As such as optimisation, modelling and lab or pilot scale testwork are now crucial in getting it right when it comes to comminution at whatever particle size and process stage. But just as in reality there is no average ore or rock type, every comminution application is unique and requires its own study. By putting up alternatives against each other, capital and operating costs can be calculated and compared in order to find an optimal solution for an individual application case. This can require co-operation between equipment OEMs, academics, consultants and engineering groups together with the mining groups, to come up with a way forward. Specialist events such as SAG 2011 and Comminution 2012 help to bring these stakeholders together and drive technology advances.

Arguments can even come down to the relative importance of crushing versus milling/grinding in terms of cost and efficiency. And despite the moves towards ever more advanced milling/grinding circuits, crusher technology is not standing still. Robert Picard, Applications Marketer - Mining Crushing & Screening at Sandvik comments: “Milling is the dominant energy consumer as well as having a high cost for mill media. We believe therefore that it is generally cheaper to crush than grind in size reduction. Today, with more efficient crushers a circuit can be built with fewer units and especially a lower energy requirement. Liners in crushers are exposed to wear. However, design and operation of a modern crusher makes it possible to have a high degree of interparticle crushing rather than against the liners. This has improved cost for wear parts considerably. Still crushers require more frequent maintenance than mills. However it can be dealt with if liner changes are planned into scheduled maintenance stops so that production loss is minimised or even totally eliminated.”

Ultrafine grinding
Ultra-fine grinding (UFG) remains a key area to achieve higher recovery rates in many mineral processing applications. But milling is inherently inefficient and this inefficiency increases dramatically as the particle size decreases. Current developments in UFG mills have tended towards high intensity mills with high rotational speeds and grinding disk tip speeds ranging from 12 to 20 m/sec. This is coupled with the development of higher density media to help achieve higher breakage rates. An installed power of 3 MW is common and installations of up to 8 MW are running successfully with the potential for even larger examples. But with research suggesting that as little as 3-5% of the input energy is actually used for grinding, some in the industry argue that there is considerable scope for energy saving.

Maelgwyn Mineral Services’ (MMS) new twin drive horizontal mill development aims to reduce this waste of energy by using a novel drive and generator system to reclaim and recycle energy from the moving media mass while grinding. It consists of a rotating drum fitted with wall mounted grinding disks, driven through a gearbox and an internal shaft, also fitted with grinding disks, coupled to a motor but configured as a generator. The interspaced drum and shaft mounted disks form a labyrinth for the slurry flow. MMS has built two prototype mills, a 400 mm diameter drum with an internal volume of 30 l and an 800 mm diameter drum with an internal volume of 150 l.

The drum is driven at a maximum rotation while the frictional resistance of the media on the internal rotor, in turn, drives the rotor. The internal rotor is braked electrically to control the speed of the rotor so that the relative rotational motion and consequent grinding action can be optimised. The inverters that control the drum motor and rotor motor (as a generator) are configured so that the energy generated by the rotor can be fed back to the drum drive. The power demand on the main supply is reduced to the difference required by the system.

The interspaced disks segregate the media into individual grinding chambers that reduces
the hydraulic packing of the media and together with a novel disk design, provides an axial load on the media to increase the force applied during media interactions.

The 400 mm mill has been tested quite extensively recently using fly ash in a project together with Cardiff University. The data generated by this initial trial phase has shown that the concept has some potential. The trials carried out at Cardiff University have been designed to prove the concept but has also compared the twin drive concept to typical high intensity horizontal and vertical mill configurations. The initial test results showed savings of 30% on specific energy to P90 of 10 μm, and 15% to P90 of 5 μm from a feed P90 of 275 μm.

Comparative test work was carried out using Saint Gobain Zirmil media with specific gravity of 6.2 and 2 mm diameter. Current analysis suggests that more efficient results can be obtained with finer bead sizes and lower density media. Zirmil are ceramic microgrinding beads produced from a unique yttria-doped zirconia powder.

Through its research partnership at Cardiff University MMS has also invested in Discrete Element Method (DEM) and Computational Fluid Dynamics (CFD) analysis packages to aid in the understanding of the milling environment and the effects of the process variables on the performance of the mill. The impact frequency and the energy distribution throughout the media volume is key to understanding the grinding mechanisms involved in UFG. This software has been used to model the twin drive mill configuration, as well as some comparative configurations. The actual mill data was then used to verify the model and a relatively high correlation was achieved. MMS told IM: “This analysis has been indispensable in explaining the differences in grinding mechanisms, and especially what is behind the good performance at below 10 μm. DEM analysis of the twin drive mill and comparison with models of high intensity mills shows an order of magnitude increase in the frequency of impacts per bead in the mill, with a more uniform energy distribution, indicating that the twin drive concept increases its efficiency by effectively using a greater percentage of the overall volume of media.” Other high intensity configurations rely on a very small portion of the media volume limited to the immediate inner circumference of the drum where excessively high intensity impacts effected the grinding while the bulk of the media contributed very little. CFD analysis was used to investigate the flow of slurry

**Erich MaxMill with Bitossi alumina-based ultrafine grinding beads**

through the mill. Whilst not an essential parameter for the analysis of the test work that was carried out, as all the mills were operated in a batch mode, in terms of scale up to a full scale installation, the residence time distribution is an important factor. All the mills showed fairly normalised distribution curves but it has shown that the auto-classification effect of the vertically orientated mill provides a measurable benefit to efficiency and grind curve control.

Further trials are planned as there is still a significant amount of work required to fully understand the potential of this configuration. These trials aim to optimise energy capture, disk design and bead specification over a wider range of substrates. A technical paper will be presented at the MEI Comminution 2012 conference in South Africa from April 17-20 providing more detail on MMS’s mill development and the test work that has been carried out.

UFG technology relies on the micro-bead quality as well as technical assistance to get the best results for Mainstream Inert Grinding (MIG) and UFG. **Industrie Bitossi** is a global leader in the production of Al₂O₃ based grinding beads. The company states: “Our R&D department continuously investigates new formulas in order to achieve lower consumption rate and higher grinding efficiency. In order to keep the costs down our research aims to achieve the best results with alumina products in terms of wear and energy savings. Alumina micro beads properties such as chemical composition, hardness, smoothness, roundness, specific gravity and microstructure have been specifically tailored for high intensity stirred milling. The smooth surface of the beads reduces the loss of energy caused by friction, it increases energy efficiency and it grants a longer lasting life to the internal mill wear components.” In addition to this, the company pointed out the benefits of inert grinding in the flotation process. Considering that for metal recovery, ultra-fine grinding represents a very high percentage of the total costs, the usage of cost-effective micro-media considerably helps to reduce overall operational costs.

Aside from in-house lab testing, for technical assistance, the group can assist mining customers on site in order to verify, on an industrial scale, bead wear results and also evaluate empirically all the parameters involved in the grinding process. The company states: “We have experienced how important it is to work on-site to have a clear picture of what it can happen during the grinding process. In this way we can share with each single customer the experience of many plants located all around the world. Streamlined grinding conditions optimise the micro-beads performance with a consequent beads wear cut down and they stabilise the full plant. We have also found that, to avoid abnormal increases in micro-bead wear, it is very important to have a constant slurry flow in terms of quantity and solids content.”

The grinding charge distribution has to comply with the mill size, raw material chemical and physical features, raw material grading, end particle grading, and mill rotation speed. Grinding charges are developed to have, for each specific application, the most efficient micro-bead diameter, fraction and size for refilling.

UFG is also applicable to process optimisation technology. **Loesche’s LM_Master** is a new model-based predictive process optimisation for ecologically increasing plant performance and support the operators of Loesche vertical mills. LM_Master provides for fully automatic control of the grinding process and continuously optimises regular plant operation. Online optimisation is achieved through precise depiction of the processes and increases throughput, energy efficiency and availability, states Loesche. The company comments: “The most important component in putting such a project into practice is knowledge of all aspects of the process. Loesche has the necessary experience and know-how from a diverse range of fields such as automation, commissioning and servicing, design, and R&D. This knowledge makes it possible to create models which reflect the process as accurately as possible in order to be able to derive the necessary calculations from them. These calculations show the future
The new OGPmobile is a fully functional mobile plant, which is comparable with the test circuits such as lead/zinc and nickel. It has shown that these benefits are achievable on various ore types with differing characteristics, as well as economic and ecological benefits.

The software platform required for this purpose is, irrespective of the manufacturer of the automation system, installed on a separate industry PC. With only a few interventions in the existing automation system and low investment expenditure it is thus possible to increase the efficiency of the grinding plant. The new process optimisation system is intended for use with Loesche vertical roller mills in all areas of material comminution. The application is also intended for both new installations and existing grinding systems.

The dry milling of ores in Loesche vertical roller mills has significant process advantages, as well as economic and ecological benefits, according to the group. To demonstrate these, a mobile ore-grinding plant, the OGPmobile, has been developed. This allows the customer to test the effectiveness of Loesche’s grinding technology and its influence on the total material flow of the existing processing plant. The vertical roller mill is stabilised according to the group. To demonstrate these, a mobile ore-grinding plant, the OGPmobile, has been developed. This allows the customer to test the effectiveness of Loesche’s grinding technology and its influence on the total material flow of the existing processing plant.

The degree of mineral liberation, particle size distribution, energy consumption and throughput can be optimised individually for each deposit and each treatment process, depending on the ore characteristics. The main advantages of the Loesche grinding technology, compared to conventional milling technology, are stated as: increased value recovery due to improved mineral liberation; reduced operating costs through lower specific energy consumption; less wear of grinding parts; narrow particle size distribution; rapid adaptation to changes in ore characteristics within a deposit; automatically controlled mill circuit using online control system; and reduced total water consumption due to dry grinding and classifying. Loesche told that past experience has shown that these benefits are achievable on various ore types with differing characteristics, such as lead/zinc and nickel.

The OGPmobile is a fully functional grinding plant, which is comparable with the test circuits in the Loesche Test Centre in Neuss, Germany. Being used in southern Asia, where its transport to site was handled by Loesche logistics experts. The operation of the facility and the testing program is being carried out in close co-operation between the customer and with Loesche specialists on-site. After the series of tests has been completed, further deployments are planned.

In addition to the OGPmobile, Loesche offers the Containerised Grinding Plant or CGPmobile. This newly developed containerised construction plant provides for the local supply of thermal processes and can be used at any site. This plant type fills the gap in the supply of coal dust in that it eliminates long transportation routes in special vehicles. The use of coal instead of gas and oil that is made possible by this plant reduces operating costs dramatically according to Loesche.

In the mining industry, the need for efficient fine grinding processes is increasing rapidly. As demand for ores with finer mineral intergrowth rises, grinding technology is being developed to keep up.

Jon Allen, Metso’s Project Manager for Stirred Milling Technologies, notes: “What we’re seeing now are deposits that have more finely disseminated valuable mineral. The fact is, those deposits require finer grinding to achieve adequate liberation.” The challenge in fine and ultrafine grinding applications is the increasing energy requirements and the diminishing returns that occur as operations approach smaller product sizes. The solution Metso argues is energy-efficient stirred milling machinery that maximises wear life and availability – all while achieving desired product size and maintaining profitability. This solution

**The new SMD-1100-E, Metso’s largest-scale Stirred Media Detritor**

The flexible circuit allows operation in an airflow as well as in overflow mode without external classifying. Large samples of milled material – 200-300 t for further direct processing in subsequent process steps – can be produced.

The quality of the milled products is checked by analysis in the integrated laboratory. The OGPmobile consists of three, 40 ft-long, cubic profile ocean containers, which makes global transportation easy. The mechanical equipment for grinding, sizing, material handling and product separation is installed in two containers. In the third one, the laboratory and process-control system is installed, along with the control room.

The minimum requirements for operating the OGPmobile are an appropriate power supply and a compacted base measuring approximately 17 m x 7 m. The first OGPmobile is currently being used in southern Asia, where its transport to site was handled by Loesche logistics experts. The operation of the facility and the testing program is being carried out in close co-operation between the customer and with Loesche specialists on-site. After the series of tests has been completed, further deployments are planned.

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**The new OGPmobile is a fully functional mobile grinding plant**

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has evolved into the most cost-effective fine grinding technology – from the Vertimill to the latest Stirred Media Detritor (SMD) E-Series, featuring the SMD-1100-E, Metso’s largest-scale SMD. The Vertimill and SMD are not competitors, but were developed as complementary products. The Vertimill can work with a 6 mm to 20 micron feed, and the SMD from 100 microns to a 45 micron feed size.

Metso states: “The SMD-1100-E is bringing efficient ultrafine grinding to large-scale throughput. This machine is the future of fine grinding because its efficiency and specialisation enable it to provide the lowest total cost of ownership to operators who need to achieve fine grinds.”

It is often said that lowest total media consumption is a major influencer of lowest total cost. However, if a machine requires less media – but at a higher cost per tonne, the “savings” afforded by lower media consumption are eclipsed by the material cost. The consumables – the grinding media – are the number-one operating cost in a mill. The entire SMD-E-Series, including the SMD-1100-E, offers the lowest cost per tonne processed of between $300 and $1,300 according to Metso. With lower energy inside the SMD-E-Series mills, the wear life is also extended.

The company states: “The increased volume of the SMD-1100-E is key to maximising the cost-saving potential of lower-intensity grinding. But space is also an important consideration in a plant, and the solution was to go vertical. By doing this, we can make use of a larger volume without worrying about affecting the footprint of the unit. An additional benefit of a vertically configured machine, when compared with the horizontal unit, is a simpler mechanical design. Because the vessels are pressurised, horizontal stirred milling machines require shaft seams, feed pumps for slurry and media, plus additional shaft bearings, and more concrete for the foundation. The SMD-1100-E is a streamlined unit that can achieve higher availability.”

With regard to maintenance, every wear component of the SMD-1100-E can be changed with the mill in place – without removing or disassembling the shell. Additionally, the top plate can be rotated in 65° increments, and side plates are interchangeable for multiple feed arrangements. Metso also kept ancillary equipment to a minimum with the SMD-E-Series as only one pump per SMD is needed – not five or six as on other stirred mill designs. Maintaining one pump is much simpler and less expensive.” After installing a smaller SMD-355-E at the Mototolo platinum mine in South Africa and seeing the operational benefits, Anglo American wanted to scale up. “The SMD allows us to achieve fine grinds at a high level of efficiency,” says Chris Rule, Head of Concentrator Technology at Anglo Platinum, “and the mechanical improvements with the E-series result in more uptime. In any operation, that’s how you achieve long-term success: the more tons we get through, the more revenue we’ll see, and the SMD-1100-E is going to help us do that. It always comes back to our bottom line.” Anglo Platinum expects the SMD-1100-E to provide the longest wear life and highest uptime of any fine grinding technology they have trialled. The unit is schedule for start-up in September 2012 at the Anglo Platinum Union Mortimer concentrator.

**HPGRs and IsaMill**

Moving from UFG technology to other milling and grinding developments, high pressure grinding rolls (HPGRs) continue to get a lot of attention in the industry. **Coalition for Eco-Efficient Comminution (CEEC)** members Greg Lane, Chris Morley and Mike Daniel of **Ausenco** in Australia have reviewed this topic in some detail in a paper submitted to **IM by CEEC that looks at HPGR units already installed at the Argyle, Whyalla and Boddington operations. Issues and opportunities that have arisen include the impact of moisture and particle size on roll wear; as well as issues associated with wet screening. The review also looks at circuit design issues in the context of operability, and eco-efficiency.**

The authors believe that HPGRs are being widely acknowledged as comminution tools that can be used to reduce overall comminution energy requirements when used in an appropriate circuit configuration. This is a concept that CEEC and Ausenco are trying to actively support and promote.

The expectation of the authors is that enthusiasm for the technology will continue to wax and wane as the technical, cost and operating issues arise and are overcome. This will lead to the establishment of the technology for particular applications, for example relating to the scale and ore characteristics, that SAG milling and other conventional technologies are not particularly suited to.

There are several HPGR units operating at Australian mine sites: two at Whyalla processing magnetite ore; four at Boddington processing very competent gold ore; and three at Argyle Diamond Mines.

Other HPGR units have been installed in Australia at Spinifex Ridge (molybdenum), Bendigo (gold) and Tropicana (gold) amongst others. In addition, an HPGR has just been installed at Cadia which is to be commissioned in 2012. Some early Australian HPGRs had wear issues after installation but a recent HPGR optimisation program at Cerro Verde in Peru (it has four Polysius units with studs) on the wear protection tyres – improving stud design and grade – has resulted in an increase of the lifetime to more than 5,000 h with a potential to finally exceed 6,000 h with the next design change. Other high wear HPGR operations are expected to benefit from these developments.

Argyle introduced HPGR technology in 1990 to counter the problem of increased ore hardness of the deeper competent unweathered lamproite (Bond ball mill work index 18 kWh/t and Bond abrasion index 0.60) in the mine and also to increase throughput capacity. The first of two **ThyssenKrupp Polysius** units (both installed at Argyle in the 1990s) has dimensions of 2.2 m diameter and 1 m width had twin 1,200 kW motors with fixed speed drives. The second unit was installed with twin 1,800 kW motors with variable speed drives. Both units have customised bypass rock boxes in place of the convention cheek plates. A unique on-line grinding device has been adapted to the back of the rolls to allow for regular grinding of the roll surface to prevent unacceptable bath tub profiles on the segments. A **KHD machine** was installed in the re-crush plant in 2002 to increase diamond liberation and recovery by reducing the overall crushed particle size. The KHD unit, with a diameter of 1.7 m and a width of 1.4 m with two 950 kW variable speed motors, is in the quaternary crushing building. The feed to the roller press has a top size of 20 mm and is truncated at 6 mm. The product particle size is 80% passing 8
FLSmidth engineers have been developing and testing HPGR solutions and introducing the concept to its mineral processing offering mm, with 36% passing 1.18 mm. Feed rate is around 800 t/h.

HPGRs have allowed Boddington to treat the large low grade gold-copper primary resource situated beneath the oxide cap. The primary ore is a combination of competent diorite and andesite with typical Bond ball mill work indices of 14 to 17 kWh/t. Boddington's comminution flow sheet comprises a primary crushing section, closed circuit secondary and tertiary crushing (with four Polysius HPGRs in the tertiary stage), ball milling and hydrocyclone classification. Nominal treatment rate is 35 Mt/y.

Primary crushing is carried out in two gyratory crushers. The crushed product (nominal P80 of 150 mm) is conveyed to the coarse ore stockpile. The secondary crushing circuit comprises five Metso MP1000 cone crushers in closed circuit with single deck screens with apertures to produce a size of less than 50 mm for the HPGR. Screen oversize reports to the secondary crushers and undersize reports to the HPGR. The Boddington HPGR units are large 2,500 t/h machines manufactured by Polysius.

The four Polysius HPGRs each with a 2.4 m diameter and 1.65 m width and fitted with twin 2.8 MW variable speed drives further reduce the secondary crushed ore to below 11 mm. The feed to ball milling is wet screened to remove HPGR oversize, with the screen oversize returning to the HPGR for further comminution. Screen undersize (minus 11 mm) is fed to hydrocyclones for classification which produces a final grind size of 150 μm.

Whyalla installed two Köperrn 1.4 m x 1.4 m machines with Hexadur surfaces. Köperrn developed Hexadur, a unique highly abrasion resistant material for wear protection for grinding rollers. The name is derived from the shape and arrangement of hexagonal tiles. The magnetite ore is treated the rate of 650 t/h split between two lines. The HPGR product is wet screened at 3 mm and the oversize returned to the HPGR while the finer material is subjected to wet magnetic separation. Non-magnetic materials are rejected directly to tails while the concentrate is re-screened on 700 μm aperture rougher magnetic separator screens with the undersize passing to the ball mill circuit and the oversize recycled to the HPGR.

The authors comment: “Development of modelling and simulation of HPGR unit processes and circuits has developed in parallel with the described plant applications. The proven unit process models are frequently used in simulations where SAG versus HPGR trade-off studies have been completed. The trade-off studies assess the benefits of the technology where secondary and HPGR crushing effectively replaces the relatively energy in-efficient SAG mill. These studies require comprehensive ore property data as well as the robust process models including models that describe, crushing, screening and ball milling.”

The JKSimMet comminution software tool from the Julius Krutschnitt Mineral Research Centre (JKMRC) can be used for this type of analysis. It typically requires a review of historical data/new test work data and ore property data. The data is prepared to suit an HPGR model describing throughput, specific energy and product size distribution. JKSimMet circuit models are then prepared including re-circulating loads, screening, ball milling and secondary crushing. Alternative circuit options/scenarios including energy comparisons with SAG-based circuits can be conducted.

These important aspects of overall circuit design are sometimes overlooked by the OEMs, according to the authors, as the process guarantees are generally only associated with attaining HPGR throughput capacity, whereas the circuit design, including the sizing of the ball mill relies on a detailed description of the product size distribution resulting from the HPGR in closed circuit with a screen.

The paper states: “At present, feed preparation is of paramount importance in maximising HPGR availability. Thus, efforts to simplify the current layouts used for HPGR based circuits using open circuit secondary crushing, reduced emphasis on screening and reduce circuit complexity present a real dilemma for the vendor, engineer and operator.”

Future directions include the possibility of eliminating the HPGR product screening step. The top size that can be fed to the ball mills depends on the grindability of the ore. As HPGRs find their application with competent ores, a ball mill's capability to grind coarse mill feed requires validation. This process can include an eco-efficient evaluation of the overall circuit when compared with conventional circuits.

Innovative comminution circuit design employing HPGRs has been simplified by CEEC in the past year, by the presence of the online data site www.ceecthefuture.org. CEEC has put comminution energy efficiency on the table for debate; calling on industry leaders to ask pertinent questions with respect to energy consumption in the comminution process. As a consequence, flowsheets with no screening have been reconsidered where the HPGR operates in open circuit with the potential to recycle ball mills scats to the HPGR feed after steel scat removal. Ausenco is exploring these approaches.

One of CEEC’s objectives is to disseminate technical information relating to eco-efficient comminution with the overall aim of improving the efficiency of mineral processing circuits. CEEC is sponsored by more than 10 of the world’s leading mineral processing companies – which in addition to Ausenco includes Newcrest, RME Mill Relining Systems, Xstrata Technology, Teck, Gold Fields, Gekko, JK Tech, Outotec, AMEC, Metso, AMIRA, Indophil Resources and the Sustainable Minerals Institute (SMI).
From this the OEM can determine gap sizes and wear rates. This then translates into machine size determination and performance guarantees.

Pilot test work is becoming more and more popular. With laboratory test work the supplier is comfortable with the results obtained, but there have been some cases where the actual results have not matched lab results. By re-conducting the test work it can be found that the samples may also vary, though as the samples were submitted by the customer, in this case the OEM is no longer accountable.

FLSmidth states: “The biggest problem we have with the laboratory test work is that the machine sizing and performance guarantees hinge on 3,000 kg of ore. Having said that, we can’t move hundreds of tonnes to the lab due to logistics. So the new approach is on-site multiple test campaigns with a larger lab machine.”

FLSmidth states that the majority of HPGR machines will be similar in size to those used in current cement applications with slight variations due to power draw and press force requirements. It is currently envisaged that FLSmidth will be in the position to supply large industrial machines for mining in the second quarter of 2012. The group states that it is seeing continued demand for its HPGR technology, and has been engaged in development projects at both Rio Tinto and Anglo Platinum mine sites. The equipment at the Rio Tinto plant is currently in operation and the Anglo plant will be running this year.

FLSmidth also will be installing a pilot HPGR and Wear Analysis equipment at its Salt Lake Technologies centre. This equipment will help in sizing industrial machines and evaluating surface wear. The equipment will be supported by a dedicated team that can also be dispatched to sites where pilot test plants are in operation.

Xstrata Technology has been seeing continued demand for its IsaMill range, well known to IM readers as high intensity, stirred mills used in ore fine grinding. An IsaMill has recently been selected to be part of the Russian Copper Company’s (RCC) Miheevsky project in Chelyabinsk, Russia. This will be the first IsaMill to be installed in Russia, and will form part of the copper regrind circuit in the concentrator, producing high quality copper concentrate.

The IsaMill selected is an M10000 unit, and is to be supplied by Xstrata Technology with a 3,000 kW motor and designed to use ceramic media. The Miheevsky project is an open pit mine treating porphyry copper ore, and is set to treat 18 Mt/y when in operation. It is scheduled to be commissioned in late 2013. Rakan Rahbani, Regional Manager for Xstrata Technology, based in London, said RCC was seeking innovative solutions for effective development of their low grade deposit, and the IsaMill was just one of a range of technologies they were using to maximise the copper recovery at the site. Rakan said the project was important in establishing new markets in Russia and Eastern Europe for the technology, while building on the existing IsaMill installations in Europe.

The engineering for RCC’s IsaMill will be carried out by Xstrata Technology’s engineering team in Vancouver, and will be one of several IsaMill projects being undertaken by the Vancouver team, including an M500 for Teck’s Highland Valley Co-Mo bulk regrind circuit and Taseko Mines’ Gibraltar operation using a M500 IsaMill for a molybdenum regrind. Both mines are located in Canada.

Brakes to media

Aside from the crushers and mills themselves, aspects of delivery such as brake systems, grinding balls and wear parts can play a crucial role in comminution. Twiflex and US distributor Hilliard are currently working on a very large grinding mill brake system for Newmont. The system will be installed on both 26 ft gearless driven ball mills and a 42 ft gearless driven SAG mill being supplied by Metso for the Minas Conga oxide copper-gold project in Peru near the group’s existing Yanacocha operation. Conga is Peru’s biggest mining project and will be Metso’s biggest installed SAG mill to date. The Twiflex scope of supply for the project includes two off pedestals (brake stations) each with four off VMS-DP brakes plus hydraulic power packs for each of the mills.
The Conga project is located approximately 900 km north of Lima at an altitude of 4,100 m above sea level. It is 24 km northeast of the Yanacocha mine where in 2008, Twiflex installed the brake system on its 32 ft 16.5 MW SAG mill. Conga is a joint venture between Newmont and Buenaventura. The $8.4 billion copper-gold project is expected to start production in late 2014 or early 2015. Forecasted production for the first five years is between 580,000 and 680,000 oz of gold with 155 to 235 Mlb of copper.

The Twiflex brake system is designed specifically for mine grinding mill installations giving both static and dynamic braking functions. In static operation the brakes are used to hold the mill during liner replacement and general mill maintenance. For dynamic operation the system can operate in two modes, stopping the mill from full speed in an emergency or giving inching / creeping operations in the event of bearing lubrication problems or power failures. For the first a controlled application of the brakes is required and for the second the brakes are operated quickly to give accurate stops needed by the mill operator.

The Twiflex VMS-DP has an adjustable braking force from 590 to 737 kN and is a floating spring-applied, hydraulically-released brake suitable for disc/flange thicknesses from 117 mm to 130 mm. It can be used on installations with a disc/mill flange diameter of at least 6.5 m providing the braking path is over 300 mm (there is no upper limit on the disc/mill flange diameter). The hydraulic powerpack offers an advanced and versatile brake control as it allows both local and remote operation for inching and creeping duties through a control panel.

The braking system on the Conga 26 ft ball mill will generate up to 34 MNm braking torque acting on a 9.4 m diameter mill flange and 51 MNm on the 42 ft SAG mill when acting on a 14.2 m diameter flange. The VMS-DP calipers weigh 1.85 t each and are able to deliver a 940 kN clamping force.

With a full process charge of 1,360 t (SAG mill) and operating at 9 rpm the braking system is able to stop a mill in less than two seconds.

**Magotteaux** provides solutions to industries where comminution processes are essential in the manufacturing of finished products, including mines, and regards itself as a world leader in differentiated solutions against wear. In 2011, Magotteaux was taken over by Chile’s Sigdo Koppers. The operation was meant to open up new market possibilities and progress is being made. At the end of 2011, it bought the remaining 50% of its joint-venture in Chile, Proacer. The target is to increase the group’s presence in the low chromium cast grinding media market. At the end of January 2012, the company invested in the capital of Sabo Chile, a producer of forged grinding media, and now owns 55% of the shares. The group told *International Mining*: “These acquisitions will add an extra production capacity of approximately 95,000 t to our existing figure. They allow Magotteaux to offer the complete range of grinding media solutions – forged, low-chromium cast, high-chromium cast and ceramic media in all diameter ranges to suit all their customers’ applications.” Magotteaux is also looking to expand in Asia where a new production unit for vertical mill parts will soon start production in Thailand.

The market for replacement SAG and ball mill media is huge globally. OneSteel has consolidated its position with the acquisition of Moly-Cop in 2011 recently has introduced the 0.95%C Mining Ball which has become the industry standard for use in tumbling ball mills. High-performance SAG mill balls are supplied by Comsteel in many domestic and export destinations.

The new Moly-Cop Australian business will continue to offer a comprehensive range of grinding media for wet and dry grinding, semi-autogenous (SAG) and ball mills of all sizes, rod mills, and stirred mills as well as maintaining an “energetic focus on continual media development.” Ball mill grinding media products are offered from 25 mm to 94 mm in a range of steel grades to suit any comminution application. SAG mill products range from 105 mm up to 150 mm, with steel grades and hardness properties suitably matched to the application. In recent years Moly-Cop has systematically increased the surface hardness and wear resistance of its SAG mill products without sacrificing ball toughness.

Moly-Cop grinding media is statistically sampled from production runs and routinely tested in the OneSteel Waratah NATA Accredited Metallurgical Laboratory. The laboratory is equipped with modern specialised equipment, specifically selected for testing high hardness grinding media. It is equipped with manual and fully automatic Vickers, Brinell and Rockwell hardness testing machines; fracture-grain-size press; metallographic sample preparation equipment and modern stereoscopic and inverted metallurgical microscopes. The group has access to a Scanning Electron Microscope, a fully equipped and modern chemical lab, heat treatment lab and drop-ball test facility.

**Sizers – more than size reduction**

Having originally designed and developed the mineral sizer, **MMD** is the only manufacturer whose whole range of equipment is based purely on this size reduction technology. MMD’s focus on this single technology, together with sustained investment, has allowed it to extend the range of materials to which sizers are
The MMD sizer has proven itself in multiple hard rock applications at high throughput tonnages

applicable as well as expand the perceived technical boundaries in the use of sizers, well beyond its roots in the coal industry. Some of the early landmarks in this development process and a move into hard rock were the first sizer units to be delivered to the uranium mines in Niger in 1982, the UK tin mines in 1984, and the South African diamond mines in 1985. But MMD believes that it is in the field of IPCC that sizers, the only breaking system designed for mobile installation at the outset, have had and are having the greatest impact. The sizers’ compact design; low profile; minimum of external loads together with an ability to handle a wide range of materials regardless of moisture content without any modification or loss in efficiency; and their ability to handle both oversized lumps and cope with unbreakable inclusions such as tramp metal combine to make them ideal for mounting on mobile installations (either semi or fully mobile). The sizer is capable of working in conjunction with short haul trucks or being loaded directly by shovels, draglines and even dozers. The sizer's high capacity and flexibility makes them especially suitable for high capacity operations in mixed overburden.

One of the greatest issues when considering the use of a sizer, particularly in hard materials, is that of wear part replacement. Many potential users and consultants wrongly assume that having relatively small wear parts and with attrition being involved in their breaking system, that this renders certain solutions unsuitable or uneconomical. This is, however, based on largely unfounded assumptions. The fact is that the cost of the wear parts and even that of fitting them can become relatively insignificant when balanced against the cost of stopping production for maintenance or repair work. This is of particular importance in high volume IPCC operations for overburden, where it is not only the stoppage to the crushing/sizing system that is involved, but a complete IPCC system. The highly capitalised nature of modern mining making it imperative that not only the installation and operating costs of crushing/sizing system, but the cost of production stoppages, both planned and unplanned, are fully considered at the feasibility stage. The sizer has a low profile and the ability to dispense with both the need for pre-screening and heavy support structures, together with a lower power consumption. A study done for a leading coal company by a South African university compared the cost of installing and operating a sizer to that of a jaw crusher in similar conditions. Both handled 1,000 t/h of ROM coal containing sandstone, with a maximum size dimension of 1,200 mm, destined for a coal handling plant. The result showed that the total installation cost of the sizer was lower than that of the jaw, in spite of the sizers’ initially higher price. Even when based on the jaw crushers capacity, the sizer operating cost was considerably lower. The benefits of sizing can be even greater if full advantage is taken of the sizer’s significantly higher capacity, according to MMD.

Similar conclusions were arrived at by Lignitos de Meirama, in their comparison of the relative cost of using a sizer and a gyratory in overburden consisting of shale and granite, the latter often in the form of large lumps. The results of extensive tests showed that when operating at 1,500 t/h the operating costs of the sizer and the gyratory crusher were approximately the same. However, the sizer proved capable of handling the far higher capacity of 4,000 t/h and the balance shifted significantly in its favour.

MMD also points out that when frequent replacement of wear parts is a consideration the sizer has a distinct advantage over conventional crushers whose wear parts can involve the need for heavy lifting equipment and extended stoppages. The sizer uses relatively small individual wear “caps” the larger of which can be fitted with replaceable plates and tips, which can be changed individually without using heavy transport or lifting equipment. The company adds: “Aspects which are often forgotten or mistakenly simply regarded as being inconsequential when preparing cost projections are the sizer’s rotating screen effect, which allows material to pass through it without further degradation or consumption of energy; the size spread or gradation of the material that a sizer can handle; and the actual cost and perhaps more importantly the time taken for the relocation of the station in IPCC installations.”

The fact that the sizers don’t use flywheels and have a direct drive system also means that they only use the power required to break the material, consuming very little power when running empty or have very little material to break. This attribute, together their breaking system being based on the less resistant shear strength of rock rather than its higher compressive strength, enables them to have a lower power consumption than other mine crushing systems. Another benefit is that the inward rotating units centralize material on conveyors allowing for their being installed in-line or being used to change the direction of conveyors.

SmartTag and smaller tags

SmartTag is an RFID-based technology from Metso designed to allow tracking of ore from its source through blasting, run of mine (ROM) pads, crushers, intermediate stockpiles and finally into the concentrator. As such it is a unique tool in determining the origin of blasted ore being processed in the series of subsequent comminution steps. It also allows a mine to know exactly when a surveyed blast is being processed. A SmartTag RFID tag travels through a mine and mineral processing plant in a series of simple steps. Initially, the tag and insertion location is logged using a hand held computer or PDA, then it is inserted into the ore, such as into a blast hole. The tag travels with the ore through digging, transport and processing, before being detected at detection locations (on conveyor belts), when the time and specific tag is recorded. The RFID tag data is then loaded into a database and analysed as required.
To achieve this, the SmartTag system requires five main components. The first component in the SmartTag system is a PDA, which allows the initial RFID tag insertion process to become more efficient and accurate. Each RFID tag is added to the database using one of three options: it is associated with a GPS coordinate; it is associated with a predefined point such as a blast hole; or it is associated with a new point, which can be accurately located later.

At present the system does not allow for high precision GPS but it can locate the nearest point in a series of predefined points, such as blast holes, and allow the user to associate RFID tags with these points.

The next component in the system, the antenna, is located at the conveyor belts. The antenna both induces a charge on the tag and also receives a transmitted signal back from the tag. The design of the antenna is decided by two parameters, which are its size and its robustness. The size of the antenna dictates the size and the strength of the field it radiates. For this application the area of field strong enough to charge the tag should be as large as possible; therefore the antenna used for the SmartTag system is the largest available for this frequency of RFID system.

An RFID reader then decodes the signal from the antenna and determines the ID of the RFID tag passing the antenna. Later versions of the readers also have auto-tuning capabilities which ensure that the maximum possible read distance is achieved at all time. In the SmartTag system the reader then transmits the ID using serial communications.

A data logging or buffer stage improves the reliability of the systems and also makes movable systems possible. The data logger receives data directly from the RFID reader, stores the IDs with the time they were detected and monitors vital system parameters, such as the tuning state of the antenna. The data logging stage also makes SmartTag less reliant on communication links (such as wireless) as the data is stored at the detection point until a link is established to the software applications. The critical communications links, like the one between the antenna and the reader, are all wired and very reliable.

In order to expand the applications of SmartTag through and beyond secondary crushing, Metso recently concluded that a mini RFID tag was required. To incorporate the mini RFID tags into the SmartTag system, Metso faced two significant challenges; firstly, the reduced read distance, and secondly, making the mini tags robust.

By reducing the size of the RFID tag, the size of the antenna in the tag is also reduced. The size of the antenna in the tag is directly proportional to the amount of charge that is induced, for a given field strength. Therefore, the read range of a tag will be reduced as the size of the tag is reduced.

Through investigation, the 20 mm tags were found to have an insufficient read range for the standard SmartTag installation. The company trialled two methods for fixing this issue; one method was to use two antennas while the second method was to place the antenna closer to the RFID tags. Both systems were tested at an iron ore mine. Both approaches, dual antennas or closer antenna distance, were found to have similar detection capability. However, based purely on the ease of installation, a single antenna located under the belt, was chosen as the new standard installation method. The second challenge faced when incorporating the mini RFID tags into the SmartTag system was how to protect them sufficiently to survive a blast. A method previously used by Metso to achieve this was to encase the tags in a two part epoxy. The method works well for protecting the tags, and although it is time consuming and expensive it is currently the preferred method for protecting the tags. Different encasing materials, such as reinforced nylon, are still being investigated.

The team envisages that with the successful incorporation of the mini RFID tags into the SmartTag system it will allow applications for the system to be expanded. These new applications could include a wider use in the iron ore industry where size is the critical material quality. Metso is now working on proving the reliability of the next size of RFID tags, the even smaller micro RFID tag, which can pass through a 10 mm mesh screen.

New developments
As noted in last year’s comminution review (IM, November 2011, pp42-53), Sandvik recently launched two new cone crusher models that it believes are giving the market even more efficient alternatives. The new CH890 and CH895 models have an increased power input, a new dedicated topshell design and a mainshaft made from a new high-strength material. “These improvements were made in order to push the performance for production of even finer sizes than has been possible before. These latest design improvements of the crushers can – with considerably increased safety margins – produce a finer mill feed and thus off load work from the downstream milling process”, said Robert Picard.

The design philosophy of the CH series cone crushers is to optimise crushing force using the ASRI and Hydroset system. As a result, the power draw is correlated to the load and adjusts automatically. Furthermore, by continuously measuring and compensating for crusher liner wear, ASRI allows customers to fully utilise crusher liners and schedule liner replacements to coincide with planned maintenance. Sandvik also offers its customers an 800 hp and a 1,000 hp motor for the CH890 and CH895 crushers. The part commonality between the two crushers, allows for easy service and support which should facilitate efficient inventory management and parts forecasting. With the CH series, Sandvik claims to be the only manufacturer to offer the constant liner performance which is a function of continuous measuring and compensation for crusher liner wear. The automatic setting system - ASRI - allows customers to fully utilise crusher liners and schedule liner replacements to coincide with planned maintenance stops.

The Sandvik CR series of hybrid roll crushers are able to store kinetic energy in the mounted pulleys (belt drive models) and the fast running flywheels (direct drive models). A flywheel on each roller gives a crushing power three to four times that of a crusher without any flywheel, increasing the capacity and improving the maximum material hardness by nearly 65%, according to Sandvik. This enables the hybrid to crush big lumps and maintain a stable crushing process even during peak conditions. As a result Sandvik states that the CR810 will handle peak loads well without over-dimensioning the installed power, which is an advantage when the material that is being crushed contains hard inclusions.

In its second significant mill order in North America, Bateman Engineered Technologies was recently contracted by the privately owned Canadian mining company, Ontario Graphite Ltd, to supply a 5.5 m diameter SAG mill to be used in the primary grinding circuit for its re-opened Kearney Mine. The order for the SAG mill, which has an effective grind length of 2.74 m and will process 125 t/h, was placed in early October 2011. Delivery is due in July / August 2012 and commissioning in November 2012. The scope of work covers design, engineering, manufacture...
and supervision of installation and commissioning. A unique feature of the mill is the incorporation of a hydraulic drive, which eliminates the need for the gear, pinion and conventional gearbox and gearbox motor, thereby significantly reducing maintenance requirements. In addition, as the girth gear is generally the longest lead item in the mill assembly, replacing the mechanical drive with a hydraulic drive reduces delivery time. Design of the hydraulic drive, which will be free issued by the client and the interface between the drive and the mill, will be a collaborative effort between both parties. Since this is a re-opened mine with an existing plant footprint, a design challenge will be to fit the dimensions of the mill according to the existing mill foundations. Design and engineering are being carried out at Bateman Engineered Technologies in South Africa and a global manufacturing process is being utilised. Various parts of the mill are being manufactured in several different countries, under the supervision and stringent quality control of Bateman Engineered Technologies. This strategy has worked well with previous mill orders aimed at reducing cost, delivery time and risk.

Kearney mine, located in Kearney, Ontario, is the largest confirmed graphite mineral resource prospect in North America. It is also one of the largest individual deposits in the world. Kearney Mine has been under care and maintenance since its closure in 1994 and is presently undergoing a recommissioning process that will lead to it re-opening by mid-2012. When reactivated, it is estimated that it will process approximately 1 Mt/y of ore, while producing 20,000 t of natural, large flake, high carbon graphite concentrate. In a contract awarded earlier in 2011, a SAG mill is being supplied to be used in the primary grinding circuit of a 9,400 t/day iron ore concentrator in the USA. Delivery of components is underway and installation on site has commenced. Commissioning of the mill is expected in early 2012. The 8.53 m diameter mill has an effective grinding length of 3.678 m and is powered by a 6.5 MW drive. It will process 380 t/h and is designed to work in conjunction with an existing regrind ball mill, to produce a particularly fine grind of the magnetite product.

Bateman has traditionally serviced the southern African mill market, but in recent years the industry has seen an upswing in demand from the international market. All mill designs are proven in the field and are backed by finite element analysis. SAG and AG mills are available up to 38 ft in diameter, ball mills up to 26 ft in diameter and rod mills up to 15 ft in diameter.

Well known conveyor engineering and their UK engineering facility. The largest turning centre in the Doosan range, the Puma 700XLM is one of only two machines in the UK and adds considerable weight to their extensive machine capability in their engineering facility.

Chris Sydenham, Technical Director, commented: “With an increased demand for quality UK manufactured replacement crusher spare parts these new machines will enhance our engineering capacity to complete the UK manufacture of precision machined components to suit primary gyratory crushers, cone crushers and jaw crushers, including repairs to major crusher components without the need to contract any third party supplier.”

The Doosan Puma 700XLM is designed for high-accuracy and heavy-duty machining of large, heavy and long components up to 5 m in length and has the ability to support large chucks (up to 32 in). With a bar working diameter (164 mm) capacity capable of supporting a work piece up to 8.9 t between chuck and tailstock, machining productivity and flexibility is further enhanced by the 1,140 mm swing-over-bed and 1,000mm swing-over-carriage capabilities with large turning diameter capacities of 900 mm.

The extensive CMS Cepcor engineering facilities (CNC, milling, turning, boring, slotting, grinding, drilling, welding, co-ordinate measuring & material testing) are managed by an experienced staff with expertise in the design, manufacture, operation and maintenance of crushing and screening plants. CMS Cepcor is the only aftermarket supplier that also incorporates one of the most reputable and long standing crushing plant OEMs, Goodwin Barsby. IM

The new Doosan Puma 700XLM recently installed by CMS Cepcor