HIGMILL FINE GRINDING TECHNOLOGY OPTIMISES RECOVERY AT CRACOW GOLD, AUSTRALIA

ESTIMATED 1.62% AVERAGE INCREASE IN GOLD RECOVERY

Evolution Mining is a leading, growth focussed Australian gold miner. Evolution’s consistent strategy of upgrading the quality of its asset portfolio has seen it become the second largest gold miner listed on the ASX. Evolution operates five wholly-owned gold mines and also has an economic interest in the Ernest Henry copper-gold mine.

Evolution has owned and operated Cracow since November 2011 and has a current mine life to 2023. The Cracow Gold project is located 500kms north west of Brisbane, Queensland, Australia.

This is an abbreviation of the paper “Fine grinding implementation at the Cracow Gold processing plant” (Paz et al), from the AusIMM’s MetPlant 2019 conference, in Perth, Australia.

Processing
Gold within the ore is very fine grained, ranging from 150µm to less than 10µm and commonly less than 40µm. The Cracow processing plant consists of a three-stage crushing circuit, primary and secondary ball milling, pre-leach thickening, fine grinding and conventional cyanidation leaching (CIP).

CHALLENGES
- Optimise gold recovery
- Challenging footprint and timelines
- Optimisation of HIGmill to existing circuit
- HIGmill first-of-its-kind application for whole ore tertiary grind duty

SOLUTION
- HIGmill fine grinding technology
- Turnkey package
- Post commissioning optimisation

RESULTS
- 1.62% average increase in gold recovery in the first year of operation
- Performance parameters achieved
- Following onsite optimisation, HIGmill exceeds operating expectations
Process equipment selection

In 2016 Evolution investigated maximising gold recovery from the CIP plant at Cracow. After an extensive feasibility study preceded by a test work campaign into the nature of the gold mineral association, grinding and leaching kinetics, Evolution decided a stirred media (fine grinding) option offered the best value against alternatives.

Ore samples were sent to Outotec and another stirred vertical mill supplier’s laboratory for grindability tests. By comparing the grinding efficiency results, equipment footprint and required capital, the decision was made to proceed with an Outotec HIGmill™ turnkey package.

The HIGmill was required to grind to 25-27 µm depending on the ore type and process 60tph at 45% w/w density. The installed mill power limitation of 500kW gave a design specific grinding energy (SGE) of 7.84 kWh/t. The HIGmill size was a 500kW unit with a 4000L body (HIG500/4000, henceforth HIG500). This mill size has a small footprint of ~2.7m x ~2.3m. The small footprint made fitment into Cracow’s existing plant possible.

HIGmill technology

The Outotec HIGmill™ is a stirred milling technology which provides modern, sophisticated, flexible and energy-efficient solution for fine and ultra-fine grinding. The mill is vertically oriented, with feed slurry pumped into the bottom of the mill. As the feed flow transfers upwards, the ore slurry passes through a series of GrindForce™ rotors and chambers. The chambers are formed by the static counter rotors mounted on the shell wall lining.

Due to the vertical arrangement of the mill, classification is conducted simultaneously throughout the grinding process with larger particles tending to remain longer at the peripheral, while smaller particles move upwards. The GrindForce rotors ensure the entire volume of the mill is well mixed and minimises dead zones, significantly increasing grinding efficiency.

Outotec conducted a methodical approach to Cracow’s turnkey project to ensure the delivery time was achieved.

Process and mechanical design

The process design of the HIGmill was conducted upfront during model selection. A process flowsheet was designed in a way to ensure the HIGmill could be commissioned with minimal impact to the plant’s production.

The HIGmill was integrated into the operating plant seamlessly through the use of laser scanning, a customary process for all Outotec brownfield projects. The support structure for the HIG mill was designed to consist of a combination of concrete plus structural steel elements, a process optimized via finite element analysis.

Delivery

The short (31 week) project schedule included delivery, installation and commissioning of the HIGmill and all associated ancillary equipment to support the HIGmill operation.

Outotec, working in cooperation with Cracow operational and maintenance personnel, created a detailed installation schedule to capture all site works required for this project. The schedule was broken into several discrete install stages; from the removal of the decommissioned ball mill, to the installation of new civil, mechanical, electrical and piping works. Each stage was planned for the installation and tie-in work to coincide with planned shutdowns and other site maintenance activities to minimise disruption to the normal processing operations. Delivery of all the equipment was completed on time for the installation.
Outotec worked with a local engineering contractor to install the mill. This local contractor was familiar with site regulations and safety practices and also provided jobs for the local community.

Work commenced in earnest with the removal of a decommissioned small ball mill. The HIGmill was delivered to site in a modular form, which allowed mechanical installation within 2 weeks. Another benefit of the plant 3D laser scan was that parts of the ball mill foundation were incorporated into the HIGmill foundation.

Poor grind was experienced during commissioning, which was put down to several factors: the media charge was not seasoned as it contained only 2.5mm media; the processed ore at the time contained higher clay content, resulting in higher viscosity slurry at 45% w/w solids density; and media packing in the milling chambers. Furthermore, media loss was observed to be exiting the mill with the product.

**Initial operation**

As with conventional grinding mills, stirred milling requires a seasoned charge for the first fill. In this case there was no ceramic media present in the charge between the 2.5mm and 1mm size fraction. A seasoned charge reduces the voidage and maximises the surface area of the charge, this being beneficial to fine grinding. Based on the signature plot monitoring, it was estimated that it took 2 to 4 weeks of operation to season the charge.

The amount of clay and ultrafine particles present in the feed greatly influences the viscosity. The thicker underflow viscosity is closely linked with the lime addition, while treating clay-type ore. The HIGmill, while in constant power draw mode, was observed to be speeding up and slowing down depending on the lime addition pH CV.

Media packing was observed during the first inspection. The media packing is thought to accelerate the wear of the steel rotors which achieved a life of only 8 weeks for the first rotor set.

A small amount of media loss was observed to be exiting the mill with the product. This was thought to be due to the combination of high flowrate through the mill and the resulting high mill speed required to draw the power, which creates a vortex. The variation of media filling level was investigated. It was found that the SGE efficiency increases by ~2.4% with increasing mill filling level from 60 to 72% v/v. This is most likely due to the improving residence time distribution in the mill. It was also found that a reduction in flowrate greatly improved the SGE efficiency and allowed the mill to run at slower speeds at the same power draw.

**Process power and control**

Process control of the HIGmill was straightforward given the open circuit arrangement. The feed density is controlled by the pre-leach thickener, which has been configured to run on bed pressure control.

The HIGmill starting and stopping sequences are fully automatic, requiring no operator input. The HIGmill power can be set in various ways, Cracow opted for power control as the primary control method as it achieves the minimum grind size and maximises gold recovery.

**Optimisation testwork**

Following commissioning, Outotec implemented an onsite testwork programme to optimise the HIGmill. The Outotec process team conducted onsite pilot scale HIGmill (HIG25) testwork and benchmarked the performance to the full scale HIG500.

**Improvements**

Outotec also worked closely with the Cracow processing team on the optimisation of mill internals, process performance reviews and establishing operating guidelines.
The life of hard steel components was considered unsatisfactory in the Cracow application so numerous alternatives, including rubber and polyurethane coatings, were trialed. Currently the shell lining solution is fully vulcanised rubber coated static rotors and shell lining. This shell lining wear solution now achieves a life of 36 weeks.

Cracow required longer service life to maximise operating time. Four rubber grinding rotors were trialed at the bottom of the shaft where the highest wear rates are experienced. It was observed that the OWI performance of the rubber rotors was around 10% less than that of the steel rotors. However, the minimal drop in performance was outweighed by the 3 to 4-fold increase in rotor wear life.

Media optimization
The media used at Cracow was also investigated to optimize performance. With the introduction of SG 4.5 media at site, this higher SG media aids the retention of finer media and contributes to maximising grinding efficiency.

The performance of SG 4.0 vs SG 4.5 media resulted in a 5-10% loss in SGE efficiency in the first month of operation, however the media retention in the mill was greatly increased such that the loss of fine ~0.8mm media is only 0.1kg/h. Ultimately the increase in fine media retention is expected to improve SGE efficiency. The higher media SG, although more expensive, has its cost offset by the media retention.

Performance guarantees
The HiGmill completed and passed the performance guarantees. During the testing period, the actual plant throughput average was 60.2 tph, feed size 80% passing [F80] average was 47.5 µm and feed % solids average was 44.5%. During the performance testing the plant processed a blend of ROM ore equivalent to the high-grade ore (see table). The HiGmill final product size 80% passing [P80] average achieved is 25.1 µm, which falls within the target of <27 µm for High Grade Ore (Ghattas 2018).

The power draw for the performance test was 449.2 kW, which indicated an SGE of 7.58 kWh/t. This result is more energy efficient than the design SGE point, and matched test 2 in the HiG5 testwork.

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<th>No.</th>
<th>PARAMETER</th>
<th>UNIT</th>
<th>VALUE</th>
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<tr>
<td>1</td>
<td>Mill dry solid feed flowrate</td>
<td>mtp/h</td>
<td>≤60 [thickener underflow]</td>
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<td>2</td>
<td>Mill feed size 80% passing, F80</td>
<td>µm</td>
<td>≤50 [thickener underflow]</td>
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<td>3</td>
<td>Mill feed %solids</td>
<td>%</td>
<td>Nominal 45% Range 40 - 50%</td>
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<tr>
<td>4</td>
<td>Mill final product size 80% passing, P80</td>
<td>µm</td>
<td>&lt;27 High Grade Ore &lt;25 Empire &amp; Kilkenny Ores</td>
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<tr>
<td>5</td>
<td>Solids SG</td>
<td>kg/dm³</td>
<td>2.71 High Grade Ore 2.75 Empire &amp; Kilkenny Ores</td>
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Next steps
The feed rate to the HiGmill has been pushed to 122 m³/h and around 70 tph, the increase in tonnage has increased the HiGmill feed F80 which has caused the feed size to increase to F80 = 56µm.

In the future a scalping cyclone circuit upgrade may be investigated. The scalping cyclone overflow could be placed into the leach feed thickener and the scalping cyclone underflow sent to the HiGmill. This could offer the unique opportunity to further increase production or increase gold recovery.

Conclusion
The regrind project at Cracow mine has achieved an estimated average increase in gold recovery of 1.62% in the first year of operation.

This HiGmill has achieved its required performance and continues to be operated beyond its design. After a challenging commissioning and optimisation process, the HiGmill exceeds operating expectations. The mill currently draws full power at rates up to 122 m³/h, while achieving a rotor wear life of 44 weeks and a shell liner life in excess of 36 weeks.