent
- resulted in an energy saving of over 17 kWh/t (20 per cent) to be achieved
- significantly reduced the wear on the IsaMill internal components and
- reduced media consumption by 85 per cent.

* Ultra-Fine Grinding (UFG) M3000 IsaMill is a registered product of Xstrata Technology.
** Magotteaux Keramax is a registered product of Magotteaux International SA.