Outotec HIGmills; A Fine Grinding Technology

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**ABSTRACT** Global ore grades are declining while commodity demands continue to increase. Ore bodies requiring treatment are becoming increasingly complex requiring a finer grind size for maximum mineral recovery and grade. The demand for a finer grind size has set new challenges especially for grinding technology. Energy efficiency is a major driving force targeted for environmental sustainability and project viability. Fine grinding technology is utilized especially in concentrate regrinding to liberate the valuable minerals after the first stage of concentration. Maintaining the correct particle size and particle size distribution of the regrind product is crucial for downstream process performance.

Outotec HIGmills™ being based on existing, well proven stirred milling technology provide modern, sophisticated, flexible and energy efficient grinding solution for fine and ultra fine grinding. Outotec HIGmills™ offer the unique possibility for online control and optimization of regrind product particle size. This paper describes the basis of this online control possibility and how this fine grinding technology can be implemented in minerals processing especially in regrinding applications. The main focus of this paper is to describe the flexibility of this grinding solution to respond the fluctuations in feed rate tonnages as well as particle size fluctuations in concentrate regrinding.

**1 INTRODUCTION**

In 2012 Outotec launched a new fine grinding technology for the mineral processing industry. The technology has been utilised for more than 30 years in the calcium carbonate industry, its application, until recently, was unavailable for mineral processing. Further development backed by intensive test work has brought this technology to the minerals processing industry. Outotec is pleased to present a summary of this fine grinding technology.
2 HIGMILL OPERATIONAL PRINCIPLES

In a typical application, the HIG process begins with the regrinding circuit feed being pumped to a scalping cyclone upstream of the mill which classifies the target size material off from the feed and defines the pulp density. The defined underflow is then mixed with water to optimal grinding density and pumped into the mill at base level. The slurry enters a grinding chamber containing grinding media (beads) and rotating discs which provide momentum to stir the charge against a series of stationary counter discs. The particles are ground by attrition between the beads.

As the flow transfers upwards, the ore slurry passes through the rotating discs and the free space between the static counter discs lining the wall (see Fig.2). Depending on the application there may be up to 30 sets of rotating and static discs. Due to the vertical arrangement of the mill, classification is conducted simultaneously throughout the grinding process with larger particles remaining longer at the peripheral, while smaller particles move upwards. The process is typically a single pass with no external classification necessary.

Gravity keeps the media compact during operation, ensuring high intensity inter-bead contact and efficient, even energy transfer throughout the volume. The disc configuration and the whole chamber geometry have been optimized for efficient energy transfer to the bead mass, internal circulation and classification.

With the grinding media evenly distributed, the ore particles remain in constant contact, significantly increasing grinding efficiency. The product discharges at atmosphere at the top of the mill. The combined cyclone overflow and mill discharge are the circuit product.

2.1 HIGmill™ Control Philosophy

The flow from upstream processes can vary remarkably due to fluctuations in ore grade and quality. Also the target fineness can vary because of variations in the ore mineralogy.

HIGmill offers a unique opportunity to optimize product fineness on-line through the use of ACT (Advanced Control Tools) expert system. This is due to the HIGmill™ having a variable speed drive to control the impeller shaft speed, which in turn controls the power input into the material.

A set point for the specific grinding energy (SGE) is determined to achieve the product fineness. The ACT expert control system uses feed forward and feedback control principles.

The feed forward control principle is used by measuring scalping cyclone feed quantity which is measured by flow and density meters and adjusts the mill shaft speed to reach target energy per total feed flow. This principle ensures the target SGE is reached at all times even the throughput varies.

The feedback control principle is used by measuring the particle size distribution with...
an on-line by Outotec PSI and adjusts the shaft speed to maintain a constant product size, (see fig. 5).

The make-up grinding beads are fed continuously to the mill along with the slurry feed. If there is a permanent large scale change in throughput or in PSD target level the bead charge is increased or decreased to the new optimal level to ensure that the online control with tip speed can be fully utilized.

![Figure 5. HIGmill Flowsheet](image)

### 3 BENEFITS

#### 3.1 Largest Units in Operation

Over 260 HIGmills have been put into service, with installed mill power up to 5,000 kW, making the HIGmill™ the largest fine grinding units in the market place to date. The Outotec HIGmill™ comes in various drum diameters. The Mill heights can be varied to optimize the media load and power input for specific applications. Chamber volumes range from 400 to 27,500 litres with corresponding drives from 132 to 5,000 kW (table 1). The HIGmill™ is the only ultrafine grinding technology in commercial use that can use small size high density grinding media in mill sizes above 3,000 kW.

![Figure 3. Typical HIGmill Installation - 3 x 5MW](image)

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</table>

#### 3.2 Compact and Simple Installation

The benefit of high power intensity and vertical installation is a very small foot prints (see fig. 3). The head room over the mill is small and the flanged, split shell construction reduces the space needed for maintenance. The top supported, hanging arrangement keeps the floor and sides clear, simplifying maintenance and emptying the beads.

Gravity together with an internal hydroclassifier prevents the grinding media from escaping the mill by pushing the grinding beads back down into the milling process, and lets through only the fine ground slurry.
3.2.1 Maintenance Issues
The drum segments and wear components have been specifically designed to make maintenance simple and quick. The casing is flanged vertically so that it can be split down the centre into two halves that can be moved apart on a railing system. After exposing the internals, changing of discs and liner segments can be done individually by a team of two skilled mechanical trade personnel.

Wear of the discs is even around the circumference. The wear is faster in the bottom part of the mill and typically the lowest discs may have to be replaced before the total set is changed. For total set change, a spare shaft ready for installation is an option (see fig. 4). Wear components can be lined with polyurethane, metal hard facing or natural rubber depending on application. The critical components of the mill and gears can be delivered in short time. A large number of spares are available in stock for fast shipment and delivery.

3.3 Operational Flexibility
A wide range of grinding applications can be addressed as the HIGmill™ has an excellent flexibility to adapt to fluctuating process conditions. Typical applications for the HIGmill™ is the regrinding of concentrates (e.g. magnetic, flotation), iron ore tertiary grinding, precious metal ores, and fine grinding for hydrometallurgical processes.

Both ceramic and steel beads can be used. Ceramic media is typically used for sulphide concentrate regrinding to prevent iron contamination on the sulphide mineral surface, which would otherwise result in poorer flotation recovery and grade.

The HIGmill™ can use a wide range of grinding media diameter which depends on the application: 0.5-1.5 mm in ultra fine, 1-3 mm in fine grinding and 3-6 mm in coarse grinding, where the grinding size is defined as follows:

- Coarse range, F80 100-300 µm, P80 50-100 µm
- Fine range, F80 50-100 µm, P80 20-60 µm
- Ultra fine range F80 <70 µm, P80 <20 µm

4 TEST WORK

4.1 Test Units
Outotec has two test unit sizes available for pilot test work. The test work produces a performance curve: particle size distribution versus specific grinding energy (SGE).

A semi-continuous test can be conducted in the HIG 7 unit (6 litre/7.5 kW) and is performed with a 50kg sample. The test sample is fed several times (steps) through the mill with one set of parameters and constant SGE which increases SGE in steps. Sampling is performed at each step.

A continuous test is conducted with the HIG 30 unit (18 litre/30 kW) and is performed with a 150kg to 250kg sample. The test sample is fed only once through the mill with multiple SGE points. The tip speed (m/s) is changed to deliver different SGE. Sampling is performed to represent each SGE point.

A continuous test can also be performed with HIG 7.5 unit with the same principles.
Minimum of a single parameter basic test is required for process sizing. In an optimal case, a larger sample is required so that more basic parameters can be tested. Test parameters are slurry milling density, retention time, tip speed, mill internal geometry, media charge, bead size/distribution and bead material. The measured test variables are power draw, feed rate, milling density solids and product particle size.

Typical process parameters for industrial operations are:
- Feed solids 30 % by volume (i.e. 50 % by weight if solids density 2,7)
- About 60 % of the mill volume is filled with beads
- Typical bead material is ceramics (i.e. zirconia-alumina-silicate, density 3.8-4.2 kg/dm³). Steel and high density (<6 kg/dm³) ceramics are options
- Bead size 0.5-6 mm depending to the F80 and P80
- Tip speed 4-8 m/s in smaller units, 8-12 m/s in larger units
- Typical Retention time 1-3 minutes
- Specific grinding energies from 5 up to 100 kWh/t
- Power intensity, kW/m³, is high 100-300 kW/m³

4.2 Test Results
Outotec has undertaken test work on a wide range of minerals and process variables which enabled Outotec to gain a better understand the process variables effect on process design.

A special feature of the HIGmill is that energy efficiency remains constant through a wide variety of operational parameter combinations; flow rates, tip speeds, and media filling rates. Figure 6 depicts three different flow rates with specific grinding energy (SGE) versus product fineness. Within each flow rate, each SGE point is generated by varying the shaft speed. The graph shows the product fineness is directly proportional to SGE input.

Power draw increases exponentially if the tip speed is increased (see fig. 7). If the shaft speed is doubled the power draw is tripled. This makes it possible to control PSD on-line and dampen flow rate and quality fluctuations. The PSD set point can be changed on line by changing tip speed.

The same energy efficiency is achieved with different grinding media filling volumes (see fig. 8). This makes it possible to control the PSD on-line and to account for filling volumes or bead wear. The power input and PSD can be changed on line by changing tip speed.
In figure 9, it can be seen that there is almost linear correlation between media filling rate and power draw. Thus, media charge increase is directly related to power draw increase. The power draw is directly related to SGE (kWh/t). If there is a 10% v/v decrease in media charge from 70%v/v to 60%v/v, the result is a ~20% decrease in SGE. Therefore to obtain the same SGE and grind size; the feed rate must also decrease by ~20%.

Semi-Continuous and continuous test work has given similar results (see fig. 10). These results give a reliable scale-up from semi continuous (HIG 7) to continuous (HIG 30). As per other fine grinding technology we expect the HIGmill™ to scale directly up to the industrial size.

Comparison test work was conducted with a tertiary / regrind ball mill in the magnetite application. The HIGmill™ minimised energy usage by up to 40 to 50% compared to the process benchmark, (see fig 11). We can clearly see that the Energy efficiency in HIGmill™ is significantly better compared to process benchmark values, the difference being up to 5 kWh/t (~50 %).

The HIGmill™ is an innovative and unique grinding tool provides advanced, energy efficient fine and ultra-fine grinding for new projects or can deliver value-adding, optimisation solutions for existing installations. The HIGmill™ is supplied with a variable speed drive which enables an effective control strategy for controlling the product fineness.