Downsizing for the future

Paul Moore reviews developments in comminution, from standardisation of measurement tools, to further HPGR application and grinding media

Comminution has long been touted as an energy intensive and inefficient process. The Coalition for Eco-Efficient Comminution (CEEC) is well known to ***IM*** readers as the global non-for-profit industry funded organisation which aims to raise awareness of comminution research findings, alternative mineral processing strategies and installed outcomes. CEEC aims "to accelerate information, knowledge and technology transfer with the objective of lower processing costs and improved shareholder returns as a result of improved comminution practices."

The 2012 CEEC Roadmap, freely available on CEEC's website, recommended that the mineral processing sector develop clear benchmarks and standards for use by process designers, equipment manufacturers and project operators. This allows performance to be compared with industry standards and with others operating in similar circumstances so that strategies can be devised to achieve best practice. Best practice needs to be viewed as a full system initiative, and include strong leadership from executive level; overall operational efficiency; planning systems; equipment efficiency; maintenance systems; control systems; and technical support systems.

Sarah Boucaut, CEEC Executive Officer told ***IM***: "The first step toward realising large or small efficiency improvements are possible is through an understanding of best practice and the use of industry benchmarks. In fact, the 2012 CEEC Roadmap identified best practice and benchmarking as immediate actions to achieve efficiency in mineral processing. Examples of best practice need to be supported by evidence of their impact on financial outcomes. Delegates at the 2014 CEEC Workshop identified a number of examples of best practice currently in operation. For example technologies such as Orica's high intensity blasting can improve ore separation effectiveness; and the use of MineSense Technology's integrated sensors and data analytics can optimise pre-concentration adding 15-50% to a project's NPV."

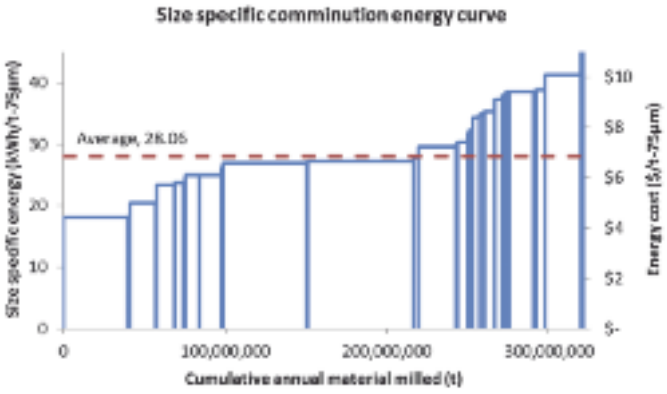
Achieving standardisation in comminution

Guidelines for measuring standardised industrial comminution throughout are still in development by the Global Mining Standards group. The adoption of these standards will form a common platform on which comparisons of processing efficiency may be made. CEEC argues that multiple benefits will results from the measurement of current practice using a standardised set of measurements tools and common comparison tool. They include comprehensive monitoring of energy use; improved budget planning; more appropriate KPI measures; team building across production silos; optimised equipment performance; improved risk tolerance for trials of different processes; accurate cost analysis to support business case development; and improved collaboration with business partners and communities. Other benefits include improved energy efficiency in mineral processing and more efficient energy use on site.

Grinding media represent a significant cost for miners, with demand set to increase with head grades of copper and gold mines decreasing and therefore higher ore throughput. Courtesy Arrium

Dr Grant Ballantyne from the University of Queensland's JKMRC presented a survey of the comminution energy requirements of gold and copper producing mines at the 2014 Mill Operators' conference. His work provides reliable benchmarking data that can be used to compare comminution energy consumption across different mine sites. The total gold and copper production of the mines included in the study equated to 15% and 24% respectively of global production and all of Australian production.

The comminution energy per unit metal product is presented in a graphical form similar to a cost curve. This simple technique allows individual mines to be ranked with respect to energy consumption and clearly displays the potential energy and cost benefits of moving down the graph into more efficient operating regimes. The anonymity of the comprehensive, mine-specific data is



Size specific comminution energy intensity curve (Ballantyne et al 2014)

maintained and the variability is visualised by constructing an 'energy curve.' This approach allows flexibility in the way comminution energy intensity is displayed (such as energy per rock milled or metal produced) thus providing a fairer comparison between sites.

In 2015, CEEC told ***IM*** that it will host the use of the easily interpreted energy curve format to collate and compare efficiency in mineral processing. Using a secure log in, operators will be able to enter specific performance parameters, and view their current operating efficiency on the curve format, relative to other operators. The applications of energy curves are many and varied. They can be used to map the position of the mine as production progresses with year-on-year analysis. Circuit design proposals can be compared to assess the position of the mine on the energy curve when operational. Operational efficiency improvements can be mapped on the curves to visually assess the magnitude of reductions achievable through various strategies. The efficiency with which the various comminution devices achieve size reduction can be mapped down a circuit to identify opportunities for improvement and the magnitude of achievable gains. CEEC is due to hold an industry review in September 2015 for gold processing efficiency. The same process will be used for comparison of copper, nickel and platinum production efficiency in the future.

Evolution at Weir Minerals

The recent acquisition of TRIO has further allowed **Weir Minerals** to become a fully comprehensive supplier of mineral processing equipment and designs, including primary gyratory and secondary jaw crushers, cone crushers, HPGRs, conveyors and feeders. The name will be retained as a secondary brand, as in Weir TRIO in the same way that others such as Weir GEHO have been, due to the extensive TRIO market recognition in mining. The TRIO team also includes expertise in full circuit/system design meaning Weir will be able to offer full processing plant design and commissioning services to EPC and EPCM level. Weir's market position has always been one of premium wear life in mineral processing. The TRIO deal also means Weir can help the large TRIO installed base of mining customers (its sales are already over 50% in mining versus quarrying and other markets) with aftermarket including retrofitting high wear parts and more efficient machines in their circuits. Equally Weir already having a huge installed base of mining customers for its pumps can introduce TRIO equipment to this customer base; particularly in hard rock. TRIO already has 800 hp conveyors, large jaws and gyratories such as the GC84.

Weir Minerals HPGR at a mining customer application

However, the crushing equipment is not currently at the top end in terms of size and capacity and this is something Weir has the investment to work on and significant progress has already been made.

In specialised markets such as IPCC, where TRIO already had a tracked design, the MTJ3254, working in Brazilian iron ore, Weir is in the process of looking at these designs and assessing how it can enhance them and grow its presence in this market.

TRIO also has washing and screening equipment such as log washers; and Weir is also moving into larger screens for mining such as large banana screens of 14 ft width, which will soon be available on the market and are all being developed within Weir.

The HPGR can effectively eliminating the ball mill in the milling circuit; replace the impact crushing and/or cones in tertiary crushing stages; or act as a regrind mill. For example one HPGR can replace a tertiary cone and regrind mill with one stage with an air classifier.

A key move in the mining market by Weir Minerals is to introduce the HPGR for dry grinding by enabling 40 mm crushed material to be reduced to 15 micron levels of particle size in one stage, ie fine grinding. A project has already been successfully commissioned at an iron ore operation in Australia but the technology is potentially applicable to any type of grinding circuit. A key advantage is using dry grinding in regions where there is water scarcity; also there are energy savings on not requiring the large geared drives used on SAG and ball mills. The simplification of the circuit also makes for space savings. The Australian project is running well, with other dry grinding projects having been quoted for final product from 80 down to 15 microns.

However, a major part of the savings are to be found in terms of wear life when comparing dry grinding using an HPGR with other equipment such as impact crushers, where wear parts may only last for weeks. HPGR roll parts, though dependent on the material being ground, can last for 20,000 hours plus.

The company told ***IM*** that 100% of the Weir Minerals HPGR offering to mining is now designed and built by Weir, with KHD retaining the cement market supply. The move by Weir into HPGR began in 2011 when for the first two years, it took the form of an exclusive licensing/marketing agreement with KHD for the HPGR. However, the mining team at KHD was subsequently hired by Weir and production of the machines was commenced at the Weir Minerals site in Venlo in The Netherlands, probably best known as the location where Weir manufactures GEHO pumps. The site had the advantage of having enough factory space to accommodate the HPGR production and there was some commonality between the pump and HPGR hydraulics meaning for high efficiency.

Weir told IM that there are five main areas where it sees its HPGR as having a competitive advantage versus others in the market. The first is the studs on the rolls, where KHD was the original inventor. The pattern and density of the studs on Weir Minerals HPGRs makes for very long life meaning Weir is able to offer some of the longest warranties in the industry on HPGRs. Secondly, Weir has changed the frame around the HPGR making for very quick changeout of HPGR tyres and therefore achieving higher operating availabilities. The Weir HPGR also has

a lower aspect ratio in that it has a smaller diameter but greater width which makes for a greater circulating load but lower wear rate. The Weir HPGR also utilises cylindrical roller bearings as opposed to the spherical bearings used on competitor machines; which allows the Weir machine to have a smaller housing. These bearings also allow the use of oil lubrication, again giving them the longest life in the industry of 30,000 to 50,000 hours. Other designs using spherical bearings with grease lubrication can only achieve a third or less of this life.

Mill lubrication and gearing

Lubrication of bearings in mills is important in maintaining uptime. A Peruvian mining company was operating a Metso 32 ft x 34 ft SAG mill for gold ore processing. One recommendation was to lubricate the mill bearings with a standard mineral oil, and set oil drain intervals at one year. However, with hopes of increasing productivity and reducing the total cost of ownership, company managers approached **ExxonMobil** to determine a lubricant solution capable of safely extending oil drain intervals beyond the one year mark.

ExxonMobil recommended transitioning to Mobil SHCTM 630 bearing oil. Formulated with high viscosity base fluids and a unique, proprietary additive system, the company states that it is "scientifically designed to provide outstanding performance in extreme service applications. Mobil SHC 630 is also laboratory proven to provide significant efficiency improvements over standard mineral oils."

Complemented by good maintenance practices and routine oil analysis, Mobil SHC 630 bearing oil helped the mining company extend oil drain intervals from one year to three years on the SAG mill without any identified concerns. ExxonMobil states: "Maintenance personnel were so impressed by the lubricant performance, they've considered extending drain intervals even further to five years. By tripling oil drain intervals, the company has reduced oil consumption, decreased labour costs, increased plant availability and conserved energy resources, generating an estimated savings of $1,112,000 over three years."

Since the development of its fabricated girth gear in 2013, **David Brown** says it has had "an unprecedented level of success" manufacturing gears for major grinding mill OEMs, not only across Africa but in Europe and the Americas. As a key part of the comminution process, girth gears drive processing equipment such as AG and SAG mills, often in arduous environments where strength and robustness is imperative. As previously covered in ***IM***, David Brown girth gears are manufactured at its Mining Centre of Excellence in Benoni, South Africa, which has developed a global supply chain to ensure cost effective, high quality gearing. For decades, David Brown in Benoni has delivered gears to the comminution process, including mill drives, pinions and its largest girth gear at 12.5 m diameter.

Henk du Preez, Engineering Manager and Girth Gears Lead told ***IM***: "Our customers can choose to operate both cast and fabricated girth gears and we are proud to be a leading engineer of both. We recommend the best manufacturing method based on key factors such as the customer's technical specification, their application and lead time. We are currently experiencing an even split of cast and fabricated girth gear orders – arguably cast gearing is the more traditional method and possibly perceived to be lower risk. However, it is important to stress that fabricated gearing has excellent material properties, especially when manufactured using the unique hot forming method David Brown is known for. It is also a cost effective, speedier option for the customer."

David Brown's first fabricated girth gear was delivered in June 2014 to drive a SAG mill at a platinum mine. Since then, David Brown has developed key girth gear business from the mining majors, which it will continue to deliver over the course of 2015.

Grinding media Americas growth

Arrium is a global leader in the supply of forged grinding media though Newcastle, Australia headquartered subsidiary **Moly-Cop**. In a recent presentation, the company says it aims to capture market share based on growth in demand for grinding media in North and South America, as well as maintain existing strong market position in Australasia. Moly-Cop is completing capacity expansions in Canada and Peru (equivalent to 295,000 t/y) on time and budget. At Kamloops, Canada commissioning is planned for mid-2015 (120,000 t/y), while in La Joya, Peru, completion is scheduled for mid-2016 (175,000 t/y). The company is also working on the market roll out of its next generation SAG ball, which it says is progressing well with strong customer support. The group says it is continuing its long-term supply contracts approach with strategic customers, with the industry dominated by a top list of about 20 customers that account for about 80% of grinding media sales; and basically equate to the key global copper, gold and iron ore mining companies. Customer contracts and supply agreements are typically 10,000-50,000 t/y and are two to five years duration with Moly-Cop having some supply relationships with certain customers that have lasted for over 30 years.

Grinding media consumption are relative tonnages of copper, gold and iron ore being milled worldwide. Moly-Cop's ball demand is about 80% from copper and gold mines and 20% other, the majority being iron ore. In the medium term, head grades of copper and gold are

expected to continue deteriorating over next 10 years which should increase grinding media demand

Strong growth in copper expected with global copper ore milled expected to increase 45% from 2014 to 2019, and the most significant growth anticipated in North and South America. There is a stable outlook for existing mines with low numbers of closures expected with a good pipeline of new projects and expansions.

Equally, strong growth in gold is expected, with global gold ore milled expected to increase 32% from 2014 to 2019, again with the most significant growth anticipated in South America and North America

John Barbagallo, Chief Executive, Mining Consumables at Moly-Cop estimates additional grinding media demand of some 460,000 t/y in 2018 in North and South America alone. Expansions aside, key projects in Chile include Codelco MMH, Caserones and Sierra Gorda, all of which have commenced operations. In Peru, Toromocho has commenced operations, and Constancia and Las Bambas are under construction. In Canada Mt Milligan is up and running, Red Chris is being commissioned and Goldcorp Eleonore is under construction.

Moly-Cop sees its strengths as being located close to its customers, "assuring timely and

Moly-Cop grinding media facilities – capacity 2014-2016 ('000 t)

	2014	Interim additions	2016
Newcastle, Australia	250		250
Cilegon, Indonesia	80		80
Kansas City, USA	180		180
Talcahuano and Mejillones, Chile	430		430
La Joya, Peru		175 by mid-2016	175
Lima & Arequipa, Peru	195		195
El Salto, Mexic	170		170
Kamloops, Canada	115	120 by mid-2015	235
Totals	**1,420**	**295**	**1,715**

flexible delivery of products" and minimising risk of interruption to operations. "On-site support develops an understanding of customers' business operations and requirements", while targeted product development activities with tailored solutions aim to "deliver high quality value-in-use outcomes to customers. Moly-Cop is recognised for its superior product quality and performance, helping customers maximise throughput and yield. The company says it has a strategy of building capacity ahead of forecast market demand, to secure a 'first mover' advantage with current expansion projects securing a longer-term "in-region position."

Wear studies in grinding media

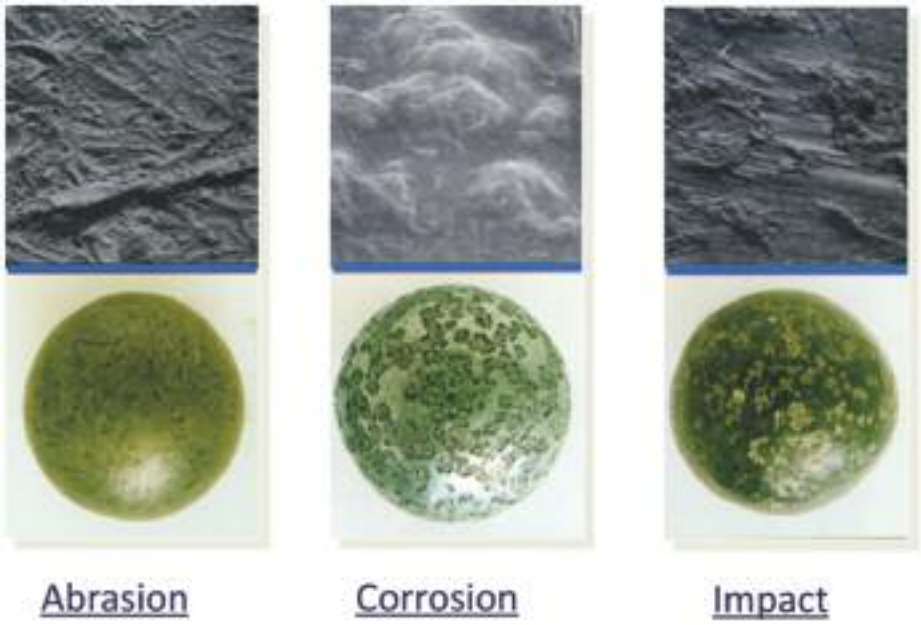
Specialist in high chromium grinding media, **Maggoteaux**, which is based in Chaudfontaine, Belgium but since 2011 part of the Chilean Group Sigdo Koppers, recently presented an in-depth paper entitled *The use of high chromium content grinding media in the mining industry*.

A range of media alloys with different chromium content has been developed by the group for different milling applications but when selecting the grinding media alloy for a specific application, Maggoteaux emphasises that "consideration must be given to the mineralogy of the ore as well as the water chemistry and mill operating conditions."

The paper describes the influence of the microstructure of the alloy on the wear resistance and the influence of the chrome content on the pulp chemistry and downstream processing. It also provides information about the in-house tools which Magotteaux has developed to predict the media wear rate with different chromium content alloys and predict their flotation efficiencies that can be expected when the right alloy is selected for a particular application.

The range of grinding media available on the market consists of high carbon steel balls as well as an extensive range of high chromium content media. The percentages of chrome in the high chrome balls vary from 11% to 30%. The high chrome balls are produced by casting the liquid metal into moulds, followed by different heat treatment cycles to obtain the desired properties. These balls structure consists of a matrix in which carbides are distributed.

Wear in a grinding mill can be attributed to abrasion, corrosion and impact. The overall wear is generally a combination of all three wear mechanisms, and each wear mechanism can also influence the other ones. For instance, in cases of high abrasive wear the influence of corrosion becomes less important. Wear due to abrasion, in extreme cases, can be observed by the removal of ball material due to the scratching of hard constituents in the ore on the ball surface and thus removing part of the surface. The main factors influencing the abrasive wear are the type of the minerals in the ore, their percentage and their hardness; the granulometry of the feed and ball size; and the mill diameter. For abrasive cases, the solution is to maximise the hardness of the matrix and the percentage of chromium carbides.



Wear in a grinding mill can be attributed to abrasion, corrosion and impact

Corrosive wear can result in the typical golf ball-effect where corrosion pits are formed. The main factors influencing the wear by corrosion are the water composition: pH, aggressive ions like Cl^- and S^{-2} ; and the ore composition, especially conductive minerals such as sulphides, magnetite and haematite. For corrosive cases, the solution is to maximise the chromium content in the matrix.

Repetitive high impacts will lead to small metal pieces come off the ball surface due to stresses being build up in the ball. In case of extreme impact conditions the media can even break. The main factors to be considered in impact wear are the size of grinding media and mill diameter; the type of discharge, whether by overflow or grate discharge mill; the influence of the liner design and mill speed defining eventual ball trajectories; and the total filling degree in the mill, as well as the grind-out procedure in grate discharge mills.

A high impact case will require a higher toughness usually obtained through a tempering heat treatment. Maggoteaux states: "By analysing the above mentioned factors, we determine the importance of each wear mechanism which enables us to define the required ball specifications and properties for the specific milling application. In case of corrosive conditions it is possible to carry out some additional test work to be able to better judge the influence of corrosion on the wear rate. Using the pulp from the mill the polarisation curves are recorded for different ball alloys. The polarisation curve is established by imposing a potential over the ball alloy and measuring the resulting current. High levels of current indicate a higher risk of corrosion.

In order to test different alloys (including new developments) in the industrial mill at the same time, a marked ball test is carried out. The test consists of loading drilled balls into the mill and to retrieve them from the mill during a mill stop. Each alloy in the test is drilled with a different pattern of holes (two holes of 4 mm diameter at 180°, two holes of 6 mm at 90°, etc.) to allow easy recognition. The main advantages are that different alloys can be tested under the same operating conditions without having to do a full scale industrial test. Results are obtained quickly and the cost is far lower than an industrial test. The loss of weight for the different alloys is then extrapolated to obtain a wear rate expressed in grams per tonne milled for each alloy.

In its databank, Maggoteaux has information on more than 2,000 plants and the results of in excess of 900 marked ball tests with on average five alloys per test or 4,500 test results with different ball alloys. On the basis of these data a mathematical model has been developed to calculate the wear rate of the different alloys in ball mill applications. The inputs into the model are factors mentioned above as well as the throughput of the mill and mill absorbed power. The foreseen wear rate for the different alloys is expressed in grams per tonne milled or grams per KWh.

Depending on the specific case, the use of high chromium balls can reduce the wear rate by between 26% and 67% compared with standard steel balls.

Pulp chemistry and grinding media

One of the most significant differences between the various geological ore types is the pyrite content, which has a major influence on the mineralogical character of the ore. To investigate the pyrite influence on the pulp chemistry of the system, it was monitored during grinding using the Magotteaux Mill®. In the first instance the Eh of the laboratory mill discharge was plotted against the pyrite content when the various ores were ground with steel grinding media. Broadly, as the pyrite content increased the Eh of the system becomes more reducing, suggesting that the grinding environment became more corrosive with increasing pyrite feed grades.

Interestingly, for the steel media system the porphyry copper ores recorded laboratory mill discharge Eh values around 95 mV (SHE), and comparatively low EDTA levels (0.05 m^2). The sedimentary copper deposits tended to behave in a similar fashion to the porphyry ores. However, the iron oxide copper/gold and VMS style deposits exhibited more reducing pulp potentials and higher EDTA extractable iron values – so higher corrosion rates.

The application of a more chemically inert grinding media should have an impact on the pulp chemistry of the system, particularly if the alternate media is a high chrome white iron which has inherent corrosion resistance. Within an alloy, as the pyrite content of the ore increased, the Eh of the mill discharge became more reducing, the oxygen content of the pulp decreased, the oxygen demand increased and the EDTA extractable iron increased. This suggests that as the pyrite content increased the ore became more reactive. However, for the same geological ore type, as the chrome content of the grinding media increased, the Eh of the system shifted to more oxidising pulp potentials, the dissolved oxygen content increased, the oxygen demand was reduced and the corrosion rate (EDTA extractable iron) decreased.

Maggoteaux states: "It is apparent from this data that the porphyry copper ores, with their low pyrite feed grades, produce ball mill discharges that have comparatively oxidising pulp chemistry when grinding with steel balls. Changing to high chrome white iron grinding media does shift the pulp chemistry to more oxidising Eh values, higher dissolved oxygen contents, lower oxygen demands and produces less EDTA extractable iron. The difference between high chrome alloys is relatively minor."

At the other end of the geological ore type spectrum the VMS ores with their high pyrite content are very reactive, and produce ball mill discharges with very reducing pulp chemical conditions. These ores have very high oxygen demands and exhibit high corrosion rates. The conversion to high chrome grinding media does shift the Eh to less reducing values, but the dissolved oxygen remains very low, with high demand for oxygen, but the corrosion rate is reduced (ie lower EDTA extractable iron). The variation in pulp chemical parameters, particularly EDTA extractable iron is marked.

"It is expected such changes in pulp chemistry would have a bearing on the metallurgical performance on the various ores. Further, the variations in pulp chemistry also suggest that the grinding media best suited for a porphyry copper ore is unlikely to be optimal for a VMS style of deposit."

Finally, laboratory copper rougher rate flotation tests were then completed on each of the samples for each alloy in triplicate. The data suggests for all alloys tested that the copper recovery decreases as the pyrite content increased. The second and probably the more important point, is that the high chrome alloys produced markedly different copper recoveries depending on the alloy and the pyrite content.

For low grade pyrite ores (porphyry copper deposits) the low chrome alloy produced superior maximum copper recoveries to steel and the two higher chrome content alloys. As the pyrite content of the ore increased the metallurgical performance of the low chrome alloy deteriorated to below that of steel. The reasons for this behavior are related to this alloys poor corrosion resistance. The vast majority of the chrome in this alloy is present as chromium carbides that give this media excellent abrasion resistance but poor corrosion resistance. Consequently, these low chrome alloys work well in low pyrite (low corrosion) systems but do not survive in highly corrosive environments (VMS ore types).

"As the pyrite content increases there appears to be a transition from low chrome to medium and high chrome alloys at around 10 to 15% pyrite. At the intermediate pyrite feed grades (10 to 25%) it is probably that the medium chrome alloys produce the best pulp chemistry for copper flotation and this ultimately results in improved copper recoveries when compared with tests where steel grinding media is used. For VMS ore types the high chrome alloys tend to produce the optimum pulp chemistry and yield the best copper recoveries."

Comminution at SME 2015

A number of papers at the recent SME Annual Conference & Expo in Denver, February 15-18 covered key developments in comminution research and technology.

CITIC SMCC says it has developed a comprehensive system for the design and optimisation of comminution circuits, which is primarily based on the broad range of comminution simulation models developed by Dr Stephen Morrell and validated against CITIC SMCC's large industrial database generated by over 150 operating plants around the world. Besides circuit design and mill sizing, now the system has incorporated the full functionalities of mass balances for various flowsheet configurations as well the process optimisation tools, through a third party platform. Various circuit configurations are structured to allow the equipment models to combine together to describe the performance of each circuit being studied. The circuit models can then be used in simulation mode to predict "what if" scenarios. This simulation approach allows wide range potential circuit configurations to be investigated within the known limitations of the circuit and unit process models as trade-offs during plant design.

High Pressure Grinding Rolls (HPGR) technology is the continuous version of the confined particle-bed breakage. Feed size distribution has a key role in total specific energy consumption and product size reduction. Fines in the HPGR feed are defined as relatively small particles that should not undergo much breakage while assisting the breakage of larger particles. Extensive testwork has been performed on a 200 mm by 100 mm lab-scale HPGR at the University of Utah on different ore types. Various artificial feed size distributions have been prepared by mixing large narrow-sized particles as the main portion of the feed and different sizes and percentages of fines to complete single-pass and closed-circuit tests. The effect of the fines content is evidently dependent upon the size ratio between the feed main portion and the fines. In addition, fine particles help with better energy transformation in the grinding zone to a specific level depending on the size for the feed main particles. The presence of the fines in the closed-circuit configuration helps with improving the breakage rate and the total energy consumption when compared with closed-circuit grinding on a narrow-sized feed.

Edge effect is the widely observed condition of impaired comminution performance at the edges of HPGR tyres. This effect is caused by a reduction in the local crushing pressure at the edges of the tyres resulting from the interaction between the static cheek plates and HPGR feed material. In open circuit operations, this effect results in coarser particles reporting to downstream equipment. In closed circuit applications, edge effect results in an increased circulating load and diminished HPGR circuit capacity. Results were presented at SME 2015 to demonstrate how edge effect was significantly reduced through innovations in the Metso HRC™ HPGR design, which incorporates an arch-frame and a flanged tyre design.

Through a series of pilot plant tests comparing a 750 mm x 400 mm HPGR with flanges versus the same HPGR with traditional cheek plates, the

enhanced performance when operating with a flanged tyre design was demonstrated and a detailed description of the pilot testing protocols, results and analysis are presented. In addition, insights into the implications for circuit design, energy efficiency and overall plant performance were presented.

The use of laboratory HPGRs has also been investigated to improve the separation efficiency of dolomite and clay minerals (kaolinite) from apatite. This paper included characterisation studies on dolomitic phosphate ores, and data from an applied **PerUsa EnviroMet** physical model of the HPGR to develop preliminary comminution data; as well as laboratory HPGR evaluations to determine crushing parameters, such as feed rates, rolls speed and gap, and applied torque, pressure and energy. Complementary work on lab rod mill grinding, and flotation studies were conducted to assess dolomite/apatite separation efficiency. The HPGR tests showed that commercial products for all mines can be obtained.

Recoveries of 74% to 82% of P_2O_5 and rejections of 46%-83% of MgO were reported with specific energy consumption of 20% to 50% of that of a laboratory rod mill. In the case of kaolinite/apatite separation prepared at 2x 0.02 mm particle size, the results showed an increase in both the recovery from 63.4% to 73.2% of P_2O_5 and rejection of 70% to 84% of Al_2O_3, with specific energy consumption of 3.88 KWh/t.

The ball mill is a critical piece of equipment for most mineral processing plants and reliability of the ball mill is key. Presenting "a unique design" in the Eriez-JinFa metal magnetic liner (MML) at SME 2015, the group stated that over 600 ball mills have been installed with Eriez-JinFa MML worldwide. These MML liners are manufactured by embedding a magnet into an abrasion-resistance alloy. "It is easy and safe to install and it runs for many years without any maintenance. The MML is attracted to the mill shell or head by magnetic force. The fine ball chips or magnetite fill up all gaps, preventing ball chips wedging into the back of liner and sealing up the whole mill, and eliminating leakage and back washing wear." A comparison test between MML and conventional steel liner was performed at a iron ore processing plant. It was found that throughput increased by 2.96% while power consumption decreased 5.79%.

Aearo Technologies, LLC a 3M company, reported at SME 2015 on a recent application, where 3M responded to a customer request to quiet operations of ore-crushing ball mills. The large cast mill cylindrical drums are loaded with 76 mm steel balls and ore and are rotated at low speed. The ore crushing ball mills operated in a sheet steel structured shed building with considerable reverberation times. Rather than treating the building shed as is typically done, 3M innovated by attacking the problem at the source, the ball mill. "Successfully treating the noise emissions from the mill required a thorough assessment, then solution modelling and application of vibration damping and isolation materials. The engineered acoustic solution made a significant decrease in ball mill noise resulting in an environment noise reduction of up to 5 dBA. In addition, the solution employed is proving significantly more durable than the traditional noise blankets or curtain typically used."

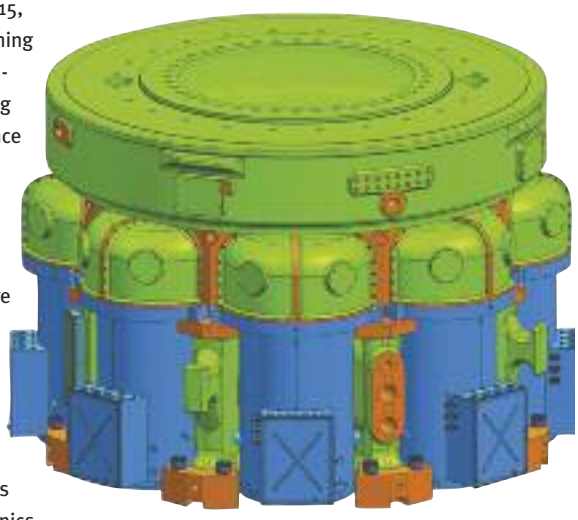
ROM particle size distribution and comminution

A recent oaper from **Split Engineering** and Rocha Blast Engineers, presented at the recent New Orleans ISEE conference and at SME 2015, tackled the impact of ROM PSD on crushing and grinding circuit throughput. The run-of-mine size distributions due to blasting have a great influence on the performance of a SAG mill. In this paper, a mine case study was conducted where there are four primary geologic units and the material properties between the four units vary considerably. Also, the mixture of the four unit that will be mined at any given time also vary considerably. This presents a challenge in terms of optimising the blasting for mill production throughout the mine life. As part of the case study, field rock mass characterisation, laboratory rock mechanics tests, and laboratory breakage tests were conducted. The field characterisation and rock mechanics tests provide material properties used to simulate the effect of different blast designs on run of mine particle size distributions (ROM PSD). The JKSimBlast software was used for these simulations. The rock breakage tests provide material properties used to simulate crushing and grinding performance. The JKSimMet software was used for these simulations.

The goal of the mine is a mill throughput of 95,000 t/d. Based on this goal, run-of-mine fragmentation analysis was conducted for four blasting designs resulting in powder factors of 0.44, 0.54, 0.64, and 0.94 kg/t. The powder factor of 0.44 represents a standard blasting design, while the 0.54 and 0.64 kg/t designs are high-energy blasts specifically to assist with mill production. The 0.94 kg/t design was investigated for the one geologic unit with very high strength. The results of the run-of-mine fragmentation analysis were then inputted into a crushing and grinding simulation model to predict the mill throughput for the time periods of 1-5 years and 6-10 years. The results indicated that certain blast designs are able to achieve the 95,000 t/d goal, while other blast designs were not. A standard blast design with a 0.44 kg/t powder factor, for example, was not able to achieve the throughput goal, while a design with a 0.64 kg/t powder factor was able to achieve the goal in both the 1-5 and 5-10 year time periods.

Increasing roller mill outputs

Requirements in the mining and cement industries for mill output continue to increase, with the result that Loesche has adapted its well-proven module concept to this greater mill output. Now, alongside the mill types with 2+2 and 3+3 rollers, the customer can also use a mill with 4+4 rollers. Loesche has already been building on this patented technology for over two decades. In the early 1990s, the 2+2 concept was patended, and later extended to the 3+3 module design. Now, a few years later, the development of the 4+4 grinding concept follows, which offers the customer outstanding flexibility. "On the one hand, this allows the desired high throughput capacity to be achieved, and on the other hand, it offers the possibility of running just as well in 2+2 roller operation, thereby generating a mill output of 60%."



COPE drive on largest Loesche mill type LM 70.4+4

The success of having sold over 300 mills for grinding clinker and slag on the market allows Loesche "to use this experience to further develop the trusted concept and to continue to provide customers with the well-known technology." The innovative development in the Loesche mill type LM 4+4 is not only the expanded module concept but also the drive. The increasing performance requirements of cement producers led to rethink the further developments in drive technology but the mills also have applicability in mining. Particularly for larger mill outputs, Loesche favours a drive

system with multiple motors and gearboxes with milling force decoupling.

In order to meet these demands, Loesche will use the COPE gearbox developed in cooperation with Renk, which offers a redundancy of up to eight motors at the motor end. With all eight motors in operation, a capacity totalling 8.8 MW is achieved. The new COPE gearbox contributes the feature of working without variable speed drive and also operating with a reduced number of motors. This means the new drive concept allows for operation with, for example, 7, 6 or only 4 of the available motors. Even in operation with only 7 motors, 100% mill output can be attained.

Because this drive train works with the normal dimensions, the system is also suitable for retrofit gearboxes in existing mills. With this drive concept, “Loesche can put a highly redundant, innovative drive system for the new Loesche mill type LM 70.4+4 on the market with short delivery times and low investment and construction costs.”

The new Loesche mill type LM 70.4+4 will be used with an output of 370 t/h 4,700 Blaine in UNICEM Nigeria's new line in Calabar, Nigeria. The delivery period is 14 months with commissioning due in 2015. ***IM***