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Fine grinding—Developments in ceramic media technology and resulting improved plant performance at Anglo Platinum

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The use of ceramic beads as grinding media within high intensity stirred mills is desirable to maximize the energy efficiency of these processing units. Using ceramic media with properties tailored to high intensity stirred milling further increases energy efficiency and extends the practical operating range of these mills to coarser feed and product sizes. Historically, the economics of using ceramic media types in stirred mills in the minerals industry has not been attractive. Driven by a request from Anglo Platinum to increase plant performance, Magotteaux International and Xstrata Technology cooperated in the testing and product development of a new ceramic media, known as Keramax® - MT1™ for the mineral processing industry. This paper will present a description of the Keramax® - MT1™ media and industrial results from various users within the Anglo Platinum group since the first stirred mill using ceramic media was commissioned in November 2006. This paper will furthermore highlight operational benefits in terms of improved performance.

Introduction

The high energy efficiency of stirred mills compared to ball mills is well understood within the industry. The use of tower mills as an energy efficient alternative to secondary and regrind ball milling became a standard flow sheet inclusion in the latter part of the previous century and is still common today. The modern high intensity stirred mills (such as the IsaMill) further extend the energy benefits of this technology by using higher agitation speeds and smaller media particles. Media selection has a major influence on mill parameters such as energy efficiency, internal wear and operating costs. An inert grinding environment is beneficial to avoid mineral surface degradation and obtain downstream processing and cost advantages. Ceramic media have a profound implication to these parameters and the availability of economic ceramic media has given significant benefits to the users of IsaMills.

Grinding media types

Until 2005, all IsaMill installations have taken advantage of the technology's ability to use low cost, but relatively low quality grinding media such as silica sand, river pebble, smelter slag or fine primary mill scats (autogenous milling). Whilst the IsaMill produces high energy efficiencies compared to conventional milling when using these media types, these 'naturally occurring' materials handicapped the technology in several ways. The energy efficiency was low compared to what is possible with higher quality media, such as ceramic-based compounds. The angular shape and small grain size of the natural media types limit the size of media, and therefore size of feed that can be milled. For example, sand media typically breaks down to its natural grain size when exposed to the high intensity milling environment. Generally sands have grain sizes finer than 5mm. This limits the feed size that the mill can treat. The ideal media type for high intensity stirred mills has consistent, reproducible characteristics as shown below, and is further detailed by Lichter and Davey:

- Definite initial charge PSD and top up size
- Chemical composition
- Hardness (related to chemical composition and grain size)
- High sphericity
- High roundness
- Competency (mechanical integrity)
- SG (as designed for machine operation/ore breakage requirements).

A media type that can be manufactured to the ideal qualities is therefore desirable. This reduces power costs and extends the benefits of the technology to treatment of coarser feed sizes. Despite this, until 2005, the use of manufactured media such as ceramic beads has generally been uneconomic, as the combination of low consumption rate, high energy efficiency and low unit cost have not converged. This has limited the application of such energy efficient grinding technology such as the IsaMill, and restricted its application to regrind and ultra fine milling only.

Keramax® - MT1™ development

Magotteaux International has developed a ceramic grinding media specifically applicable to high intensity stirred milling in the minerals industry. In cooperation with Xstrata Technology, the performance and cost effectiveness of the Keramax® - MT1™ grinding media has been tested and verified using laboratory, pilot and full-scale IsaMills. The first industrial application combining Keramax® - MT1™ and IsaMill technology was successfully commissioned at Kumtor's Gold Mine in Kyrgyzstan in late 2005. Many have followed since then, with Anglo Platinum being the champion in the industry with five IsaMills currently running on Keramax® - MT1™ and another 16 due to be commissioned over the coming 12 months.

Ceramic grinding media overview

Two manufacturing processes may be distinguished in the production of ceramic media commonly used in fine grinding for non-contaminating applications:

- Sintered ceramic beads obtained by a cold forming of ceramic powder and by firing in high-temperature kilns
- 'Fused' ceramic formed by electric fusion of oxides. The majority of these ceramic beads are named 'zirconium silicate'.

Ceramic beads are usually classified according to their chemical composition and physical properties such as bulk density, hardness and fracture toughness. The bulk density has a large influence on the mill power draw. Hardness and fracture toughness give an indication of the bead's wear resistance. The zirconium oxide beads are the highest quality grinding media with the highest initial cost. Keramax® - MT1™ beads have been developed in the view to provide an economic ceramic media for the mineral processing industry.

Keramax® - MT1™ properties

Keramax® - MT1™ is a high density alumina grinding media with consistent microstructure to provide high resistance to wear and high energy efficiency. The media features a smooth bead surface which is 'pearl-like' to touch. The surface properties suggest that the energy loss in grinding due to friction could be far lower than with other media and that the lifetime of the internal mill wear components will be increased.

Some low unit cost alumina media types have previously been tested in the IsaMill, both at laboratory and full scale. The consumption rate of these media types was very high (higher than silica sand) due to inconsistencies throughout the bead cross section. Some beads were very soft in the centre and others had air inclusions. The microstructure of Keramax® - MT1™ is consistent throughout the cross section.

Surface properties of grinding media

Grinding media selection is usually focused around the parameters listed previously. In testing of Keramax® - MT1™ during product development, it was found that grinding efficiency was greater than other media types of similar size, shape factors and SG. In fact, grinding efficiency was better than could be predicted with stress intensity calculations. Of significance was the power trend that occurred during test work under the conditions of

Table I
Summary of ceramic bead compounds

Ceramic bead	Chemical composition
Alumina	$A1_2\,0_3 \geq 85\%$ - SiO_2
Yttrium stabilized zirconium oxide	$ZrO_2(95\%)$ - $Y_2O_3(5\%)$
Cerium stabilized zirconium oxide	$ZrO_2(80\%)$ - $CeO_2(20\%)$
Magnesium stabilized zirconium oxide	$ZrO_2(97\%)$ - $MgO(3\%)$
Zirconium silicate	$ZrO_2(69\%)$ - $SiO_2(31\%)$
Aluminium silicate	$Al_2\,0_3\,(34\%)$ - $SiO_2\,(62\%)$

Table II
Summary of ceramic bead physical properties

Ceramic beads (K1C)	Bulk density	Hardness (HV)	Fracture toughness
Alumina	2.0 – 2.1	1 500 – 1 700	3 – 5
Yttrium stabilized ziconium oxide	3.6 – 3.8	1 300 – 1 400	13
Cerium stabilized zirconium oxide	3.9 – 4.0	1 100 – 1 200	13
Magnesium stabilized zirconium oxide	3.2 – 3.4	900 – 1 100	6
Zirconium silicate	2.2 – 2.4	600 – 800	3
Aluminium	1.7 – 1.8	800 – 900	3

Table III
Keramax® - MT1™ compound

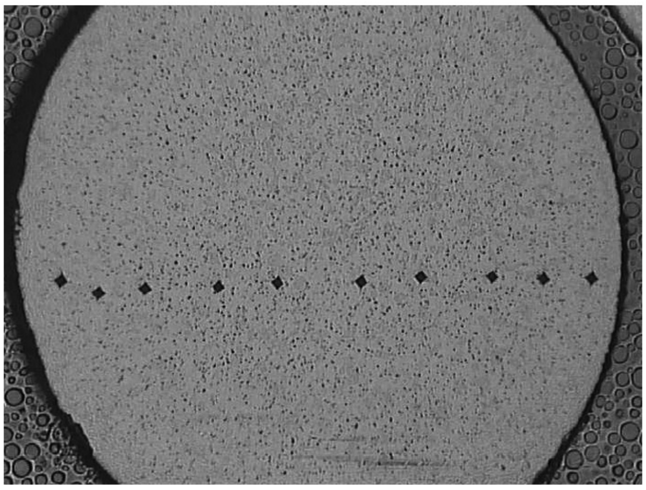
Ceramic bead	Chemical composition
Keramax MT1	$Al_2\,O_3\,(79\%)$ - $SiO_2\,(6.5\%)$ - $ZrO_2(14\%)$

Table IV
Keramax® - MT1™ physical properties

Ceramic beads	Bulk density	Hardness (HV)	Fracture toughness (KIC)
Keramax MT1	2.3 - 2.4	1 300 - 1 400	5 - 6

Table V
Keramax® - MT1™ cross sectional hardness

Location	1	2	3	4	5	6	7	8	9	10	Ave	SD
HV	1 308	1 301	1 308	1 351	1 322	1 294	1 366	1 322	1 396	1 294	1 326	34



Keramax® - MT1™ cross sectional hardness

media-water and media-slurry. In all other media types ever tested by Xstrata Technology (including ceramics), an IsaMill will draw more power when operating with a media-water system than with a media-slurry system (i.e. motor power would always decrease when slurry was introduced to a mill operating with grinding media and water–in a start-up situation for example). With Keramax® - MT1™, the reverse occurs. It was hypothesized that slurry 'lubricates' a typical media charge as the frictional loss between media particles in motion is lower in the presence of fine feed slurry than media on media interaction in the presence of only water. Further to this, and considering the unique reverse trend with Keramax® - MT1™, it was proposed that the media on media interaction of Keramax® - MT1™ in a water environment resulted in minimal frictional loss, compared to what now would be considered an abrasive slurry environment with slurry being fed to the mill.

The appearance of the Keramax® - MT1™ surface and observing how easily the media flows certainly supported the theory of lower frictional loss. Xstrata's Discrete Element Method (DEM) model was used to verify the sensitivity to energy distribution and power draw of surface friction coefficients.

Test work

Laboratory

The aim of laboratory tests was to obtain comparative results of different grinding media in terms of relative consumption rate and grinding efficiency. Combining the energy and consumption data produces a kg/t consumption figure for each media type. This presented the first evaluation of the economic potential of Keramax® - MT1™ in IsaMilling applications. Tests were performed in Netzsch LME4 (IsaMill M4) machines at both Magotteaux's Belgian facility and Xstrata's Brisbane laboratory. This section describes test work performed on a gold-bearing pyrite concentrate from the Eastern Gold Fields region of Western Australia.

The simplified test procedure is described below:

- Media is preconditioned in water before testing on slurry to simulate a conditioned charge. Media is dried, weighed and reloaded in the mill. (Note the Keramax® - MT1™ media charge did not lose any mass after 60 minutes of grinding in water).
- Pyrite concentrate slurry with a F80 = 170 μm is pumped through the LME4 in a single pass of ±10 minutes. Energy, flow rate and pulp density are measured during this time.
- A sample is taken for particle size analysis using a Malvern Microsizer.
- This process is repeated a minimum of three times to produce size/energy data pairs.
- The test rig is then placed in closed circuit with the slurry stock, and operated for a further 60 minutes to maximize the accuracy of energy measurement and media consumption.
- The loss in mass is measured at the end of the test. Dividing this mass by total net energy, gives a g/kWh media consumption rate.
- A size value (eg. P80) is plotted against its respective energy value and a measurement of grinding efficiency is obtained (a signature plot).

The consumption rates of different media types on the pyritic concentrate, under identical grinding conditions are shown in Table VI. Keramax® - MT1™ exhibited the lowest consumption rate, giving a relative wear ratio of 1. The relative wear ratios of the other media types are shown in the right-hand column.

The size distribution of the media types (with exception of the nickel slag) were not representative of fully conditioned charges; most media types only had particles in the -4 +3 mm range as this was how they could be ordered from the suppliers. The absence of -3 mm media would lead to inefficient grinding to ultra fine sizes. Because of this, a coarser target product size was selected where all media types could produce a product of acceptable efficiency. A P80 = 47 μm was selected, as it met the above criteria for the narrowly-sized media charges, and also presented as the only data point produced for Alumina 2 (due to a pump failure during testing, more data points were not produced for this media type). Therefore, the energy efficiency of all media types are compared at a P80 = 47 μm and shown in Table VII. All tests were performed in open circuit.

The next best media to Keramax® - MT1™ required 50% additional energy to produce the same product size. Significantly, this media was an Australian silica sand which required less energy than the two alumina ceramic media types. The silica sand was however, coarser than either of the alumina media which would result in higher wear rates of internal mill components, so maintenance costs would need to be evaluated.

Using the available media consumption and energy data, the media consumption per tons of concentrate treated can be calculated and is shown in Table VIII.

It is clear that Keramax® - MT1™ has economic potential in IsaMill applications, as the consumption per tons milled in this test is at least an order of magnitude less than the next best media. The higher energy efficiency also has capital cost benefits, as a lower installed power can be selected to optimize project economics. For example, Table IX shows the net power requirement for this concentrate type to treat an arbitrary 250 t/h. Once a specific project's power cost is factored in, the relative performance of Keramax® - MT1™ further improves. Based on this outcome, further work at pilot scale was planned.

Pilot test

Pilot testing was conducted at a South African platinum concentrator treating MF2 tail (i.e. secondary ball mill /flotation circuit tailing) on UG2 ore in the Western Limb of the Bushveld Igneous Complex near Rustenburg. This site was selected because a full scale IsaMill is already operating in cleaner circuit regrind on silica sand which would permit full scale verification of the pilot results. Also, the M100 pilot IsaMill (55 kW) was located near this site which is an ideal mill for this work.

Four media types were selected, however only two were able to grind the extremely hard chromite in the plant tail. The two media types that failed to grind the feed were a silica sand and alumina ceramic (both having SG = 2.6 t/m 3). Neither of these media types are available in coarse enough sizes to break the chromite in the feed. 'Ceramic A' was of similar SG to Keramax® - MT1™. The simplified test procedure is described below:

- Equivalent volume of media is loaded into the IsaMill.
- The power draw is recorded, and maintained by pumping fresh media in with the feed slurry.

Table VI
Grinding media consumption rates per unit energy

Media type	Consumption Rate (g/kWh)	Relative Consumption
Keramax® - MT1™ (-4 + 3 mm)	15	1.0
Alumina 1 (-4 + 3 mm)	128	8.5
Alumina 2 (-4 + 3 mm)	295	19.7
Australian river pebble (-4 + 3 mm)	200	13.3
Australian silica sand (-6 + 3 mm)	781	52.1
Ni slag (-4 + 1 mm)	1 305	87.0

Table VII
Grinding media consumption rates per unit energy

Media type	Specific energy (KWh/t)	Relative energy
Keramax® - MT1™ (-4 + 3 mm)	7.6	1.0
Alumina 1 (-4 + 3 mm)	13.1	1.7
Alumina 2 (-4 + 3 mm)	12.4	1.6
Australian river pebble (-4 + 3 mm)	27.0	3.7
Australian silica sand (-6 + 3 mm)	11.2	1.5
Ni slag (-4 + 1 mm)	17.0	2.3

Table VIII
Grinding media consumption rates per unit energy

Media type	Specific energy (KWh/t)	Relative energy
Keramax® - MT1™ (-4 + 3 mm)	0.11	1
Alumina 1 (-4 + 3 mm)	1.68	15
Alumina 2 (-4 + 3 mm)	3.66	32
Australian river pebble (-4 + 3 mm)	5.58	49
Australian silica sand (-6 + 3 mm)	8.77	77
Ni slag (-4 + 1 mm)	23.23	203

Table IX
IsaMill net power requirements – illustration at 250th treatment rate

Media type	Net power (MW)
Keramax® - MT1™ (-4 + 3 mm)	1.9
Alumina 1 (-4 + 3 mm)	3.3
Alumina 2 (-4 + 3 mm)	3.1
Australian river pebble (-4 + 3 mm)	7.0
Australian silica sand (-6 + 3 mm)	2.8
Ni slag (-4 + 1 mm)	4.4

Table X
Specific energy and media consumption rate

Media type	Specific energy (Per % - 25 pm)	Consumption rate (gkWh)
MT1™ (-3.5 + 1.8 mm)	74	20
Ceramic A (-3.4 + 1.7 mm)	108	81

- Media consumption is calculated by recording the mass added during the test and by measuring the mass variation of the load before and after each test.
- Composite samples are taken every day for particle size analysis.
- All the operating conditions such as slurry flow rate, pulp density and mill speed are identical for each test.
- Each media type was tested for five days to generate sufficient data.

The IsaMill was running in a continuous mode in a single pass operation.

Table X summarizes the consumption and specific energy data per % -25 μm produced.

Ceramic A required 46 % more energy to produce the same product size, whilst consuming over 400% more media in the process.

It was suspected that the observed 20 g/kWh consumption rate was high. This was confirmed during full scale tests, as detailed further down.

Full scale supply at Anglo Platinum

There are two applications for IsaMills, namely recent Mainstream inert grind (MIG) and Ultra fine grind (UFG). The main purpose of MIGs is to increase recovery in the mainstream flotation circuit. The main purpose of UFGs is to increase grade without losing recovery in the cleaner circuit. The world's first M10,000 IsaMill was commissioned in Anglo Platinum's Western Limb Tailings Retreatment Plant in South Africa in a UFG application.

Typical particle size distributions currently targeted in the PGM industry are:

- MIG – F80 75–150 microns reduction to P80 45–60 microns
- UFG – F80 40–80 microns reduction to P80 15–25 microns

The five Mig IsaMills commissioned within Anglo Platinum to date treat scavenger flotation feed and the basic flow diagram can be seen in Figure 1.

The circuit feed is generally the primary rougher tail or secondary mill product. The rougher tail is pumped into a surge tank which provides a 20 to 45 - minute effective residence time so as to ensure a stable feed to the downstream cyclone clusters and IsaMill. The surge tank discharge is pumped to desliming cyclones which remove the ultra-fine slimes fraction to the overflow and provide a thickened underflow of approximately 65% solids. The underflow is pumped into the IsaMill. The desliming cyclone overflow and the IsaMill discharge report to the product sump which is then pumped to Scavenger flotation.

Media is delivered to site in 2 ton bags which are loaded into the media bin. The screw feeder adds the media at a controlled rate into the IsaMill feed tank which is then pumped into the IsaMill together with the slurry.

MIG installations

Anglo Platinum mines process three different ore types: Merensky, UG2, and Platreef. Merensky and Platreef are pyroxenite silicate reefs, and UG2 is predominantly a chromitite reef. Platreef, unlike Merensky and UG2, can be an extremely wide reef and subject to alteration and variable gangue mineralogy. PGMs are associated with silicates and are often very fine grained which makes recovery problematic. Typically PGMs are less than 10 microns in UG2 ore, for example.

Mogalakwena

The Platreef mineralogy is particularly complex and has been subjected to alteration of the silicates, making it difficult to process with high metals recoveries. Mineralogical investigations show that 55–65% of the PGMs occur as locked or middling particles with gangue association (Clark-Mostert, 2006, Nichol, 2006, Schalkwyk, 2007).

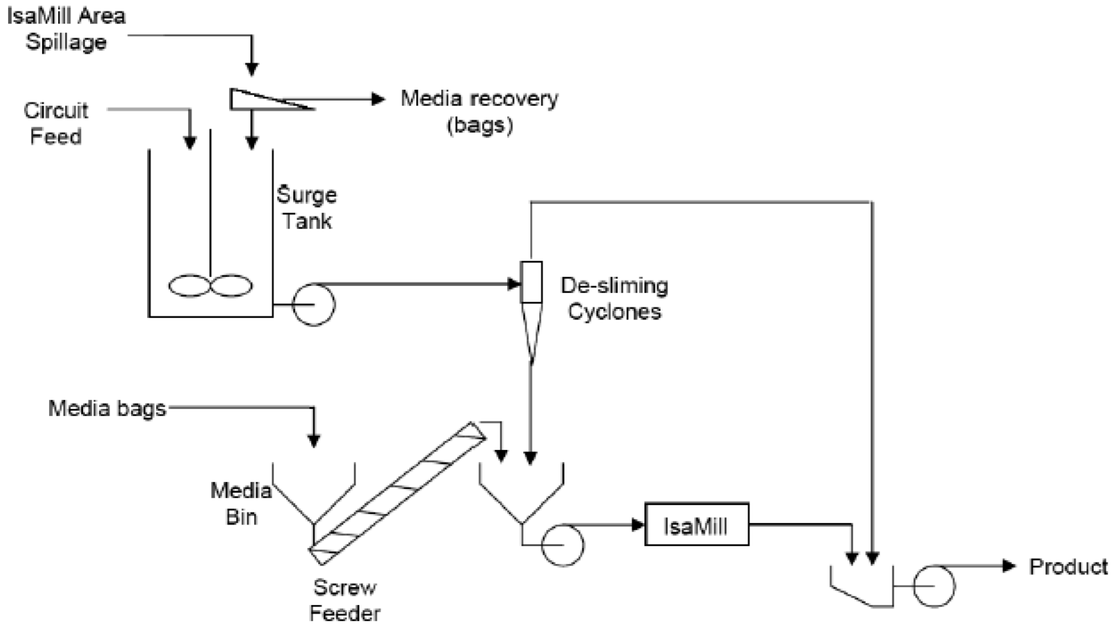


Figure 1. Basic flow diagram of a typical MIG circuit

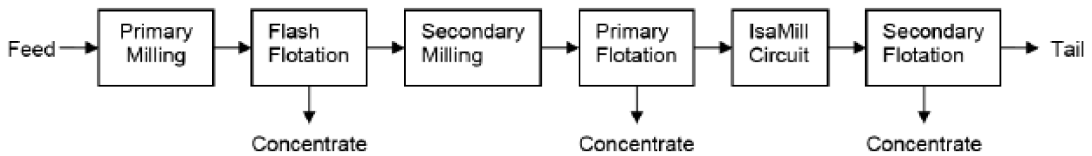


Figure 2. Block flow diagram of Mogalakwena C Section

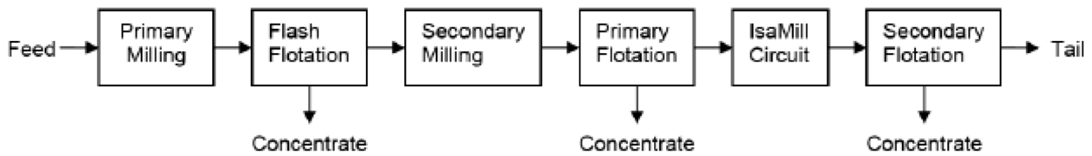


Figure 3. Block flow diagram of Mogalakwena A Section and B Section

In late 2006 the 'hard rock' mineral processing industry's first M10,000 MIG IsaMill was successfully commissioned in a regrind application at Mogalakwena Concentrator's C Section with the aim of increasing recovery by milling the scavenger rougher feed or mill product to a P80 of 53_μm (Figure 2), thereby increasing flotation performance and PGM liberation.

Furthermore, in August 2007, two new 3 MW, M10,000 MIG IsaMills were successfully commissioned on the Mogalakwena Concentrator A and B Sections to replace the duty of the two 1.8 MW tertiary ball mills (Figure 3).

Waterval UG2

Mineralogical analysis of the final tails of Waterval UG2 concentrator showed that 70–75% of the PGMs in the final tail occur as locked or middling particles with gangue association (Nichol, 2006,Van Staden, 2006, Van Staden, 2007). Furthermore, 55% of the PGMs are in the +53μm particle size fraction and of this, 97% is locked (Van Staden, A., 2007).

Leading on from mineralogical investigations on plant tailings streams, further investigations have centre on the chrome and silica splits around classification units of UG2 plants across the group. At Waterval UG2 in particular, this split across the Densifier cyclones has been investigated (Anyimadu, 2007). Of the PGMs in the cyclone feed, 80% report to the cyclone overflow. The cyclone underflow, in contrast, is predominantly comprised of coarse chrome, barren of PGMs. About 90% of the particles in the underflow are larger than 53μm.

In November 2007, two new M10,000 MIG IsaMills were successfully commissioned at Waterval UG2 with the aim of increasing recovery by milling the PGM - enriched preferentially silica fraction of the Densifier cyclone overflow to less than 53μm (Figure 4), thereby increasing flotation performance and PGM liberation.

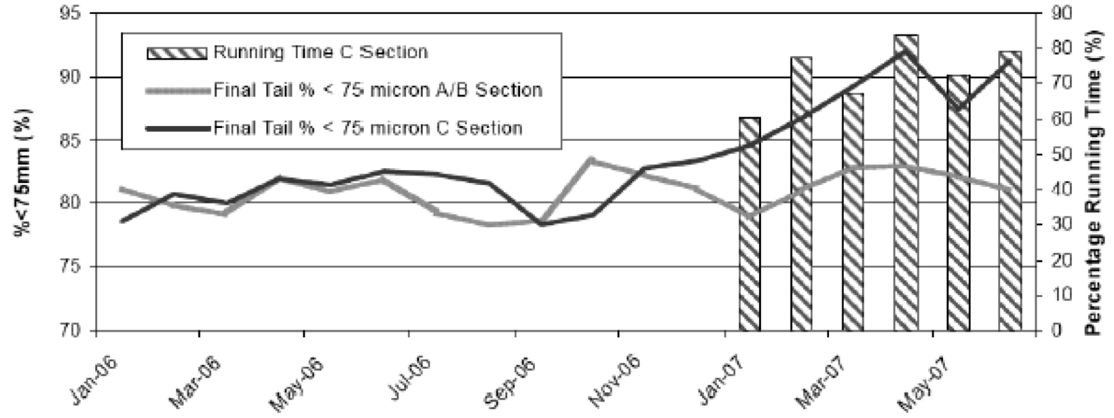


Figure 4. Block flow diagram of Waterval UG2

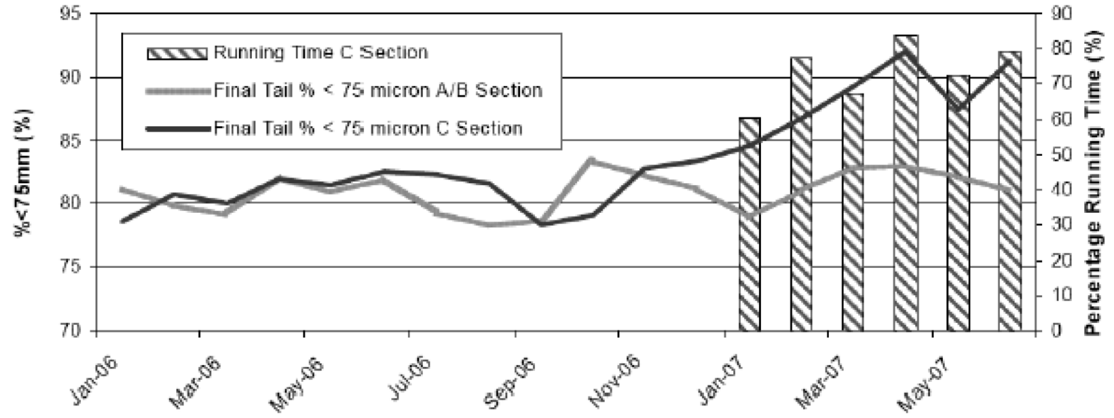


Figure 5. Mogalakwena final tail percentage passing 75micron

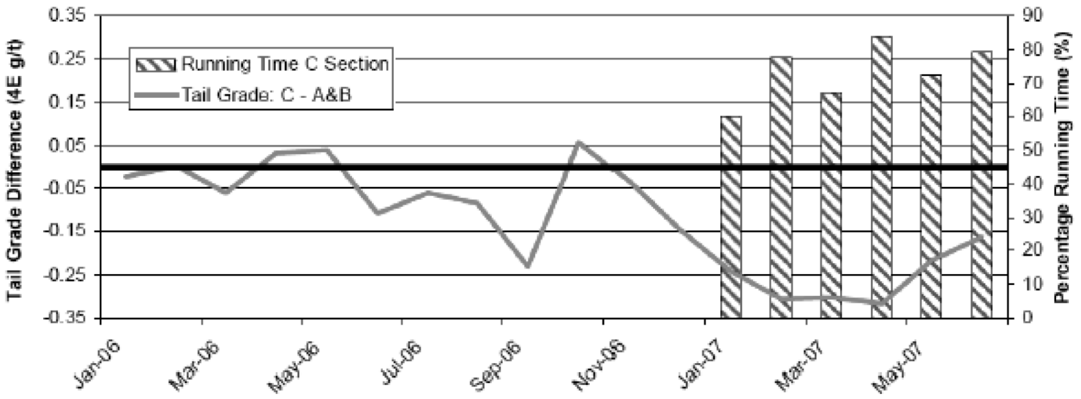


Figure 6. Mogalakwena tail grade difference per section before and after the C Section IsaMill

Metallurgical performance—Mogalakwena C Section

The ore treated by Mogalakwena Concentrator changes with ore block mined in the three open pits. Hence the mineralogy and metallurgical potential of the plant feed varies considerably with time. As such, it is not possible to judge improvements in recovery by looking at the C Section independently. Therefore, as ore feed into the plant is not differentiated, C Section performance will be discussed in comparison to A and B Section before and after commissioning C Section IsaMill.

Figure 5 and Figure 6 show the final tail, grind and 4E PGM grade difference between the sections. The final tail, grind and grade, for the three sections are similar before the IsaMills. Post commissioning the tails grind, passing 75 μm, increases for C Section. This results in improved liberation, flotation performance and ultimately a lower tail 4E PGM grade for C Section.

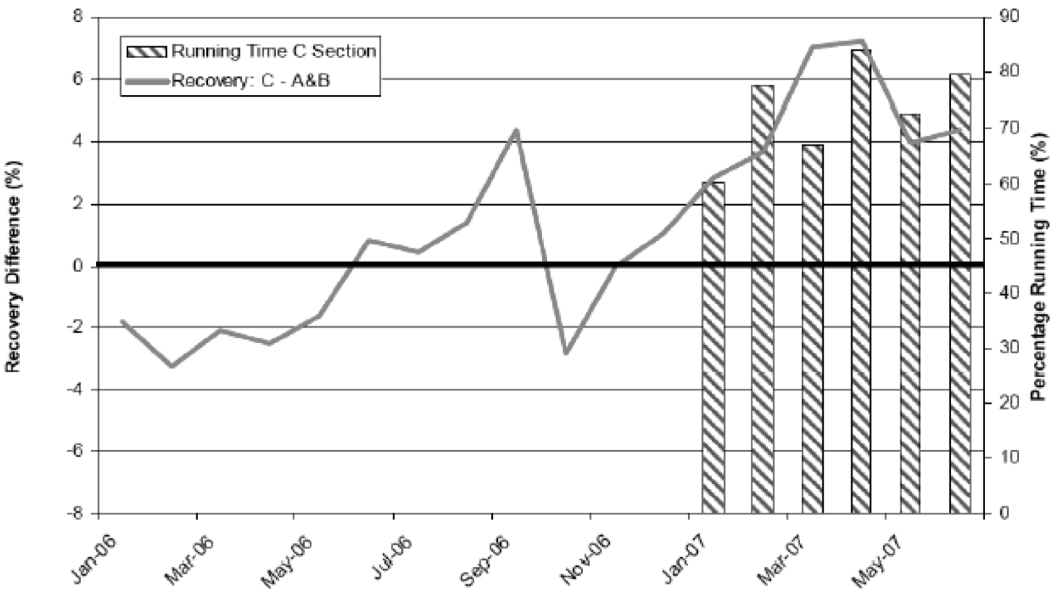


Figure 7. Mogalakwena 4E PGM recovery difference per section before and after the C Section IsaMill

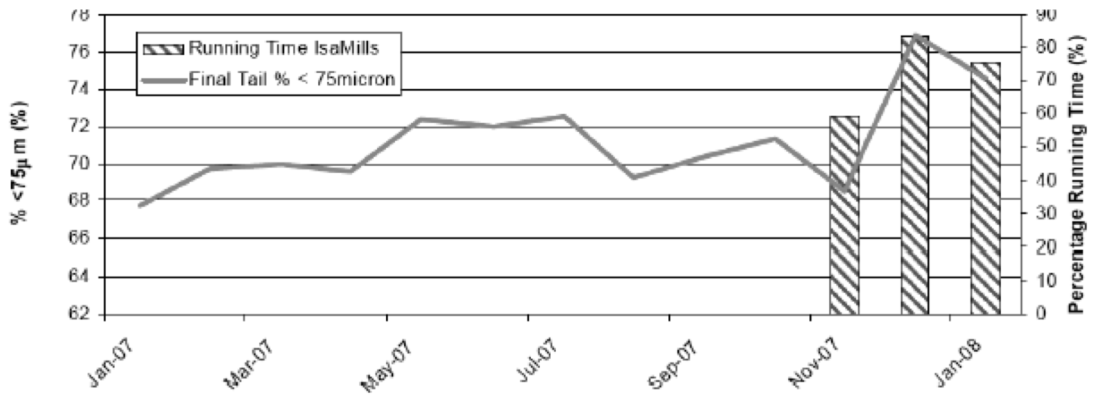


Figure 8. Waterval UG2 final tail percentage passing 75 microns before and after the IsaMills

Figure 7 shows the recovery difference between the sections. Before the IsaMill came on-line in C Section, the recoveries were similar between the three sections, except for months where there were operational problems. Once the IsaMills came on-line, the recovery of C Section was higher than A and B Section by as much as 7%.

Metallurgical performance—Waterval UG2

The ore treated by Waterval UG2 Concentrator is fairly constant in mineralogical character. This is due to the inherent geology and mineralogy of the Rustenburg area UG2 reef and mixing in the materials handling process from the wide mining horizon of the operations across the 12 km strike of the mine–hundreds of spatially dispersed panels are being mined at any one time. The head grade over the period considered thus is fairly constant.

Figure 8 and Figure 9 show the final tail grind and the final tail grade difference between the monthly value and the average for January 2007 to January 2008. The final tail grind improves after the commissioning of the IsaMills. Furthermore, the improved grind results in improved liberation and flotation performance and ultimately results in a lower final tail grade.

Figure 10 shows the recovery difference between the month and the average achieved from January 2007 to the end of January 2008. Metal recovery was fairly constant before the IsaMills. However, once the IsaMills came on-line, the 4E PGM recovery increased by a little over 2%.

Keramax® MT1™ performance—Mogalakwena

Figure 11 shows the consumption of ceramic media in the three IsaMills. The lowest values on this graph (February and April) are the results of spillage of ceramic on the ground when the IsaMills were open. These ceramic are manually picked up and reconditioned in bags and media reloaded into the IsaMills. The quantities of media used in this graph are only the fresh media i.e. some months few (or no) fresh media are loaded into the IsaMills.

Keramax® MT1™ performance—Waterval UG2

The problem of spillage of media on the floor does not appear at Waterval UG2. In effect, the IsaMill circuit is

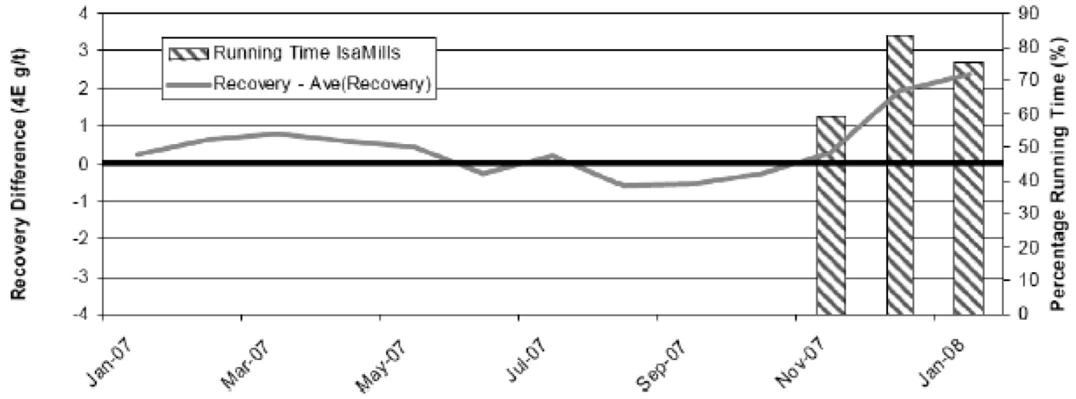


Figure 9. Waterval UG2 final tail grade difference before and after IsaMills

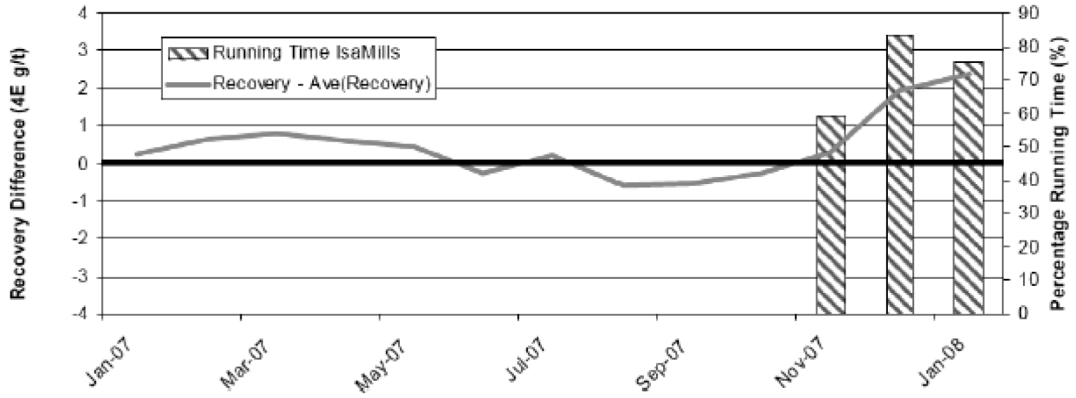


Figure 10. Waterval UG2 4E PGM recovery difference before and after IsaMills

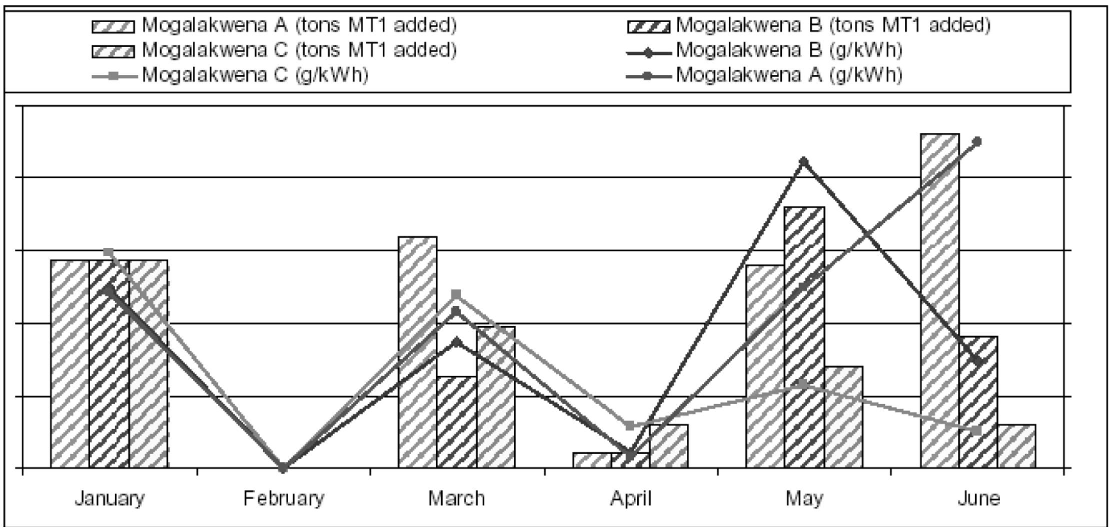


Figure 11. Mogalakwena – Keramax® MT1 ™ performance

contained within a bunded area. Spillage that may contain media is hosed to a central spillage pump and pumped to a vibrating screen above the surge tank. Slurry passes through the screen to the surge tank, and media on the overflow is directed to media bags so that the media can be reloaded into the IsaMill at a later stage.

In order to help with the handling of the ceramic media, Magotteaux has designed an automatic ceramic loader machine called MicroLoad®. The test machine will be installed at Waterval UG2 and if the test is successful, the MicroLoad® might be rolled out to all the IsaMills within Anglo Platinum.

During the month of February, the Secondary Mill was off-line (power saving) and all the throughput was passed through the IsaMills. The increased flow of pulp inside the mill pushed the media out of the IsaMill (separator at the discharge of IsaMill not designed for such throughput). Some media has been found in the float cell and even in the final tails. That explains the higher consumption in February.

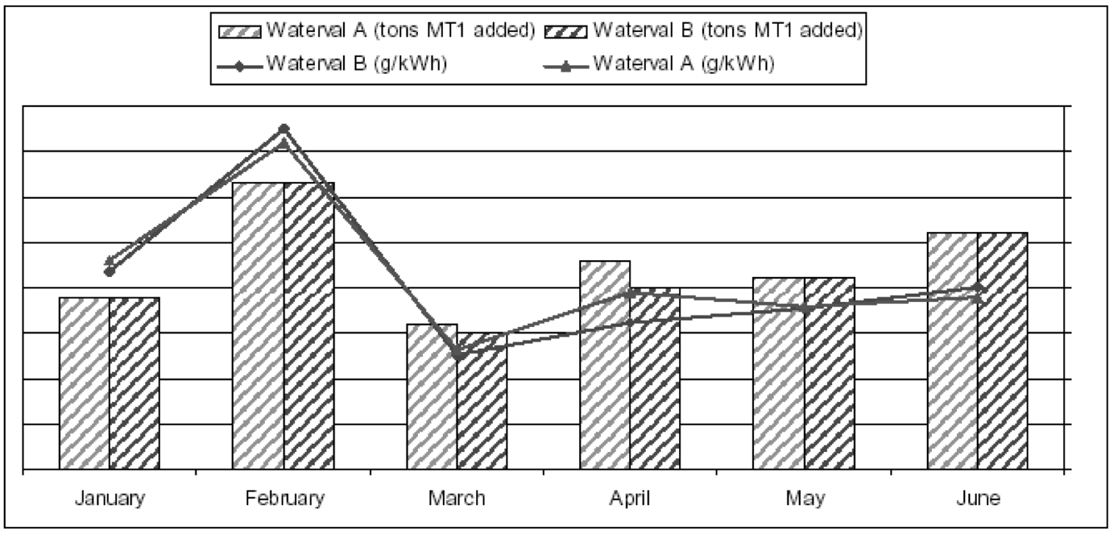


Figure 12. Waterval UG2 – Keramax® MT1™ performance

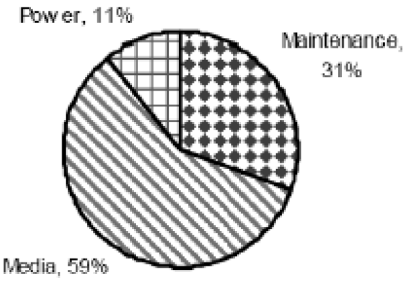


Figure 13. Operating costs for the Mogalakwena and Waterval UG2 IsaMills (Jan and Feb 2008)

Cost performance

The operation of the MIG IsaMills at Anglo Platinum in a coarse grind application is unique; at this early stage, both cost of operation and project return are not optimized. The three IsaMills at Mogalakwena and the two IsaMills at Waterval UG2 have increased the operating cost of concentrating by between 10 and 20%. However, it is estimated that from Mogalakwena C Section from January to June 2007 that there is a 600% return in terms of the value created by the increase in metals recovered, off-set by their cost of operation. This value creation will be higher as metal prices increase. The breakdown of operating costs of the five MIG IsaMills for January and February 2008 can be seen in Figure 13.

Magotteaux Keramax®MT1™ ceramic media cost represents the major MIG IsaMill operating cost at 59% of the total. Anglo Platinum is engaging with potential ceramic suppliers for cost-effective solutions which are targeted at an optimized future balance between wear rate/media cost. A comprehensive media development program has been initiated with this in mind.

Maintenance accounts for 31%, and of this the major component is disc replacement which accounts for of the maintenance cost. The wear rate of the first disc is the highest and is currently between two and four weeks. Disc wear-rates between the various IsaMills differ as a result in feed flow and density, power draw, and ore. As circuits become optimized, disc life will improve. Development of superior rubber compounds are continuously being developed for specific applications. The data presented here is for non-optimized early operation and improvements in wear component life and especially media are confidently expected.

At this stage, power in South Africa is relatively cheap in comparison to world prices and therefore accounts for only 11%. The country's current power challenges may change this in the near future. However, concentrators as a whole may be able to reduce power consumption due to more efficient comminution circuits. The IsaMills have already replaced the Tertiary Mills at Mogalakwena Section A and B. Optimum power-efficient circuit design is continuously being investigated and will result in more ball mill power being replaced as the technology is rolled out further.

The future of IsaMills at Anglo Platinum

Detailed mineralogical studies at all of Anglo Platinum's concentrators have indicated that the predominant losses of platinum group mineral species are associated with the insufficient liberation in coarser particle size fractions. Both laboratory and pilot plant studies have supported these observations and have indicated that the addition of a main stream inert grinding stage can economically enhance overall recovery.

Based on this work, a roll-out program has been initiated whereby within the next three years, most group concentrators will be retrofitted with MIG installations.

Conclusion

Historically, ceramic-type grinding media have not been economically viable for mineral processing applications with high speed stirred mills such as the IsaMill, due to high operating costs. The availability of an economic ceramic media will provide considerable benefits to the users of IsaMills, and allow the energy benefits of the technology to be applied at coarser grind sizes.

Keramax® - MT1™ ceramic grinding media was tested on various mineral concentrates and offers very high energy efficiency and extremely low consumption rates. The surface properties of Keramax® - MT1™ contribute to the high energy efficiency of IsaMilling with this media type.

DEM simulations explain the more efficient distribution of energy when using a grinding media with low sliding friction coefficient.

Keramax® - MT1™ offers the design metallurgist a way of lowering capital and operating costs for large-scale stirred milling projects. The footprint of IsaMill installations can be decreased because of the lower installed power requirement and smaller media handling system.

The industrial results at Anglo Platinum concentrators have demonstrated the effectiveness of combining a high efficiency grinding media with large scale stirred milling.

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