Continuous improvement at Edikan (with MillROC support)

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ABSTRACT

One of the blessings associated with operating a modern metallurgical facility is the multitude of technologies, techniques and processes available to improve and optimise circuits. Circuit optimisation is typically an important KPI (key performance indicator) for many metallurgical operations and its staff. Diverse process teams, often consisting of different disciplines ranging from operations experts to off-site consultants, working together to enact positive change. Underpinning this effort is the culture cultivated by management to unify the ideas and focusing the efforts toward a common goal of system improvement.

This paper provides background on the different aspects of the project, the challenges faced, the changes made and the results achieved. Specific focus is given to upgrades made to instrumentation (ie installation of MillSlicer), implementation of advanced process control (MillStar) and providing real time consultation and coaching (via MillROC).

The results of the project include better insights into what's happening inside the mill, improved process stability, consistency of operation and better utilisation of mill power. Optimisation of the ball charge and steel-to-rock ratio also resulted in more efficient milling and greater throughput.

Based on the actual circuit throughput trajectory before circuit optimisations, the net circuit benefit in terms of fresh feed processed was initially estimated at +8.5 per cent in actual terms. It is interesting to note that the circuit bottleneck then moved to the stockpile vibrating feeders, which were operating at maximum output, requiring physical upgrades to further debottleneck circuit throughput. After removal of these bottlenecks and further optimisation the circuit throughput increased to 950 t/h (January 2020 average) from the 814 t/h average in April 2019, a further +15.8 per cent benefit in average instantaneous throughput. This further benefit is attributable to a combination of MillROC consultation, improved process control, Mine-to-Mill optimisation, softer feed blends (from November 2019 onwards) and plant modifications.

All up from implementation this team ethos of optimisation in combination with state-of-the-art technology and specialist consultants has resulted in a sustainable increase of 27 per cent in 8 months which will result in tens of millions of dollars in increased revenue a year at reduced operating costs, significantly improving the project economics.

Long-term benefits to liner life and media consumption are currently under investigation.

Optimisation cannot be a once-off exercise; if not continuous, the results deteriorate quickly over time. The optimisation at Edikan is therefore an ongoing team effort, supported by remote data access, analysis, modelling and consultation.

INTRODUCTION

The Edikan Gold Mine is 90 per cent owned by Perseus Mining Limited and located in Ghana, in the Ashanti Gold belt known for a number of high-profile gold projects. Production commenced in 2011 with gold production over 1.58 Moz to date. Ore is supplied from multiple deposits, with mineralisation occurring in two principal modes: disseminated pyrite-arsenopyrite mineralisation associated with quartz veining and sericite alteration hosted by granitoids and shear-zone hosted mineralisation associated with pyrite-arsenopyrite mineralisation in and adjacent to quartz veins in deformed, fine-grained metasedimentary rocks. The yearly production target was set at 6.7 Mtpa of ore to produce approximately 180 000 to 200 000 ounces of gold per annum.

Orway Mineral Consultants (OMC) provided circuit design reviews during the original project inception and design as well as follow-up up circuit surveys and operational reviews. Although these evaluations are exceptionally useful from a value-add perspective, they evaluate specific periods only and are not frequent enough to cater for the dynamic changing operation of the circuit. In most cases, the lack of continual evaluation and implementation of change result in lost revenue, ie opportunity cost losses due to optimisations that could have been implemented sooner.

A period of declining throughput prompted site to pursue various optimisation projects, consisting of Mine to Mill optimisation, advanced instrumentation (MillSlicer), advanced process control (MillStar) and ongoing, real time consulting services (MillROC). MillROC (Milling Remote Optimisation Consulting) is provided by OrwayIQ and consists of frequent and real time feedback to the operations based on live data. Orway IQ is a JV company, harnessing the modelling and consulting expertise of OMC and the control and cloud-based platform of ProcessIQ, to deliver real time consultation and coaching.

The initial installation and set-up of MillSlicer, MillStar and MillROC was completed by April 2019. The rapid and frequent feedback enabled significant optimisation through the ongoing MillROC service during a period where changes to the feed blend resulted in challenging operating conditions.

CIRCUIT DESIGN

The Edikan comminution circuit consists of a primary crusher feeding a single stage semi-autogenous grinding mill (1C SS SAG) operating in conjunction with a pebble crusher. The simplified flow sheet is shown in Figure 1 and a photograph of the comminution circuit in Figure 2.

The circuit design criteria are summarised in Table 1, with Tables 2 and 3 summarising the crushing and milling equipment specifications.

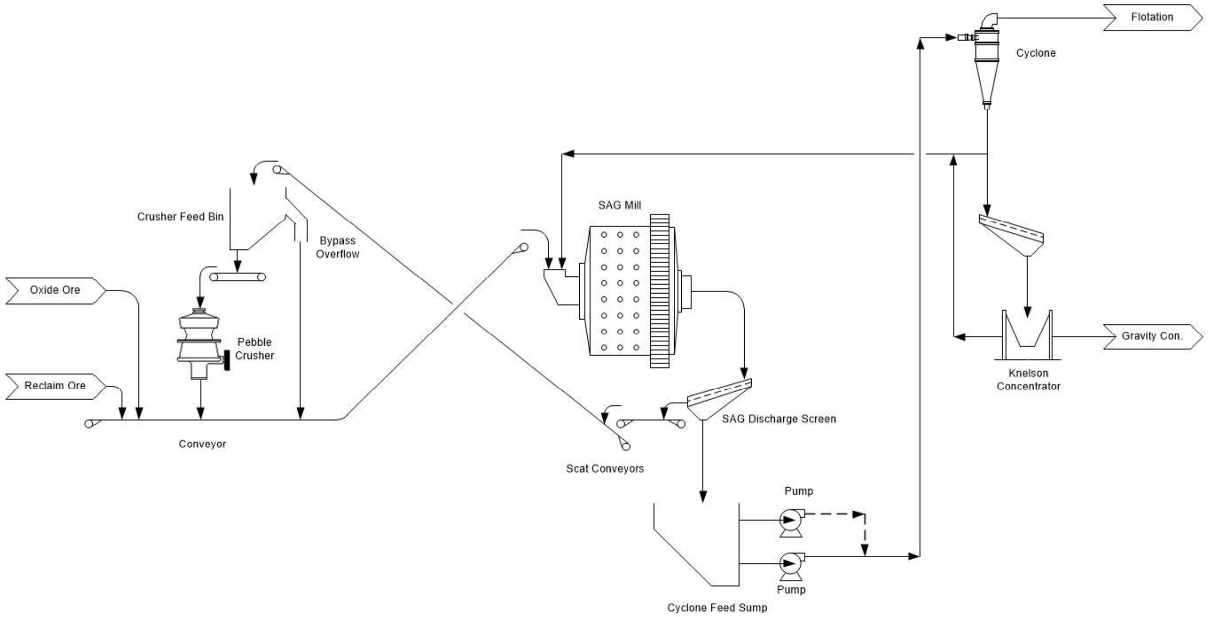

FIG 1 – Simplified flow sheet.

FIG 2 – The Edikan SS SAG mill.

TABLE 1

Design criteria.

Parameter	**Units**	**Design**
Plant throughput	Million t/annum	6.5
Head grade	g/t Au	1.0
Recovery	%	87
Crushing		
Availability	%	75
Throughput	t/h	989
Milling		
Availability	%	91.3
Throughput	t/h	813
Grind size P_{80}	µm	212
Ore characteristics		
UCS	MPa	76–165
Abrasion index	g	0.20–0.45
Bond rod work index	kWh/t	12.1–19.1
Bond ball work index	kWh/t	11.6–17.1
JK drop weight parameters (Axb)	-	28.0–80.7

TABLE 2

Major comminution equipment – crushing.

Parameter	**Units**	**Value**
Primary crusher		
Make	-	FLSmidth
Model	-	1400 × 2100 TS
Number installed	-	1
Installed power	kW	600
Pebble crusher		
Make	-	Sandvik
Model	-	CH660
Number installed	-	1
Installed power	kW	315

TABLE 3

Major comminution equipment – milling.

Parameter	**Units**	**Value**
SS SAG mill		
Make	-	FLSmidth
Inside shell diameter	m	10.36
Effective grinding length	m	6.10
Imperial measurements (flange to flange)	ft × ft	34.0 × 22.0
Installed power	kW	14 000

OPERATIONAL DATA

To effectively quantify the before and after effect of the continual improvement initiatives (Blasting pattern, MillROC, MillSlicer, MillStar etc), a review of operational data in relation to the various implementation dates of ongoing projects are required. Thereby accounting for external factors that may already be influencing the circuit, prior to, or at the same time as other modifications or circuit changes (Napier-Munn, 2014).

Major circuit changes were recorded, reflective of operating personnel feedback and observations made during the various evaluation periods. This gives a firsthand account of factors which influenced the Edikan circuit performance, such as when the MillSlicer data came online and the initial feedback was given from 06 April 2019.

Where changes to the operational data is noted, the preceding corresponding cause is highlighted (where known). This will be discussed in relation to the relevant circuit changes put forward to counteract negative circuit trends and improve the overall circuit efficiency.

A review of the long-term throughput data, contributing feed blend, received F_{80} feed size and achieved P_{80} product size was analysed to account for uncontrolled circuit inputs (ore hardness and feed size) and control targets (throughput and grind). A circuit power efficiency evaluation is therefore useful to normalise these factors and achieve a like-for-like comparison (Putland, 2019).

Long-term throughput data

Figure 3 depicts the long-term daily dry throughput achieved in the circuit, with specific reference to the period leading up to the implementation of the MillROC system and associated circuit optimisation. When considering the increased ore hardness, it is safe to assume that the declining throughput would have continued if intervention was not initialised by plant personnel.

Key observations include the cyclical nature of the SAG power draw (as shown by the bright blue line) increasing as the liner mass loss is offset by a higher overall SAG total charge (as the same weight set point). The recorded throughput (dark blue circles) has a high degree of variability, and changes depending on the feed blend ore characteristics.

Similarly, as shown by the black line, the amount of oxide decreased which contributes to the throughput. Two key events to note is shown by the red line (when MillSlicer was implemented) and the light grey line indicating when the mining powder factor was increased. Considering the feed blend change for the period and associated increase to ore hardness, it is expected that the downward throughput trajectory would have continued if intervention was not implemented.

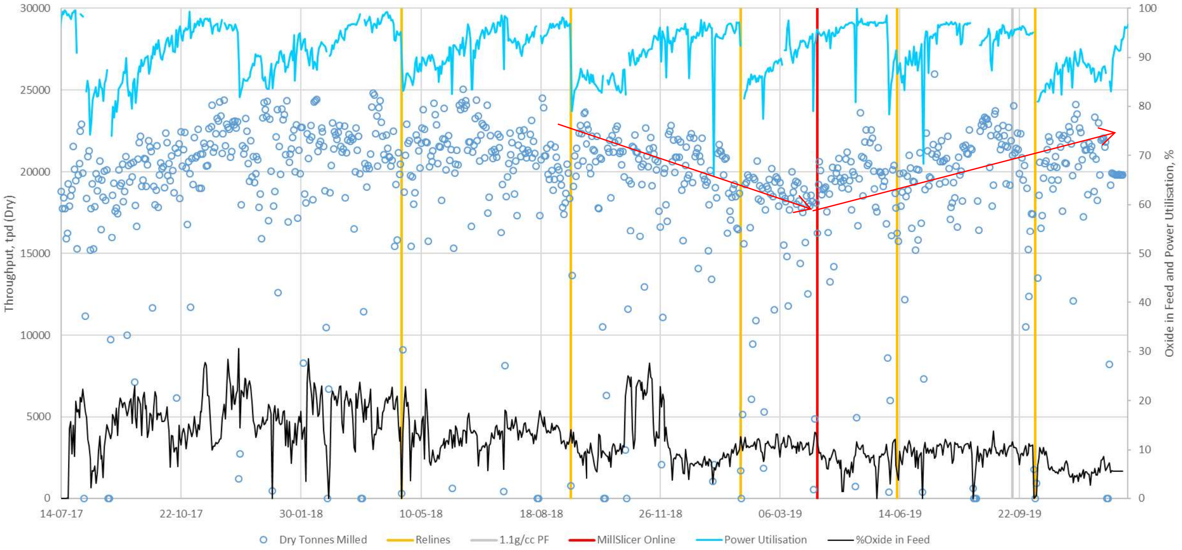

FIG 3 – Long-term throughput data.

Figure 4 illustrates the recorded feed blend to the Edikan circuit which corresponds to the long-term throughput data with Table 4 summarises the associated comminution characteristics. It is important to note that the feed blend corresponds to increasing quantities of harder ore material. This is especially noticeable from December 2018, where Esuajah North material became the predominant fresh feed component, while the oxide component remained fairly well regulated, although at slightly reduced levels. From November 2019 onwards a small component of Bokitsi (softer) ore has formed part of the feed blend.

It should be noted that Run-of-mine (ROM) denoted material stockpiled prior to crushing with untracked blend, and Coarse Ore Stockpile (COS) material denoted stockpiled feed prior to milling with untracked blend.

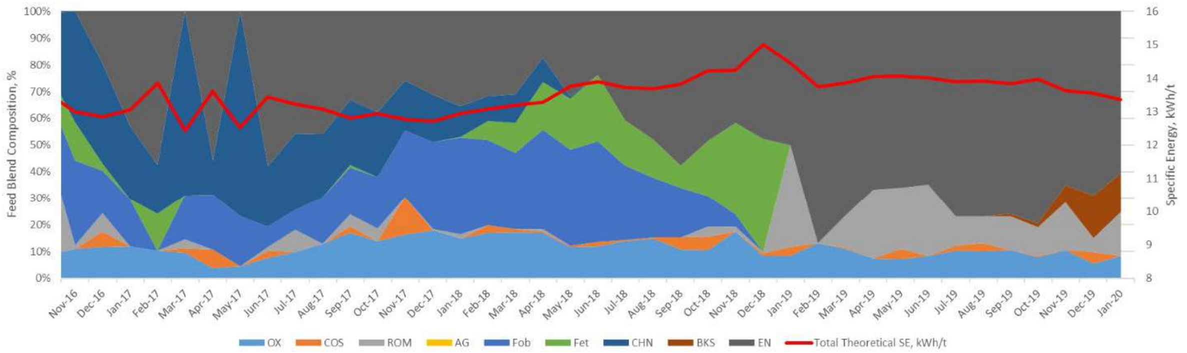

FIG 4 – Long-term feed blend and theoretical SE.

TABLE 4

Feed sources and comminution characteristics.

Feed source	Abbreviation	BWi, kWh/t	Axb
Abnabna Gap	AG	13.8	49.1
Bokisti	BKS	14.3	68.4
Chirawewa	CHN	13.4	48.4
Esuajah North	EN	15.9	41.6
Fetish	FET	16.8	32.2
Fobinso	FOB	14.9	47.9

The total theoretical specific energy (SE) highlights the expected grinding energy required to achieve the grind target. The theoretical energy calculations are based on the 85th percentile BWi and 15th percentile Axb design values where available.

Power efficiency evaluation

As part of OMC's standard procedure to evaluate circuit efficiency, the Operating Work index is used as defined in Equation 1, which accounts for circuit variability typically associated with changes in the mill power draw, feed/product size distribution variations and circuit inefficiencies.

Operating Work Index, kWh/t:

$$W_{io} = \frac{SE}{10\left(\frac{1}{\sqrt{P_{80}}} - \frac{1}{\sqrt{F_{80}}}\right)} \tag{1}$$

Where, SE, kWh/t:

$$SE = \frac{(SAG\ Power\ ) * Eff_{DriveTrain}}{Throughput} \tag{2}$$

The feed size (F_{80}) is based on the average of the measured fresh mill feed, as a combination of both physically sampled (belt cut) and digitally estimated (WipFrag) data. The product size (P_{80}) is taken as the average of the shift samples used to monitor the daily circuit performance.

It should be noted that the drive train efficiency ($Eff_{DriveTrain}$) was assumed to remain constant for the evaluation period, as this relates to the energy losses from where the power consumption is measured (incomers) to where the power is utilised (pinion power).

Another evaluation matrix typically considered is the circuit f_{SAG}, which denotes the circuit efficiency of a single stage SAG milling configuration when evaluated against a typical SABC circuit receiving a 150 mm feed F_{80} and grinding down to a product P_{80} of 75 µm and using the laboratory Bond Ball mill work index (BWi) as typically used by OMC (Siddall, 1996).

The f_{SAG} therefore takes into account the breakage inefficiency typically not correctly represented by the Bond equation. Equation 3 defines the f_{SAG} calculation, with Edikan having an averaging f_{SAG} of 1.3.

SAG Circuit Efficiency Factor:

$$f_{SAG} = \frac{(Total\ SE) + \left(10 * \mathrm{BWi} * \left(\frac{1}{\sqrt{\mathrm{F}_{80}}} - \frac{1}{\sqrt{150000}}\right)\right) + \left(10 * \mathrm{BWi} * \left(\frac{1}{\sqrt{75}} - \frac{1}{\sqrt{\mathrm{P}_{80}}}\right)\right)}{10 * \mathrm{BWi} * \left(\frac{1}{\sqrt{75}} - \frac{1}{\sqrt{150000}}\right)} \qquad (3)$$

Figure 5 shows the mill power utilisation (as a percentage of the installed power) and the calculated operating work index as normalised data points on a time relationship basis. As shown by the operating work index, when accounting for changes in the circuit power draw and grind target, the inferred ore hardness has been increasing steadily, typically associated with increased quantities of fresh material as mining advances progressively deeper into the pit.

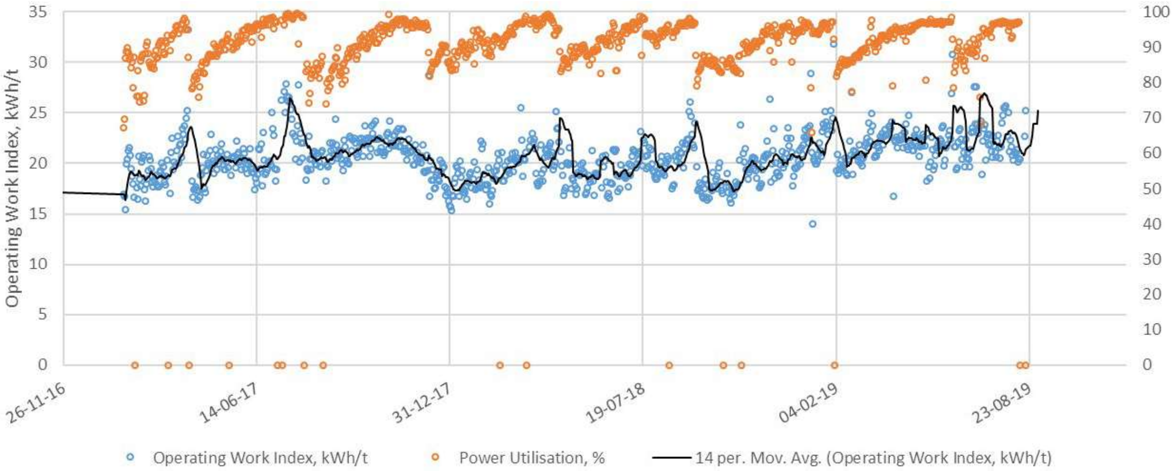

FIG 5 – Operating Work Index (Wio) versus Time relationship.

It is interesting to note how the utilisation of installed power (ie operating power as a per cent of installed power) is affected by relining periods, typically occurring every 4.0 to 4.5 months as the historic baseline.

It should be noted that the SAG mill effectively operates at maximum output as a fixed speed mill, despite having a VSD drive installed. This is due to higher than tolerable vibrations being encountered within the drive train when transitioning through the lower speed range spectrum. Fluctuations to the mill power draw is therefore mainly a function of the SAG operating volume and steel charge.

Relining typically results in a drop to the SAG mill power draw, due to lower operating mill volume when operating at the pre-reline SAG weight (or bearing pressure) set point. This effect is counteracted by the fresh (unworn) lifter angle having a fairly aggressive ball trajectory which emphasises breakage in the SAG mill. The operational risk is therefore having a too low SAG operating volume for the aggressive ball trajectory, which increases the likelihood for steel ball to steel liner impacts. Optimisation of the pebble port fraction of total grate open area is used to further manage this risk (Putland, 2018).

Figure 6 depicts the Cumulative Sum (CUSUM) analysis of the SAG mill specific grinding energy (SGE) for the circuit. As shown, compared against a constant SGE of 13.5 kWh/t, the inferred ore hardness was softer than average leading up to January 2019. The SGE inverted post January 2019, indicating significantly harder than average ore characteristics were being processed during the optimisation period.

The Operating work index and SGE recorded is expected to follow each other closely, as no ball mill is available to influence the power split. The pebble crusher is therefore used to coarsen the circuit grind target.

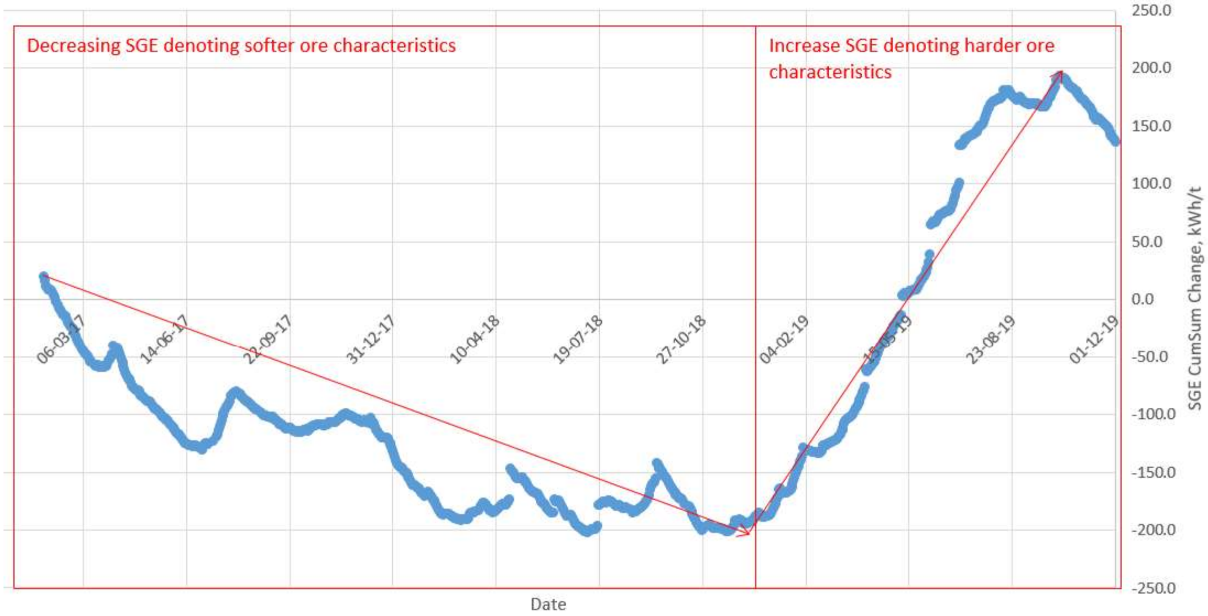

FIG 6 – SAG mill specific grinding energy cumulative sum.

Comparative throughput and grind analysis

Since long-term data obscures numerous smaller effects influencing circuit operability, it is useful to evaluate more detailed operational data directly before and after circuit changes, to better establish a like-for-like comparison.

For the comparison, an evaluation period of 128 days (64 before and 64 after the MillROC implementation period) was considered. It is important to note that this is associated with the initial optimisation and operational changes, namely setting the optimal operating mill weight set point and accompanying ball addition rate.

In the case of the Edikan data, there were a number of fortuitous factors occurring which greatly simplified such an evaluation. Most notably, Figure 7 gives a higher resolution view of the feed blend to the circuit directly before and after April 2019 implementation data. As shown, the primary feed source did not change significantly, with an actual reduction to the oxide proportion fed to the mill.

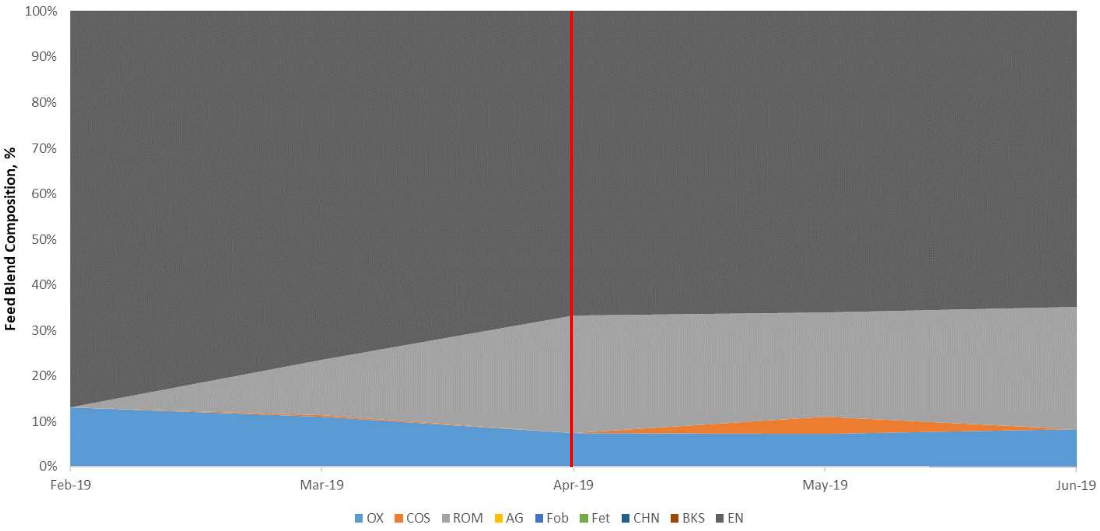

FIG 7 – Comparative period feed blend.

Figure 8 depicts the near instantaneous throughput improvement by operating the SAG mill at an improved breakage state, while the circuit grind improvement was being maintained at constant levels. Figure 9 shows the corresponding mill feed PSD data as recorded. Throughput benefits were therefore achieved despite the mill feed size (F_{80}) and fines content (%Passing 50 mm sieve) not changing significantly either before or after optimisation and without compromising the circuit grind target.

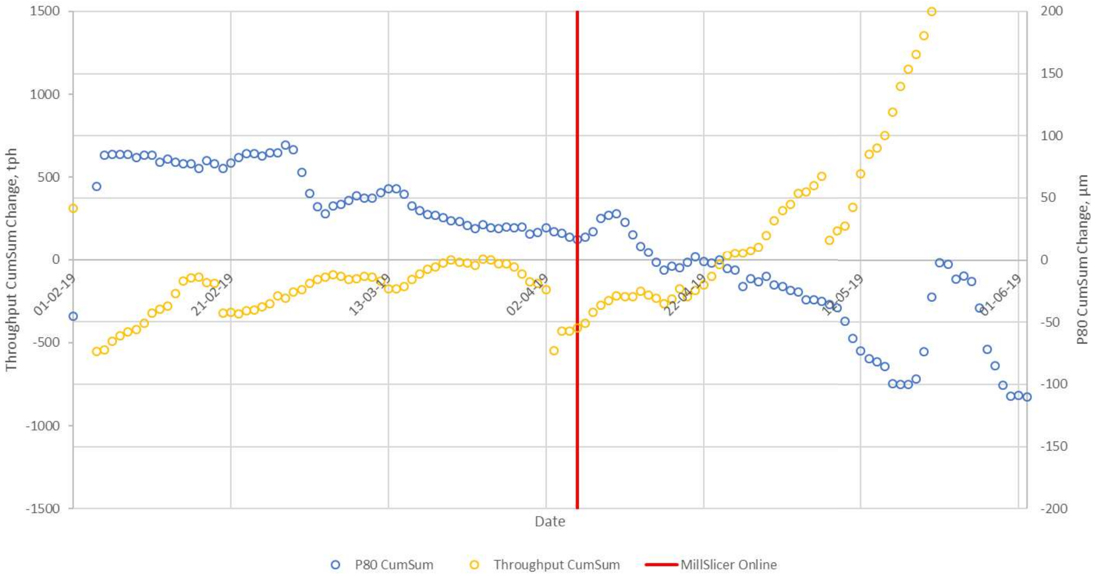

FIG 8 – Comparative throughput rate and circuit grind P_{80}.

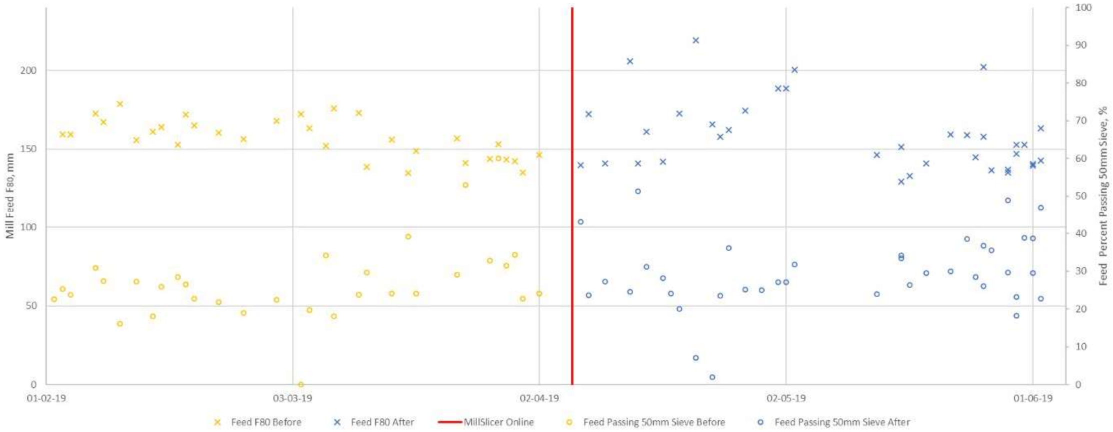

FIG 9 – Comparative feed PSD change.

Before implementing changes, the mill feed PSD was shown to improve, but despite this, throughput rates continued to decline. Conversely, after implementing optimisation changes, throughput continued to improve, despite coarsening of the mill feed PSD. This is pertinent as deviating from typical SAG mill considerations (Putland, 2011) requires specific control philosophy considerations to maintain optimal performance.

Since the daily data points tend to obscure frequent circuit changes associated with the overall stability and control of the circuit, the average five minute data for the before and after period is compared in the histogram format, to indicate the relative shift in overall accuracy and precision. Figure 10 depicts the change in SAG mill Power draw, where Figure 11 shows the reclaim feed rate. Similarly, Figure 12 depicts the cyclone pressure control and Figure 13 the circuit grind P_{80}.

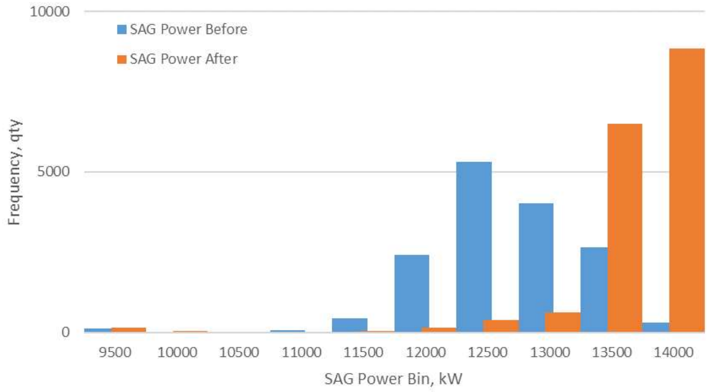

FIG 10 – SAG power bin.

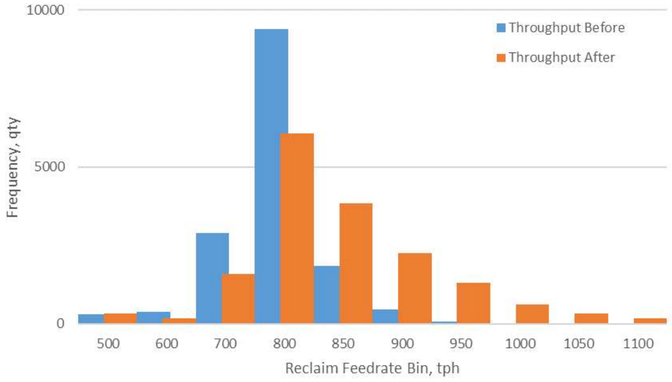

FIG 11 – Reclaim feed rate bin.

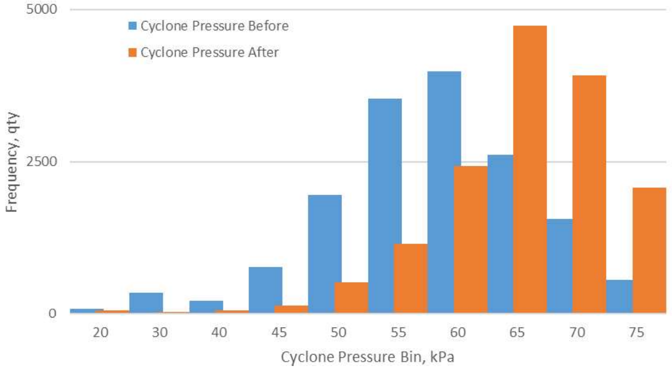

FIG 12 – Cyclone pressure bin.

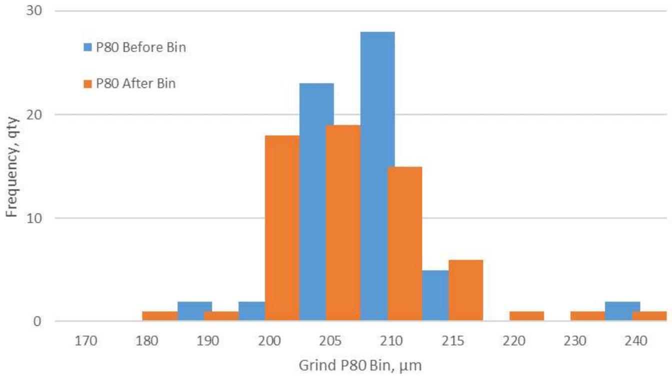

FIG 13 – Circuit grind P_{80}.

One of the future optimisation targets under consideration is relaxing the circuit grind to a P_{80} of 280 µm, at which point throughput can be further maximised. Downstream recovery past this point requires careful consideration, as it can impact the overall profitability.

Mill control

To visualise the operating conditions within the SAG mill, Figures 14 and 15 depict the MillSlicer data interpretation as recorded before (when brought online 6 April 2019) and after the SAG weight setpoint has been adjusted and allowed to stabilise (25 April 2019).

It is important to note the 'sawtooth' pattern as recorded in the impact intensity graph, signifying significant ball on liner impacts, with reverberations recorded throughout the mill shell. After appropriate adjustments to the SAG weight (volume), a notable drop to the maximum impact intensity was recorded. This signifies reduced liner damage and optimised breakage by aligning the estimated toe of the charge to the maximum recorded intensity angle within the SAG mill.

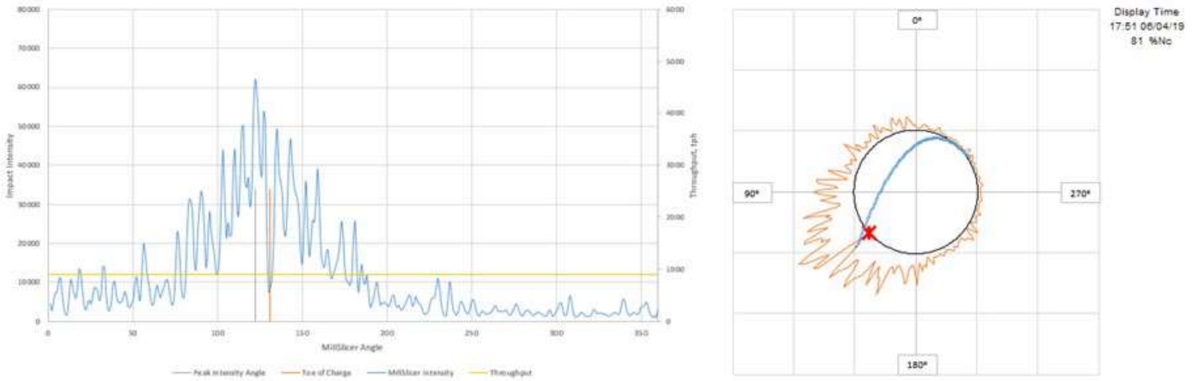

FIG 14 – MillSlicer impact intensity before (06 April 2019).

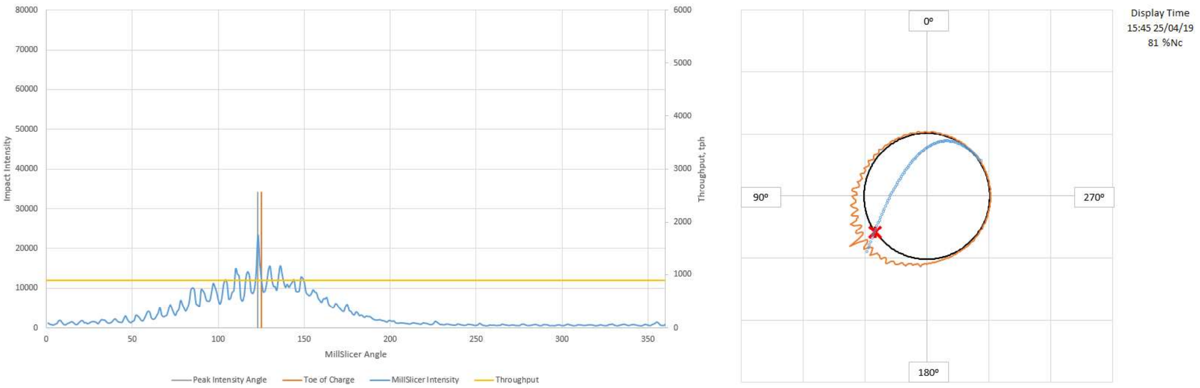

FIG 15 – MillSlicer impact intensity after (25 April 2019).

Figure 16 illustrates the effect of improved operating milling conditions, where the throughput to mill power draw relationship indicates how quickly the MillStar control system is able to rectify circuit upsets. Due to the rapid power draw fluctuation encountered due to changes in the mill weight, the average instantaneous 5 min data-points were used for the comparative periods.

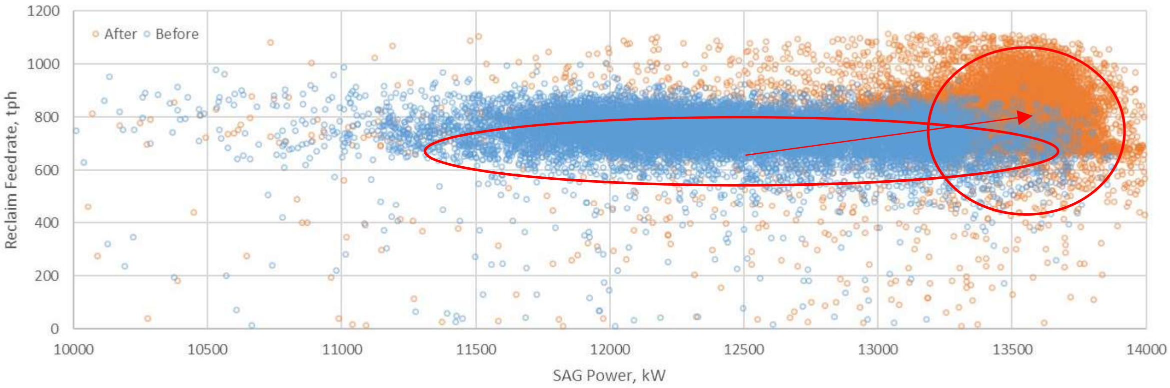

FIG 16 – Circuit reclaim throughput versus SAG power (5 min instantaneous average).

As shown by the accuracy and precision of the SAG power draw at variable feed rates, after the implementation was significantly improved, with less energy wasted by under-filling the mill and even potentially damaging the liners. This was achieved by understanding the mill power draw in conjunction with the likely impact trajectory, mill load, impact intensity and more precise control.

Table 5 summarises the statistics for this comparison period as a like-for-like evaluation, as well as the most recent production data (for equal periods of time).

TABLE 5

Comparative circuit data.

Parameter	Unit	Before implementation	After implementation	Before/after difference %
Start date	-	1 February 2019	6 April 2019	-
End date	-	5 April 2019	8 June 2019	-
Total fresh tonnes	t	910 245	1 075 094	**+18.1%**
Total oxide tonnes	t	111 695	92 341	-17.3%
Total tonnes milled	t	1 021 941	1 167 435	+14.2%
Mill feed rate, total	tph	779	818	+5.0%
Mill feed rate, fresh	tph	694	753	**+8.5%**
Mill feed rate, oxide	tph	85	65	-24.0%
SAG power	kW	12 430	13 334	+7.3%
Mill availability	%	83.0	91.0	**+9.6%**
Primary grind	% passing 212 µm	80	82	+2.3%

The key takeaway for operating the milling circuit at optimised conditions is not only to stabilise reducing throughput rate but increase the circuit performance in terms of efficiency when considering both higher proportions of fresh feed and harder ore characteristics than what was historically processed in the circuit.

Continual improvement

After the initial circuit optimisation, additional targets were set to further maximise the circuit operating parameters. The net effect of which was achieving maximum throughput, with higher proportions of fresh material, while maintaining the circuit grind. The circuit bottleneck moved to the vibrating feeders that required upgrading, as they could not keep up with mill demands.

The following subsections highlights the various continual improvement initiatives implemented and the corresponding effect to the circuit associated circuit said changes made.

Blasting practice

Blasting optimisation was completed, with specific focus on delivering both a more consistent top size to the primary crusher and a higher proportion of fines to improve throughput (McKee, 2013). Table 6 summarises the changes made during 2019 to the powder factor (PF). Changes in blast practice post May 2019 were made in consultation between site and an external specialist consultant (Hatch).

TABLE 6

2019 blasting practice changes.

Change description	**Date**
Higher PF in ore (0.7 g/cm³ to 0.8 g/cm³)/lower in waste	15 March 2019
Improved QAQC	11 July 2019
Focused blast evaluation and monitoring	15 July 2019
Explosive density review (1.1 g/cm³)	16 September 2019

Figure 17 depicts the primary crushed product P_{80} and fines component reporting as mill feed.

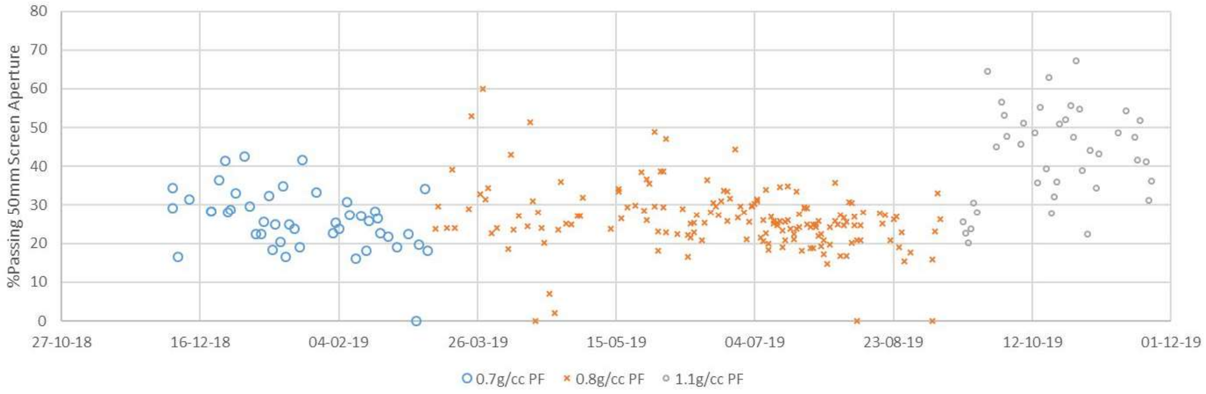

FIG 17 – Primary crusher product fines content.

Prior to March 2019, the amount of fines being generated per blast was starting to decline in line with an increasing trend to the primary crusher product size. Therefore, the updated blasting pattern notably assisted in maintaining feed conditions to the milling circuit as the ore hardness is increased by mining depth. It is interesting to note that average fines generation gives a convenient indication of excessive SAG grate wear when the pebble extraction rate increases (Putland, 2019).

Mill weight set points

One of the techniques utilised in the process of maximising throughput is optimisation of both the SAG weight control (to accurately manage weight via feed rate) and ball charge (Kock, 2019). The optimal mill weight, to account for the ore breakage characteristics, state of liner wear, ball charge and trajectory is selected and adjusted regularly. Figure 18 depicts the SAG weight set point changes and how the actual mill weight control is achieved in relationship with the feeder output.

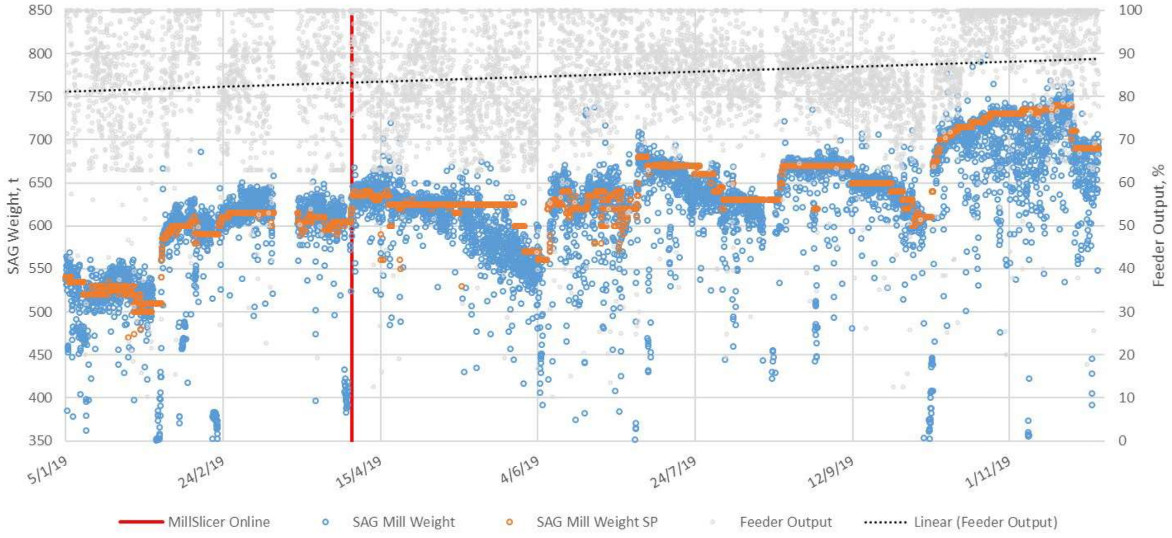

FIG 18 – SAG weight control and feeder output.

The most recent challenge to the circuit is the physical limitation of the feeder system, as shown by the upward trending average output required to achieve the weight set point, which operates at near maximal output from mid-October 2019.

Since the physical feeder limitations have been debottlenecked in early January 2020, it is intended to further fine tune the SAG weight set point to allow for optimal control of the ball trajectory in relationship with the charge load within the SAG mill (Giblett, 2019).

Liner wear rates

Consideration is given to the change in relining schedule, which is a function of the ore abrasion index, mill specific energy consumption and operating practices (such as liner impacts) which influence the overall wear life of the liner set. Table 7 depicts the five most recent periods preceding a mill reline. Key observations include reduced operating life and effective tonnes treated as the ore abrasiveness increased.

TABLE 7

Liner performance on daily COS tonnes treated.

Liner set	**Average abrasiveness, g**	**Operating life, d**	**COS tonnes treated, t**	**Effective treatment rate, t/d**
Before optimisation				
A	0.248	141	2 506 938	17 780
B	0.288	142	2 418 079	17 029
C	0.301	131	2 098 579	16 020
After optimisation				
D	0.299	115	1 978 297	17 203
E	0.283	62	1 160 847	18 723

The liner life started to decline in line with the reduced throughput rate discussed above, which corresponds with the expected ore hardness increase. By adjusting the optimal SAG weight set point, and by proxy the interface between the maximum impact angle and the toe of the charge, the liner impacts have been reduced to maximise throughput and liner life.

By continually operating at the optimal conditions, the liner wear profile can be reviewed to identify areas in the liner design where excess liner weight can be shaved, to save cost and reduce wastage.

Culmination of effort

Based on the various circuit improvements and optimisation outlined, the progressive circuit throughput for the remainder of 2019 is outlined in Table 8 with Figure 19 depicting time normalised reclaim throughput rates extracted from the online system. As shown over a two-month period the throughput increase is sustained without excessive high and/or low values artificially impacting the average data summarised below.

TABLE 8

Summarised operating data (Kock, 2020).

Parameters	**Units**	**Mar-19***	**Apr-19**	**Nov-19**	**Dec-19**	**Overall % change April versus December**
Production statistics						
Reclaim feed rate	tph	710	749	913	943	+19.1 %
Oxide feed rate	tph	87	65	56	51	-21.9 %
Scats production	tph	231	267	254	156	-41.6 %
	% New Fd	29	33	28	17	-
Total feed	tph	798	814	969	943	+15.8 %
Circuit product P_{80}	µm	250	245	237	240	-2.0 %
Oxide in feed blend	%	11	8	6	6	-25.0%
Power utilisation						
SAG mill measured power	kW	12 676	13 242	12 290	12 884	-2.7 %
SAG mill specific energy	kWh/t	14.1	14.4	11.7	12.0	-16.7 %
Operating work index (WiO)	kWh/t	23.2	23.5	18.8	19.4	-17.4 %
Operating parameters						
MillSlicer – delta intensity	Deg	-	-	11	9	-
Mill speed	rpm	-	10.3	10.7	10.6	+2.9 %
SAG milling density	% solids	-	71.3	73.4	75.6	+6.0 %
Cyclone feed density	t/m^3	-	-	2.07	1.97	-
Cyclone pressure	kPa	61	63	67	64	+1.6 %
No. cyclones		6	6	6	5	-16.7 %
Circulating load	%	-	319	259	203	-36.4 %

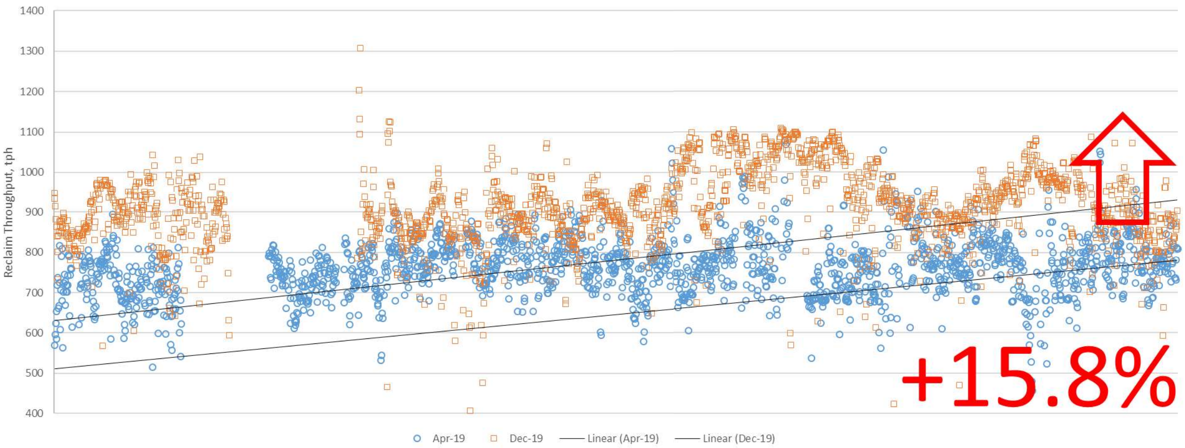

FIG 19 – Relative reclaim feed rate for April and December 2019.

CONCLUSIONS

As shown by the supporting data, continual effort by all personnel involved, Perseus staff and consultants on and off-site, managed to achieve a notable shift in circuit throughput. This effort is enabling the circuit to operate near or at the optimal throughput and grind range of the circuit for extended periods of time.

The main areas of optimisation to achieve this included:

- Optimal set point management.
- Improved control and measurement.
- Improved maintenance and equipment operability/stability.
- Improved blasting practices.

Based on the actual circuit throughput trajectory before circuit optimisations, the net circuit benefit in terms of fresh feed processed was initially estimated at +8.5 per cent in actual terms. It is interesting to note that the circuit bottleneck then moved to the stockpile vibrating feeders, which were operating at maximum output, requiring physical upgrades to further debottleneck circuit throughput. After removal of these bottlenecks and further optimisation the circuit throughput increased to a constant 950 t/h (January 2019 average) from the 814 t/h average in April 2019, a further +15.8 per cent benefit in average instantaneous throughput while the average ore hardness for the comparison period being within three per cent of each other.

The benefit of this optimisation strategy is that it identifies and actions most of the low capital-intensive circuit changes. This translates into an approximate monthly net cash flow benefit of A$6.3 million (per month), when considering the difference in tonnes treated (Apr 2019 versus Dec 2019) and assuming similar recovery and feed grades. Further circuit throughput increases are likely to required major modifications, signifying that utilisation the existing capital has been optimised.

All up from implementation this team ethos of optimisation in combination with state-of-the-art technology and specialist consultants has resulted in a sustainable increase in throughput of 27 per cent in 8 months which will result in tens of millions of dollars of increased revenue a year at reduced operating costs, significantly improving the project economics.

Once the maximum operating limits of the existing equipment has been achieved, physical upgrades will be required to further improve throughput. It is therefore useful to complete bottleneck evaluations to proactively identify where engineering consideration has to be focused, to minimise future time required to enact circuit upgrades.

Similarly, by applying the knowledge gained in a single circuits' optimisation to the other assets in the mining company's portfolio, the benefit gained can be multiplied through various sites.

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