Comminution research at the University of Cape Town

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Synopsis

Comminution is a vital part of minerals extraction, and therefore of the South African economy. The high cost and throughput-limiting nature of comminution forms a strong motivation for research directed at improving the efficiency of the process. Building on a ten year background of fundamental charge motion research, a new formal UCT flotation and communication group has been formed. The group is also moving strongly into the field of milling circuit modelling and simulation, based on close links formed with the Julius Kruttschnitt Mineral Research Centre (JKMRC) of Australia, and an international collaborative research programme.

The need for comminution research

Comminution involves the reduction in size of ore to a degree that is sufficiently fine to allow the liberation of the valuable minerals. Fundamentally this is a simple operation, requiring only a hammer and a large flat rock as a base, as can be witnessed at small 'mines' around the third world. Primary crushing is achieved through use of a large hammer, secondary crushing with a medium hammer, and tertiary (fine) crushing by a converted maize pounder, as in Figure 1. The throughput limitations of such an operation are obvious. It was estimated at this plant that, at best, a worker could process one ton per day. To put this into perspective, a large semi-autogenous grinding (SAG) mill can treat 7000 t/day of run-of-mine (RoM) ore. It would require 7000 workers using large hammers, medium hammers, and maize pounders to match one mill!

Having moved on through stamp mills and the likes 100 years ago to crushers and rotary mills, most of the industry has not progressed much since then. Granted, equipment has grown enormously in size and throughput and there has been a big swing to SAG, but this has been driven by improved equipment production techniques and the economic benefits of fewer units to purchase and maintain. This simple technique of breaking rock works, hence its enduring use. Specialist alternative grinding techniques have been demanded such as very fine grinding, where crushers and mills are inadequate. Generally these are developed through experience, trial and error, and pilot tests. A notable exception is the high pressure roller mills developed from a fundamental understanding of the breakage mechanism of rocks.

The thrust at UCT

This preamble leads into the reasons for our research. Considering the huge numbers of rotary mills, (well over 1000 in this country), the vast tonnages treated annually, and the relative success of mills as production machines, rotary milling is a good aspect of comminution to study. Digging a bit deeper, one discovers that rotary mills have energy efficiencies estimated to be between 10 and 50% depending on the investigator! They use in the region of 20% of the mining industries total energy requirements, and consume kilo tons of balls and liners per year. The number of mills in production and new ones coming on line, are many and will remain in operation until they or the mines disintegrate. For many years the unwritten motto on South African mines has been 'If they work leave them. Don't mess with my production, and don't try anything risky!' There is some merit to this philosophy, as production is important, but in the long term this has backfired. Production costs have risen while mineral values have waned, resulting in a critical need to improve the overall efficiency in the mining process. Moreover, it is only through a fundamental understanding of the grinding action that one

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Figure 1—Basic comminution technique, using hammer and pounder

can, in the long term, make a meaningful contribution to reducing running costs. These factors add up to form a firm motivation for studying how mills work.

The influence of liner design on charge motion in a mill

Considering that the basic form of a rotary mill is fixed, it was decided to concentrate on what can be varied—the mill liner. The liner is seen primarily as the sacrificial layer protecting the mill shell. However, this overlooks its other fundamental function—transferring the rotary motion of the mill to the charge in a form of useful grinding energy.

The influence of the liners on the overall grinding action of the charge, tends to be dismissed as insignificant. But consider the following. The 10% of the charge that is in direct contact with the liner transfers the grinding energy to the rest of the charge. Whatever energy is lost between the liner and the outer layer of the charge is lost to all the charge. Additionally, the trajectory of the outer layer of the charge forms the envelope within which the bulk of the charge is contained, and can be used to predict the tumbling process of the charge.

In work begun in 1986, the fundamental equations of motion of a ball being lifted up and projected off a lifter bar, were developed by Powell[1] (while at Mintek). The predicted trajectories were compared to those observed in a 600 mm diameter glass-ended rod mill, as recorded using a high speed ciné camera. The use of rods minimized the end effects of the windows—as stressed in investigations by Vermeulen[2]. In Powell's work, great care was taken to measure all physical variables in the experimental work, so that there were no adjustable factors to be arbitrarily assumed in the equations.

These equations of motion were found to give excellent predictions over a wide range of conditions, such as mill speed, lifter height and lifter angle. Industrially relevant conclusions from this work were the importance of lifter angle relative to the speed of the mill, constraints of the height of the lifter, and prediction of the impact points of the cataracting charge. These equations have been developed into a computer program[3] that can be of benefit in the design of mill liners.

An investigation into the slippage of particles on a smooth lining was conducted by Nates[4]. This highlighted how slippage occurs and the resultant energy losses. This was followed by extending the equations to a corrugated liner (Von Bentheim[5]). Milner[6] continued this work with a study

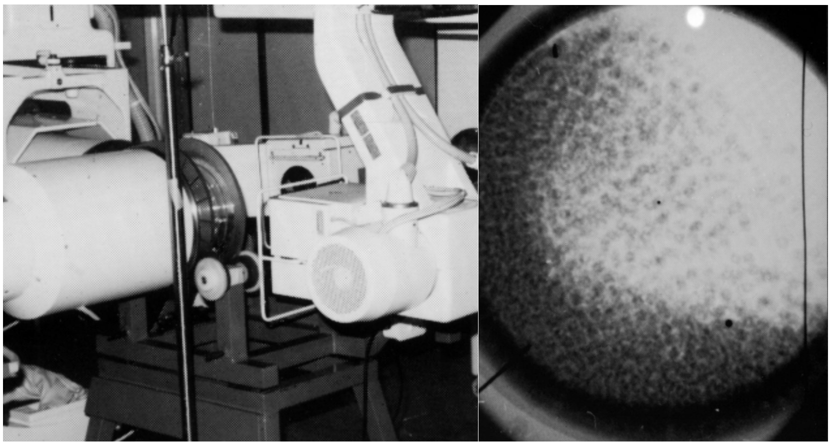

Figure 2—X-raying equipment, and an image of the mill charge

of how worn or rounded lifters influenced the charge trajectory, which can be used to predict the trajectory of the media throughout the life of the liner, and indicate at what point it should be discarded.

Powell extended his earlier work to study the motion of the bulk of the charge in the mill[7]. This study required a novel approach to filming the charge in motion—for how does one see inside a mill beyond the outer layer? The solution lay in the bi-planar angeoscope of the Cardiology Unit at Groote Schuur Hospital, where heart valve movement is filmed. A transparent model mill was filmed with X-rays in two perpendicular planes at 50 frames/second. The paths of four marked balls were traced and very clear images obtained (Figure 2). This allowed the paths of the balls to be traced both in the plane of rotation, and along the axis of the mill. The paths of the balls, and distribution and transfer of energy, were analysed in detail. A number of novel findings of importance to industrial mills were made regarding the rotation of the balls, such as where the maximum energy transfer takes place, and how liner design can influence energy transfer. New techniques for correctly calculating the power demand of a mill from fundamental principles were developed.

While at Mintek, Powell conducted extensive plant trials on liner design and materials of construction[8]. These were extended to developing a pilot plant unit for materials testing.

The establishment of a comminution research group at UCT

In April of 1997, Powell joined UCT as a full-time researcher in comminution, thereby expanding the interests of the Flotation Research group of the Department of Chemical Engineering, and reflecting the commitment of the university to the field of minerals processing research. At the same time, the scope of work was substantially expanded by linking up with the Julius Kruttschnitt Mineral Research Centre (JKMRC) as their South African representative in the internationally sponsored AMIRA P9L project[9]. This project has been ongoing for 35 years and aims to model the operation of components in minerals processing, so as to effectively simulate and optimise the minerals extraction process. Work has already commenced on conducting a thorough sampling campaign which is followed by modelling the plant with the JKSimMet[10] minerals processing software. The plant operation is then simulated and improvements to the operation can be tested on the simulator, prior to being implemented on the plant with a high degree of confidence in their success.

Our aim

An important aspect of comminution is that it is not an end in itself. It is merely an intermediate stage of production. The objective of comminution is to produce a product of suitable size, geometry and exposed surface, to allow the extraction of the mineral. This is generally overlooked and the milling section is compartmentalised to processing A tons of ore (A ≡ an arbitrary amount of ore produced by the miners), to a certain fraction passing a given size S (S ≡ a size deemed to be sufficiently fine for mineral extraction to take place).

The product P = SA, is the sole requirement of the milling plant. S and A have an inverse influence on P, but A dominates. It is generally accepted that economics dictate that the plant must process as much ore as the miners can produce, thus maximising the quantity of final product per month. This may leave more minerals in the tailings dump, and shorten the life of the mine, but these considerations do not enter the equation of short-term returns. Through the formation of the UCT flotation and comminution group, we aim to address the issue of the reduction and extraction processes being a single continuous process, and the production of optimum benefit.

Drawing on the years of industrial and modelling experience of the JKMRC, and working in close co-operation with them, we can progress towards this goal at a significant rate. This will, hopefully, contribute towards the maintenance and growth of the South African mining industry.

The future

We aim to continue developing a fundamental understanding of the motion of grinding media in a rotary mill, capitalising on our years of knowledge and experience in this field.

We will be conducting plant surveys and modelling exercises to help optimise plant operation. From this we will endeavour to refine the JKMRC models of the SAG mill to accommodate the local design and operation of RoM mills.

The comminution and flotation research groups have formed the Mineral Processing Research Unit (MPRU) with the aim of optimising mineral extraction as a whole, not leaving the extraction section to handle unsatisfactory material from a poor milling plant.

With support from the industry, and with high quality students, we expect to be able to make a significant contribution to the efficient operation of mills, and to produce skilled graduates well versed in a major economic activity of this country—the extraction of valuable minerals.

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Major safety achievement for cementation mining at South Deep*

The Cementation Mining crew sinking the ventilation shaft at South Deep has celebrated the achievement of 300 000 fatality-free shifts.

This shaft has been fatality-free since work began three years ago in July 1995. It is part of Cementation Mining's R192 m contract to sink the world's deepest single lift shafts at the South Deep section of Western Areas Gold Mine for JCI.

The ventilation shaft will be 2 760 m deep and the main shaft 2 765 m, both with a lined diameter of 9 m. Completion is scheduled for July 2001. Current shaft bottom is 1 450 m on the ventilation shaft and 1 620 m on the main shaft.

Addressing guests at a celebration to mark this milestone Mike Wells, Cementation Mining business unit manager responsible for the contract, said a major contributing factor to the ventilation shaft's fatality-free record had been the stability of the crew. 'About 99% of the people involved in this shaft have been on the project since 1995,' he pointed out. 'We have an extremely close-knit crew in which every man knows his exact task and the safe way to execute that task.'

Wells paid tribute to the ventilation shaft master sinker Deon van Heerden and his crew, as well as Cementation Mining's site safety officer Dries Kirsten and training officer Hewitt Holton.

In another major safety achievement, the site has just been awarded its third successive 5-star safety grading by NOSA. Each grading has resulted from an unannounced audit.

Among the main requirements for the achievement of five stars is a disabling injury incident rate (DIRR) of less than 1, which equates to less than eight lost time injuries in a year on a high risk project employing 625 people daily. The site has a DIIR of 0,87, likening it to low risk operations such as hospitals, ready-mix concrete suppliers and traffic departments.

Another requirement for 5 stars is an overall score above 91% in the grading programme which, for mining activities, consists of five main sections with 73 sub-elements. The South Deep site achieved 96,1% on its most recent audit.

Mike Wells attributes the site's good record to the fact that full-time safety and training officers were appointed at the start of the contract.

'A comprehensive set of shaft-sinking procedures, including an all-embracing safety and health programme, was developed especially for this project,' he says. Site manager Hennie Rautenbach and site engineer Ian Wallace lead the safety and health programme on site. ◆

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Latest NOSA awards*

On 14 May, at the annual Mining Awards Banquet hosted by NOSA (National Occupational Safety Association) at the Sandton Sun Hotel in Johannesburg, South African and international mining companies received honours awards for their continued efforts towards improving the occupational health and safety of their employees.

The following NOSA graded companies received top honours.

Crammix Bricks in the Western Cape for the best one-star mine, Cementation Mining—Joel Development in the Free State for the best two-star mine, Gold Fields South Africa—East Driefontein on the West Rand for best three-star mine and Alpha Lime—Daniëlskuil in the Northern Cape for the best four-star mine.

The top five-star companies were Alpha Magnetite in the Northern Province for the category of less than 500 employees and for the category of more than 500 employees the winner was Sasol Coal—Syferfontein Opencast in the Eastern Transvaal.

Mines throughout the world have successfully implemented the NOSA Five-Star System which provides guidelines for lowering incident rates, reducing losses and costs and increasing availability of machinery, profits and improved productivity.

Bulkmech Tavistock in the Eastern Transvaal won the best contractor site award whilst Bayer Vergenoeg in the Northern Province won the best mine laboratory. Iscor's Rosh Pinah in Namibia took top honours for the most improved safety programme.

Several awards were made to individuals who dedicate their time and effort towards occupational health and safety in the workplace. Theo Norman from Foskor in Phalaborwa was honoured for being involved in 19 Noscar ratings. The prestigious Noscar awards are made to NOSA-graded companies with excellent occupational health and safety standards. The Noscar Awards Banquet took place at the Sandton Sun Hotel on the evening of Friday 15 May. ◆

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