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IsaMill™ TECHNOLOGY IN THE PRIMARY GRINDING CIRCUIT

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IsaMill™ TECHNOLOGY IN THE PRIMARY GRINDING CIRCUIT

ABSTRACT

Originally developed as a step change in ultrafine grinding efficiency, the IsaMill™ has made inroads into conventional ball mill and tower mill mainstream grinding duties during the last 5 years - beginning with the Anglo Platinum mainstream grinding projects in South Africa. At the 2006 SAG Conference, plant testwork on the incorporation of IsaMill™ technology into the McArthur River (Northern Territory, Australia) Pb/Zn primary grinding circuit was reported. The IsaMill™ has now become an integral component of that circuit, treating up to 1mm top size feed and directly producing P_{80} 45 µm rougher flotation feed. Two 1.1 MW IsaMills™ are now used in this duty contributing to a 27% increase in overall plant throughput and a reduction in rougher feed size distribution. In this paper, we report on the current state of development and performance of the IsaMill™ in the primary grinding duty at McArthur River and also consider future directions.

KEYWORDS

IsaMill™, McArthur River, efficient, energy, ceramic, inert, primary grinding, stirred milling.

INTRODUCTION

IsaMill™ technology was developed to address the ultra fine grinding (UFG) requirements of Mount Isa Mines (MIM, now Xstrata), particularly for the McArthur River lead/zinc deposit where a 7 µm grind was required, under efficient and inert conditions, in order to make a saleable concentrate (Logan, Leung & Karelse, 1993). The 1.1 MW, 3000 litre IsaMill™ (M3000) became the enabling technology for McArthur River in 1995 and remains critical to its ongoing viability today. The history of McArthur River, the development of the IsaMill™ - between MIM and Netzsch Feinmaltechnik of Germany, as well as the operating characteristics of the IsaMill™ have been well documented elsewhere (Nihill, Stewart & Bowen, 1998; Enderle, Woodall, Duffy & Johnson, 1997; Pease, Anderson, Curry, Kazakoff, Musa, Shi & Rule, 2006).

Since its development and use for UFG duties, the IsaMill™ was commercialised and has now moved into coarser grinding, mainstream applications; allowing the key benefits of improved energy efficiency, small footprint and inert grinding environment to be applied to a range of different mineral types (Anderson & Burford, 2006). Key to this development was both the scaleup of the IsaMill™ from 3,000 litres (1.1 MW, M3000) to 10,000 litres (3 MW, M10,000) (Curry, Clark & Rule, 2005) and the development/use of ceramic media (Curry & Clermont, 2005).

Anglo Platinum lead the way in the rollout of IsaMills™ into mainstream duties based on the successful commissioning and operation of the first 10,000 litre IsaMill™ (in an ultra fine grinding application) in 2003 (Buys, Rule & Curry, 2005) and the significant evidence generated by Anglo Platinum's own mineralogical studies, suggesting that finer grinding was required to improve PGM recoveries, particularly across the Platreef and UG2 orebody types (Rule, 2010). Between 2006 and 2009, 54 MW of MIG (Mainstream Inert Grinding) IsaMills™ were commissioned across the Anglo Group in South Africa. Despite some early commissioning and operational issues, the IsaMills™ have proved their value adding in excess of 3% to platinum recoveries (Rule & de Waal, 2011). Anglo Platinum currently has a total of 18 IsaMills™ in MIG duties and four IsaMills™ in UFG duties.

At McArthur River, life of mine optimisation studies determined that conversion from underground to open cut mining was required, with a subsequent increase in plant throughput requiring additional grinding capacity. Given their history of development and operational familiarity with the IsaMill™, McArthur River initiated their own testwork into coarse grinding applications around the same time the Anglo projects were proceeding to full scale, with a view to investigating the potential of the IsaMill™ to contribute to the expansion of the primary grinding circuit at McArthur River.

MRM PRIMARY GRINDING CIRCUIT EVOLUTION

When commissioned in 1995 with nameplate capacity of 1.5 mtpa, the MRM primary grinding flowsheet consisted of a single stage 3.5 MW SAG mill. Mill discharge was screened over a 1.8 mm screen with the oversize recycled back to the SAG mill feed chute. Screen undersize was pumped to a set of cyclones that produced an overflow at around P_{80} 45 µm for rougher flotation. Cyclone underflow returned to the SAG mill feed chute.

Over time, ore sourced from the initially targetted high grade number 2 orebody depleted. Additional ore was sourced from the number 3 and 4 orebodies with interbed inclusions. This material was harder and at lower head grade. As a result, numerous changes were implemented to the primary grinding circuit to increase throughput, including additional crushing stages ahead of the SAG mill, increased SAG ball loads, uprating the SAG Mill to 4 MW and the addition of a locally sourced second hand tower mill. This allowed plant throughput to be increased to 1.8 mtpa by 2006 but also resulted in the primary grind size increasing from P_{80} of 45 to 70 µm. The 2006 flowsheet (after crushing) is shown in Figure 1.

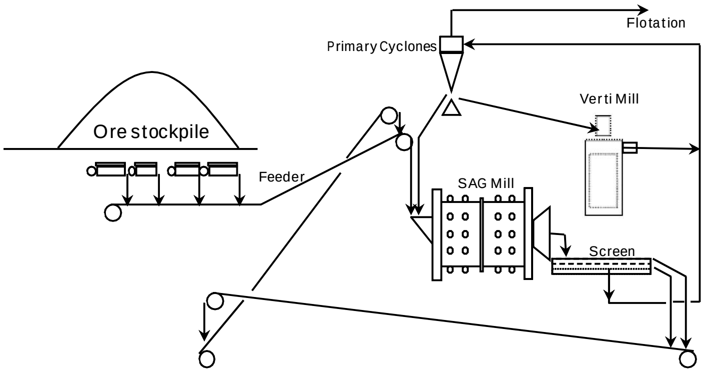

Figure 1 - McArthur River Primary Grinding Circuit 2006

In 2005, a change from an underground operation to an open cut operation was under consideration, requiring the plant to process up to 2.5 mtpa - at further reduced head grade.

IsaMill™ LAB AND PILOT WORK

A testwork program commenced to determine the suitability of using the IsaMill™ to increase the plant throughput at McArthur River. Initial scoping work was carried out at laboratory scale in 2005, followed by two separate on site pilot plant testwork campaigns in 2006 using an 18 kW 20 litre (M20) IsaMill™ - this was reported at SAG2006 (Pease et al, 2006). The on-site pilot work, treating a bleed stream from the SAG mill classification circuit, predicted that a product size P_{80} of 45 µm could be produced at approximately 10 kWhr/t using the IsaMill™.

FULL SCALE 1.1MW M3000 IsaMill™ TRIAL

Following the success of the pilot scale work, one of the six 1.1 MW M3000 UFG IsaMill™ units was reconfigured to operate in the MRM primary grinding circuit to confirm the results from the pilot work. The circuit was configured as per Figure 2 with the bleed stream originating from a modified SAG cyclone. A magnetic separator was included on the feed stream to protect the IsaMill™ from tramp SAG Mill steel - which had been identified as a potential issue during the pilot work. The IsaMill™ operated in open circuit with the product joining the SAG circuit cyclone overflow as feed to the rougher flotation circuit. The full scale trial commenced in May 2007 using 3.5 mm ceramic media with a feed size of F_{80} of 180-200 µm. Figure 3 shows the 6 x M3000 IsaMills™ at McArthur River.

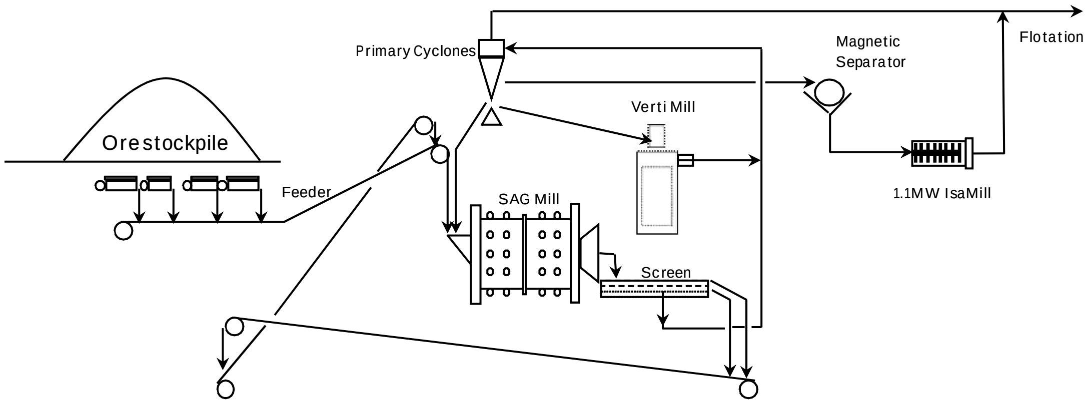

Figure 2 - Circuit Configuration for Full Scale IsaMill™ Trial

Figure 3 - 6 x M3000 IsaMills™ at McArthur River

This application stepped well outside the boundaries of previous IsaMill™ experience and a development phase was needed to optimise the grinding conditions to produce a satisfactory result. As for SAG or ball milling, in stirred milling it is also crucial to break the top size particles fast enough to avoid critical size buildup within the mill. The initial mill internal configuration and 3.5 mm media was unable to do this efficiently or quickly enough, resulting in the IsaMill™ becoming unstable after several hours of operation due to a critical buildup of unbroken coarse material at the front end of the mill. This was confirmed during crash stop inspections of the mill which revealed a large volume of unbroken compacted and dewatered coarse material at the front of the mill and internal wear patterns indicating the incoming feed bypassing this built up stationary area. The buildup of stationary media and unbroken coarse material caused a 30% drop in power draw and resulted in the product from the mill becoming unacceptably coarse due to an effective reduction in the specific energy applied. This was initially overcome by changing to a coarser 5-6 mm top size media and the derating of the internal product separator rotor, which effectively decreased the degree of media compression at the front of the mill and allowed the media and fresh feed to agitate correctly, allowing the coarse feed particles to be ground.

Following several months of development and optimisation, a mill configuration and operating parameter regime was arrived at that resulted in the IsaMill™ being able to treat an F_{80} of 200-250 µm to produce a P_{80} of 35-45 µm at 10-15 kWhr/t. When the IsaMill™ was operating at 800-900 kW, treating approximately 60-70 tph of material, that would otherwise have been returned to the SAG Mill circuit, the overall plant throughput was able to be increased by 12%, from 260 tph to 290 tph, at an overall combined grind size P_{80} of 55-65 µm.

Due to the success of the trial and the impact on the overall plant production, it was continued as a permanent addition to the primary grinding circuit. Eventually a second M3000 IsaMill™ was converted to operate in the primary grinding duty allowing a further increase in overall plant throughput.

GRINDING SURVEY DATA

Numerous surveys across the IsaMill™ circuit were taken under varying operating conditions including changes in internal disc configuration and wear compounds, media type and size, feed size distribution and ore types. Figure 4 illustrates some of the survey data collected over the last two years – all using 5-6 mm ceramic media, grouped by feed size. This is plotted against the graph originally published in SAG 2006 illustrating the testwork data and the predicted operating point for the IsaMill™.

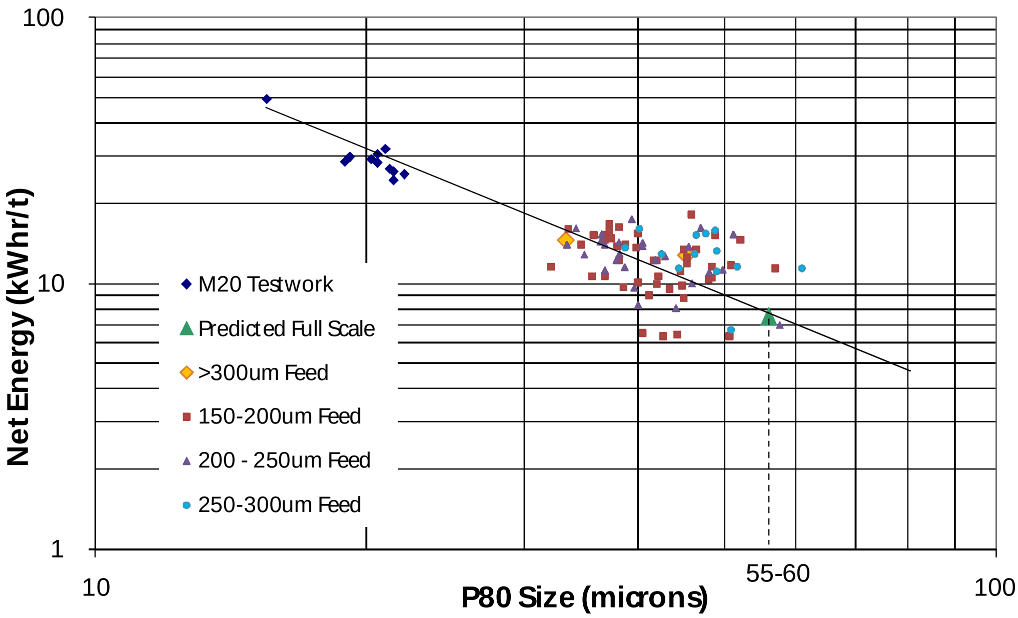

Figure 4 - IsaMill™ Operating Signature Plot

It is evident that, while there is a fair degree of scatter, the points are generally in agreement with the size-energy relationship predicted from the pilot testwork. The different feed sizes show a fair degree of overlap – indicating that the feed size did not have a noticeable impact on the product size–energy relationship. Of note are the two samples where the feed size was F_{80}>300 µm which are within the grouping of data generated from the feed sizes that were F_{80}<200 µm. This suggests that, of the energy consumed in grinding to the product size, very little is required to reduce the top end of the distribution. This is however contingent on the fact that the media is large enough to break the particles at the top end of the distribution at an adequate rate.

EFFECT OF MEDIA SIZE

Ceramic media was trialled at two different sizes in the IsaMill™. Initially the same 3.5 mm ceramic used during the pilot plant work was used. This was changed out to a 5-6 mm top size ceramic during the early stages when there were problems with achieving the grind size and mill operational stability. Once the issues had been resolved, the 3.5 mm media was retrialled. It was found that both media sizes were able to grind the IsaMill™ feed without critical buildup of unbroken coarse material occurring, provided the density was controlled below 40% solids at the targetted specific energies. However, significant differences in the breakage rates and resultant product size distributions of the two media sizes were noted.

Figure 5 compares the 3.5 mm top size media and the 5-6 mm top size media where the same product P_{80} size of 37 µm was produced. The feed size distribution was slightly coarser for the 5-6 mm media case. The 3.5 mm media consumed 16 kWhr/t to produce the P_{80} of 37 µm and P_{98} of 220 µm. The 5-6 mm media required only 11 kWhr/t to produce the same P_{80} of 37 µm but a much finer P_{98} of 110 µm. Therefore, the 5-6 mm media was able to produce the same P_{80} as the 3.5 mm but consumed less energy and produced a tighter size distribution through more effective breakage of particles at the coarse end of the feed distribution.

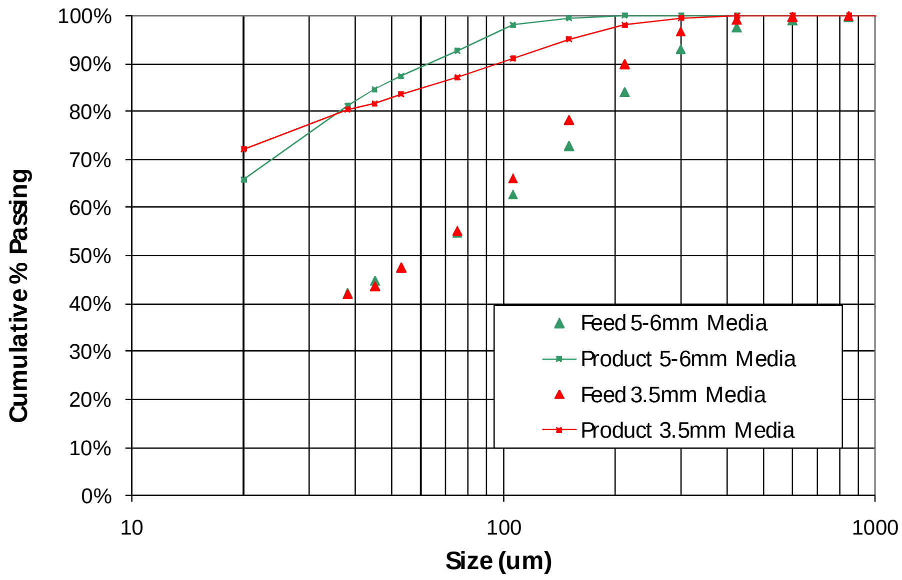

Figure 5 - Performance of 3.5 mm Media at 16 kWhr/t and 5-6 mm at 11 kWhr/t

The 5-6 mm media was able to successfully break the top size of the feed due to its ability to impart greater stress intensity as a result of its increased size (stress intensity is proportional to the cube of the media diameter). As a result, the 5-6 mm media was more efficient at achieving a given product target size. This reinforces one of the key points of stirred milling at coarser sizes – that the top size of the media must be chosen to adequately break the top size of the feed. If the top size is not broken quickly enough, it will remain in the mill leading to higher wear rates, coarser and wider product distributions, lower power efficiency and in worse case scenarios, sanding of the mill.

A second example, in Figure 6, shows the same curve at 16 kWhr/t for the 3.5 mm top size media with the energy input for the 5-6 mm top size media increased to 16 kWhr/t as well. Again, the feed size distribution for the 5-6 mm media was slightly coarser than that for the 3.5 mm media. The product size distribution from the 5-6 mm media (P_{80} of 29 µm and a P_{98} of 75 µm) was superior to that produced by the 3.5 mm media (P_{80} of 37 µm and P_{98} of 220 µm). The improvement was driven by the increased breakage rates at the top end of the distribution.

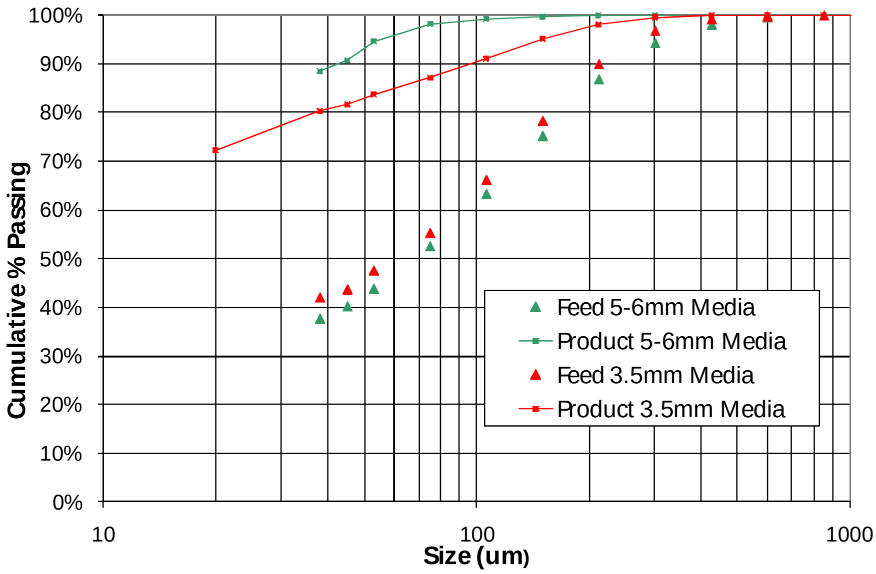

Figure 6 - Performance of 3.5 mm Media at 16 kWhr/t and 5-6 mm at 16 kWhr/t

Based on this data and the fact that it was aimed to increase the target feed size distribution to a P_{80} of +250 µm, 5-6 mm top size media became the standard for this project. This size media has proved adequate in handling the range of feed size distributions fed to the IsaMill™ up to an F_{80} of 350 µm.

The best example of coarse particle breakage was achieved when the feed to the IsaMill™ was significantly coarsened for a two day trial period through adjustment of the sample preparation cyclone. This produced feed distributions with P_{80} values >350 µm. Results of the two surveys taken during this period are included in the Figure 4 data. The distribution curves for one of the data points is shown in Figure 7 at a specific energy of 12.8 kWhr/t.

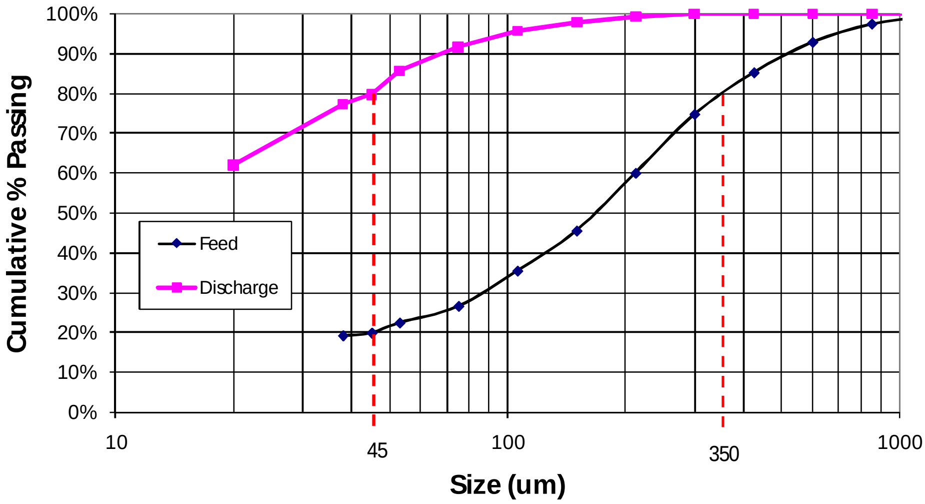

Figure 7 - Size Distributions for F_{80} 350 µm Feed at 12.8 kWhr/t using 5-6 mm media

This can also be compared to the 11 kWhr/t grind for 5-6 mm media (used in Figure 5), for a much finer feed size distribution. This reiterates the point made in the discussion of Figure 4 where the feed size distribution seems to have little impact on the energy required to reach a certain grind size. For a given media size, and provided that size is adequate, the overall energy consumption is largely determined by the target product size, rather than the feed size distribution.

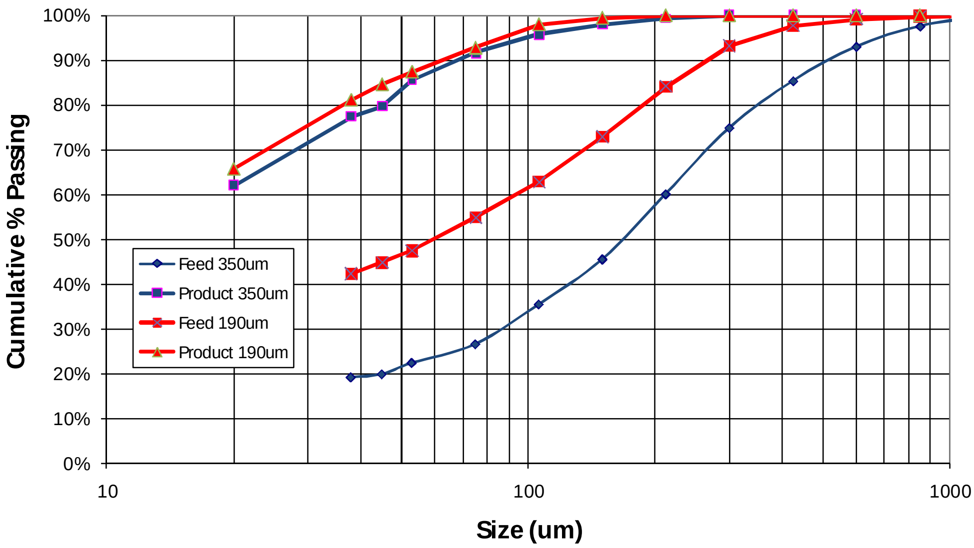

Figure 8 - Size Distributions for F_{80} 350 µm Feed at 12.8 kWhr/t and F_{80} 190 µm Feed at 11kWhr/t

MEDIA DATA

Since the project was commenced a number of ceramic medias from different suppliers were trialled with the aim of optimising performance on a supplier cost/consumption basis. Media wear rate in terms of g/kWh was monitored on a continual basis to allow the different media types to be compared on a consumption basis. Table 1 summaries the data for the 5-6 mm media top size.

Table 1 - Media Performance Data

	Media A	Media B	Media C	Media D	Media E	Media F
Cost $(AUD)/t	$ 4.60	$ 2.70	$ 4.60	$ 4.60	$ 4.60	$ 4.00
Consumption g/kWh	11-14	11-16	11-14	11-14	7-8	10-17
Max $/kWh	$ 0.064	$ 0.043	$ 0.064	$ 0.064	$ 0.037	$ 0.068
Relative Max Cost	1.00	0.67	1.00	1.00	0.57	1.06

The data gathered has not been able to discern any quantifiable information with regards to the effect of the different media types on grinding efficiency or mill internal wear. It is likely that these factors do exist but the changes have not been significant to be highlighted within the noise of the data obtained here and at the relatively coarse grind sizes. Xstrata Technology has previously conducted numerous controlled laboratory scale tests that highlight the effect of different media types on grinding efficiency. These effects are also more pronounced at finer (<20 µm P_{80} target) sizes than were targetted here.

COMPONENT WEAR RATES

In the ultra fine grinding duty at McArthur River, IsaMill™ inspections are typically at 2,000 hours. Typically a shell liner lasts 2,000 hours, feed flange lasts 10,000 hours, discharge flange lasts 15,000 hours and 3-4 of the 8 discs are replaced each inspection. While typical component lifetimes are longer - eg shell liner life is 6,000+ hours at Mt Isa – it is lower at MRM due to the high operating temperatures involved and the inability to rotate the shell liner due to the old style shells used. Newer IsaMills™ have a shell liner that can be rotated to maximise the rubber wear, therefore extending the useable life of the liner.

Initial wear rates of the IsaMill™ internal components in the primary grinding duty were significantly higher than UFG duties. The change in wear rates is a function of the feed size distribution and the presence of more gangue mineralogy - particularly silicates. In this case the feed size distribution increased from an F_{80} of approximately 45 µm to 200-350 µm and the silicate content of the ore is about 26-35% compared to 17-20% in the UFG duty. It should be noted that the use of coarser grinding media, whilst impacting the liners with a higher stress intensity due to its larger size, actually assists to reduce the amount of time the coarsest particles spend in the mill and therefore limit their influence on wear. This was demonstrated during the change from 3.5 mm to 5-6 mm media where it was assumed that the wear rates would increase due to the coarser media presence, however the overall wear rate remained the same due to the reduction in time the coarsest particles spent in the mill. Figure 9 shows some data from another IsaMill™ treating two separate feed types. The media size was the same in both cases but the change in feed size from 80% -75 µm to 40% -75 µm resulted in a nearly 5 fold increase in disc consumption. It is likely that larger media would have reduced the overall wear rate in the mill at the coarser feed size distribution.

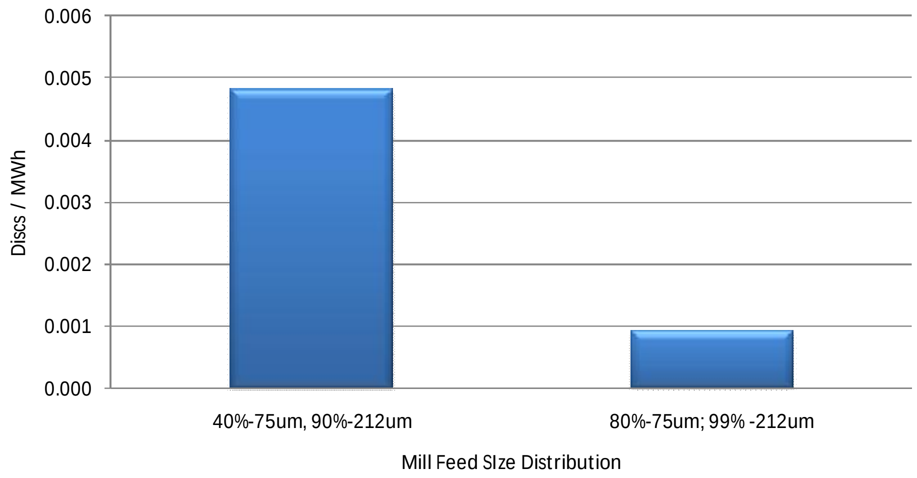

Figure 9 - Effect of Feed Size Distribution on Disc Consumption

In the initial primary grinding trials, the MRM M3000 IsaMill™ was serviced every 400 hours and usually required replacement of the shell liner as well as a complete set of discs. While it was still proving beneficial to the plant to operate the IsaMill™ in this duty there was a real need to reduce the maintenance cost and time.

Based on successful development work for the M10,000 IsaMills™ in South Africa (Rule & de Waal, 2011), a trial using reduced diameter discs (1,050 mm compared to standard 1,200 mm) was made on the M3000 IsaMill™ at McArthur River. The first 7 discs were replaced by the smaller discs, the final disc was left at 1,200 mm so as not to influence the product separator performance. The mill was able to run for 1,200 hours between inspections where a full disc and liner change was required. The drawback was a (not unexpected) reduction in power of about 35% as a result of the reduced diameter, limiting the power draw to about 650-700 kW maximum. The reduction in power draw limited the throughput by the same percentage in order to maintain the same grind performance. The disc consumption per MWh (Figure 10) reduced by more than half, however is still significantly higher than the data presented in Figure 9. Measures to address the power draw issue are discussed later in the paper.

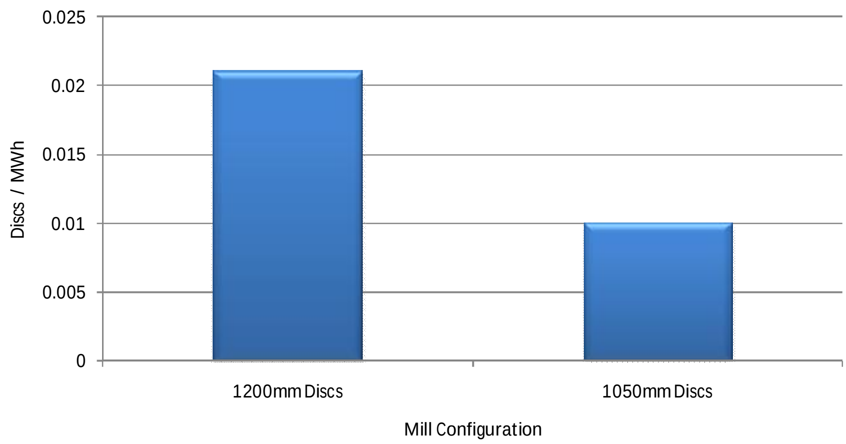

Figure 10 - MRM Disc Consumption Reduction per MWh after Mill Configuration Change

3.0 MW M10,000 IsaMills™

Based on the positive results from the M3000 IsaMill™ testwork and subsequent conversion to full time production, MRM made the decision to purchase and install two 3.0 MW M10,000 IsaMill™ units with the intention that they be configured in the primary grinding duty for the plant expansion. During the project construction phase, the M3000 development work continued. For a variety of reasons including that a lot of development work on the coarse grind had been done on the M3000 IsaMill™ and at that stage there wasn't scope to go through that learning experience again on the M10,000 IsaMill™, it was decided that the M10,000 IsaMills™ would be commissioned into a reconfigured UFG circuit (November 2008). This provided extra UFG capacity for the increased plant throughput and allowed free use of two of the M3000 IsaMills™ for the primary grinding duty.

Only one of the M10,000 IsaMills™ can be currently operated due to power supply limitations at site. The M10,000 currently treats all of the rougher concentrate (precyclone underflow) prior to grinding in the M3000 UFG IsaMills™ to produce the 7-8 µm cleaner feed.

Figure 11 - 3.0 MW M10,000 IsaMills™ at McArthur River

CURRENT PRIMARY GRINDING CIRCUIT PERFORMANCE

Currently, two 1.1 MW M3000 IsaMills™ are used in the primary grinding duties. Each of these mills process 40-60 tph at 80-95 m3/hr. The mills are operating with the reduced diameter discs to extend the service life intervals to 1,200 hours. The operation of both coarse grinding M3000 IsaMills™ allows plant throughput to be increased from 260 tph to 330 tph – a 27% increase in primary tonnage at reduced rougher flotation feed size distribution.

Summarised data from a recent survey across the entire primary grinding circuit is included in Table 2 where the circuit was configured as per Figure 2. The data shows the plant operating at 330 tph with both primary grinding IsaMills™ on line operating at 15 kWhr/t producing a product P_{80} sizing of sub 40 µm from a feed F_{80} of around 250 µm.

The primary grinding circuit is currently constrained by the dewatering capacity of the original double deck SAG discharge screen. The large recirculating load in the circuit is diverted away from the SAG mill and consequently the SAG discharge screen via the tower mill into the cyclone feed sump. The power to tonnage ratio of the tower mill is very low and the size reduction is minimal – however it plays a significant role in this circuit by effectively bypassing slurry around the SAG discharge screen. As a result, when the tower mill is offline for shoe replacements, there is a plant throughput decrease of 60 – 70 tph required to ensure that the screen deck does not become dewatering constrained. New trial pipe work is currently being installed to allow a bypass of the tower mill (during maintenance) – this will allow an evaluation of the real impact of the tower mill on the overall throughput and grind size.

Table 2 - Primary Grinding Circuit Survey Summary

	P_{80}	tph	kW	kWhr/t*
Fresh Feed to SAG Mill	6377	323	3800	11.76
SAG Cyclone Feed	586	1548		
SAG Cyclone OF	87	245		
SAG Cyclone UF	582	1303		
Tower Mill Feed	582	1187	950	0.80
Tower Mill Discharge	571	1187		
1st IsaMill™ Feed	253	39.6	600	15.15
1st IsaMill™ Discharge	43	39.6		
2nd IsaMill™ Feed	247	38.7	600	15.51
2nd IsaMill™ Discharge	36	38.7		
Total Rougher Feed	76	83.4		
Total		323	5950	18.41

*kWhr/t is based on the fresh feed tonnage actually processed through the individual unit.

FUTURE DEVELOPMENT OF THE PRIMARY GRINDING IsaMill™ AT MCARTHUR RIVER

Experience under the extreme grinding conditions of the McArthur River circuit has improved the understanding of wear in the IsaMill™ and the interactions of feed size distribution, feed density, media size, disc design, disc tip speed etc. These learnings have been adapted to other duties to improve wear life in all IsaMill™ applications – UFG, regrind and primary mainstream grinding. Work is currently underway on a number of initiatives to further improve the wear performance at McArthur River.

Laboratory testwork of a redesigned IsaMill™ disc has shown a 25% increase in power draw. Several of these discs will soon be trialled at McArthur River with the aim of restoring the mill to its full 1 MW power draw, thereby allowing further throughput increases using the M3000 IsaMills™.

Investigations into retrofitting the latest design M5000 (5,000 litre) IsaMill™ shell to the existing M3000 layout are underway. This would permit the mill to operate with the standard 1,200mm diameter discs at lower wear rates and regain the full power draw potential. The M5000 was developed as a result of lessons learned from the McArthur River experience. It is aimed at several market areas but its key advantage is in its geometry which allows it the ability to treat coarse feed distributions and draw up to 1.5MW without the high wear issues experienced in the M3000, which was specifically designed for UFG applications.

FUTURE DEVELOPMENT OF THE PRIMARY GRINDING CIRCUIT AT MCARTHUR RIVER

Xstrata Zinc has recently announced a proposed Phase 3 Development for McArthur River which includes increasing the processing capacity to 5 mtpa. The primary grinding circuit options for this increase are currently under investigation - with 3.0MW M10,000 IsaMills™ included in each of the cases under consideration. The M10,000 IsaMills™ will be used in either a secondary or tertiary duty to take F_{80} 150 µm feed to the rougher flotation feed size of P_{80} 45 µm. These mills will be configured in a similar manner to the two existing M10,000 mills, providing operational options for either primary or regrind duty. The project is scheduled to commission in 2014.

CONCLUSIONS

Successful laboratory, pilot scale and full scale testwork has seen the incorporation of IsaMill™ technology into the primary grinding circuit at McArthur River. The IsaMill™ has now been part of the primary grinding circuit for more than four years. The use of two IsaMills™ in the primary circuit has enabled a 27% increase in primary grinding throughput.

Significant improvements were made to the IsaMill™ wear performance albeit at some sacrifice of power draw and mill throughput. Initiatives are underway to recover the lost power draw without losing all of the gains made in wear performance. Learnings from this application have improved understanding of wear mechanisms and have led to improved designs for all IsaMill™ applications.

The success of the work is reflected in the fact that additional 3.0MW M10,000 IsaMills™ are under consideration for use in the primary grinding circuit of the upcoming expansion to 5mtpa processing capacity.

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NOMENCLATURE

kWhr/t = specific energy

REFERENCES

Anderson, G.S. & Burford, B.D. (2006). *IsaMill – The crossover from ultrafine to coarse grinding*, in Proceedings MetPlant 2006, Perth, Australia.

Anderson, G.S. (2006a). *SAG cyclone underflow grinding: M20 pilot plant – stage 1.* (Internal Technical Report). Brisbane, Australia.

Anderson, G.S. (2006b). *SAG cyclone underflow grinding: M20 pilot plant – stage 2.* (Internal Technical Report). Brisbane, Australia.

Buys, S., Rule, C. & Curry, D.C. (2005). *The application of large scale stirred milling to the retreatment of Merensky platinum tailings,* in Proceedings of the 37th Meeting of the Canadian Mineral Processors (CMP 2005) , Ottawa, Canada.

Curry, D.C., Clark L.W. & Rule C. (2005). *Collaborative technology development – Design and operation of the world's largest stirred mill,* in Proceedings of the Randol Innovative Metallurgy Conference 2005, Perth, Australia.

Curry, D.C. & Clermont, B (2005). *Improving the efficiency of fine grinding,* in Proceedings of the Randol Innovative Metallurgy Conference 2005, Perth, Australia.

Enderle, U., Woodall, P., Duffy, M., & Johnson, N.W. (1997). *Stirred mill technology for regrinding McArthur River and Mount Isa zinc/lead ores,* in Proceedings of the XX IMPC 1997, Aachen, Germany.

Logan, R.G., Leung, K & Karelse, G.J. (1993). *The McArthur River project,* in Proceedings of the International Symposium on Zinc (World Zinc 1993), Hobart, Australia.

Nihill, D.N., Stewart, C.M., Bowen, P. (1998). *The McArthur River mine – The first years of operation,* in Proceedings of AusIMM '98 – The Mining Cycle (1998), Mt Isa, Australia.

Pease, J.D., Anderson, G.S., Curry, D.C., Kazakoff, J., Musa, F., Shi, F. & Rule, C. (2006). *Autogenous and inert milling using the IsaMill,* in Proceedings SAG 2006, Vancouver, Canada.

Rule, C. (2010). *Stirred milling – New comminution technology in the PGM industry,* in Proceedings The 4th International Platinum Conference, Platinum in Transition 'Boom or Bust', SAIMM, Capetown, South Africa.

Rule, C. & deWaal, H (2011). *IsaMill design improvements and operational performance at Anglo Platinum*, in Proceedings MetPlant 2011, Perth, Australia