Comminution: waging war on Watts

So far as crushing and grinding circuits are concerned, the present century has seen a growing emphasis on the need for more efficient use of energy. Today accelerating progress is evident in concerted advocacy and collaborative thinking, optimised circuits and new comminution machines.

Hillhead 2012: A Tier 4/Tier 3 engine module combined with improved hydraulics and new hardware enables Metso's new Lokotrack LT 106 jaw plant to consume up to 20% less fuel than the predecessor model.

Sandvik's new CI511 horizontal shaft impact crusher can also achieve large energy savings, in this case by only using the hydraulic system when necessary. It can be used in mobile or stationary plants and as either a primary or a secondary crusher.

Meanwhile, the energy efficiency of mobile crushing and screening plants is being improved, as evidenced at the Hillhead 2012 show in the UK in June, and the use of in-pit crushing and conveying technology is increasing.

Consensual process engineering

In 2002 Rob La Nause (then general manager – technology for WMC as well as chairman of the Australian Mineral Industry Research Association (AMIRA)) and John Temos presented a graphic analysis of the carbon footprint at Leinster nickel operations in a paper on technologies for sustainable operations. This dramatically illustrated the major contribution to mine total CO_2 emissions made by comminution processes.

At IIR's 5th crushing and grinding conference in Townsville, Australia in 2004, Bernard Siddall of Orway Mineral Consultants argued that the power inefficiency of comminution circuits was already seen as a problem. It would become increasingly significant as energy costs rise and an ever greater part of world mineral production is mined from complex and lower grade orebodies.

Australian scientists and engineers did respond to the situation with a coordinated research effort funded by government and the mining industry and involving among others AMIRA, the CSIRO, the Julius Kruttschnitt Mineral Research Centre (JKMRC) within the University of Queensland and Rio Tinto Technical Services. Researchers in South Africa, Latin America, Canada and Europe were also active by this time.

At the 5th Minerals Engineering International (MEI) Comminution meeting in 2008, the drive to lower energy consumption was one of two main themes. Commenting on the proceedings, Professor Sandy Lambert was impressed with the progress reported. But he also suggested it was time to target a 50% decrease in power drawn for comminution and that integration of chemical and physical processes was now essential. What, he asked, was the next great comminution device? Two years later, one of the papers presented to the 6th MEI Comminution conference by Mike Daniel et al covered "efficiency, economics, energy and emissions – emerging criteria for comminution circuit decision making".

In the August 2010 issue of the Australasian Institute of Mining & Metallurgy (AusIMM) Bulletin Dr Zeljka Pokrajcic, who is principal process engineer – metals and minerals at the engineering firm Worley Parsons, and Elizabeth Lewis-Gray, CEO of the process technology company Gekko Systems, put down a marker. They argued that advanced comminution circuit design is essential for industry and made the following points.

- Electrical energy consumption in comminution has a major impact on the planet's carbon footprint
- Only a small percentage of the grinding energy offtake is used in particle size reduction
- The widely adopted large and generic comminution circuits may well not meet the requirements of the changing economic and social environment; rather,

energy efficient comminution circuit design requires a holistic approach based on the inherent properties of the orebody in question
- Relatively simple strategies and newer crushing and grinding technologies can assist in minimising costs and carbon footprint.

But, the authors suggested, despite systematic and detailed research in this area, the industry remains somewhat reluctant to implement these strategies. They suggested several possible reasons for this slow pace of change, one being that much of the research supporting change and providing better strategies has not been available to smaller miners – who are conversely less risk averse. Pokrajcic and Lewis-Gray concluded that it is imperative the need for change in comminution practice be debated and reviewed at all levels in the mining sector. Most critically, awareness and knowledge of this issue must be pushed up into the boardroom of mining companies so that key decision makers are aware of the alternatives and their implications.

Coalition for eco-efficient comminution

Elizabeth Lewis-Gray, together with like-minded experts, moved swiftly on to realise the concept of a not-for-profit industry voice addressing the urgent need to reduce energy consumption in mining. This would be managed by the mining industry and funded from within it. The Coalition for Eco-efficient Comminution (CEEC) was officially formed as a not-for-profit company in May 2011. Owen Hegarty of G-Resources Group is patron and Elizabeth Lewis-Gray chair. Drs Wayne Stange of AMIRA International, Mike Daniel of CMD Consulting and Zeljka Pokrajcic of Worley Parsons are directors as are Paul Griffin of Newcrest Mining and Prof Tim Napier-Munn of JKMRC. Sarah Boucaut is the executive officer. In September it was announced that Nick Holland, CEO of Gold Fields Ltd had excepted the company's invitation to become a patron.

The initial sponsor organisations were: the mining firms Gold Fields, IndoPhil Resources, Newcrest Mining and Teck Resources; the technology companies Ausenco, Gekko Systems, Russell Mineral Equipment and Xstrata Technology; and the AMIRA International and Sustainable Minerals Institute organisations. These were subsequently been joined by JKTech, Metso and Outotec and most recently by Anglo American and MMG (previously Minmetals Resources). More are in the pipeline says CEEC.

The Coalition has focused firmly on enhancing information flows into and within the mining community, the basic objective being to raise the rate at which more energy-efficient comminution data sets, processes and technologies are developed, demonstrated, shared and applied. The premise is that this process will contribute to the industry's target of reducing both operating costs and carbon emissions. Activities and KP indicators were established accordingly.

CEEC immediately started a programme of eco-efficient knowledge capture and transfer, creating the information portal www.ceecthefuture.org and encouraging debate at a senior technical and board level through a LinkedIn discussion group. The website keeps members informed about Coalition activities and incorporates a database of relevant and peer-reviewed technical papers and articles. Membership of the discussion group has already grown to over 500.

Almost immediately too, the directors and colleagues started "walking the talk". As well as persuading and helping international mining media to promote the coalition's role and message, CEEC representatives have put the company's case to numerous major industry meetings around the world. For instance, since August 2011, the Coalition has participated in the AusIMM Metplant conference, an Energy Efficiency Opportunities Workshop in Perth, the World Gold Workshop in Montreal, a Workshop and the Procemin conference in Santiago, SAG '11 in Vancouver, the 2012 Indaba in Cape Town, PDAC in Toronto, the SME annual meeting in Seattle, Expomin 2012 in Chile, the Australian Copper Conference in Brisbane and MEI's Comminution 2012 in Cape Town. Representatives at both Procemin and SAG '11 posted Blogs covering the proceedings to the CEEC website which were linked to LinkedIn. Assuming that the CEEC representatives involved would have attended these gatherings anyway this looks to be pretty eco-efficient promotion. At MINExpo CEEC was represented on the Gekko Systems booth in the Australian pavilion.

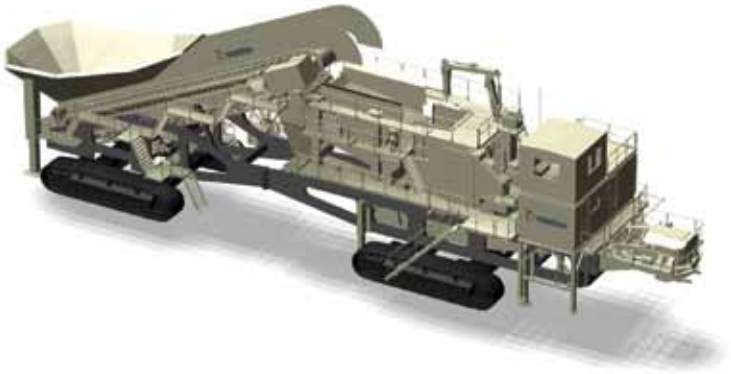
Meanwhile in November 2011, supported by AMIRA International, CEEC inaugurated an annual medal award

Hillhead 2012: The Terex Finlay J-1175 tracked mobile jaw crusher can be powered by either a Tier 3/Stage 3A Caterpillar C9 or a Tier 4i Scania DC970A engine used with hydrostatic transmission.

Powerscreen says the new Warrior 1400X screening plant can be equipped with a Tier 3/Stage 3A or Tier 4i/Stage 3B Caterpillar engine. Using reduced running speed and enhanced hydraulics the 1400X offers up to a 15% reduction in fuel consumption compared with its predecessor.

in June. The intention was to raise the status of beneficial eco-efficient comminution strategies by recognising and celebrating the contribution made by outstanding relevant papers, articles or case studies published during the year. A CEEC Medal Evaluation Committee assessed the many nominated papers and presented a shortlist of three to the CEEC Board. The runners-up were: Amelunxen P, Meadows, D. Not another HPGR trade off study (2011: Minerals & Metallurgical Processing Journal, February - Volume 28, No1); and: Buckingham, L et al: Improving Energy Efficiency in Barrick Grinding Circuits (2011: Proceedings of 5th International Conference on Autogenous and Semi-Autogenous Grinding Technology (SAG 2011)). Another SAG 2011 paper, Optimisation and continuous improvement of the Antamina Comminution Circuit, was unanimously selected as the winner, the authors being Rybinski, E, Ghersi, J, Davila, F and Linares J of Cia Minera Antamina and Valery, W, Jankovic, A, Valle, R and Dikmen S of Metso Process Technology & Innovation.

Each year the recipient will have the right to use the winner's logo indefinitely and the Metso PTI website has it on display. Nominations for the 2013 Medal close on 15 March 2013.



Another way to reduce overall comminution energy consumption is to use mobile in-pit crushers and conveyor (IPCC) systems, eliminating fuel cost of truck haulage. Having pioneered the use of Lokotrack mobile crushers and linked conveyors in the 1990s, Metso will now supply the world's biggest fully mobile track-mounted crushing plant, the almost 400t LT200 jaw crushing plant shown here, to the Altay Polimetally LLP copper and gold mine in Kazakhstan. The complete IPCC system will be electric powered.

Sandvik also competes with other bulk handling equipment specialists in the IPCC market and has been commissioning two of the PF300 roll crusher systems (shown here with a PB400 belt bridge) this year. Reportedly the manufacturer is to supply a PF200-9500 IPCC system to Vale's massive Carajas S11D iron ore project in Brazil.

Technology propositions

CEEC is not preaching revolution. Addressing a South African Institute of Mining & Metallurgy meeting in Johannesburg, Elizabeth Lewis-Gray pointed out that energy intensity reduction is not just a topic for talking heads: savings can be achieved using available technology. For instance, Barrick has reduced comminution energy consumption at three mine sites by a total of 5.3%, equating to an annual saving of $5.2 million. The company has focused on crushing and grinding circuit feed size optimisation, mill drive methods and mechanisms, and mill liner profiles. Barrick plans to achieve an overall 8% reduction in mine energy consumption for 2012, Ms Lewis-Gray said.

Nevertheless, available numbers indicate that, while 4% of total world electrical energy and 30 – 40% of global mine electrical energy is consumed by comminution processes, the use of all this energy is worryingly inefficient. For example, ball milling applies only 5% of the energy it uses to particle size reduction. So neither is the Coalition is advocating conservative technology choices.

LinkedIn discussion group members rapidly mapped a broad spread of comminution issues with energy efficiency dimensions. The thread spread has examined drill and blast optimisation; pre-crusher sorting; total systems measurement; fraction of installed power typically consumed in crushing or grinding circuits and the means used to monitor the effectiveness of this power consumption; and alternative pre-crushing rock treatments such as high voltage pulse and microwaving. Weaving these threads, CEEC has proposed the following basic steps: optimisation of feed size distribution by modifying blast patterns; crushing to finer sizes; gangue rejection at as coarse a particle size as possible, probably by using sorting or gravity separation; and liberation of valuable minerals directly from the mineralogical matrix of the feed, for instance by using HPGRs and vertical shaft impact crushers.

In the October 2011 AusIMM Bulletin article, Comminution efficiency attracts attention, Mike Daniel and Elizabeth Lewis-Gray looked at current mining and comminution electricity consumption and suggested energy saving project evaluation and flowsheet design strategies. Specific evaluative steps advocated included detailed ore mineralogical profiling; testwork to assess liberation and recoveries of mineral and gangue at various crushing and grinding sizes; examination of possibilities for ore sorting prior to grinding; and reviewing all the technology options now available.

At the Australian Copper Conference held in March 2012 Prof Napier-Munn discussed "Comminution energy and how to reduce it". Outlining the energy problem, he pointed out that comminution is an important component of project capex and opex as well as a large electricity

consumer and major source of GHGe. Meanwhile, average grades for key non-ferrous ores have declined in the past 20 years: today's massive mills do not come cheap and even lower grades will most probably have to be exploited in the future. Continuing with current technology this will require finer grinding and, hence, greater electrical energy consumption. On the other hand, according to a draft mining energy bandwidth study in 2007, energy savings opportunities in the mining industry included 25 trillion Btu/year in crushing, 356 trillion Btu/y in grinding and 198 trillion Btu/y in mobile equipment operations.

Turning to potential solutions Napier-Munn referred to the Barrick study mentioned above, emphasising that it is here and now possible to achieve incremental reductions in energy consumption (60,000 MWh annual savings) and CO_2(e) (43,000t annual reduction) through technical improvements. Further comminution cost reduction options include smarter blasting, pre-concentration by, for instance, jigs and electromagnetic sorters, and novel grinding flowsheets with early waste rejection offering up to a 60% cut in total energy use with a 3% increase in metal recovery. Do we need AG/SAG mills at all, he asked, given "new" comminution devices such as HPGRs, fine grinding mills, plasma mills and SelFrag's high voltage pulse power selective fragmentation technology.

Meanwhile, said Napier-Munn, research into the fundamentals of rock fracture, plus more effective geometallurgical data gathering and analysis, offer potential for technology step change. Similarly, continuing and more extensive professional development could lead to new operator initiatives. Stretch targets for energy reduction might be 20% 'now', 40% by 2020 and 80% by 2050.

He concluded that there is no shortage of smart ideas to reduce comminution capex, opex and GHGe. But we need a synthesis – the whole needs to be greater than the sum – and investment in innovation. Prof Napier-Munn finished with a classic double entendre, quoting the Greek philosopher Plato: the measure of a man is what he does with power.

Routeing a paradigm change

Later, commenting that much good work had been done to address the comminution energy challenge but paradigm change remains elusive, Prof Napier-Munn announced a CEEC international Workshop to be held at Noosa Heads, Queensland, in June 2012. Organised by Napier-Munn in collaboration with JKTech Ltd, the by-invitation-only Workshop attracted 40 senior delegates from 30 organisations around the world The practitioners came from mining firms (including AngloGold Ashanti, Barrick, BHP Billiton, Gold Fields, MMG, Newcrest, Newmont, Scott Mining, Vale), technology suppliers and consultants (including Amec, Ausenco, Gekko Systems, Hatch, Metso, Outotec, Whittle, WorleyParsons, Xstrata Technology), and research groups (AMIRA, JKMRC, the SMI and the University of Utah) from around the world, reported Sarah Boucaut.

The Workshop invitation challenged delegates to resolve firstly what can be done now in design and operation to implement what is already known about energy-efficient comminution and thereafter what R&D needs to be undertaken to deliver paradigm change, for example a 75% reduction in comminution energy in the next 10 years.

Innovation is fundamental to paradigm shift and Dr Geoff Garrett, the Chief Scientist of Queensland opened the first day's proceedings with a compelling argument for the need for far more innovation both in Australia and in the mining sector. Scandinavians, he said, could take solace that by size and sector their companies collaborating on innovation lead the rest of the world, with countries such as UK and Australia a long way down the list (OECD Science, Technology and Industry Scoreboard 2009 - OECD 2009).

Chris George, of bhp billiton, made the point that, as well as solving present efficiency issues, mining companies need technology breakthroughs in order economically to exploit lower grade deposits. Using ever larger sizes of conventional equipment to offset falling ore grades is unlikely to suffice in future. As far as feed size reduction electrical energy offtake is concerned, using chemical blasting energy to achieve a greater part of the overall task has potential.

Noko Phala of AngloGold Ashanti postulated that to meet sustainability challenges we need discontinuous improvements in mineral liberation energy efficiency. Key targets for AngloGold are energy efficient gold liberation from all ores and more economic ways to increase gold extraction rates from refractory ores. An innovative mindset is a business imperative, he argued, facilitating the application of technology intelligence in an open innovation environment such as InnoCentive, the open innovation and crowdsourcing pioneer that enables organisations to solve their "problems by connecting them to diverse sources of innovation including employees, customers, partners, and the world's largest problem solving marketplace".

Strategies for energy management and conservation were presented by Alan Bye of SMI CRC-ORE and previously with Anglo American Platinum, and Victor Bush of Newmont.

Michael Young with Xstrata Technology and Greg Lane from Ausenco each presented an engineering view of energy efficiency issues. Lane pointed out that hybrid cars are energy efficient but are also cost inefficient for most people other than taxi drivers. He said that both energy cost and supply risks are now factored in to project feasibility studies and corporate 'good citizen' policies are considered. Paradigm shift will only happen when it is cost efficient and optimising energy efficiency requires a whole business optimisation perspective

Next, small groups were asked to define the problem and identify the key obstacles to change, ranking these in order. Issues identified included a lack of use and

CEEC Directors L-R: Elizabeth Lewis-Gray (Chair), Dr Mike Daniel, Dr Zeljka Pokrajcic, Prof Tim Napier-Munn. (Absent: Dr Wayne Stage, Mr Paul Griffin)

implementation of existing tools; poor maintenance practices; lack of skills; lack of metallurgists and operators; failure to respond to the characteristics of the rock and its variability; lack of appreciation of the size of the prize; poor spending on R&D; work in “silos”; the need to tackle the system and not focus on individual components; fear of change; lack of documented operating strategy and operation outside the design of the site.

Sharing and collaboration was strong says Boucaut, the teams wasting no time in getting down to business and openly discussing the issues from their own perspective. They were asked to select the key topics for both short term and long term roadmaps, looking specifically at what can be done now in design and operation, what R&D and other outputs are required to achieve a paradigm change, and what intra-industry collaboration may be needed in each case.

The day concluded with a second presentation considering innovation, this one by Dr Tim Kastelle from the University of Queensland Business School. He discussed three paths to discontinuous innovation: achieving a 10 x performance improvement, developing a new idea, and finding a new business model. He pointed out that major innovations do not necessarily have an immediate economic impact, invention must be followed by diffusion to achieve market penetration, as for instance was the case with xerography. Kastelle drew many analogies with the challenges for crushing and grinding rock, leaving delegates to ponder if existing technologies outside the mining industry could be applied in innovative ways to reduce energy consumption in the mineral processing system.

The Castlemaine Goldfields Ltd Ballarat gold project has a three-stage crushing only comminution circuit minimising comminution energy consumption

On Day Two Prof Mike Nelson (Mining Engineering Dept, University of Utah) and Prof. Malcolm Powell (SMI - JKMRC) challenged the delegates to consider a leap in thinking. Robots sorting ore had smiles on everyone’s faces; use of selective breakage technology and dry separation were suggested. Powell explained what a professor of comminution lies awake thinking about. He stated six caveats that must change mining culture and design: decreasing grade, decreasing grind size, increasing rock hardness, access to potable water, energy shortage and forced accounting of carbon. He stressed that theoretical considerations must be connected to on-site reality and processes be designed accordingly. Design and simulation must consider whole circuits not individual machines. Decisions must be based on a complete picture: given a circuit using 30% less energy and yielding 3% more recovery, would you build it, or one giving 35% more production and half the operating cost, Powell asked.

Prof Powell proposed a staircase to step change starting with geometallurgy and mine planning, including smart blasting, coarse gangue removal and ore sorting, liberation modelling, integrated simulation and multi-component modelling, to be followed by something as yet indeterminate. He also mentioned another cooperative effort, the Global Comminution Collaborative between the Rio de Janeiro, Chalmers, Cape Town and Hacettepe universities and the JKMRC. The group is dedicated to total circuit modelling and simulation in order to design circuits beyond 2020.

Thereafter groups got down to road mapping from a strategic perspective. Groups critiqued each other’s work at midday, then polished their strategies for sharing with the full assembly after lunch. Some “light bulb” moments were achieved, says Boucaut, with ideas flowing even after the Workshop closed, via text and email. Suggestions for change included more open collaboration and better idea collection and management.

Techno-orienteering

Tim Napier-Munn, Diana Drinkwater and Grant Ballantyne had the not inconsiderable task of analysing these deliberations in order to compile the CEEC Roadmap for Energy-Efficient Comminution. This was duly published in August 2012 and scheduled for presentation at Enermin 2012 (Bahia, Brazil 10-12 September) as well as IMPC 2012 (New Delhi, India 24-28 September).

Targets. The Roadmap sets out four groups of EEC performance targets: performance measurement, adoption of best practice technology, identification and implementation of appropriate business drivers and KPIs, and communicating the benefits of these improvements to all stakeholders – at the same time developing the necessary skills and communication channels within the industry. A key recommendation is the introduction of a four star energy rating system covering operational efficiency, planning systems, equipment efficiency, maintenance systems, control systems, and technical support systems. Specific suggestions on establishing benchmarks and standards are provided.

Barriers. Like the 2010 Pokrajcic and Lewis-Gray article mentioned previously, the Roadmap examines barriers

to action, here including intellectual property protection, risk-averse attitudes to circuit design and new technology, and the defects of Net Present Value as a measure of economic impact. The authors suggest various reasons why well established efficiency improvements are not being made even though there is no obvious technical barrier.

Action Plan. Section 5 and Appendix 1 of the Roadmap provide respectively broad and detailed possible actions. These are intended to assist the formulation of a site-based or company-based action plan covering the four performance target groups. The authors recommend the formation of a cross-disciplinary study group to determine a base-line for current energy use, applying a clearly articulated formal methodology. Providing a business structure that encourages both cross-team engagement and external collaborations is also recommended, including high levels of cooperation between industry, R&D and consulting organisations. In Australia, the Roadmap advises, operating strategies should include long term planning in terms of the federal government's Energy Efficiency Opportunities (EEO) initiative.

Appendix 1 lists 14 short-term actions using mature approaches that concern Technology and 19 relating to People and Planning. A further nine longer term actions using existing technology are listed while the following ten long-term actions involving "some risk" are suggested.

Reverse the trend towards lower grade deposits with high grade undersea mining.

Enable cheap in-situ or dump leaching.

Develop pre-treatment separation processes that will remove 100% of free gangue ahead of surface rock breakage.

Pre-treat or liberate by electric pulse fragmentation, microwave or ultrasound.

Develop separation devices that will allow primary selection at >250 microns, reducing volume of material in breakage.

Develop selective breakage and liberation capability using SelFrag or similar technology, and based on specific liberation requirements.

Develop new sensors/markers for ore classification and sorting (learn from robotics).

Revert to largely dry processing leading to an order of magnitude reduction in water consumption and associated energy savings. This may involve air cycloning or other dry classification.

Develop and use cheaper renewable energy, for example power generation by small portable nuclear reactors at remote sites.

In the future no operators will enter the mine, as all equipment will be fully automated. All geological data will be gathered by remote imaging techniques and from drilling. This will drive the blast design and lead to selective mining of ore to minimise waste coming from the pit and appropriate sizing for downstream breakage. Only maintenance personnel will be on site in the concentrator with full sensory in field equipment feeding all data to a control centre in a major city – the mining industry will become the 'sexy' industry for the tech savvy graduates of the day.

New comminution machines

Perhaps Prof. Lambert's wished for new comminution device has been developed. At SAG 2011, Lawrence Nordell and Alexander Potapov of the Washington State, USA based company Conveyor Dynamics, Inc. described a Conjugate Anvil-Hammer Mill (CAHM) which they claimed has the potential to replace conventional crushers and SAG mills, plus their respective conveyors and stockpiles, in an SABC circuit. It may improve comminution circuit efficiency by 100%, they said. And, at MINExpo, Sandvik launched a revolutionary eco-efficient comminution machine that will produce a finer mill feed and help customers address the energy challenges facing them both now and in the future.

New power-efficient mill

Conceptually similar to C19th stamp mills, CAHM compresses rock in a more efficient way which, like the HPGR, follows the fundamental research of Schönert. Nordell and Potapov explained that the starting point for the development of the CAHM was a 2001 Discrete Element Method (DEM) study of the SAG mill comminution zone which indicated two ways to improve the process: by increasing intensity and by raising circulation rate. Subsequent DEM studies showed that a 20% increase in the material flow rate can be achieved by changing the Lifter geometry in the mill. At SAG 2006 a new patented lifter was shown to control lateral ore motion and thereby improve fine grinding in the SAG mill by over 20% with equal power input. Lifter lifetime was also improved, said the authors.

The CAHM, a patent for which has been applied for, is basically a short wide drum comprising a rotating outer anvil ring and a significantly smaller inner hammer ring. The anvil ring has a retainer shield at each side through which a pair of chutes feed material to the centre line of the mill while ports in the anvil ring discharge product. The shields have a larger closed section where the efficient breakage zone is located and a narrower open side. The axis of the hammer ring is located below that of the anvil ring and it is supported by bearings on either side. The anvil ring is supported by bearing support pads on the floor. Hydraulic cylinders apply force on the hammer ring. The basal and smallest conjugate ring gap sets the maximum product particle size.

The Gekko Python 500 modular plant at the Gold Fields Kloof Growth project uses InLine pressure jigs to reject gangue from vertical shaft impact crusher product, eliminating ball milling and reducing comminution energy consumption.

For treating fine feed the mill is 0.4m wide, the outer shell rotates at 14.3 rpm and the mill feed rate is 750t/hour. CAHM efficiency is being proven through simulations using of the ROCKY (2011) DEM which indicate that when treating fine feed an HPGR would draw 0.77 kWh/t and the equivalent CAHM 0.38 kWh/t. Similarly, when treating coarse feed with equivalent machines an HPGR would draw 0.48 kWh/t and a CAHM 0.25 kWh/t. However, because the CAHM produces a higher voids rate it will not break to as fine a particle size as the HPGR. But the CAHM can be customised, with many geometries that are rock-property specific.

New crusher - with grinding performance

Sandvik's revolutionary innovation is the Vibrocone, a new type of crusher that changes the rules for comminution and opens the way for major energy savings, the manufacturer says. Well-known technologies are combined in a variant of the cone crusher. The Vibrocone is a cone crusher driven by a vibrator instead of the traditional eccentric drive mechanism. This design can achieve much higher reduction ratios than traditional cone crushes can. The Vibrocone was launched as a new product at Minexpo. However the crusher had already clocked more than 10,000 hours of field experience at 24/7 operations in gold, copper and iron ore mines.

Vibrocone applies the same major rock breaking principles as other comminution processes. Like a traditional cone crusher it can accept a feed with a large top size and crush the material by multiple compressions.

But unlike conventional cone crushers the Vibracone crushers rock in a thick material bed, which is exposed to a controlled optimum force that can be adjusted -- a process very similar to that employed in high pressure grinding rolls. As well, material is crushed against material in an "autogenous" process that is related to the operation of AG and SAG mills. While the main shaft in a conventional cone crusher moves a given distance, the Vibrocone allows it to move inside the crushing chamber with full force as far as the material bed allows. The mainshaft is supported by a spherical bearing and the crushing action comes from an unbalanced weight rotating around the mainshaft. The process control system includes a frequency converter to control the speed of the main motor.

The Vibracone crusher introduced by Sandvik at MinExpo 2012. Not quite the Hadron Collider perhaps but a step change on the way to eco-efficient comminution?

The minimum size of the output is no longer determined by a fixed closed side setting as in conventional cone crushers. Rather, product size is controlled by the high pressure in the high frequency multiple crushing actions. In turn this makes it possible to use a much larger discharge opening, increasing crushing capacity with the same minimum product size. In normal operation the Vibrocone is preferably choke fed and the machine can easily start and stop at any time with material in it. The design also makes it possible to automatically detect and safely react to uncrushable objects like tramp metal. As foreign objects restrict the movement of the mantle the power input will drop immediately. The control system will react to this and reduce speed. This in turn will reduce the force while crushing continues until the object has passed through. If by chance the uncrushable object is too large to pass then the feed will be automatically stopped and operation will continue gently at reduced speed and force to crush material still in the crushing chamber until the machine is stopped again and the object can easily be removed.

The Vibrocone's performance -- crushing capacity and product size -- are determined by the main motor speed and the discharge opening.The rotational speed is controlled by the automation system. The discharge opening can also be changed from the control panel as crushing proceeds by means of the hydraulically driven adjustment ring. Combined with the automation on the crusher this enables the Vibrocone to crush a considerably finer product than a conventional cone crusher can ever reach. The Vibrocone is a crusher moving into the grinding performance area. Since crushing is more energy efficient than milling, the machine paves the way for a technology change that could meet the need for new energy saving processes.

Sandvik says the product from the Vibrocone is so fine that new solutions for eco-efficient comminution will be possible.

- In an existing circuit with a rod mill stage, the rod mills can be replaced by Vibrocone crushers and the product can be sent straight to a ball mill stage.
- In an existing plant with ball mills, the Vibrocone crusher can be installed as a pre-grinder and the performance of the ball mills will be considerably improved. Throughput of the mine can be increased, energy consumption and total cost per ton can be decreased.
- In a green field project a Vibrocone solution can be evaluated against SAG mill or HPGR alternatives. A case study by Ausenco of a 10 mtpa copper operation in South America has shown the Vibrocone alternative to be the lowest cost option and to deliver energy savings of 19% relative to the SAG mill alternative.

The Vibrocone technology is based on several major patents (approved or pending) owned by Sandvik Intellectual Property AB, Sweden. Specific technical data for a Vibrocone CO865 include rated power of 400kW, a capacity of 200-300t/h (220-330st/h), a feed top size of 150mm, less sensitive to fines, and product sizes of 80% passing 6-8mm (1/4" - 5/6") and 50% passing 2-4mm (1/16" - 3/16") in open cycle. No closed side setting, of course.