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IsaMill™ Design Improvements and Operational Performance at Anglo Platinum

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ABSTRACT

In 2003, Anglo Platinum, in a joint development with Xstrata Technology, installed the world's first 10 000 litre IsaMill™ in a concentrate regrind duty at the Western Limb Tailings Re-treatment Plant. The success of that installation was the enabling event for Anglo Platinum to proceed with a substantial investment in horizontal stirred milling technology. Since 2006 an additional three IsaMills™ in concentrate regrind duties and a further 18 IsaMills™ in the more technically challenging coarse grinding mainstream applications, have been commissioned in group Concentrator operations - bringing the total number of IsaMills™ installed in Anglo Platinum plants to 22 .

A collaborative approach between Anglo Platinum and Xstrata Technology towards improving milling efficiency and reducing operating costs, through internal mill component wear optimization and operating recipe development, has resulted in further improvements in the overall success of IsaMills™ in the flow sheets of many Anglo Platinum operations. The addition of IsaMills™ in the Anglo Platinum flow sheets has improved plant PGM recoveries by as much as 5%.
This paper explores the improvements made to the IsaMills™ flow sheet and mill internal design and shares some of the operating experience with IsaMills™ technology in Anglo Platinum

INTRODUCTION

IsaMill™ technology has been applied to a number of different ore types and process applications in an ongoing drive to liberate valuable minerals from complex ore bodies.

The need for ultrafine grinding arose at McArthur River mine in the Northern Territory of Australia where finely grained lead/zinc concentrates required a grind size P80 of 7 microns to produce a saleable product. The high energy intensity and inert grinding benefits of this unique stirred milling technology further contributed to producing a suitable final concentrate (Barns et al., 2006).

Anglo Platinum pursued stirred milling technology as an economically viable option to improve liberation following successful scoping work on bench scale initially using a 4 liter bench scale IsaMill™. Thereafter a series of off-site and onsite pilot scale tests were conducted which ultimately led to the installation of a large scale 10 000 liter mill at their Western Limb tailings retreatment project. This mill has subsequently been deployed in a number of grinding duties with varying coarseness of feed, allowing investigation on the wear rates of mill internals (Rule C M, 2010).

Further requirements for liberation of finely grained platinum group metals (PGM's) in the main stream process flow resulted in IsaMills^{TM} allocated to a coarser grind duty as tertiary grinding applications, producing a pre-scavenging flotation product at an approximate P80 of 53 microns (µm).

The coarse grinding applications typically receive feed at F80 of up to 100 µm although coarser feed sizes of ten – 15 % >150 µm has been observed in certain cases (Rule et al.,2010)

The coarser feed sizes have been shown to impact negatively on wear performance of grinding discs and wear of shell liners to a lesser extent.

To date Anglo Platinum has installed 17 IsaMills^{TM} in main stream inert grinding (MIG) applications and 4 units in an ultrafine concentrate regrind duty (UFG).

Since the installation of the first MIG mill a number of improvements have been made to subsequent flow sheet designs and mill internal components to optimize the component life and value gained from this technology.

This paper explores some of these changes and highlights the benefits realized and value gained from the collaborative efforts of Anglo Platinum and Xstrata Technology towards unlocking the true potential of IsaMill^{TM} technology in the PGM industry.

DESIGN IMPROVEMENTS

The majority of IsaMills^{TM} in Anglo Platinum have been installed in MIG grinding applications where the mills receive feed from a secondary or tertiary ball mill. IsaMill^{TM} product will then report to a scavenging flotation stage to capitalize on the improved liberation state and flotation kinetics of the ground pulp.

Due to the inherent variability of the upstream operating plant; i.e. highly variable mainstream slurry flow rate and slurry particle size distribution, the need arose to modify the process flow sheet and mill internal component design parameters to better adapt to this variability. Media handling systems were also improved to facilitate faster reloading of media after maintenance inspections with a reduction in mechanical wear on this equipment and an improvement in spillage generation and media accounting.

Constant Flow Concept

The internal classification functionality of the IsaMill^{TM} utilizes a product separator at the discharge end of the mill to centrifuge coarse material to the outer circumference of the mill and transport this material back towards the feed end of the mill.

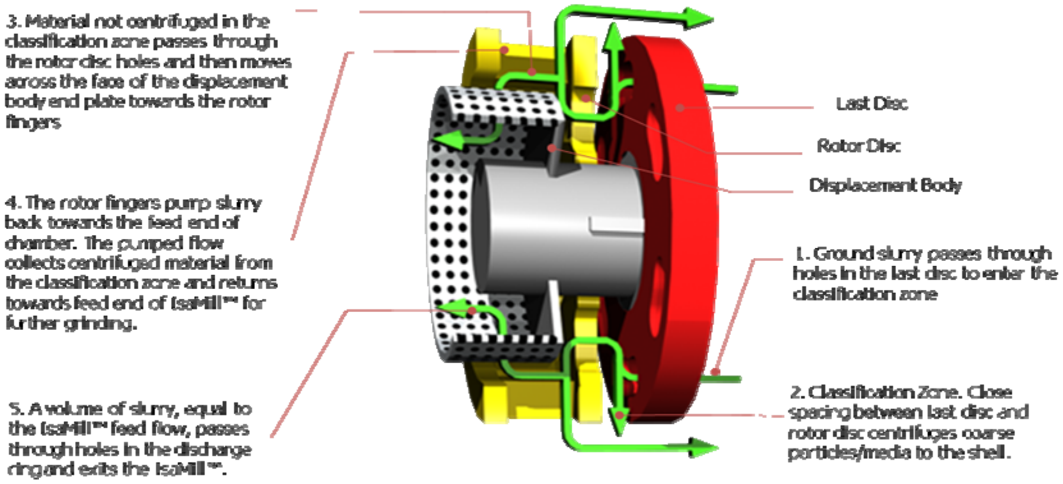


Fig. 1. IsaMill^{TM} internal classification

Fig. 1. depicts the internal configuration of the IsaMill^{TM} detailing the classification function performed by the product separator (rotor).

Due to the pumping effect of the product separator towards the feed end of the mill a certain degree of compression is generated towards the feed end of the IsaMill^{TM}. Slurry feed into the mill counteracts this back pressure to provide a net positive flow through the mill. Conventional PI level control in the IsaMill^{TM} feed tank cascades the change in feed tank level onto a flow rate set point for the feed pump. A reduction in volumetric flow rate into the IsaMill^{TM} circuit due to upstream process changes will result in a reduction in flow rate into the IsaMill^{TM} and subsequent increase in compression towards the feed end of the IsaMill^{TM}. This concentrates the grinding action towards the front end of the mill with the majority of the grinding chambers not contacting with a slurry / media mixture, and promoted uneven and accelerated wear rates of mill grinding discs particularly towards the feed end of the IsaMill^{TM}.

A constant flow concept was subsequently devised to fix the flow rate set point of the IsaMill^{TM} feed pump and return a portion of the milled product to the feed tank, thus maintaining feed tank level set point while achieving a constant flow. The original valves in the discharge line was used during the starting and shut down procedures, these were replaced by ceramic lined variable split range control valves during the modification. The recycled portion should however be maintained to a minimum and advanced process controllers were utilized to maintain the recycle portion to a minimum as shown in Fig. 2.

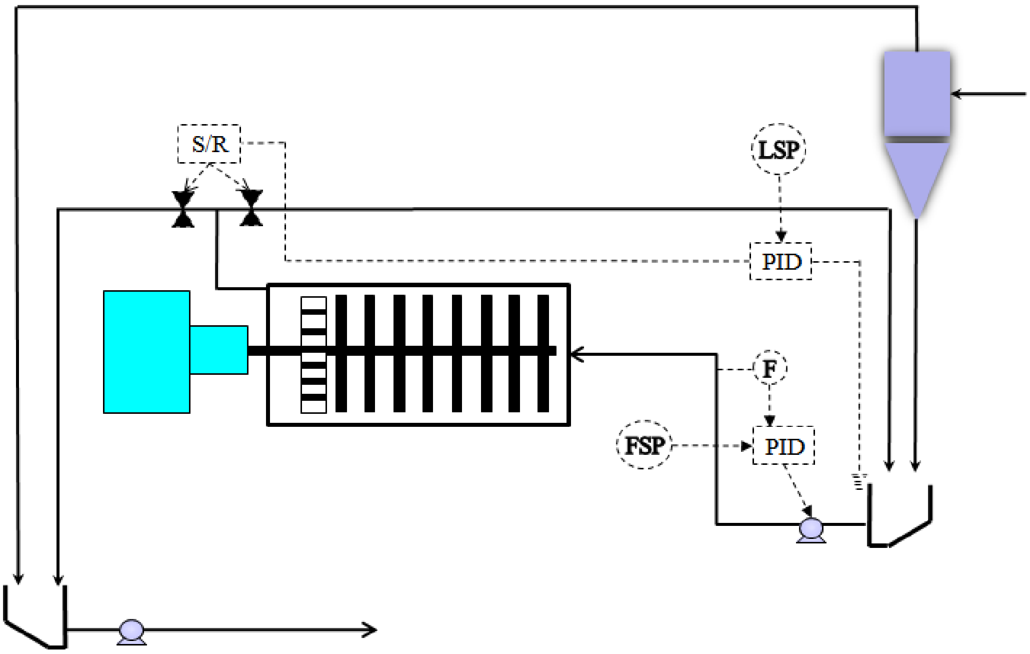


Fig. 2. – IsaMill™ recycle flow control

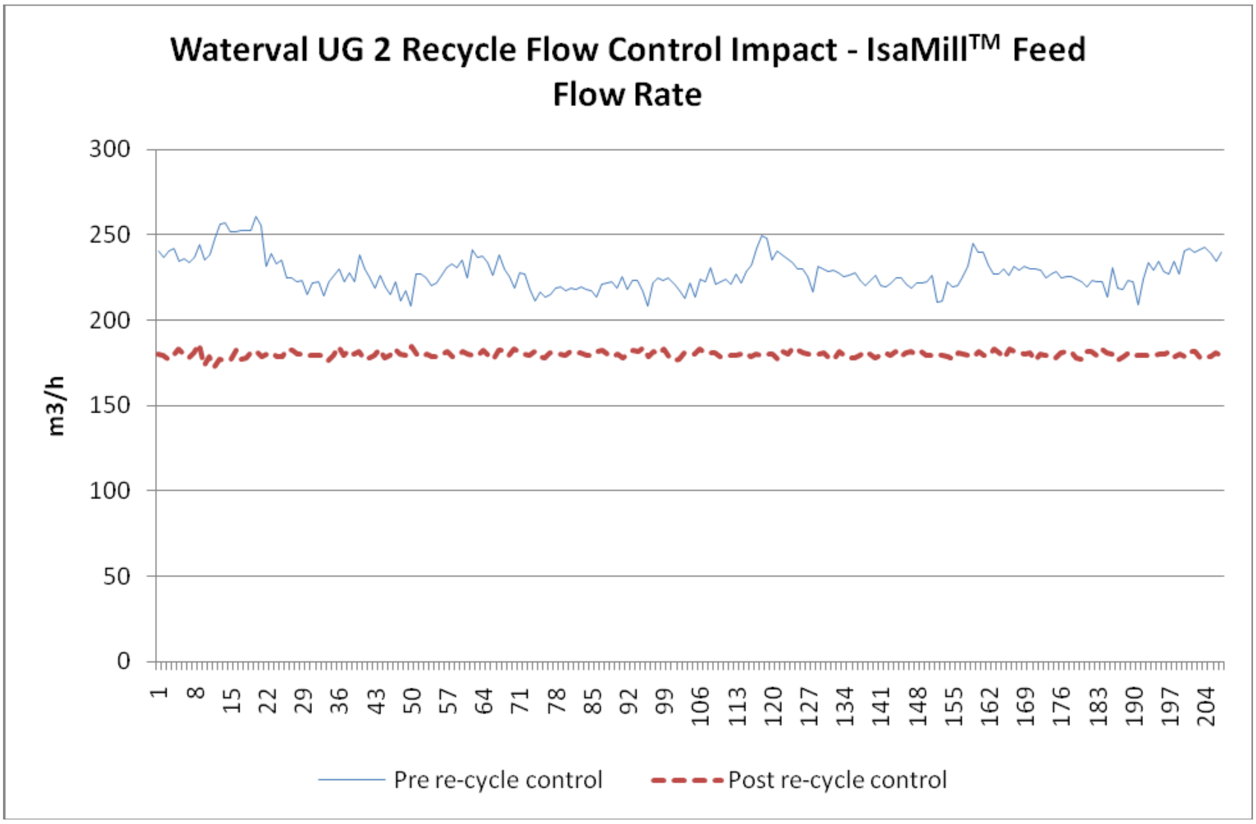


Fig. 3. – Waterval UG 2 A-Section IsaMill™ Flow Control Impact

The result of the new control system can be seen in Fig. 3. where the stability of feed flow increased drastically after the modifications to the recycle flow control were made to this mill. The operating recipe was also altered to achieve the best media distribution and grinding efficiency, thus the reduction in slurry feed flow rate set point to 180 m^3/h. The average flow rate achieved before re-cycle flow control was between 200 and 250 m^3/h, the variability in flow rate during normal plant operation can result in drastic changes in feed flow rate to as low as 50 m3/h as displayed in Fig. 4. The modification to recycle flow control has proven to be significant during periods of low feed flow to the IsaMill™ circuit.

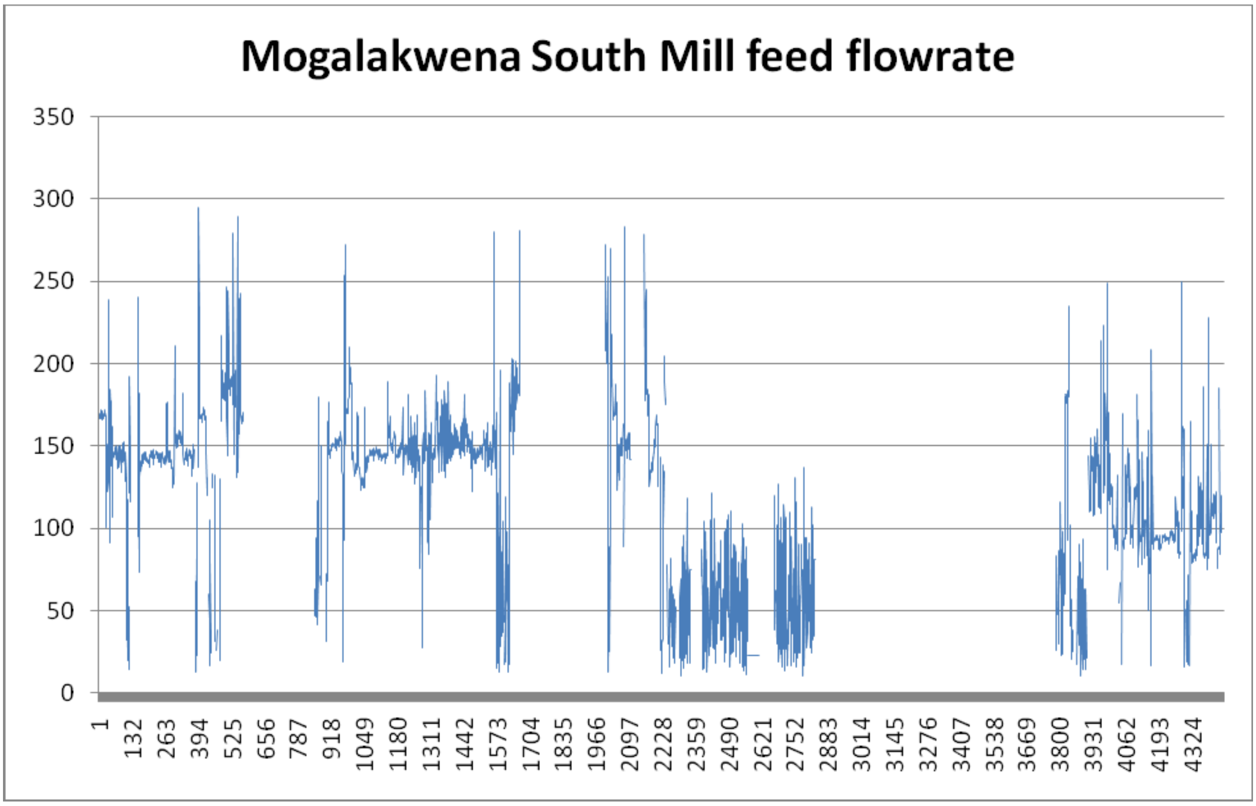


Fig. 4. – Mogalakwena South IsaMill™ Feed Flow Rate

All MIG installations in Anglo Platinum have subsequently been fitted with this modification with similar improvements in flow rate stability realized.

Reduced Diameter Discs (RDD's)

Case Study One – Mogalakwena South Concentrator disc trial

The major wear component inside the MIG IsaMills™ in Anglo Platinum is the grinding disc which enables the agitation of media for attrition grinding between agitated media and solid particles in the slurry stream.

The original grinding discs at 1720 mm in diameter showed some degree of wear particularly towards the feed end of the mill. The high tip speeds and distance between the disc outer circumference and mill shell resulted in accelerated wear of the discs and shell liner.

The MIG installations in Anglo Platinum have displayed the most aggressive wear rates of all main stream installations worldwide. Installations in a main stream copper processing plant in Australia have shown much lower wear rates at similar specific energy consumptions as the Anglo Platinum installations (refer to Fig. 8.) This could be attributed to the specific mineralogy of the reefs in the Bushveld complex mined for its PGM content. Many Anglo Platinum operations treat Upper Group 2 (UG2) reef known for its chromite spinel content, which comprise about 70 % of the Chromitite reef. The angular crystal structure and high specific gravity of chromite can contribute to higher wear rates on grinding discs if allowed to accumulate inside the IsaMill™. Chromite content in the mill can be controlled by ensuring that coarse chromite is treated separately from the IsaMill™ circuit or that the size fraction of chromite reporting to the IsaMill™ circuit has been sufficiently reduced to allow treatment through the IsaMill™. Typical F95 sizes suitable for treatment through the mill are approximately 110 - 115µm. This grind can normally be achieved with conventional ball mills as a pre-IsaMilling stage.

Merensky and Plat Reefs also form part of the PGM rich deposits in the Bushveld Complex.
Less aggressive component wear rates have been reported for the mills deployed in a MIG duty on these reefs although the pyroxenite gangue rock associated with the Merensky reef and the weathering alteration effect on Plat Reef are known to be some of the hardest ore types to beneficiate.

The main wear dimension on the grinding discs was in thickness wear with much lower wear rates recorded in disc diameter. Disc replacement requirements are mainly as a result of width or thickness wear where the steel reinforcing inside the rubber moulded discs are exposed after the majority of rubber has worn away, thus necessitating the replacement of a disc. .

The first IsaMills™ where reduced diameter discs were installed was at Mogalakwena South's C Section IsaMill™. This mill was installed in a tertiary grinding application receiving feed from the secondary ball mill product stream. Slurry entered the IsaMill™ circuit at a P80 of 75 µm producing a product at P80 53 µm.

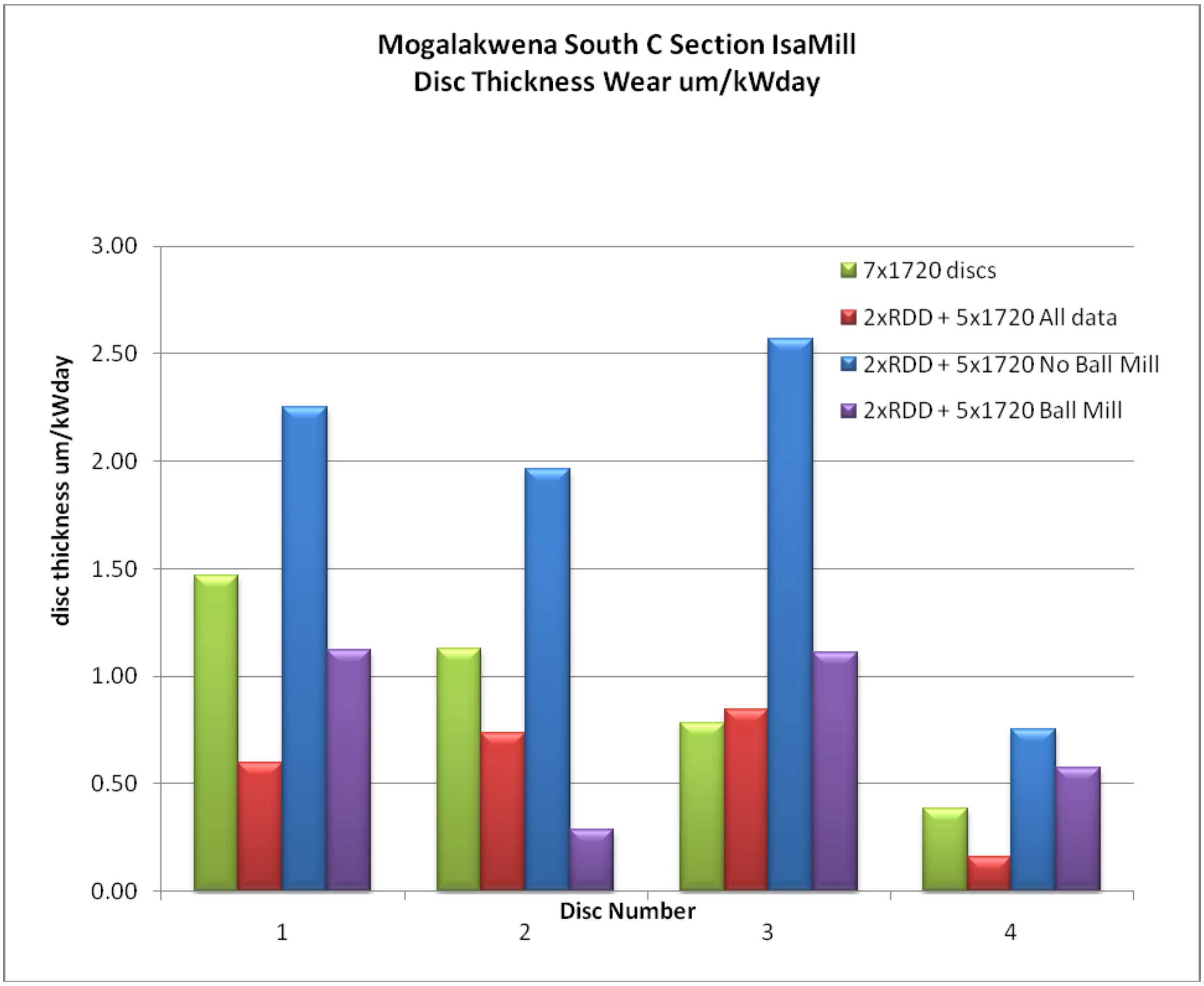


Fig. 5. – Grinding disc wear rate comparison

Fig. 5. show the reduction in disc thickness wear after changing to reduced diameter discs from normal discs. An immediate reduction in wear rates can be observed in grinding discs 1 and 2.

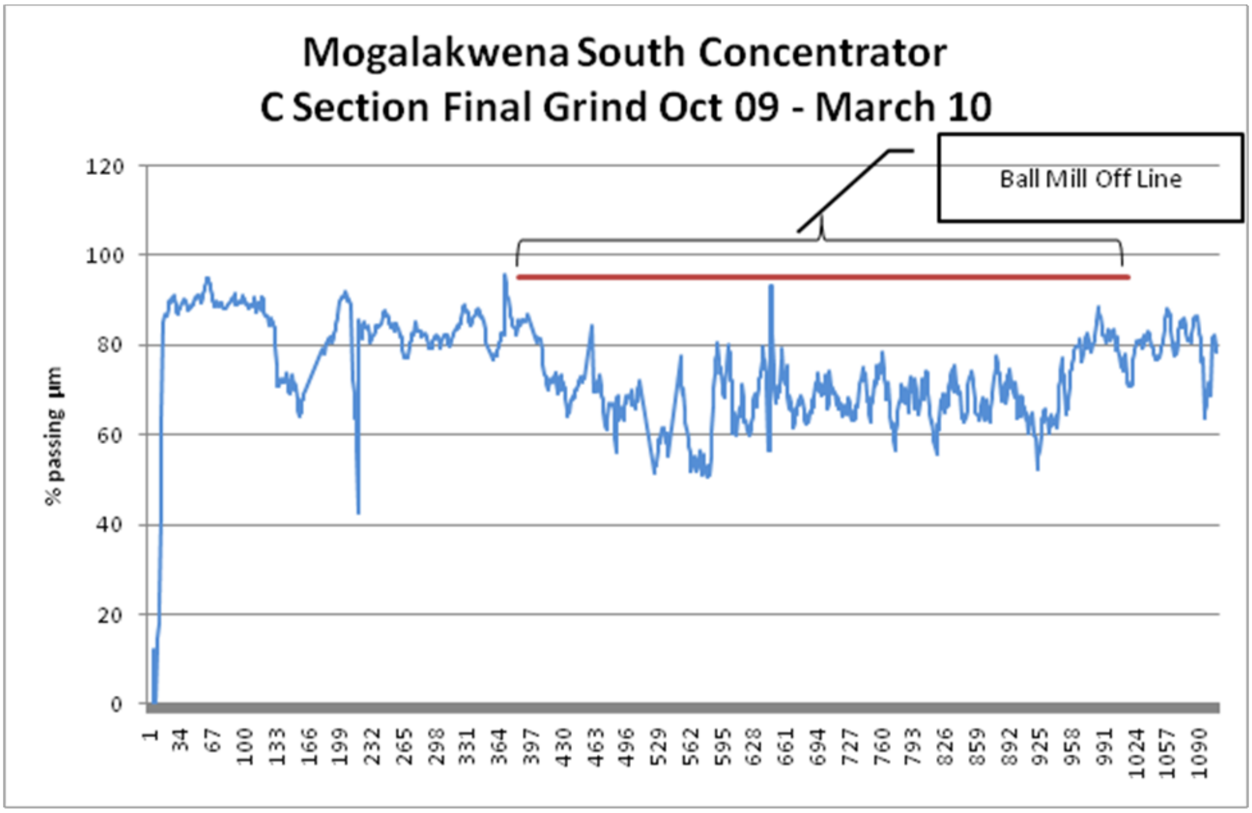


Fig. 6. – Mogalakwena South C Section Final Grind

Of additional interest is the effect of slurry feed particle size distribution on disc thickness wear. The IsaMill™ was employed in secondary regrind duty for a period when the secondary ball mill was off line for major repairs. During this period the feed particle size distribution to the IsaMill™ circuit increased due to the absence of the secondary ball mill in the circuit, with a consequential increase in disc wear rates.

Fig. 6. displays the reduction in final grind during the period while the secondary ball mill was off line. No process data was available for IsaMill™ feed particle size distribution but the final tailings grind clearly shows a reduction in grind during the period in question. The operating recipe of the IsaMill™ remained the same with no changes to grinding media type or size and the same specific energy (kWh/ton) throughout.

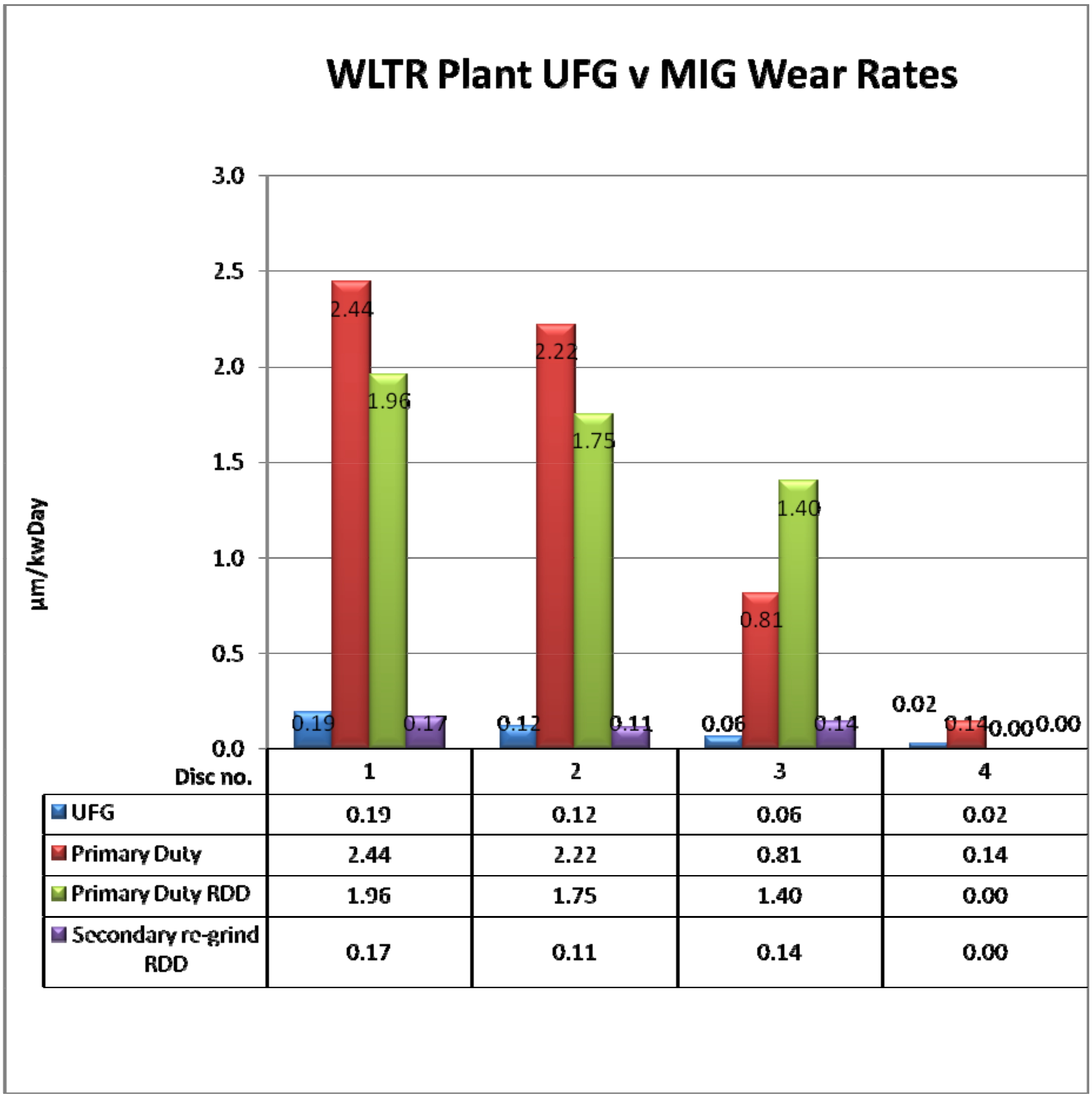
Once the secondary ball mill was returned to duty the disc width wear rates reduced although not to previous rates observed when originally switching to reduced diameter discs. This could be attributed to a change in the pebble crushing circuit preceding the grinding circuit in C Section, where the cut point of final product from the crushing circuit was increased to capitalise on the expected additional grinding capacity with the re-introduction of the secondary ball mill into the circuit.

Case Study 2 – Western Limb Tailings Re-treatment Concentrator reduced diameter disc performance

The IsaMill™ at the Western Limb Tailings Re-treatment (WLTR) Concentrator was originally installed as a concentrate regrind mill. The WLTR plant processes PGM tailings material from historical dumps in the greater Anglo Platinum Rustenburg concentrator operations area.

This mill was later converted from using sand as grinding media to ceramic beads to allow treatment of coarser slurries in main stream grinding applications.

Initial disc width wear while in concentrate regrind duty was between 0.19 – 0.02 µm/kWday. See Fig. 7.



Disc no.	1	2	3	4
UFG	0.19	0.12	0.06	0.02
Primary Duty	2.44	2.22	0.81	0.14
Primary Duty RDD	1.96	1.75	1.40	0.00
Secondary re-grind RDD	0.17	0.11	0.14	0.00

Fig. 7. – WLTR Concentrator comparative disc wear rates

Disc wear rates increased rapidly to 2.44 µm/kWday when the mill was deployed as a primary grinding unit treating ore in a parallel side stream to the primary ball mill. Reduced diameter discs were then installed on discs one and two with normal diameter discs remaining in the rest of the mill. Disc width wear rates reduced on the first two positions with an expected increase in wear rate on disc three due to a shift in the media distribution profile towards the discharge end of the mill. In essence the discs after the first two discs started working a bit harder and this was illustrated in the increase in wear rates on disc three.

Comparative wear data

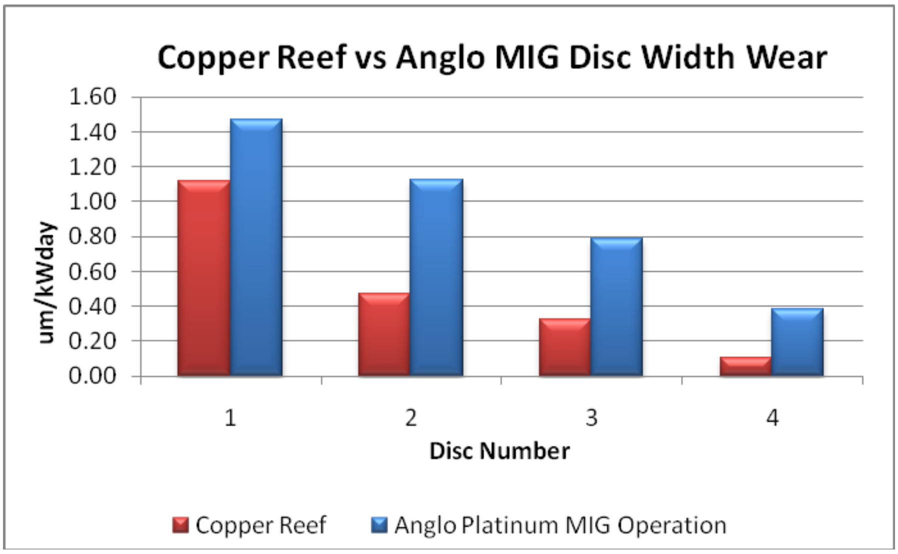


Fig. 8. – Comparison between PGM and Copper reef disc wear rates

Disc width wear rates in the majority of MIG installations in Anglo Platinum have shown significant differences when compared with "softer" ore types. A typical MIG installation on a copper ore as trended in Fig. 8. shows the difference in wear rates between this IsaMill^{TM} and Mogalakwena C Section IsaMill^{TM}. Both these mills operate on very similar specific energy consumptions with similar operating recipes.

IsaCharger™ hydraulic media transfer

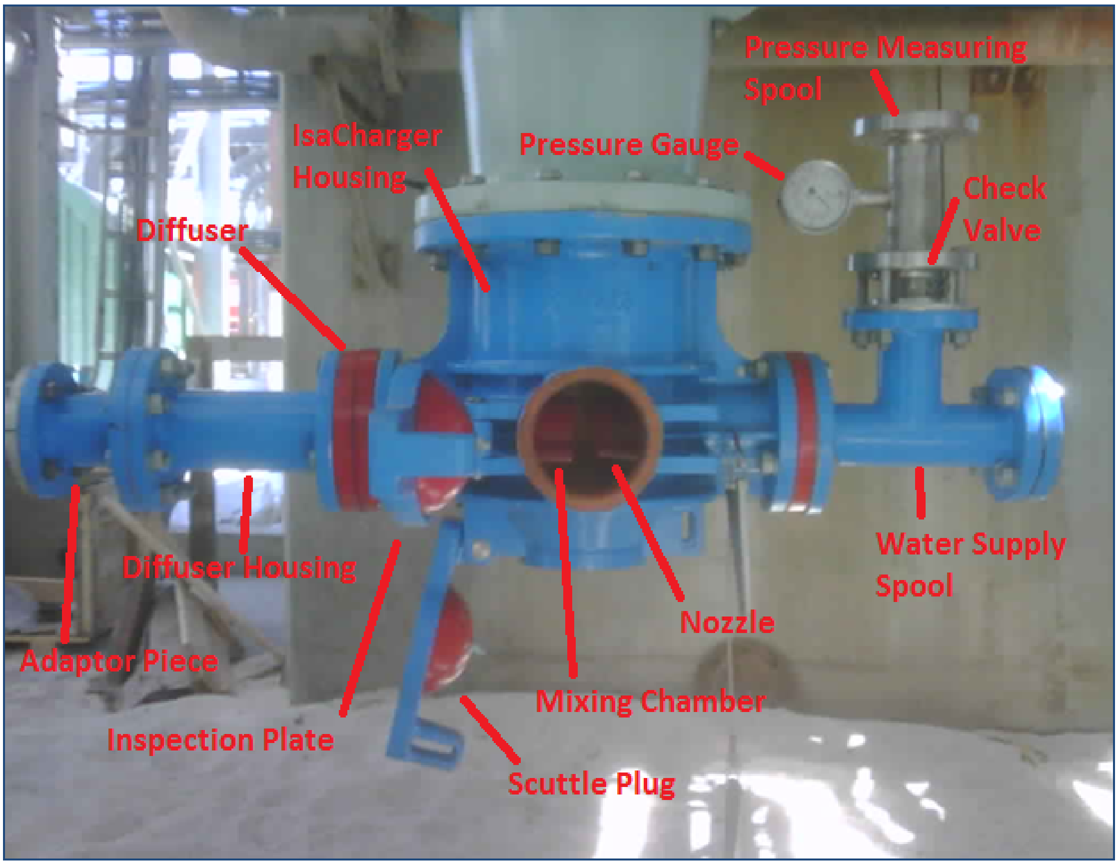


Fig. 9. – IsaCharger™ unit

The IsaMill™ require that the complete grinding media charge be removed from the mill prior to an internal inspection. A media hopper is situated underneath the mill shell to contain media scuttled from the mill. The media hopper is also used to store new media required to replenish the mill charge as the media is consumed as part of the grinding process. A screw feeder was originally used to transfer ceramic media from the media hopper into the IsaMill™ feed tank, from where it is pumped into the IsaMill™ as a slurry/media mixture.

The screw feeder consisted of numerous moving mechanical parts like gland seals, greased bearings etc. which required routine maintenance interventions to ensure high equipment availability was maintained. Xstrata Technology subsequently developed a hydraulic transfer device called "IsaCharger" to transfer media from the media hopper to the feed tank. The IsaCharger™ consists of no moving mechanical parts and utilizes a custom built high pressure venturi type device to transfer media by means of a high powered jet of water from underneath the media hopper into the mill feed tank. See Fig. 9.

Most IsaMill™ installations in Anglo platinum have been fitted with IsaChargers™ with reported improvements in equipment on-line and similar media recharge times as achieved by the original screw feeders.

To date no maintenance interventions have been required on any of these units installed on the Anglo Platinum IsaMills™. Some of the units have been in operation for up to 6 months.

OPERATIONAL PERFORMANCE

Case Study – Amandelbult Concentrator UG 2 # 2 Plant

Fig. 10. – Amandelbult UG 2 IsaMills™ showing MIG and UFG concentrate regrind mills.

Table 1 – IsaMill™ installations at Amandelbult

Plant	Number and duty	Total Installed Power (kW)	Commissioning Date
Merensky	2 Parallel Tertiary MIG M 10 000	6 000	April 2009
UG 2 no. 1	1 Tertiary MIG M10 000	3 000	April 2009
UG 2 no. 2	1 Tertiary MIG M 10 000	3 000	March 2009
UG 2 no. 2	1 UFG, M 3 000	1 500	March 2009

Table 1 list the IsaMills™ installed at Amandelbult.

The Merensky IsaMill™ circuit comprises two 10 000 liter mills treating Merensky reef exclusively while the two UG 2 plants combined contribute approximately 57 % of the total production throughput at Amandelbult.

The importance of UG 2 reef as a contributor towards the total PGM ounces produced at Amandelbult is apparent and optimizing the PGM recovery for this reef type is vital.

The UG 2 # 2 plant IsaMill™ ties into the plant flow sheet as a tertiary regrind mill on the silicate stream. Chromite is removed from the process stream by means of cyclones after the primary roughing flotation stage. The chromite stream reports to a dedicated tumbling mill regrind circuit while the silicate stream is reground in a secondary ball mill prior to reporting to the IsaMill™ circuit. Fig. 11. illustrate the basic flow sheet of this circuit.

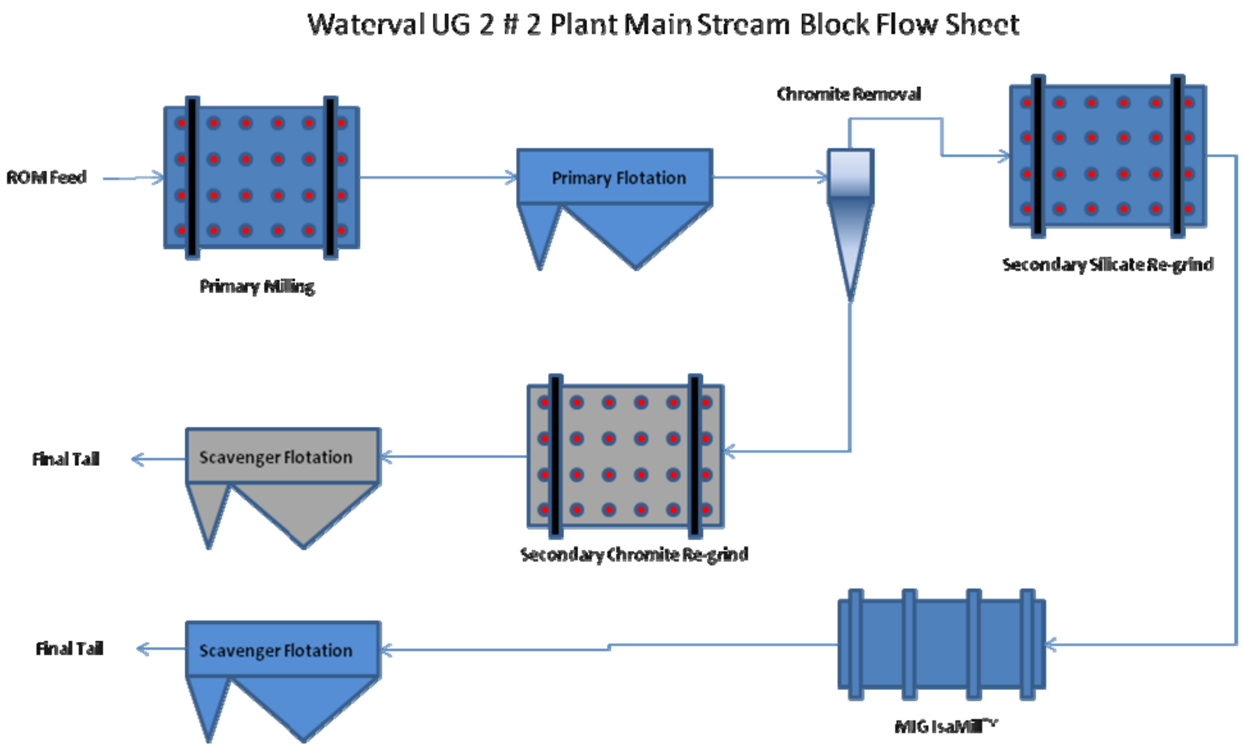


Fig. 11. – Amandelbult UG 2 # 2 Plant basic flow diagram.

This case study on the Amandelbult UG 2 # 2 plant explores the performance of the IsaMill™ and quantifies the benefit realized after commissioning of the IsaMills™

UG 2 Plant Mineralogy

Table 2 details the mineral association in composite samples from the plant pre-IsaMill installation.

A significant portion of PGM's are enclosed in gangue as a result of incomplete liberation, in particular the > 53 µm fractions in the final tailings sample comprise 57 % of mineral deportment in tailings in that size fraction.

The liberation issues on the final tailings streams could be addressed through main stream inert grinding with ultrafine concentrate regrinding of attached mineral particles in the sub 25 µm size ranges.

Table 2 – Mineral Association table for typical Amandelbult UG 2 process samples

Association	Feed	Concentrate	Tailings	Tailings <10 µm	Tailings >10 µm	Tailings >53 µm
Liberated	49.2	53.1	31.3	82.3	18.5	2.4
Enclosed in BMS*	23.6	15.8	4.7	4.1	9.7	1.6
Attached to BMS	7.9	12.7	0.3	0.4	0.6	-
PGM/BMS/Silicate	5.6	6	7.7	-	5.6	15.5
Enclosed in Silicate	7.5	8.4	36.0	2.7	44.3	57.0
Attached to Silicate	0.6	2.7	9.3	3.5	13.9	6.8
Enclosed in Oxide	4.8	1.3	7.6	4.3	6.0	11.7
Attached to Oxide	0.8	-	3.1	2.7	1.4	5.0
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0
Midlings	7.2	14.6	7.0	8.3	14.8	-
Locked	43.6	32.1	61.7	9.4	66.7	97.6

**BMS – Base metal sulphides*

Grind Performance

The grind performance achieved by the MIG IsaMill^{TM} on the UG 2 # 2 plant showed significant reduction in the coarser size fractions (>150 µm) with a marked improvement in IsaMill^{TM} product towards the end of 2010. This improvement was mainly due to an increase in mill power draw from 1500 kW to 2000 kW as illustrated in Fig. 12.

Fig. 13. illustrate the increase in finer size fractions passing 53 µm primarily as a result of the increased power draw. This result is vitally important for the UG 2 operations as a significant proportion of PGM's was locked in the > 53 µm fraction of the final tailings plant composite samples. Ref. Table 2.

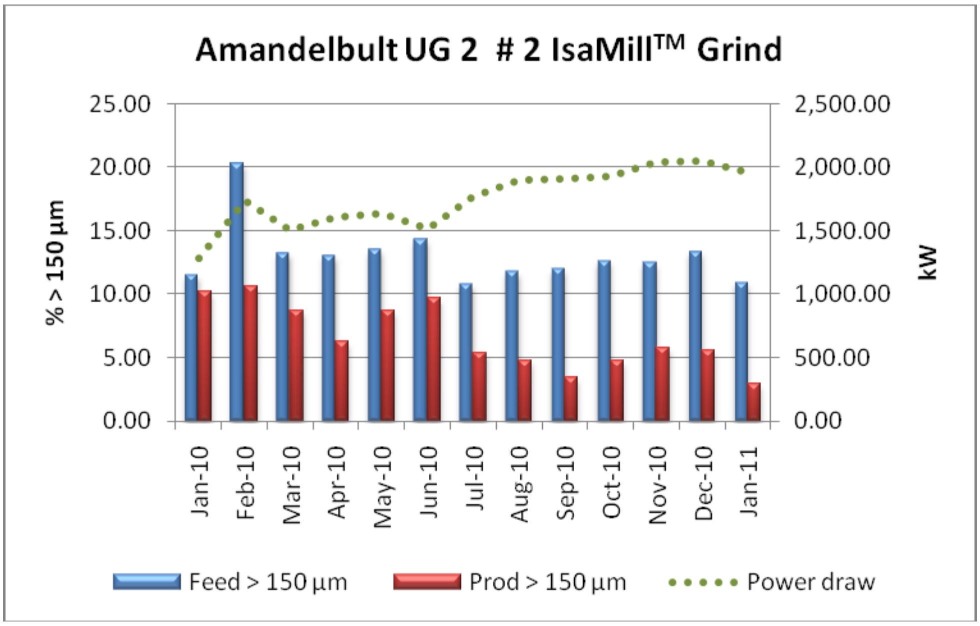


Fig. 12. – Amandelbult UG 2 coarse fraction size reduction

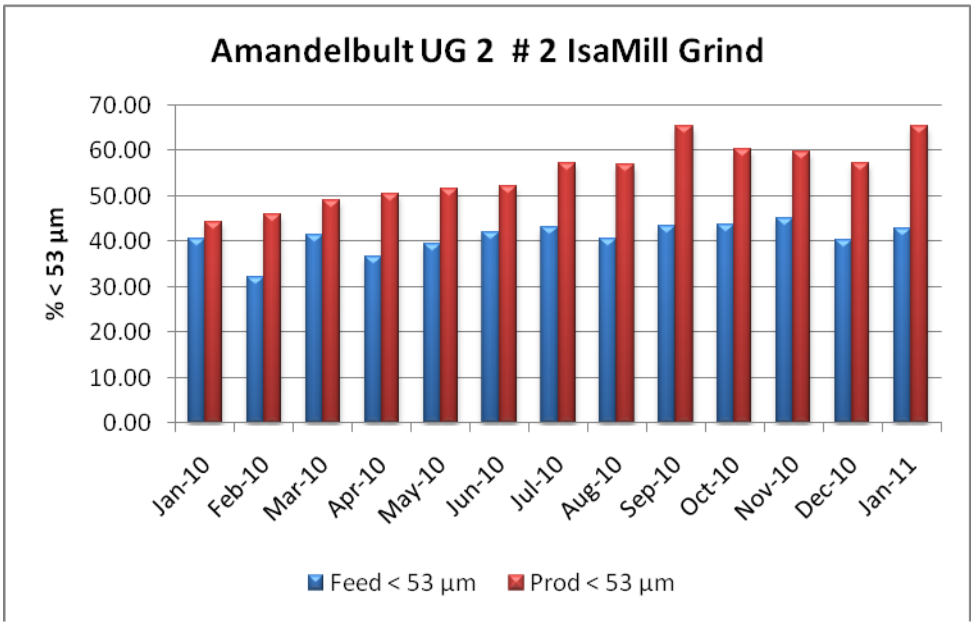


Fig. 13. – Amandelbult UG 2 fine fraction size reduction

Recovery benefit

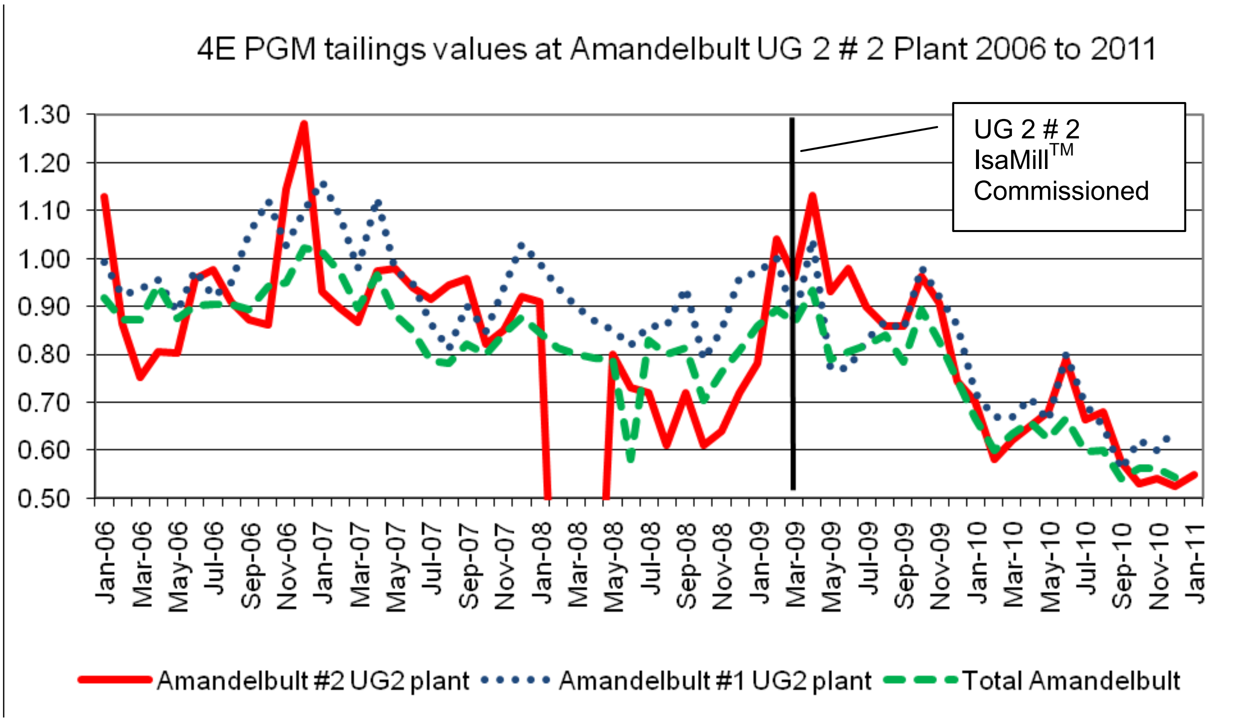


Fig. 14. – Amandelbult UG 2 fine fraction size reduction

Fig. 14. shows the historical tailings grades achieved in the two UG 2 plants as well as the contribution of these two process streams towards the final tailings grade of the concentrator complex. The IsaMills™ were commissioned in March and April 2009 and after a period of grinding and flotation circuit optimization, the tailings grades shows a marked improvement with tailings grades averaging between 0.5 and 0.6 g/t PGM and gold.

The reduction in final tailings grades on the other Anglo Platinum operations where IsaMills™ have been installed has shown similar trends as in the Amandelbult UG 2 # 2 plant.

CONCLUSIONS

IsaMill™ horizontal stirred mills have been successfully introduced in the majority of Anglo Platinum's operations in South Africa. Further advances made in wear component design and circuit layout have further improved the results obtained from these mills from a component wear and grinding efficiency perspectives.

As an illustration to the importance of PGM recovery in the Concentrator Operations in Anglo Platinum, a one % increase in PGM recovery in the concentrators equates to approximately 75 million US$ at recent market prices and exchange rates. The following extract from the Anglo Platinum Annual report for 2009 puts further emphasises on the magnitude of the recovery improvements directly contributed to IsaMills™

"Early indications during the latter part of 2009 were promising; for example, **platinum metal recoveries** for the last quarter of 2009 at Rustenburg increased substantially post IsaMill™ commissioning by **in excess of 3 percentage points."**

ACKNOWLEDGEMENTS

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REFERENCES

Barns K E, Curry D C, Pease J D, Rule C M and Young M F, 2006. Transforming flowsheet design with inert grinding – the IsaMill™, paper presented to CMP conference 2006.

Rule C M, 2010. Stirred Milling – new comminution technology in the PGM industry, paper presented to the 4th International Platinum Conference, platinum in transformation "Boom or Bust", 2010, (The South African Institute of Mining and Metallurgy)

Rule C M, Knopjes, L, Jones, R.A, 2010. The introduction of main stream inert grinding, or "MIG" IsaMilling technology at Anglo Platinum, paper presented to Comminution 2008 conference, 2008.

Anglo Platinum Annual Report, 2009, page 85.