STEP CHANGE IN LINER DESIGN FOR THE KANSANSHI 32FT SAG MILL

*C. Faulkner[1] and S. Mwansa[2]

[1]*Bradken,*
76 Nathan Road
Runcorn, Queensland 4113, Australia
*(*Corresponding author: cfaulkner@bradken.com.au)*

[2]*First Quantum Minerals, Kansanshi Mining PLC*
Off Old Congo Road, PO Box 110385
Solwezi, Zambia

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ABSTRACT

The Kansanshi 32ft SAG mill commissioned in July 2008 operates as the primary grinding mill for the second sulphide (S2) processing Comminution circuit. From commissioning, the 32ft SAG mill was fitted with radial and single high profile shell liners. However, in 2012, a full review of the existing liner design in the 32ft SAG mill was undertaken to investigate the opportunities to increase mill performance and production, reduce the frequency of relines of the liners and increase the wear life in critical areas of the mill. During the early stages of the program, the SAG mill reline machine capabilities were also considered to see what restrictions it played in achieving the end goal. This paper outlines the advances made from 2013, during the implementation of a new innovative design across all areas of the mill lining, including installation of high-low liners, a single directional vortex discharge, as well as the selection of a range of materials to maximise wear life on the overall performance in the Kansanshi 32ft SAG Mill. The paper also shows what the selection of the correct reline machine and SWL capacity has on the liner design and relines times.

KEYWORDS

32ft SAG mill, Liner design, Reline, Vortex discharge, Liner life, throughput.

INTRODUCTION

First Quantum Mining Limited (FQML) Kansanshi mine is the largest copper mine in Africa, and is situated north of the town of Solwezi and 180 kilometres to the northwest of the Copperbelt in Zambia. The Kansanshi mine operates three milling trains, with the largest milling circuit treating about 36,000tpd and comprised of a 32ft primary SAG mill closed with a secondary ball mill and pebble crusher in an SABC circuit configuration. The entire grinding circuit is closed with hydrocyclones with the coarse underflow recirculated back into the grinding circuit and the finer overflow reporting to the flotation circuit giving a product with P80 of 150µm. A picture of the Kansanshi 32ft SAG mill is shown in Figure 1, and a schematic of the S2 Comminution circuit layout is shown in Figure 2.

Figure 1 – The Kansanshi 32ft SAG mill during the night

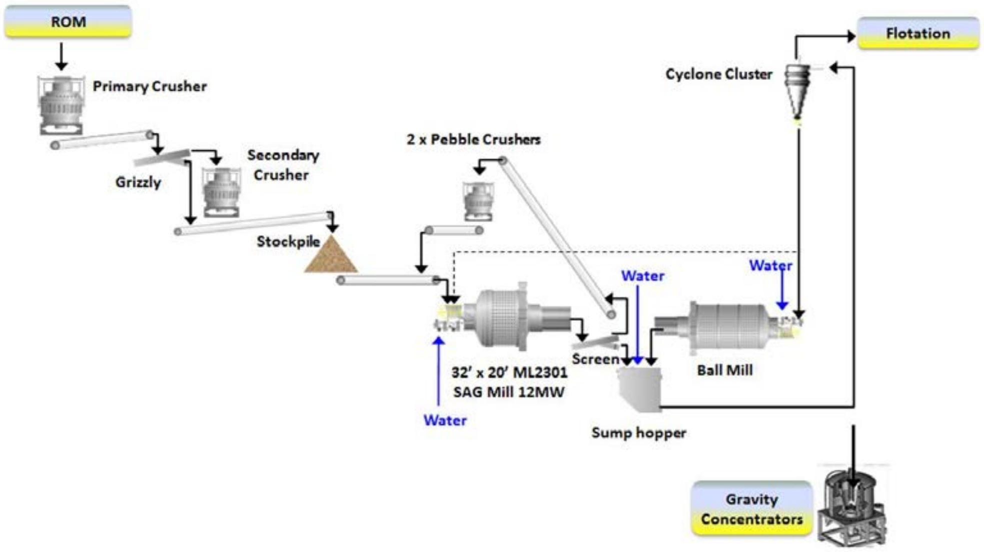

Figure 2 – The Kansanshi Second Sulphide (S2) Comminution Plant layout with the 32ft SAG Mill

The 32ft SAG mill has a design maximum throughput of 1500tph, operating with the coarsest transfer size of 2mm, at a mill discharge percent solids of 75%. The mill discharge is classified on a single deck linear vibrating screen, giving a maximum pebble recycle of 25% on Sulphide ore.

Ore characteristic parameters for the two ore types treated in the Kansanshi 32ft SAG mill are summarised in Table 1.

Table 1 – Ore Characteristics of the two Kansanshi ores Processed through the 32ft SAG mill

Ore	A*b		t_a		Ball BWi at 150µm limiting screen	
	Value	Category	Value	Category	Value	Category
Sulphide	51.0	medium	0.36	hard	8.32	soft
Mixed	47.9	medium	0.54	moderately soft	12.35	medium

From the ore characterisation data in Table 1, it is evident that the Sulphide ore is more competent than the mixed ore relative to impact breakage and is therefore the more difficult ore to process in SAG milling. However, for ball milling, the mixed ore is characterised as moderately soft to abrasion resistance, while the Sulphide ore is considered soft in ball milling. For this study, emphasis is placed on the impact breakage resistance dominant in SAG milling.

Since commissioning in 2008, the 32ft SAG mill processes mostly Sulphide ore, and occasionally based on the mine plan and the ore resource model, mixed ore is also treated through the milling circuit. A historical breakdown of ore swap between Sulphide and mixed ore is summarised in Table 2.

Table 2 – Historical breakdown of Ore type processed annually through the 32ft SAG mill

	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015
Sulphide	Jan-Dec	Jan-Dec	Jan-Aug	May-Dec	Jan-Dec	Jan-May	Aug-
Mixed	-	-	Sep-Dec	Jan-Apr	-	Jun - Dec	Jan-Jul

The proportion of ore type processed through the 32ft SAG mill since commissioning in 2008 as a percentage of the total ore milled per year is summarised in Figure 3. The data shows that from 2008, only Sulphide ore was treated through the 32ft SAG mill until August 2011. The SAG mill has treated Mixed ore on two long spells; first from September 2011 to April 2012, and the second recently from June 2014 until July 2015. The liner change was in January 2013, which makes it possible to compare the mill performance between previous liners as well as the performance relative to the two ore types.

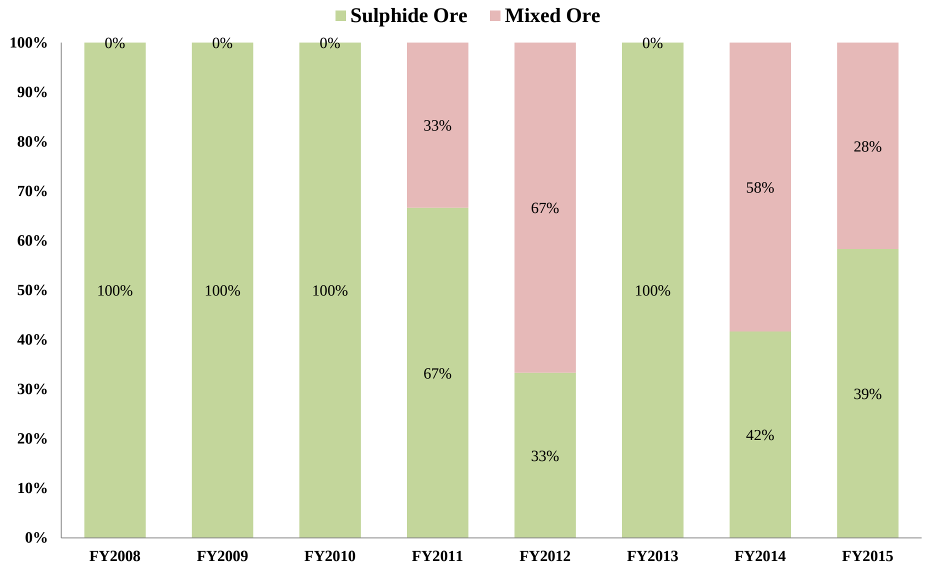

Figure 3 – Proportion of ore type processed through the 32ft SAG mill since Commissioning

The 32ft Kansanshi SAG mill is operated with a traditional bi-directional liner system manufactured from chrome moly steel. The Outotec manufactured mill has a variable speed drive (VSD) and has total installed power of 12MW, supplied by two drives. It has inching capability for barring the mill during retorque or relining. The mill feed chute is retractable and rail mounted, allowing quick pulling of the chute during mill stops.

Key mill equipment data is summarised in Table 3.

Table 3 – The 32ft SAG Mill Key Data Summary

Mill Manufacturer x Motor drive	Outotec x VSD
Mill dimensions (m) – Diameter x Length	9.75 x 6.1
Grate Discharge (mm) – Pebble ports x Grates	60 x 35
Mill Charge (%) – Total x ball load	27 x 16
Top-up make-up ball size (mm)	125
Operating Speed (% critical)	68 to 75
Installed power (MW) – Supplied by 2 drives	12

LINER OPTMISATION IN THE KANSANSHI 32FT SAG MILL

In 2012, liner design optimisation was commenced to combat excessive high wear areas in the 32ft SAG mill. The project scope included upgrading the RME reline machine to handle movement of liners in and out of the mill during shut downs, so as to reduce reline times per annum. The main objectives of the optimisation work were to improve liner life, increase mill throughput, and improve plant profitability as outlined in Napier-Munn *et al* (2005).

Liner Optimisation Design Criteria

Criteria for optimisation of the 32ft SAG mill included incorporation of Discrete Element Modelling (DEM), to determine charge motion for defining the appropriate face angle to achieve the optimal ball and charge trajectory. It was also envisaged to optimise liner life of regular changed parts by the use of alternative wear materials. The new design was to meet criteria of safety whilst making it easy to install. No additional liner mass was to be gained in the new design, and wear data analysis was to be captured during planned mill shut downs, and sections of the mill were to be interchangeable. Figure 4 shows a DEM visualisation for shell liner modelling, highlighting a 2D charge motion trajectory, with colour scale indicating speed profiles and the centre of circulation (slow movement) in blue whilst fast particles are in red colour near the mill toe position.

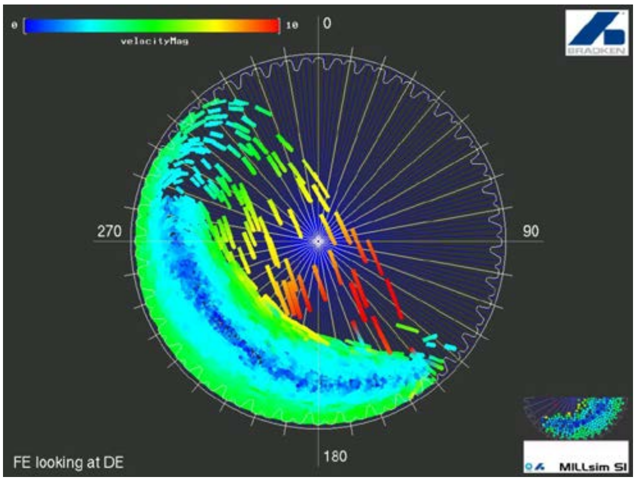

Figure 4 – DEM Shell Liner modelling Visualisation

Finally, maximising liner design required upgrading to a 4.5T RME reline machine shown in Figure 5.

Figure 5 – The 4.5Tonne RME reline machine Installed at Kansanshi

Implementation Process

3D modelling of the mill liner design was conducted, where DEM simulations were run to finalise liner profiling and a transition plan for installation was laid out. For product improvement, a UT wear monitoring system was implemented followed by a full liner installation. Figure 6 shows the general assembly including the feed head, shell, grates, and bullnose that was installed by Bradken in January 2013.

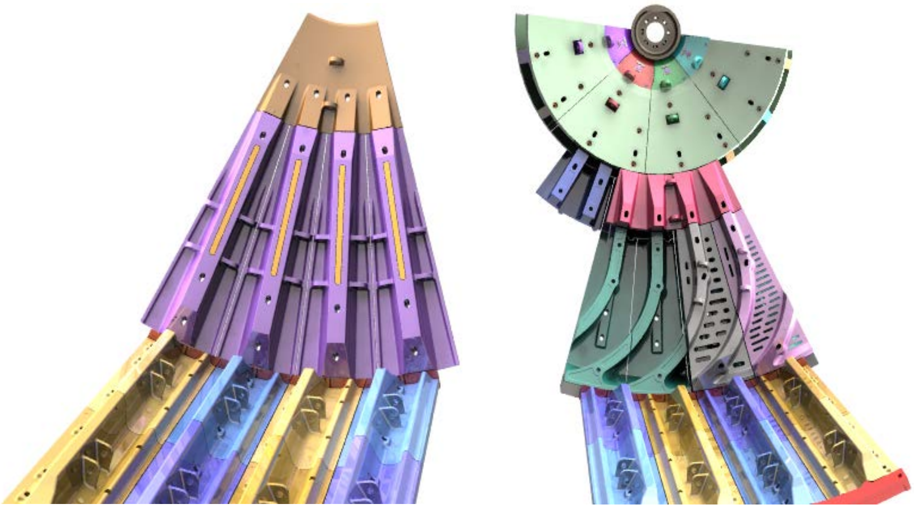

Figure 6 – General assembly of the 32ft Kansanshi SAG mill showing feed and discharge liners

The liner configuration of the Feed End of the mill was enhanced with a single one piece composite liner to include a high chrome insert to combat the high wear zone. The single one piece liner now covers the full volume of the charge and reduces relining annual, which was originally covered by two liners up the length of the mill.

The Shell lining was overhauled with a row reduction integral shell liner with changes to the profile to improve charge trajectories and increase wear life. The two piece shell liner design was optimised to suit the larger capacity reline machine and further reduce the quantity of liners in the shell. Wear data and liner profiling of the worn liners shows the excellent use of the lifter material used during the full liner campaign.

The discharge end of the SAG mill was originally fitted with straight radial grates and pulp lifters, which were replaced by a Bradken Vortex discharge design as shown in Figure 7. The Vortex discharge end encourages early discharge of coarse product and improves pulp movement down the pulp chamber per revolution of the mill, reducing the effects of flow back.

Figure 7 – Vortex discharge design installed

In January 2013, Kansanshi and Bradken successfully and safely completed a full SAG mill reline with a new feed end, shell, grates and pulp lifters. Figure 8 shows the previous discharge cone (left) and the new improved Bullnose discharge cone (right) viewed from the discharge trunnion. The Bullnose discharge cone system is manufactured from composite high chrome and rubber design to improve overall wear life of the product whilst reducing the liner mass over the existing steel discharge cone assembly.

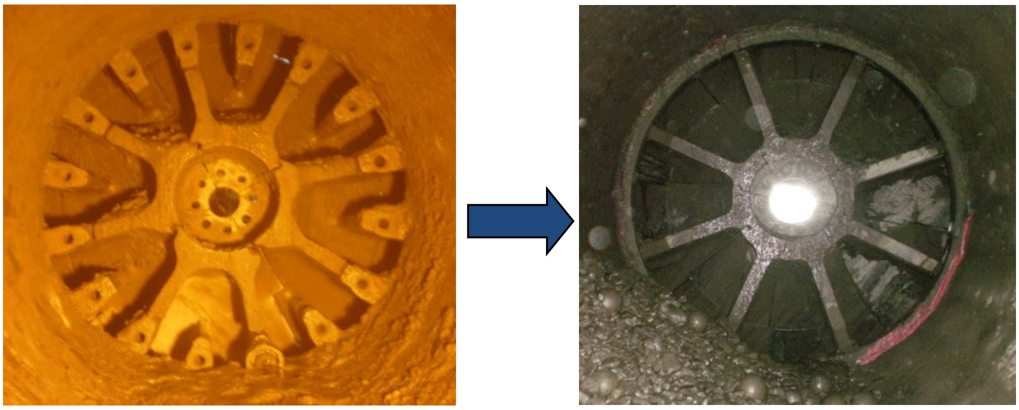

Figure 8 – Kansanshi 32ft SAG mill Discharge Cone view

BRADKEN LINER PERFORMANCE POST FY2013

Upon completion of installing the liners, Kansanshi and Bradken implemented a robust wear monitoring system to track the wear rates across the liners and wear profiles by using the Bradken in-house Ultrasonic wear program and independently verified using a Faro scanner with results processed by

Outotec and summarising the wear information through a flag report. The wear monitoring was conducted four times spread across the 12 month shell liner life to quantify liner shape influence on throughput, as outlined by Toor, Franke, Powell, Perkins, Bird, & Robertson, 2011.

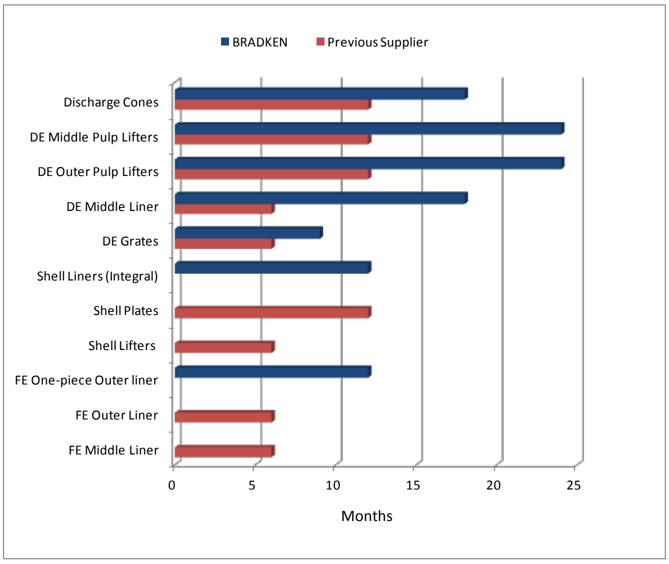

Figure 9 – Wear Life in Months

Figure 9 shows the comparison of wear life in months of liners installed by Bradken and those by the previous supplier. The liner design and the selection of liner materials improved the liner life considerable in key areas of the mill and doubled the life of the pulp lifters.

CIRCUIT PERFOMANCE POST LINER CHANGE

Circuit performance has been analysed to compare "like to like" periods in which the material of similar ore characteristics was processed through the 32ft Kansanshi SAG mill. Table 4 illustrates two periods when before liner change once treating sulphide ore during the entire of 2010, and when treating mixed ore from September 2011 until April 2012 just before the liner change to Bradken. For comparison, two data sets of identical timing, have being selected post liner change first covering Sulphide in 2013, and Mixed between September 2014 and April 2015.

Table 4 – Periods selected when the SAG mill Processed Identical Ore

Ore Type	Bradken	Previous Supplier
Sulphide	FY 2013	FY 2010
Mixed	Sep2014-Apr2015	Sep2011-Apr2012

Table 5 shows the SAG mill performance comparison in terms of dry metric tonnes milled through the 32ft Kansanshi mill when treating Sulphide ore before liner change and evaluated against the Sulphide tonnage after the mill was fitted with Bradken liners. The same comparison has been applied when processing mixed ore when the mill was lined by previous and analysed against the mill with Bradken liners. The data shows an 11% improvement when processing more competent Sulphide ore through the Mill fitted with the new liners and new vortex pulp discharge. When treating the softer mixed ore, the throughput gain increased to 12%.

Table 5 – Tonnes Milled Comparison between Bradken and Previous Supplier for two Ore types

Ore Type	Bradken	Previous Supplier	Change
Sulphide	11,211,914	9,954,011MT	11%
Mixed	8, 560,654	7,516,430MT	12%

Figure 10 shows that since change of the liners in 2013, a marginal 1% increase in SAG mill utilisation has occurred.

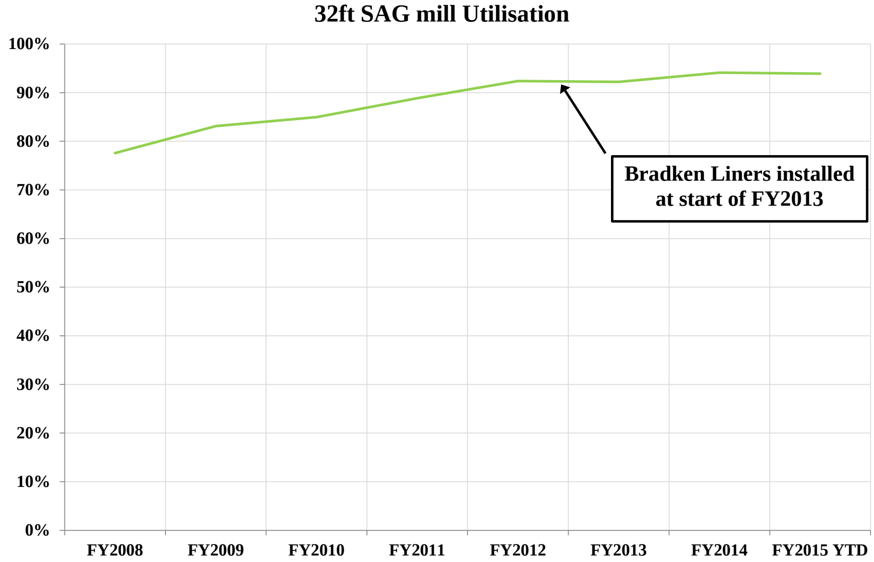

Figure 10 – Kansanshi 32ft SAG mill Historical Average Yearly Mill Utilisation

A review of dry tonnes treated through the 32ft SAG mill given in Figure 11, has risen from about 3MTPA since commissioning to a record high of 13.7MTPA in 2014. Part of the improvement can be attributed to liner optimisation.

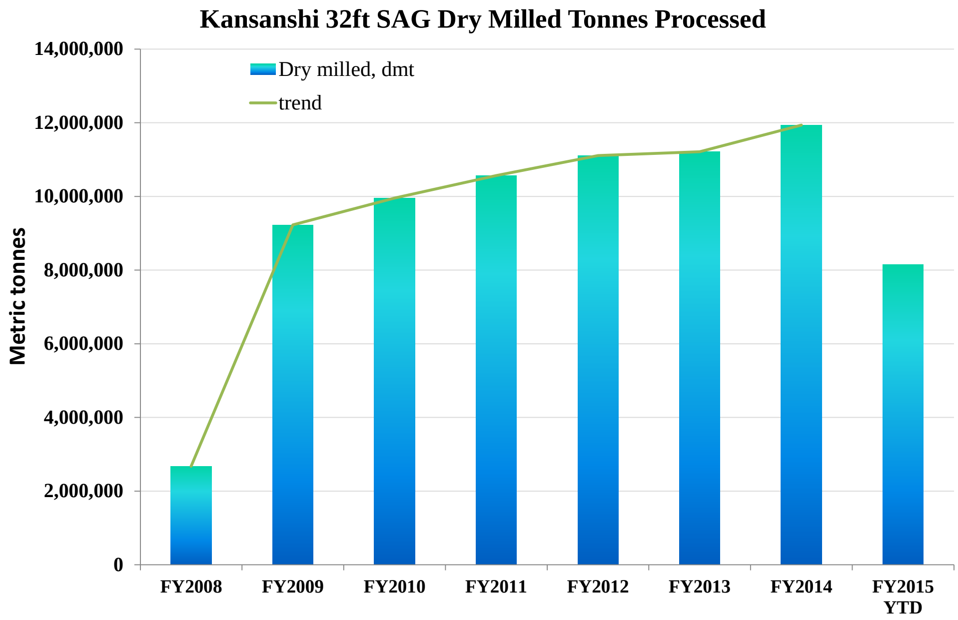

Figure 11 – Kansanshi 32ft SAG mill Historical Total Yearly Mill tonnes (DMT)

Figure 12 compares the average throughput and pebbles generation from the 32ft Kansanshi SAG mill before and after installation of Bradken liners. The data gives a significant 13% throughput increase post liner change with pebble generation going up by 25%.

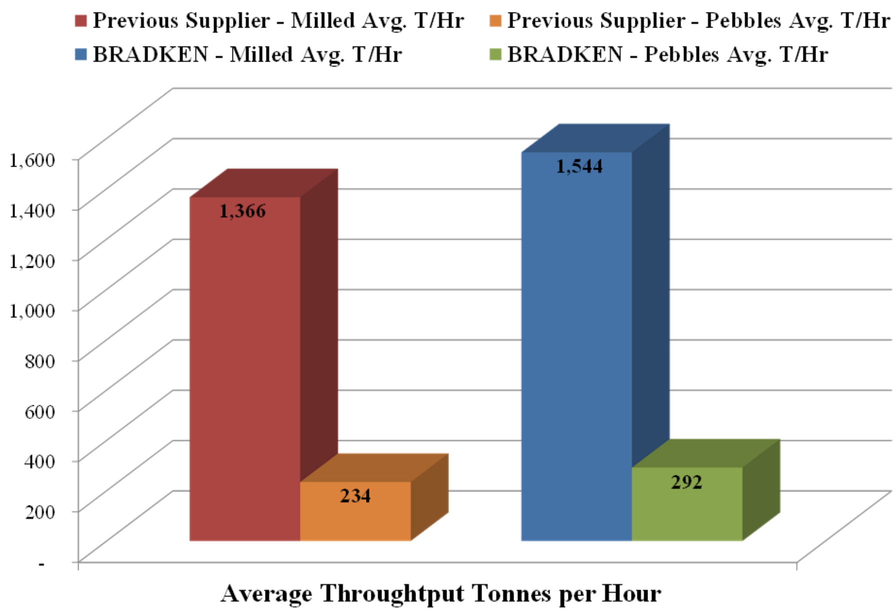

Figure 12 – Comparison of Average Throughput and Pebble Recycle Tonnes

Process Parameters Summary

A summary of mill performance for the 32ft SAG mill is presented in Table 6. The data compares pre-2012 era when the mill was fitted with a straight radial bi-directional liner design and the post 2013 results after the liner design was changed to a customised uni-directional liner design fitted with a Vortex discharge end system.

Table 6 – Comparison of 32ft SAG mill circuit Performance between Bradken and Previous Supplier

	Financial Year	Milled dmt	Utilisation %	Energy kWh/t	Pebbles %
Previous Supplier	FY2008	2,675,316	77.6%	8.5	-
	FY2009	9,227,136	83.1%	11.8	10.4%
	FY2010	9,954,011	85.0%	12.3	11.7%
	FY2011	10,567,973	88.9%	9.0	9.8%
	FY2012	11,110,488	92.4%	9.3	16.8%
Bradken	FY2013	11,211,914	92.2%	10.8	20.4%
	FY2014	11,935,966	94.1%	11.3	14.2%
	FY2015 YTD	8,158,553	93.9%	9.2	8.5%

Table 6 shows that dry tonnes milled have been on the increase since 2013, while the mill utilisation is marginally higher. Pebble generation has also increased by up to 25%. There is also a small increase in the specific energy (kWh/t) but this can be off-set by the increase in throughput and lower power cost of US 6cents/kwh in Zambia.

CONCLUSIONS

An innovative liner design change together with mill optimisation on the 32ft SAG mill as resulted in step change circuit performance. The discharge end of the mill was overhauled to include a single directional Vortex Discharge system to increase milling efficiencies and mill throughputs. The throughput gains observed are in the order of 13% when processing Mixed ore while when treating the more competent Sulphide ore, the throughput gain is about 12%. About 5% throughput gain over the first year, can be directly attributed to implementation of liner change on the SAG mill. The correct liner design, positioning of the liners in the mill and the selection of material in keys areas improved liner life considerable in high wear areas and doubled the life of the pulp lifters. Other gains include seamless installation through accurate modelling and planning that has reduced the annualised change-out of liners per year, and therefore marginally improved mill utilisation.

Other than the trunnion liner life that reduced from 2yrs to 11 months, implementation of the innovative liner design has proved successful by improving production. Improved throughput is attributable to liner change, mill scanning, and better determination of reline schedules. The change helped Kansanshi to improve calibration of mill weight against mill charge volumetric filling so that along with liner life, high throughput is sustained by adjusting mill weight in relation to liner wear and, so that the charge filling operating target is maintained

Benefits through Innovation

The performance measured in both days in service and tonnes milled has improved the profitability of the Kansanshi operation. The use of the composite materials on high wear areas on the mill internals has provided a viable solution to reduce the overall relines per annum and increase mill availability. A fully integrated approach & Innovative customised liner design has achieved significant production improvements and allowed the operation to achieve the performance targets.

ACKNOWLEDGEMENTS

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