# Comminution conundrum

How do you get the crushing and grinding equipment you need in today's market? And once you have it, how do install and maintain it to achieve its best? **John Chadwick** examines these questions and looks at technology developments

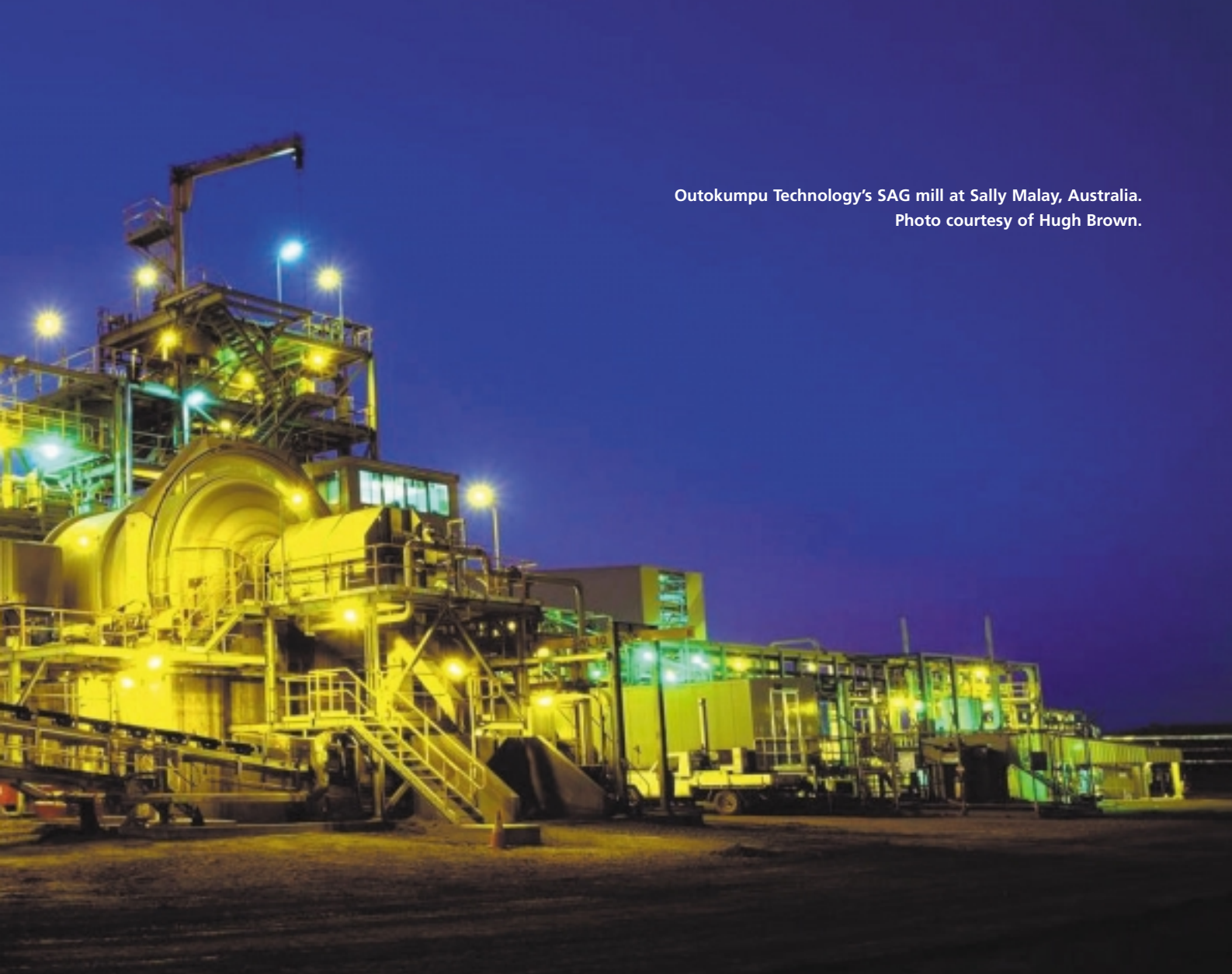
Big crushers, like big mills, are becoming more popular. FFE Minerals is supplying a crushing plant that will be one of the largest installations of its kind in the world. It will deliver eight Excel 820 kW cone crushers for Fortescue Mining's Pilbara iron ore and infrastructure project at the Cloud Break mine. The combined value of this contract and that for Konkola Deep (see pXX) is in excess of $68 million. The scope of supply to Fortescue is the design, manufacture, installation and commissioning of eight cone crushers with complete delivery and commissioning by the end of 2007. These large cone crushers are based on the acquisition of Excel Crusher Technologies, which already had developed smaller cone crushers.

Another success with Excel products is a Raptor XL400 cone crusher successfully commissioned last year at Codelco's Chuquicamata mine in northern Chile. Pebble rejects from the SAG mill are fed at 260 t/h to the Excel Raptor, which reduces the extremely hard ore from 89-mm down to 19-mm in open circuit. Prior to installing the new crusher, the crushing plant suffered frequent unscheduled shutdowns due to mechanical failures of another supplier's 300 kW roller bearing type crusher. Since the extra-heavy duty Excel Raptor XL400 crusher entered operation in April 2006, the plant has operated without incident, FFE reported in mid-2006.

Mobile crushing, and associated rock handling systems, continues to be a very efficient method in the right application. Last October, Boliden announced that it will double annual production capacity at Aitik copper mine from today's 18 Mt to 36 Mt. This will involve a new concentrator with two milling lines, nominal feed 2,025 t/h. Each primary mill in the line will have a 21 MW ring motor. There are to be three new crushing stations, including one in the open pit, and mobile crushers.

Today, however, grinding mills are becoming the most important lead item for any project that must have them. Ken Shannon, CEO of Corriente: "The availability of key mill components is one of the major bottlenecks facing new mine developments around the world. We are pleased to be able to reach reasonable economic terms with Metso and at the same time to be assured the equipment will be delivered to meet the scheduled mine start-up at the end of 2008."

Shannon said this on November 1 when Corriente announced it had signed a Letter of Intent (LOI) with Metso Brasil to supply the major components of the processing facility at the Mirador copper-gold project in Ecuador. The LOI quotes an equipment package totalling over $27 million, which includes a crusher, SAG mill and ball mill. Signing of this critical LOI allows Corriente to stay on its path to complete construction of the Mirador project in late 2008 with commissioning by the end of the year.



**Outokumpu Technology's SAG mill at Sally Malay, Australia. Photo courtesy of Hugh Brown.**

Jeff Leonard at Metso Minerals reports that lead times for grinding mills are now stretching out to around three years. This is no surprise he notes, since 2005 set a new global record for grinding mill orders and 2006 looks as if orders were something like three times higher than in 2005!

Leonard explains there is only so much foundry space available around the world and he recommends that mining companies "must get in the queue," as soon as possible. It is important to order something early. There is the potential to fine-tune the order at a later date, though having ordered a 5.8 m mill, it would not be possible to change that to an 11.6 m unit – there are only so many foundry pits available of specific sizes.

He finds the current situation interesting, with junior mining companies placing orders much more than they used to. He is pleased that the current situation is allowing Metso to get to know the end user better.

As we see from above, the fact that a project has grinding mills on order, or it has its plans in progress, is noteworthy enough for the project press releases these days.

On November 1 Osisko Exploration announced that, prior to full feasibility, it had taken the first step in its intended path to build a mine at its 100%-owned Canadian Malartic gold property. It said, "Current industry conditions dictate the need to place long lead-time equipment on order to satisfy the intended plant start-up date." In this regard, Osisko has signed a LOI, awarding Metso Minerals a contract for the timely supply of one 11.6 m diameter x 7 m long SAG mill and two 7.9 m diameter x 11.6 m long ball mills including the immediate release for manufacture of the critical lead time components. Once installed, these machines will be the largest operating mill units in North America, capable of processing between 28,000 and 40,000 t/d, depending on final design criteria."

Sean Roosen, President and CEO of Osisko said, "Our LOI with Metso Minerals for the full construction of these critical grinding mills is a major milestone in our project. Our agreement with Metso Minerals underscores that we are now capable and fully committed to proceed to production in the shortest timeframe possible, and that we are very confident of achieving this."

## Fine grinding

As the mineral liberation size of run of mine ores has significantly reduced over recent years, the challenge of developing energy efficient technologies to process them has risen remarkably. About 70% of a processing plant's operating costs are consumed in comminution energy – a cost that increases exponentially as product size decreases.

In Australia, for example, since the 1970s the standard feed size for mineral beneficiation has dropped from 74 microns, to 38 microns in the 1980s, to less than 8 microns in the 1990s in a number of major mining operations. These deposits require fine and ultra-fine grinding to be economically viable.

Jeff Leonard explains that Metso Minerals is also looking to more energy efficient, fine grinding mills, machines like its Vertimill® Grinding Mills and Stirred Media Detritors (SMDs). The company reports that in the USA alone, an estimated 32 billion kWh of power are consumed by size reduction equipment. A large percentage of that power is for fine grinding applications - not all in mineral processing obviously.

When fine grinding in a tumbling mill, the production of unwanted noise and heat wastes valuable energy. A stirred media mill, like the Vertimill or SMD, is an energy-efficient alternative to a tumbling type mill for fine

grinding applications. Such mills can be used for wet, fine or ultra fine grinding (product sizes of 200 mesh to 2 microns or finer), primary or secondary grinding, or regrind applications.

The current fine grinding mill feed material with a top size of 6 mm top, to produce product size ranges from 200 mesh (74 microns) to 2 microns or finer. It can be used in continuous or batch applications in open or closed circuit. The standard line ranges from 15 to 1100 kW with capacities of up to 100 t/h. But we are going to see larger machines in the not too distant future.

In metalliferous mining, economic pressures dictate the need to treat previously 'untreatable' ores. These include polymetallic ores with the intergrowth of mineral values, ultra fine grained disseminated ores and refractory ores. Ultra fine grinding can enable liberation of values or maximize surface area to achieve required leach kinetics. Metso Minerals characterizes ultra fine grinding as 80% passing 15 microns or finer.

To meet this need, it licensed the SMD technology from what is now trading as Imerys. Co-operatively, Metso Minerals and Imerys engineers have adapted this technology for the specific requirements of the metalliferous industry and the SMD has proven effective in producing fine and ultra fine (sub 15 microns) product size for a wide range of metalliferous feeds.

Test work is essential to establish the ore grindability and the most efficient operating conditions to achieve the required product size. Bench scale tests provide initial indicative performance. A more extensive bench scale programme can be performed to investigate in detail the principal process variables and their affect on grind. When large-scale continuous test work is required to assess differing operating conditions or to provide large quantity of product sample, a pilot 18.5 kW SMD can be provided.

The normal operating range is 5-100 kWh/t, which meets the majority of metalliferous fine and ultra fine grinding requirements. Maximum size for this type of SMD is an installed 1,100kW. Typically, feed size range is 30-100 microns and feed slurry solids concentrations range is 20-60% w/w. Metso Minerals will review specifications and recommend the optimum feed solids concentration to maximize grinding efficiency. The SMD normally operates in open circuit, although closed circuit is possible.

Media size, type and charge quantity are selected to meet process specifications. Normally, a natural silica or ceramic media is recommended. Selection of the grinding media is essential for optimum grinding efficiency. The media selected should have well-rounded particles, with minimal cracks or flaws. Imperfections in the media will result in accelerated break-down in the SMD increasing media consumption and component wear, affect charge viscosity and overall efficiencies.

> "One of the challenges is to halve the energy consumption of modern stirred mills to economically produce products below 5 m, because this will almost certainly be required by the minerals industry in the near future."

Media charges have to be monitored and replenished. Grinding media is added through a pneumatic feed port or the manual feed chute, both of which are located on top of the unit.

A launder collects the product as it flows through the screen. The number of exit screens depends on the grinding requirements and the required feed flow rate. The position of these screens automatically defines the operating level within the SMD, thereby simplifying process control.

Control of the feed mass flow, machine power draw and the correct grinding media charge ensures optimal grinding conditions are maintained for the specific feed and product parameters. Design enhancements include improved power efficiency with the following advantages:

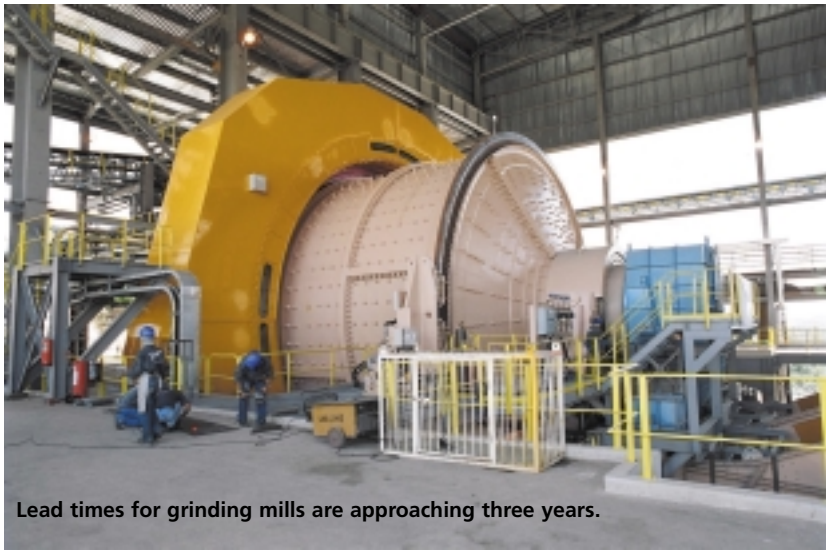
- Open circuit operation
- Mechanically simple design and competitive capital cost
- Use of low cost, ceramic, natural silica sand or pebble media - no steel contamination of product
- Capacity to operate continuously at full load power draw
- Low rotational impeller speed with shallow charge depth providing reduced abrasion of impeller and body liner coverings.

Stirred milling is also an area in which CSIRO Minerals Senior Principal Research Scientist Dr Mingwei Gao is working. He says traditional ball mills' large grinding media consume huge amounts of energy for fine grinding and the slow rotation mill speed results in low power intensity. "Low power intensity in a ball mill cannot deliver the high mill throughput required. And the impact and abrasive stresses used in ball mills do not work well for particle breakage when mineral particles are in the micron range."

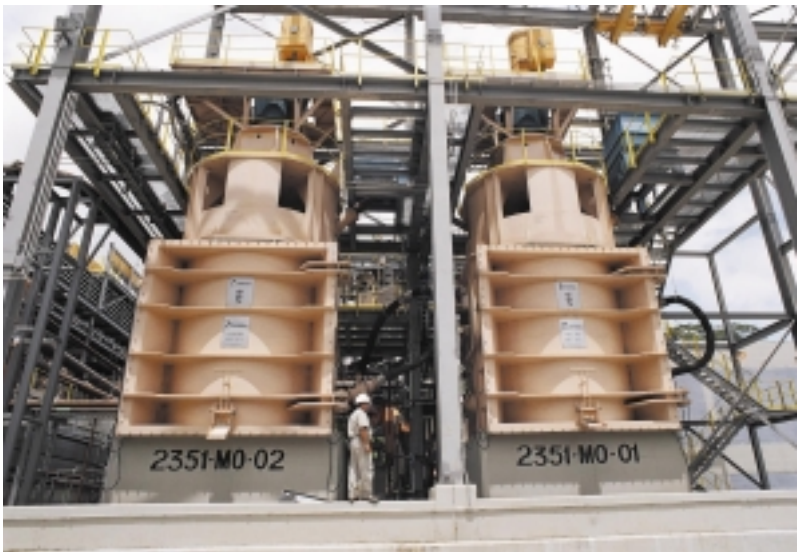
Instead vertical and horizontal stirred mills use small media and operate with a set of stirrers rotating at high speeds. They rely on high-intensity agitation action to energize small grinding media and generate compressional and torsional forces that are very efficient for breaking micron-sized particles.

"However, further development of stirred mills is critical to their broader application and this is where CSIRO is assisting the minerals industry," says Gao. "One of the challenges is to halve the energy consumption of modern stirred mills to economically produce products below 5 microns, because this will almost certainly be required by the minerals industry in the near future."

CSIRO is working on this and other developments, including coarse grinding applications, where the objective is to use stirred mills instead of secondary and regrind ball mills to avoid over grinding heavier minerals in the mill feed and to take advantage of the stirred mill's higher energy efficiency compared to ball mills. CSIRO



**Lead times for grinding mills are approaching three years.**




*Fine grinding is an area into which Metso Minerals is putting significant research and development. This picture shows its Vertimills at a copper operation in South America*

COLUMBIA STEEL

is also investigating dry processes for fine grinding, which, if successfully developed, will significantly reduce energy consumption and the cost for subsequent beneficiation processes.

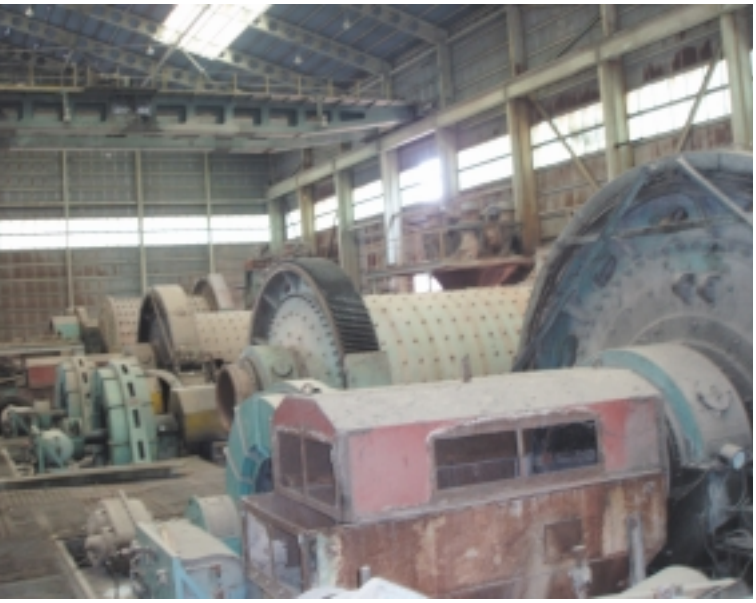
## Installing a mill

Peter Nilsson, Installation Manager – Grinding Division for Outokumpu Technology Australia, notes "the milling/grinding area is traditionally known as 'the heart of the plant'. So, when it comes to preparing the installation of a plant's 'heart', a great deal of planning is required. The following outlines some commonsense steps and pointers which are crucial to this planning process."

Preparing the method statement – "All safety aspects, especially how to handle the large components, must be the primary consideration when planning any large mill installation. If you can look through a particular installation job with all its peculiarities and challenges (be it a shell- or trunnion-mounted bearing mill, or a mill on riding rings mounted on the shell) and can clearly envisage how you are going to site rig all the components, you are in effect, mentally forming your method statement which you will have to produce to the engineer at some stage. This, in turn, helps with organizing the special equipment you need to take when building the various possible configurations of custom built grinding mills."

Preparing the schedule – "Once you have your method statement, preparation of the activity schedule is the next task. It is advisable to separate all the different tasks into groups. One method would be to group tasks according to how the various sections of the mill itself are assembled. Once you have an overview of issues like timeline, resources, personnel and tools, you are better prepared to ensure full efficiency with the workforce during the installation. Another benefit of a well-prepared activity schedule is that it then doubles as a progress report of the job itself during the actual installation."

As we all know, in today's industry ensuring you have the right people for the job has never been more difficult. As Nilsson explains, "the people you select must have heavy fitting experience and be trained in use of all the different technical equipment aspects of the jobs tasks. The people for the handling and rigging must have heavy lifting experience and preferably have worked in a similar industry for at least some 10 years." Section lifts of 100 t "are becoming commonplace as process



*Used mills are an option that many projects are finding a useful way in which to speed up project progress to production*

plants become larger, so there are pitfalls awaiting the inexperienced.

"Selecting the right tools sounds easy enough – but this can be a minefield to the inexperienced! An experienced provider's 'toolkit' can cost A$300-400,000. Items in a tool container could include temporary power generator, specially designed lifting equipment, computerized laser alignment equipment, a hydraulic torque multiplier for the large critical fasteners and temporary oil lube systems for floating the mill during construction as the main operational equipment is usually still being installed and without mains power.

"The correct clamping force on structural mill bolts is vital as these bolts are designed to last the lifetime of a mill, so choosing the right tool is crucial. An ultrasonic bolt micrometer, for example, measures the elongation of a bolt much more accurately than the 'old' (and, unfortunately, still used) method of just measuring the torque."

Other tooling issues to consider include the need to certify for use all rigging equipment and specially designed attachments, and the certification must be up-to-date. Items such as slings must be checked and registered before sending to the project.

"In order for the installation to flow smoothly, component delivery to site must be such that it arrives to compliment the progress of the installation. This avoids congestions and double handling. The weight and size of components mean crane reach and practical working space adjacent to the mill installation are usually at a premium."

Care must be taken to protect the machined items from rust corrosion or contamination while the machine is being erected. Some large mills take up to 12 – 14 weeks to build and rust/dust prevention is an ongoing task that has to be monitored through the whole erection of the mill.

Nilsson says the mining company personnel should be involved, "as much as you possibly can. Usually the various components are already exposed, thus enabling 'hands on' visual explanations. This is important not only for smooth day-to-day operation but also when it comes to choosing long-term critical maintenance spares other than commissioning and first 12 month run spares. Site operators and maintenance crews will feel more comfortable with the machine if they are involved from the beginning of the mill erection. It is human nature for people to look after a machine better if the correct operational aspects are understood."

"Commissioning is very important for compiling all electrical settings and actual starting reference trend data for monitored components,

including the mechanicals. The mill charge is normally increased gradually to full load over some days. The drive train sometimes has to be reset to suit the hot alignment and dynamic conditions experienced by the mill as load is gradually increased. Site mill staff should keep handy and retain copies of all the final full load starting data settings for reference against what were new as built data readings."

He stresses the importance of good housekeeping. "This is especially the case for those who operate in a wet area and, in the case of SAG mills, usually a messy area. It's a well-known milling fact that when housekeeping has been well maintained, there are far less instrument and mechanical problems. Care, however, should be taken when hosing down around any bearings. Operators should be made aware of what can and cannot be hosed down.

Nilsson concludes that "when it comes to planning the erection of a large mill, get advice from an experienced professional who can either assist in the project planning or manage the mill erection completely – either on a stage-by-stage basis, or from start to finish."

## Oiling the wheels

Many mills have large, open bull or ring gear and pinion gear sets as drive mechanisms. Lubrication of these large open gear systems presents a unique challenge due to the harsh environment as well as heavily loaded conditions. Historically, open gear systems used asphaltic compounds that provide a cushioning effect. In the past, most open gear compounds contained lead that provided protection for the gears. In recent years, many of the lead containing products have been removed from the market for obvious reasons. But products without the lead have diminished performance characteristics and offered less protection for the gears. Users of the asphaltic based products experienced many problems.

Housekeeping is a major consideration due to the large volume of product that must be used in an attempt to provide a continuous coating to the gears. In addition, where the asphaltic products have been used for many years, there is often a build up of hardened lubricant product in the roots of the gears. This presents multiple problems of cleaning and mechanical interference that can result in gear misalignment or stress on the pedestal mountings.

Many large open gear systems are lubricated using automatic spray systems. They function by providing the lubricants to the bull or ring gear teeth at set intervals in metered amounts. The solids in many of these asphaltic compounds can cause abrasion or erosion of the closely machined parts in the metering blocks and have plugged the nozzles. This can result in uneven or inadequate lubrication of the gear set.

Now there is at least one manufacturer, Lubrication Engineers (LE), that provides an enhanced lubricant product line that addresses the demanding needs of open gear lubrication. LE says the Pyroshield® product line provides superior lubrication and resolves the many concerns that confront the operators of large open gear driven equipment. Jeffrey Turner, Vice President of LE, reports the following benefits from using high performance enhanced open gear lubricants.

**Improved cleanliness** – The housekeeping costs associated with the use of asphaltic based products are difficult to estimate. Operators have reported labour requirements in excess of four man-days to clean some units. Due to the volume of product used, build up around the shrouds and the local area can be sticky, messy and dangerously slippery. Normally, less volume of high performance Pyroshield products are required to provide far superior gear protection while maintaining system cleanliness and, ultimately, housekeeping is improved.

**Elimination of hazardous waste disposal costs** – Today's enhanced lubricant products can be treated as ordinary used lubricants. The

asphaltic compounds can contain Polycyclic Aromatic Hydrocarbons that require disposal as a hazardous waste. Costs for disposal of hazardous waste can be very expensive, not to mention the cost and bother of 'cradle to grave' record keeping for these products.

**Improved gear protection** – Asphaltic compounds typically have Timken Load ratings of around 10 kg and rely on excessive volume for adequate protection. The Timken ratings for enhanced lubricant products exceed 28 kg. Some synthetics such as 9000, 9001 and 9011 Pyroshield Syn-Gear Lubricants and 5180 Pyroshield achieve results as high as 41 kg. The FZG gear test is used to evaluate gear protection on actual gears. Enhanced synthetics such as 9011 Pyroshield have achieved a 14th stage pass in this critically important test. This added protection reduces gear wear and extends the life of the gear system.

**Lower lubrication costs** – Although high performance enhanced lubricants may be priced higher per unit volume to purchase, reduced consumption and improved reliability of the gear train often results in an overall reduction in lubrication cost.

**Reduced electrical consumption** – Because of the superior lubricating qualities of enhanced open gear lubricants, many operators have experienced up to a 2 to 5% reduction in electrical costs. Reduced friction resulting from superior lubrication can be reflected in reduced energy consumption. LE has documented substantial temperature drops, some exceeding 18°C, during the conversion process and continuing during normal operation.



## Advanced SAG control

Finn Peacock, Advanced Control Engineer at Matrikon, notes advanced control can increase SAG mill throughput and reduce feed rate variability. The level at which a SAG mill's ore charge is set is crucial to productivity: if the mill ore charge is too low, then the throughput will be low, the mill is exposed to liner damage, and the ball consumption will be increased. If the ore charge is too high then the throughput will also be low, the power draw increased, and the mill exposed to possible overload scenarios (high torque, temperature or power).

He explains: "The optimal ore charge for maximizing throughput is found between these two points and will vary depending upon the feed ore size and hardness. The relationships at play are quadratic, so, for example, a small deviation from the mill's sweet spot can result in large hits on throughput."

To solve this problem, Matrikon developed a SAG mill optimizer that sits above the mill's existing DCS controller. "The optimizer dynamically identifies the peak on both the feed versus weight curve and the power versus weight curve for the mill. Unlike conventional controllers (both PID and fuzzy logic) the controller we used calculates, in real time, the particular model unique to that actual SAG mill. The controller then drives the mill to the optimal weight to achieve maximal throughput.

"Furthermore, if the controller detects a downstream limitation (for example the pebble crusher or ball mill are limiting overall throughput), then an algorithm known as 'constraint control' kicks in. Constraint control overrides the optimization and maintains maximal throughput subject to these downstream limitations."

The result for the plant is that constraint control ensures stability and the optimizer ensures throughput. This takes the guesswork out of SAG mill control. The benefits to production are typically several percent increases in throughput and improved circuit stability. Matrikon offers a white paper that goes into further detail on advanced SAG mill control. It is available on request. Simply email finn.peacock@matrikon.com to receive a copy.

## HPGR is available

High pressure grinding rolls (HGPR) are a viable alternative to milling in the right application, as ***IM*** has noted in previous examinations – June 2006, pp29-32. Besides possible technical advantages, HPGR equipment has shorter lead times than mills in today's climate. Another interesting project now looking at this technology is Adanac Moly Corp's Ruby Creek molybdenum project in BC, Canada. This is expected to be in production in late 2008.

HPGR grind rocks between two counter-rotating rolls, using interparticle crushing so that ore actually helps to grind material beside it. One of these rolls is floated by hydraulic pressure, and the level of rock material ahead of the unit determines the feed rate into the machine. This ensures the rock is ground at a reliable rate. The HPGR stage follows after the primary and secondary crushing operations and would normally be followed by ball milling.

Wardrop Engineering has released a new report updating the previous feasibility report. *The Ruby Creek HPGR Feasibility Process and Infrastructure Design Cost Estimate and Economic Model* proposes that HPGR replace the conventional SAG grinding mill option suggested in the April 2006 feasibility report. Use of HPGR could result in significant reductions in operating cost and increased process plant availability. Overall power demand for the 20,000 t/d Ruby Creek concentrator and infrastructure could be reduced from 19.2 to 16.5 MW, which would allow Adanac to downsize the diesel power plant used for power for the first five years. The company plans to connect to hydroelectric power after five years of operation, which will reduce operating costs.

Also by taking the HPGR option, process plant availability would be increased from 91% to 96%, which means an additional 400,000 t milled annually. Thus 2.6 Mlb of molybdenum would be added to production in the first five years of operations. Wardrop notes that while the HPGR option represents a higher upfront capital cost, its savings in operating costs and increased production should pay off in an estimated 17 months. Wardrop estimates average total cost of production in the first five full years as $5.58/lb with the HPGR option and $5.79/lb with the SAG mill. ***IM***

Multotec Manufacturing has supplied four trommels to the Vavarinskoye project in Kazakhstan. The mills were supplied by Krupp Polysius and use a slipper pad bearing design which means the mill has a flat discharge end plate and not a trunnion end like conventional mills. "This made it necessary to fabricate a flange distance piece to breach the gap between the end of the mill and the discharge sump," Anthony Yell, Product Manager - Screening at Multotec, points out. "As both distance piece and trommel are structural members, it made sense for Multotec to supply both units," Yell says.

As part of the design the trommel and distance piece were subject to Finite Element Analysis (FEA). FEA is undertaken to ensure the structural integrity of the distance piece and the trommel. An additional feature on these trommels is the incorporation of integral drip rings on the feed and discharge end of the trommels to prevent spillage.

All the components are of mild steel construction. As the outside temperatures in Kazakhstan can be severe the entire process plant is housed in a building to counter the extreme climatic conditions.

The four trommels were of different sizes and ranged from 1,516 mm inside diameter (ID) by 3,790 mm in length up to 2,293 ID by 4,491 mm long. These lengths included the distance pieces. The distance pieces were fabricated and then flange mounted onto the mill end plate and the trommel was bolted to the other end. Yell says that making the trommels and distance pieces as separate components facilitated the transportation of the trommels, as it reduced the overall length of the unit.

The trommels are fitted with Multotec modular polyurethane screen panels, while the distance pieces are fitted with solid polyurethane liners to ensure optimum wear life. The polyurethane panels manufactured by Multotec are available in a wide variety of apertures and panel thickness, and are very effective against sliding abrasion experienced in milling applications.

Multotec Manufacturing claims to be one of the largest suppliers of trommel screens to mining. Trommel screens were long regarded as unsophisticated disposable items attached to end of mills and scrubbers, but this is no longer the case. Modern technology means that they are designed to last for a number of years. The steel structure is rubber lined to prevent erosion of the steel, while the surfaces are now equipped with replaceable screen media. Flanges are machined to ensure seamless contact with the mill trunion flange ID to prevent undue stress in the joint. Trommel screens are complex steel structures that have to cater for uneven loads discharged from mills and scrubbers. As the units rotate, the product discharges through an arc of no more than 25° of the circumference, creating a preferential load bearing zone and keeping the frame under constant stress.