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The daily grind

Fine grinding and ultra-fine grinding processes are increasingly needed in the mining and mineral-processing industries. Ailbhe Goodbody investigates why:

Global ore grades are declining. In addition, orebodies are getting increasingly complex, with the valuable minerals often more finely disseminated and therefore more difficult to liberate from the associated gangue. As mining companies deal with more complex, refractory and lower-grade orebodies, the need for fine and ultra-fine grinding increases.

The main reason for this is that in order to extract value minerals from the ore, the ore needs to be ground in such a way as to achieve maximum liberation; the liberation size is important for mineral processing. Hamid-Reza Manouchehri, global manager, process intelligence and development at Sandvik Mining, says: “The liberation size is defined based on the ore’s texture, and associated value and gangue minerals within the ore.”

As a result, fine and ultra-fine grinding processes are becoming more common in the mineral-processing industry. Many of the new greenfield projects involve orebodies that were historically too complex to process efficiently. However, the demand for finer grinding has set new challenges for grinding technology; new technological advancements in mineral processing, including stirred milling, have opened the door for many new opportunities.

Lower-grade ore and finely distributed ore requires finer grinding than the traditional mill circuit product size (P80) of 75µm for liberation and flotation. Rajiv Kalra, CEO and general manager – global at CITIC HIC Australia, notes: “This is part of the focus on going for higher recoveries by fine grinding with larger and more power-efficient equipment.”

There is a Glencore Technology M10,000 IsaMill operating at Arrium’s magnetite operation in South Australia

Greg Anderson, Glencore Technology’s mineral-processing technology manager, says: “All OEMs [original equipment manufacturers] have had to cater for clients with the more difficult orebodies; whether by providing more efficient logistics solutions to cope with the higher throughput, or more bespoke processing options suited to the intrinsic nature of the orebody, which generally involve finer grinding strategies to liberate the minerals.”

Energy efficiency is one of the major topics that is being targeted in the quest for sustainability and project viability. Since comminution (or size reduction) is the most energy-intensive process in ore beneficiation, the mining industry and OEMs are focusing on reducing energy, protecting the environment and reducing the cost of mineral processing.

Existing operations are also adding fine and ultra-fine grinding circuits in the form of tertiary and regrind mills. This is in response to changes in the orebody or improving metrics for concentrator performance. Examples include more competent ore, finer disseminated orebodies, or an attempt to increase plant capacity.

Adam Moore, global product manager, stirred mills at Metso Minerals Industries, explains: “Many older plants did not have a regrind circuit due to the difficulty in efficient fine grinding with ball mills.
“We have seen the final grinding specification shift from 150µm to 75µm, to 45µm, to 20µm over time as a result of declining quality in orebodies. In the late 20th century, the focus shifted towards new technologies that can provide efficient fine grinding.”

Latest developments

There is a current trend for bigger units for fine grinding, with the aim of reducing the total capital expenditure (CAPEX) investment for mining customers. Increasing the machine size also has the advantage of minimising the number of lines, and results in savings in construction and building costs.

Mattias Astholm, HIGmill product manager at Outotec, says: “This focus leads to a reduced carbon footprint, which is crucial for any supplier and mining company to survive in a future business where focus on sustainability is vital.”

There have also been ongoing developments for smarter circuit design as ores become more complex. “One of the main developments has been circuits incorporating better use of fine grinding than in the past,” suggests Anderson.

“These circuits are designed to liberate enough of the gangue material at the head of the separation stage, reducing energy being used in traditional primary/secondary grinding circuits (which tends to be the largest and most inefficient use of grinding energy), while having larger flows to regrinding circuits, where specialised grinding mills then grind to liberate the valuable minerals (larger loads than previous designs, but more efficient). The net result is lower energy use per unit of metal.”

Also, newer processing routes are requiring fine grinding. For example, refractory gold deposits that used to incorporate roasting circuits are turning to newer processes to recover the gold, due to tighter environmental controls.

Anderson says: “Processes using simple leaching circuits incorporating fine grinding and atmospheric leaching, such as the Albion Process, are becoming more common. Plants such as those recently installed at GeoProMining’s Zod operation in Armenia and Panterra’s Las Lagunas operation in the Dominican Republic are using this process to recover fine and complex gold in concentrates and tailings respectively.”

Some operations are reprocessing high-grade tailings that have been stockpiled for decades, if not centuries. Moore states: “This, and other non-conventional duties, requires innovative circuit design. There have been developments with multi-stage classification, unique classifiers such as high-frequency screens, and magnetic-separation stages in recirculating streams.”

There is also now a large focus on minimising the operating costs of grinding circuits, especially with the current low prices of commodities. Moore says: “Some stirred mills can help achieve this goal, as their high availability, energy efficiency and low media consumption are conducive to low plant-operating costs.”

However, Andre van der Westhuizen from the Centre for Minerals Engineering at the University of Cape Town in South Africa cautions that the relatively high capital and operational costs of grinding finer are not always easy to justify with the current low metal prices. He notes: “These projects are currently therefore evaluated much more critically than a few years ago, and therefore less of them are currently being approved.

“OEMs are under pressure to lower capital cost and maintenance costs on their stirred mills. Operations are also looking at these circuits much closer and paying much more attention to effectively linking the fine liberation step (stirred milling) with the downstream processing step (e.g. flotation, leaching, magnetic separation, etc.). The ‘one size fits all’ and the ‘copy and paste’ methods can no longer be afforded. The application of stirred milling needs to be tailor-made to be as cost-effective and efficient as possible.”

He adds that stirred mills are able to receive increasingly coarser feeds and are therefore moving up the process stream towards primary ball mills, such as Outotec’s HIGmills and Glencore Technology’s IsaMills.

He says: “Similarly, dry crushing equipment is increasingly moving down the process stream towards stirred-milling territory, e.g. high-pressure grinding rolls (HPGRs) and vertical roller mills (VRMs). Subsequently, tumbling mills may in future be ‘squeezed’ out of the process stream.”

Stirred milling media (ceramic) have become significantly cheaper and more wear-resistant than a few years ago. Also, the equipment is increasingly becoming more wear-resistant and maintenance costs are coming down.

Fine-grinding challenges

The historical perceptions of the ‘impossibility’ of grinding down to below 10µm on a large scale have been one of the initial challenges that have been overcome in fine grinding. However, Anderson tells *Mining Magazine*: “We have seen operations such as McArthur River produce the majority of its concentrate at 7µm through the use of IsaMills for over 20 years now.”

There are still other challenges though, particularly in energy consumption; companies need to know how fine to grind to liberate and recover the ore optimally. The challenge is that fine grinding produces a much larger surface area, and hence larger energy is required for even low reduction ratios. Kalra says: “Vertical mills are great to undertake low reduction ratios at high volumes compared with ball mills.”

The energy consumption changes dramatically when it is sized down to below 75µm or 45µm size as the P80 for the final product. Manouchehri states: “However, the energy needed to go for finer products, in particular when P80 < 10µm is aimed for, will be extremely high.”

There is some confusion in the marketplace over how much energy it takes to grind particles at the laboratory scale. Anderson says: “OEMs have all manner of lab-scale tests, with unclear assumptions and scale-up factors, which makes it hard for users to compare between suppliers.

“Adding to the confusion is the uncertainty of how lab-scale results compare with the full installation, in part made worse through high turnover and lack of skills on site to accurately survey, analyse and query lab versus installation results.”

As a way to address these challenges, Glencore Technology routinely follows up IsaMill lab testwork with full-scale installations to produce signature plots of each (grind size versus specific energy plots). Anderson explains: “The direct scale-up between the two is a characteristic of the technology that provides a high level of certainty for a client’s new project.

“Glencore Technology also uses a number of independent licensed labs that have small-scale IsaMills for testing clients’ ores. These are regularly tested with the same standard composite sample to ensure they are within tolerances to maintain their licence, providing greater certainty for clients’ grinding energy needs.”
He adds that there needs to be better understanding and continued education in the industry of the energy used in comminution, particularly as defined as energy use per unit of metal produced. Anderson says: “Groups such as the Coalition for Eco-Efficient Comminution (CEEC) are addressing this challenge in a number of ways to improve the awareness of industry.”

Energy consumption

Fine grinding uses a large amount of energy. However, Moore points out that this is a relative term: “In actuality, secondary grinding is still the largest user of energy in today’s concentrators.”

However, fine grinding requires more energy on a per-tonne basis; there is an exponential relationship of grind size versus energy required. Nonetheless, companies can be smarter in the way they process their minerals, and optimise the process in several ways.

For any fine-grinding application at high tonnage, an important factor is to do a trade study in the laboratory of the final product required to obtain a good recovery at a reasonable cost.

Kalra notes: “Also, the method used for measurement in the lab is very important. The normal method of using sieves for getting the size analysis does not work below 45µm. These then require laser analysers, and there can be difference in measurement to a great extent. At this fine end, every few extra microns may require a larger machine with extra power and capital cost.”

Circuit design is also a crucial step in lowering the energy use, and reviewing energy use, not only as the energy used at each stage of the circuit, but more correctly as the total to produce the finished product.

Anderson advises: “Circuit design should also answer the question of whether everything needs to be ground; does it makes sense to produce a high-grade product at the start of the separation stage, eliminating the need for it to have to go through further processing? Alternatively, can a stage be put into the circuit before or during primary grinding where screening or dense-media separation can produce a throwaway gangue stream with minimal loss in metal recovery?”

Furthermore, a good classification system will help a lot in avoiding overgrinding. Van der Westhuizen says: “Classification is critical. Stirred mills are currently often run in open circuit due to the difficulty of classifying at these fine sizes. Hydrocyclones are prone to particle shape and density effects, which affects the cut point. Fine screens that can cut effectively below 100µm would improve energy efficiency.”

Media size selection is also critical. Moore advises: “We want to use smaller media to maximise the amount of available surface area, but we also need to have media that is large enough to efficiently break the largest particles in the feed.”

Furthermore, developments in materials for grinding media could lead to a potential saving for reducing energy and operation costs.

Other things that play an important role in energy efficiency include having more efficient motors/drives and operating parameters such as the slurry density; all of these things are tied together when trying to optimise any grinding circuit.

Wear parts, consumables

Wear is always an important aspect in grinding. Astholm says: “The choice of wear material is crucial to have mill availability as long as possible and reduce maintenance cost. Less material wear is important as well to the carbon footprint for sustainable product development in the mining industry.”

Through a grinding process, different types of particle interactions occur. At the start of the circuit it may be semi-autogenous grinding (SAG) mills and ball mills, where there is a high level of impact in the SAG mill, and a mixture of impact and abrasion in the ball mill. Anderson explains: “With fine grinding there is an exponential increase in the particle interaction, with particle reduction based on the abrasion of particles on particles and media.”

As the speed goes up in running mills and harder ores are being ground into finer sizes, the consumption of the media and liner increases. As a result, more durable and abrasion resistant material would be needed and this is a key area for development.

The mineral-processing industry has come a long way since the early days of stirred mills. Moore says: “Many fine-grinding mills in mineral processing were developed from industrial minerals, which tend to grind very soft, non-abrasive materials such as limestone, and are able to have tight control over their processes. We are not afforded either of those luxuries in mineral processing, so more robust liner material and better control systems are required to maximise the equipment availability, but also to ensure the highest efficiency in the process. Process control and availability of the equipment go hand-in-hand.”

Products and projects

Glencore Technology

Glencore Technology's IsaMill has been selected for several recent projects including Nevsun Resources' Bisha copper-zinc project in Eritrea. This installation will be using a M5000 IsaMill in each regrind circuit, with an installed power of 1.5MW each.

On a smaller scale, a M100 IsaMill is being constructed for Sumitomo's Pogo gold project in Alaska, US. Anderson explains: "The M100 IsaMills (75kW) are ideally suited to small-scale duties, such as those in gold and molybdenum operations, where only small tonnages are treated. Recent projects such as Las Bambas and Highland Valley Copper have incorporated them in their molybdenum circuits."

Recent installations include the M10,000 IsaMill operating at Arrium's magnetite operation in South Australia. Anderson says: "A paper presented at the MetPlant 2015 conference in Perth provided a case study on this operation.

Glencore Technology's Isamill at GeoProMining's Zod project in Armenia

"It describes the upgrading of the existing ball-mill circuit with an IsaMill, with the aim of utilising both mills in their grinding circuit, and operating each efficiently. The resulting circuit improved the magnetite liberation, and eventually throughput."

Utilising both mills with the ball mill handling coarse particles and the IsaMill handling the fines, also enabled a rejection stage producing a disposable gangue product to be installed between the grinding stages, resulting in overall energy savings.

Anderson notes: "While the M10,000 (3MW) IsaMill duty was based on being able to treat 300t/h of 60µm feed to a P80 of 32µm, plant-optimisation work resulted in a new operating set-point of 350t/h to be maintained, with good availability, and wear and media consumption either at or under forecast."
Recent plant optimisation has seen the IsaMill throughput increased to 425-435t/h on the same duty, a 43% increase on design.

A 30t/h IsaMill installation was also recently commissioned at KCGM's Gidji operation in Western Australia, replacing the roasting circuit. The M10,000 IsaMill was part of KCGM's Emission Reduction project, and plays a significant part in eliminating atmospheric stack emissions from the site.