OPTIMISATION OPPORTUNITIES AT NEWMONT GOLDCORP'S PEÑASQUITO OPERATION

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Abstract

Newmont Goldcorp's Peñasquito operation, located in the state of Zacatecas in northwest Mexico, is currently undergoing a series of optimisation works to increase throughput through the comminution circuit. Primary crusher product feeds the comminution circuit, comprising a parallel train of two SAG mills, pebble crushers and four ball mills. Additional feed is augmented through the primary comminution circuit from a separate circuit consisting of a secondary crusher and an HPGR.

As part of the optimisation plan, Ausenco, Peñasquito, and Newmont Goldcorp Technical Services defined clear strategies classified into short-, medium-, and long-term opportunities in preparation for the future competent ore sources. The comminution circuit at Peñasquito was operating below its full potential due to some unit operations not fully drawing installed power as well has material handling bottlenecks limiting individual circuit throughput.

Some of the critical comminution optimisation strategies included:

- De-constraining the SAG mill throughput with optimized operational load set points and revised process control
- Redesigning the SAG mill liners for optimum load and speed control
- Optimising crushing and HPGR operation for maximised throughput rates at the minimised product size distribution.

Ausenco's comminution optimisation tool, Ausgrind, was used to benchmark and analyse plant data with empirical models, predict circuit performance for varying ore characteristics, evaluate SAG mill liner wear, and predict the life for varying operating parameters. Variances between the actual and the predicted values were assessed in detail to identify missed opportunities and help guide operations with re-defined operating parameters to maximise throughput and productivity.

Keywords

SAG-HGPR circuit, control, SAG mill optimisation

Introduction

Newmont Goldcorp's Peñasquito operation, located in the state of Zacatecas in northwest Mexico, is currently undergoing a series of optimisation and debottlenecking work to increase throughput in the comminution circuit. The comminution circuit comprises two parallel lines with a SAG mill and two ball mills as well as conventional pebble crushers. There is an additional circuit that augments feed through a secondary crusher and HPGR, providing supplementary feed to the circuit that is scalped from the coarse-ore stockpile, shown in Figure 1. Details of the major comminution equipment at Peñasquito are summarized in Table 1.

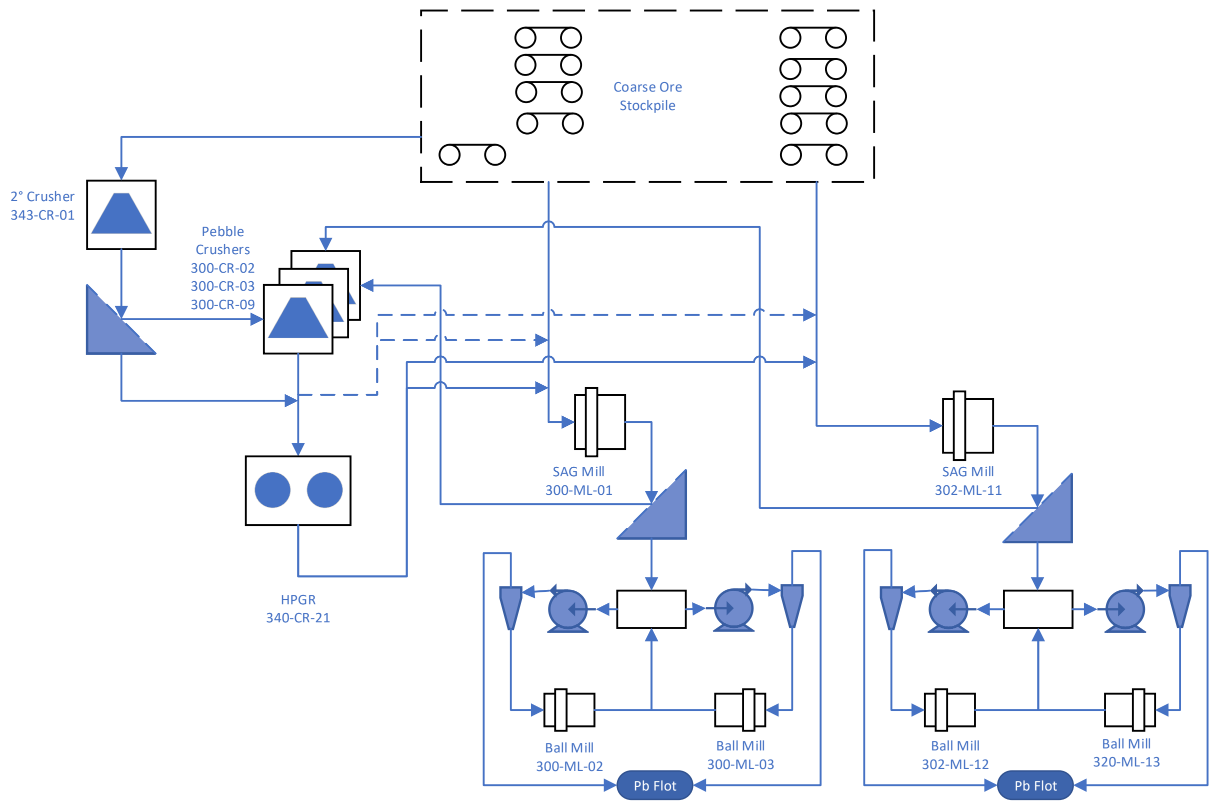

Figure 1 – Simplified Peñasquito Comminution Flowsheet (Newmont Goldcorp)

Table 1 – Major Comminution Equipment and Installed Power

Equipment	Details
1 x Primary crusher	FLSmidth 60 x 113, 750 kW
Two SAG mills	Dia 11.6 m (38') × 6.86 m (22.5') F2F, 19.3 MW
Four Ball mills	Dia 7.3 m (24') × 11.4 m, 12.0 MW
1 x Secondary crusher	FLSmidth Raptor XL1100, 750 kW
1 x HPGR	Thyssenkrupp Polycom 24/17, 5.0 MW
Three pebble crushers	Sandvik H8800, 600 kW each

Figure 2 presents some historical throughput data as well as the overall blend between two primary ore types, sedimentary and breccia (diatreme). From late July 2018, a higher proportion of sedimentary ores was fed through the Peñasquito grinding circuit. While there is some variability within the ore types, throughput is generally lower when the proportion of sedimentary feed is higher. The average throughput during this period was approximately 90 kt/d at 92% circuit availability.

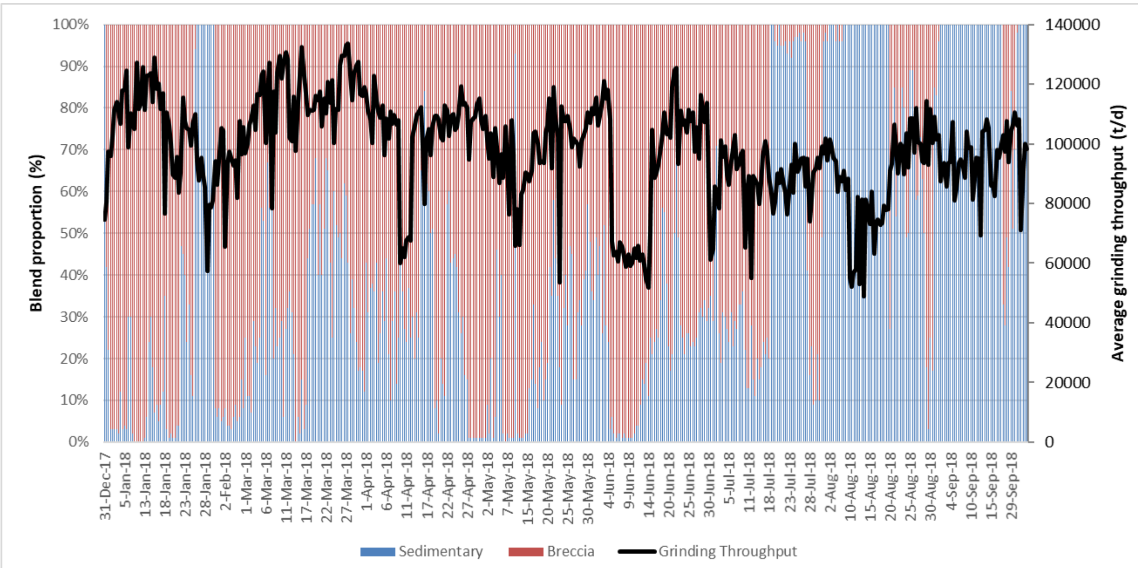

Figure 2 – Historical Data Comparing Grinding Throughput and Ore Blend Type

PROJECT SCOPE AND OBJECTIVE

A multidisciplinary and cross-functional team was established with resources from Peñasquito and Vancouver Technical Services to address debottlenecking of the comminution circuit in the context of increasing blends of harder sedimentary ore. Ausenco was selected to support the effort through the development of comminution models, review of current and historical operating data, as well as on-site support to facilitate operational improvements and process control optimization. Significant objectives of the work included:

- Determining and optimising the bottlenecks in the grinding circuit flowsheet and increasing average throughput to meet overall mine plan requirements
- Providing comminution optimisation strategies to reconfigure the circuit operations for more competent feed
- Providing training and technical support to sustain operational changes.

The initial components of the envisaged solution combined integrated optimisation, data analytics, and information management. The circuit assessment and debottlenecking opportunities were conducted through:

- Reviewing plant operating data then benchmarking and analysing those data using Ausenco's proprietary comminution platform, Ausgrind (Lane et al., 2013; Chandramohan et al., 2018), to determine baseline and optimum solutions for the Peñasquito plant

- Evaluation of technical throughput limits for each comminution circuit and assessment of root causes preventing consistent throughput at or near the technical limit
- Feedback on a daily or weekly basis, and reconfiguring the operational parameters to suit the changing feed type and operational conditions
- Implementing site-based training and optimisation strategies to minimise constraints.

Figure 3 presents the debottlenecking stages applied at Peñasquito operations. The staged approach was critical to identify the issues, develop an implementation plan, and apply short- to long-term improvement activities.

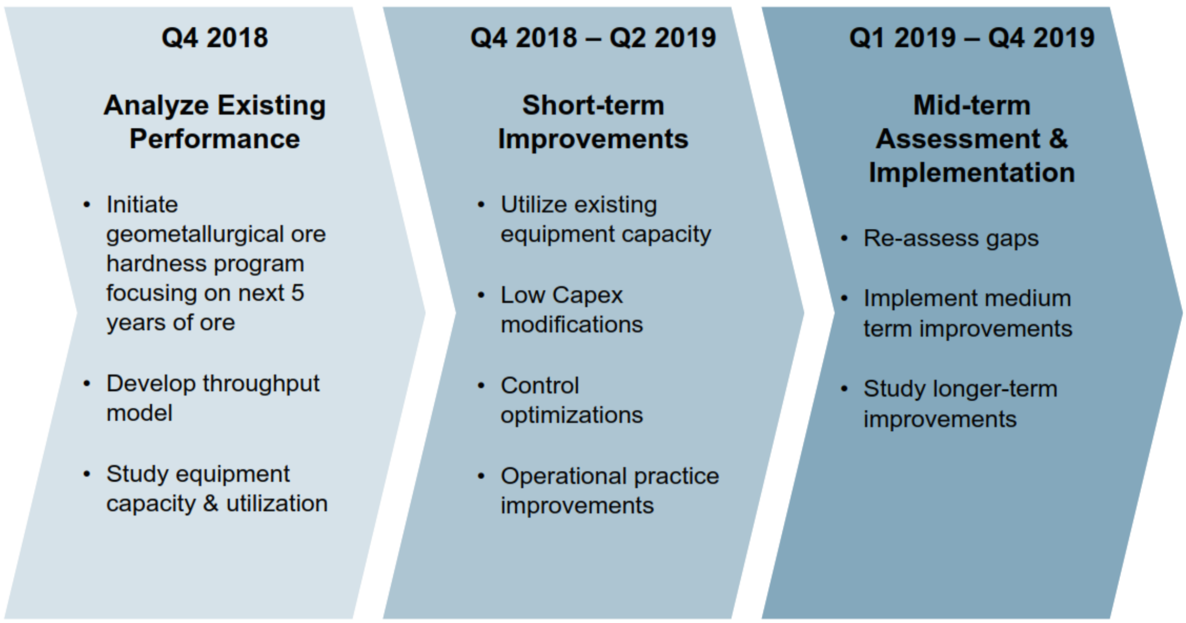

Figure 3 – Stages of Debottlenecking Activities at Peñasquito

Circuit Evaluation

For the complex grinding flowsheet, a Met-model was developed to assess the performance of each unit process as well as the overall impact to the grinding circuit for changing operating conditions for variable ore blends and operating strategies. The Peñasquito comminution circuit is relatively complex and a challenge to model comprehensively with commercially available modelling packages. Figure 4 shows the simulated Peñasquito flowsheet developed for the model. The calculation models used in the Ausgrind Expert version use a combination of power-based calculations, mass balance, and a simplified particle size distribution, which are then used to determine the throughput, grind sizes, and power draws of the various comminution unit process. The Met-model uses a combination of actual operating data and models developed specifically for each unit process (Chandramohan et al., 2018; Lane et al., 2013; & Napier-Munn, 2005). Throughput and specific energy models were developed using insight from Ausenco's Ausgrind model (Lane et al., 2013) and Morrell's comminution circuit specific energy calculations published by the Global Mining Standards Group (Morrell, 2015).

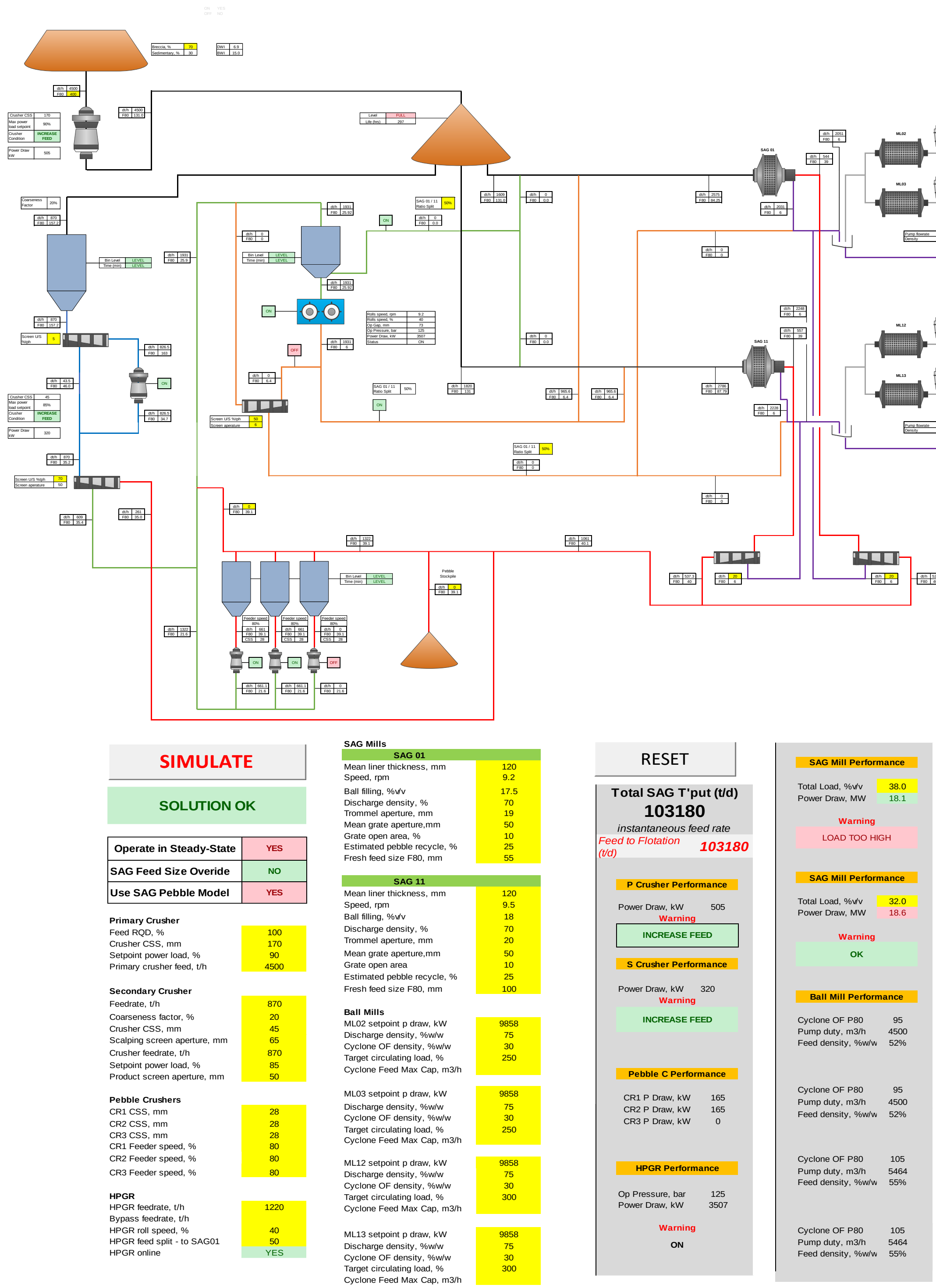

Figure 4 – Ausgrind Expert Peñasquito Met-Model

Model validation was conducted using 2018 operating data; showing good agreement with actual performance. For benchmarking, actual SAG and ball mill loads are required to accurately predict the performance of the grinding circuit for variable ore competencies/hardness and feed size distributions. However, insufficient load measurements were available for the grinding mills in the 2018 data; therefore, total filling measurements were adjusted to match the measured power draw drawn by the mills. Two main ores sources are classified in the mine plan. Figure 5 illustrates the variability of comminution properties as well as the overall higher competency associated with the sedimentary ores (lithology Kuc). Efforts are currently underway to further delineate comminution domains according to geometallurgical properties. The lithologies other than Kuc shown in Figure 5 are all diatreme or breccia ores. The model allows for forecasting of overall circuit performance with varying degrees of competent sediment and less competent diatreme ores. This forecasting ability is critical as the future mine plan indicates an average of 50% sedimentary ores in the feed.

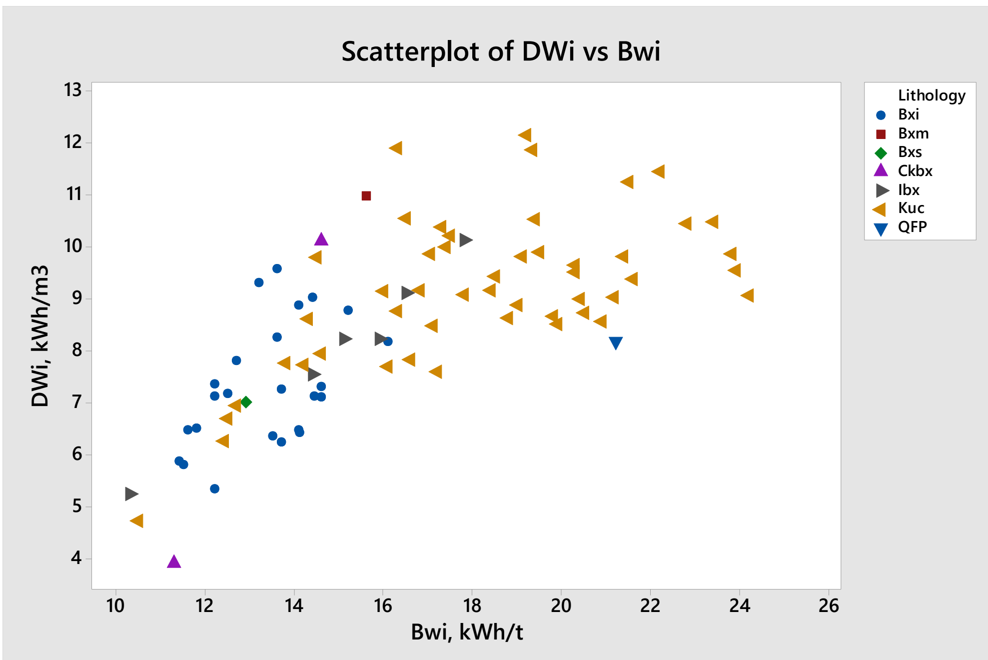

Figure 5 – Drop Weight Index and Bond Ball Mill Work Index Results by Lithology (future ores, 2019 – 2025)

The summary of the simulation benchmarking outcomes are as follows:

- Overall, the predicted throughput values closely match the measured values, demonstrating the robustness of the comminution calculations used in the Met Model
- The effect of increasing sedimentary ore content in the blend as well as operating in different operating modes (i.e., without HPGR or without the secondary crusher) can be simulated with a satisfactory level of precision
- Comminution variability within the defined ore types is significant, but as illustrated in Figure 6, the model generally predicted the actual throughput to within ± 5%
- Additional plant surveys will be needed to better simulate the overall comminution circuit, in particular around the ball milling circuit.

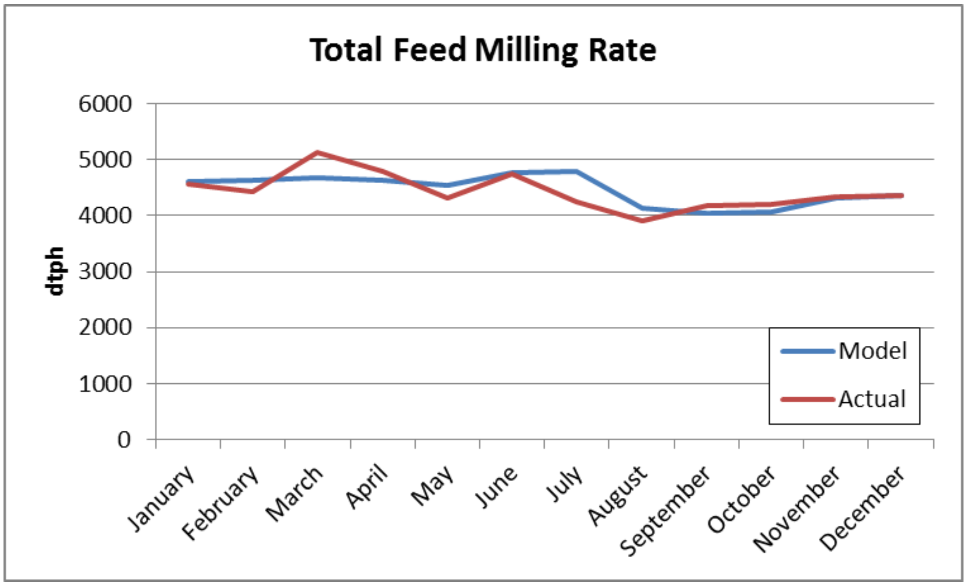

Figure 6 – Monthly Modeled and Actual Throughputs, 2018

During the preliminary assessment phase, four critical areas were identified as the constraints in the flowsheet, limiting throughput. Table 2 shows the average power draw and run-time utilisation for Q1–Q3 2018 operating data; highlighting issues and opportunities for the optimisation of the circuit.

Table 2 – Major Equipment Power Utilisation and Runtime for 2018

Equipment	Power utilisation (%)	Run time (%)
1 x Primary crusher	64	65
Two SAG mills	92	91
Four-Ball mills	80	95
1 x Secondary crusher	32	71
1 x HPGR	27	74
Three pebble crushers	26	60

The specific issues identified were:

- SAG mill:

A steep liner design was used in the SAG mills, which was limiting more extensive ranges of operational speed. The Peñasquito mill liner relines were fixed at six months for each SAG mill and at one year for the four ball mills. The mill liner design allows for bi-directional operation with a change in direction at approximately the midpoint between liner changes. At present, due to the steep liner design and fixed reline schedule of the SAG mills, the removed liners have plenty of lift, resulting in excessive steel being discarded at each change-out, as shown in

- Figure 7.

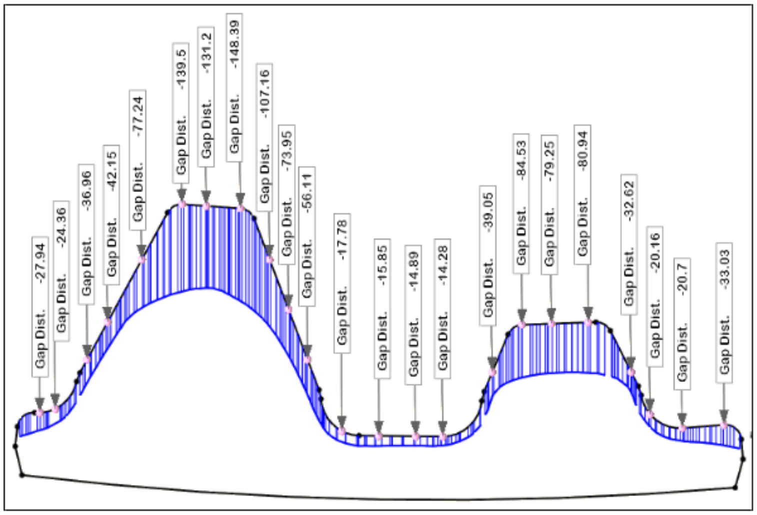

Figure 7 – New and Measured Worn Shell Liner Profiles at Change-out

- HPGR:
  - Feed to the HPGR was limited by the current configuration of the feeder, which also presented feed with significant size segregation across its profile
  - HGPR power draw was not maximised due to operation of the HPGR at a low operating speed, resulting in more material bypassing the HPGR and being fed directly to the SAG mill
  - HPGR operating speed was controlled manually and did not adjust automatically to changes in throughput levels
  - HPGR skew control settings were causing skew events are very high frequency
- Secondary crusher:
  - The coarse ore stockpile (COS) height limits the feed rate to the secondary crusher. At maximum secondary feedrate (>1,500 t/h), feed availability to the crusher is reduced due to the feeder layout. At COS levels less than 80% capacity, feedrate to the secondary crusher is difficult to sustain at a high feed rate
  - Blinding of the grizzly ahead of the secondary crusher with fines contributed to lower operating hours and reduced material throughput
- Pebble crushers:
  - Secondary crushed screen oversize and SAG mill generated pebbles are fed to the pebble crushers. The equipment selection and the type of the pebble crusher used in the flowsheet limit the minimum operable closed side setting, therefore reducing the production of the fines for optimum HPGR operation.

SAG MILLS

Ausenco's Ausgrind Expert tool was used to evaluate the performance of the SAG mills for the current operating liner design and discharge system (Chandramohan et al., 2018). As part of the evaluation process, crash stops and circuit surveys were conducted to determine baseline operating conditions.

The benchmarking evaluation of the SAG mills highlighted the following:

- Both SAG mills were operated with high total filling, largely to protect the mill shell from damage due to the steep shell lifter face angle (25°). Figure 8 presents the simulated results of the Peñasquito SAG mill liners. The benchmarked results show that the steep liner design was limiting the effective operation of the SAG mills.

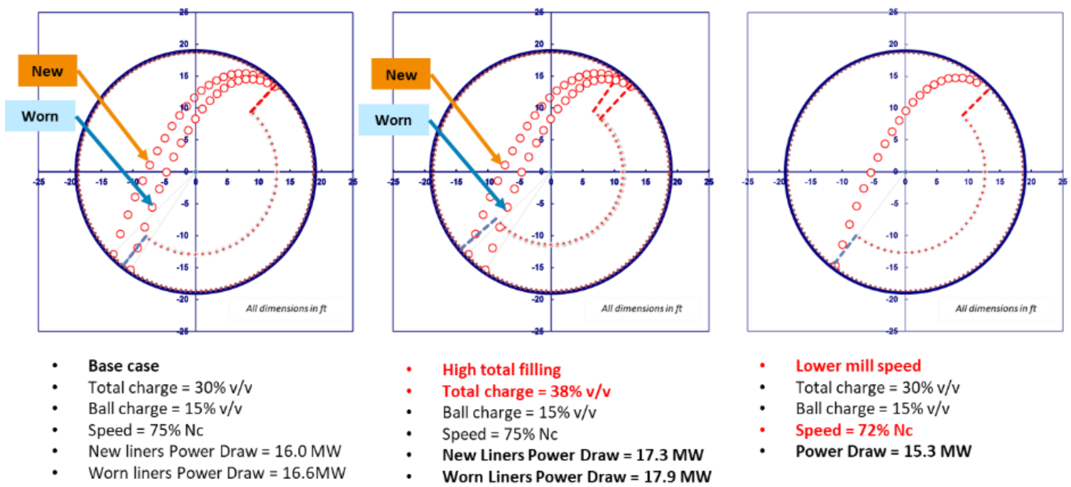

Figure 8 – SAG Mill Liner Assessment

The further evaluation was conducted on the liners to optimise the SAG mills; Figure 9 and Figure 10 show the new and worn profiles (RED highlight) of the shell lifters. Discussions with the maintenance and reliability teams indicated the shell lifter and liners have sufficient metal at change out for both bi and uni-directional operation for a six-month fixed schedule. A revised design was already being planned by the site maintenance team and is scheduled to be installed late in 2019 (Figure 10).

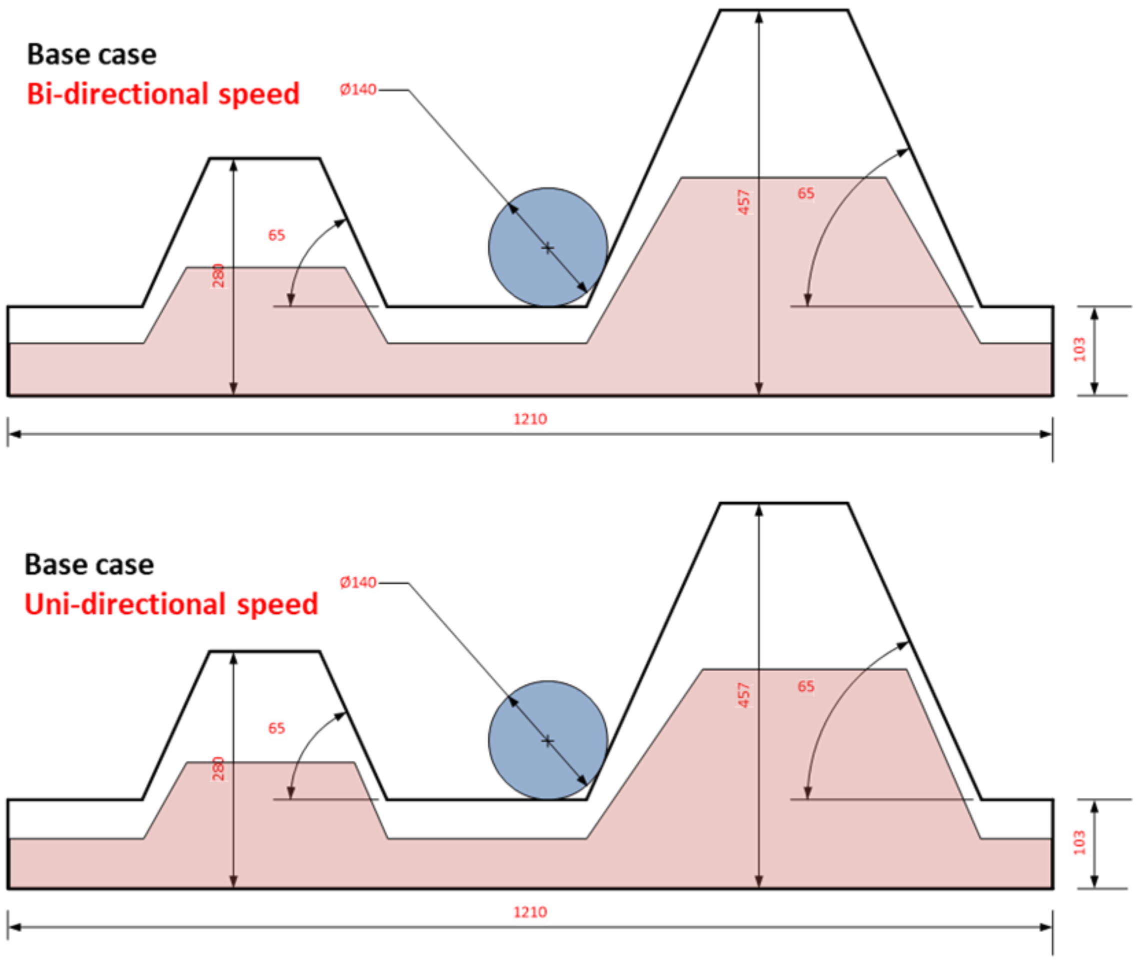

Figure 9 – Current Shell Liner Package, Modelled for Bi and Uni Directional Operation

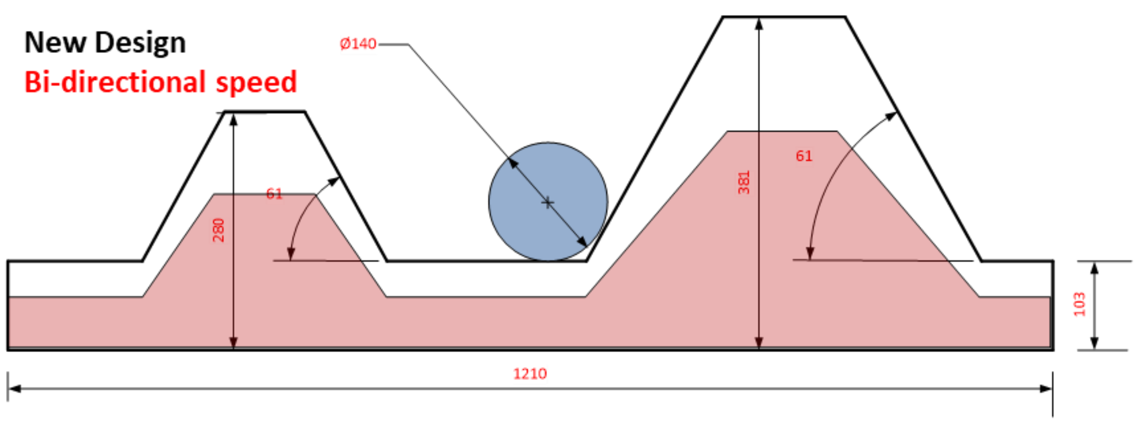

Figure 10 – Proposed New Design to be Installed Later in 2019

SAG mill control optimisation was identified as a quick-win opportunity to stabilise, de-constrain and maximise throughput. During the evaluation phase, SAG mill noise was identified as a critical measurement that was not calibrated properly in control. The Peñasquito SAG mills are equipped with shell-mounted Mill Slicer vibration sensors (Mill Slicer, 2019); a noise signal from the vibration sensors is then used by the Expert control system to adjust the speed of the SAG mill to maximise power draw, (Van Zyl et al., 2013).

Performance evaluation of the SAG mill Expert system indicated unusually high controller activity to maintain SAG mill load. The increased controller activity minimised the effectiveness of the controller, causing significant instability of the SAG mill load, therefore resulting in reduced overall throughput. External consultants were engaged in tuning the Expert system and in optimising the logic in the system. Tuning of the SAG mill Expert system showed positive results; indicating the lower frequency of large feedrate changes, improving SAG mill load control and therefore resulting in stable SAG mill operations, per Figure 11. SAG mill control change was implemented at the beginning of February 2019, showing reduced controller activity to maintain optimal SAG mill load when compared with December 2018 and January 2019 periods. Figure 12 highlights the resulting change to the SAG mill load after control optimisation (left chart) where the load variability has lessened significantly.

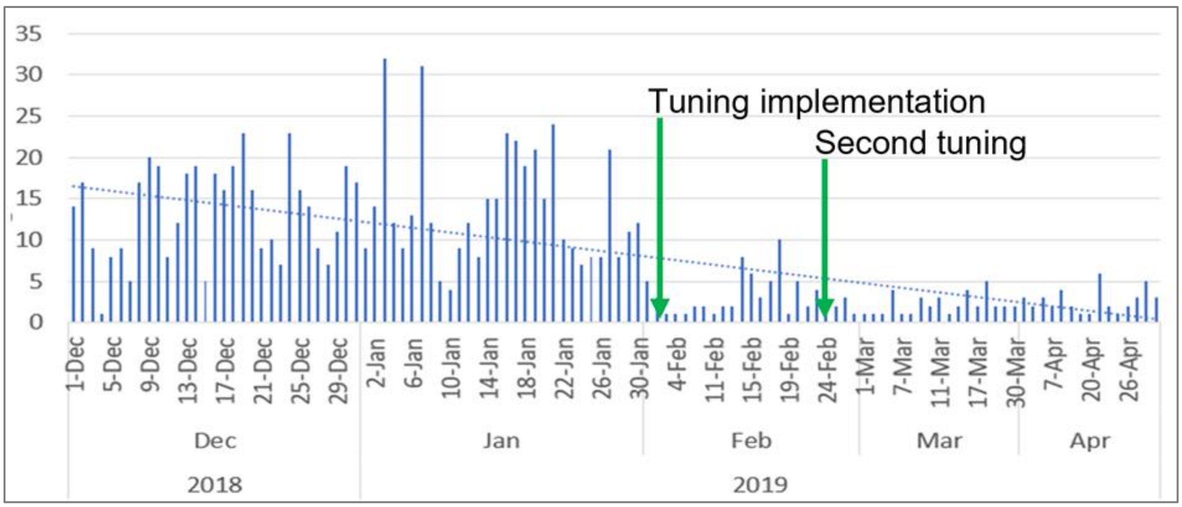

Figure 11 – Daily Frequency of Expert System Changes >600 t/h in 15 minutes

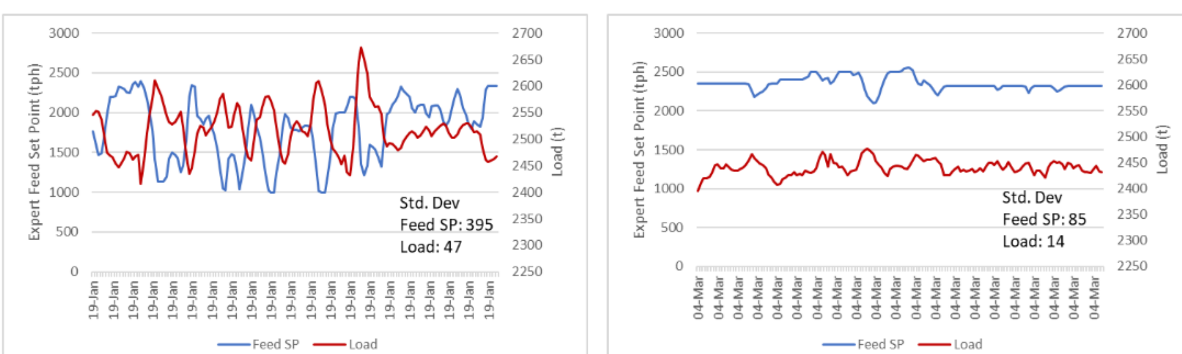

Figure 12 – SAG Mill Control Optimisation – Before the change (left), and after the change (right)

CRUSHING CIRCUIT: HPGR + SECONDARY CRUSHER + PEBBLE CRUSHERS

Historical performance evaluation of the HPGR unit shows low utilisation since installation. Historically, the unit rarely exceeded 2.5 MW power draw (installed 5.0 MW). The lower utilisation was a symptom of insufficient supply of secondary crusher product and coarse product produced by the pebble crushers as well as HPGR feeder capacity constraint. Additionally, if the HPGR throughput was less than the material being fed (pebble crusher product and secondary crusher product undersize), it could be bypassed directly to the SAG mills. As part of the optimisation strategy, circuit stress tests were conducted to determine the physical and operational restrictions limiting plant throughput.

Figure 13 presents the model throughput (RED and BLUE) vs filtered January 2019 operational data (GREY). During this period, a higher proportion of the lower competent breccia ore was treated. The results show that for increasing secondary crusher feed (Raptor), increasing circuit throughput is also observed due to the higher utilisation of the HPGR. Earlier works by Parker et al., (2001) and Lane and Siddal (2002), showed the potential benefit of increasing SAG mill throughput by substituting SAG mill feed with HGPR product; resulting in significant throughput increase and higher grinding efficiency.

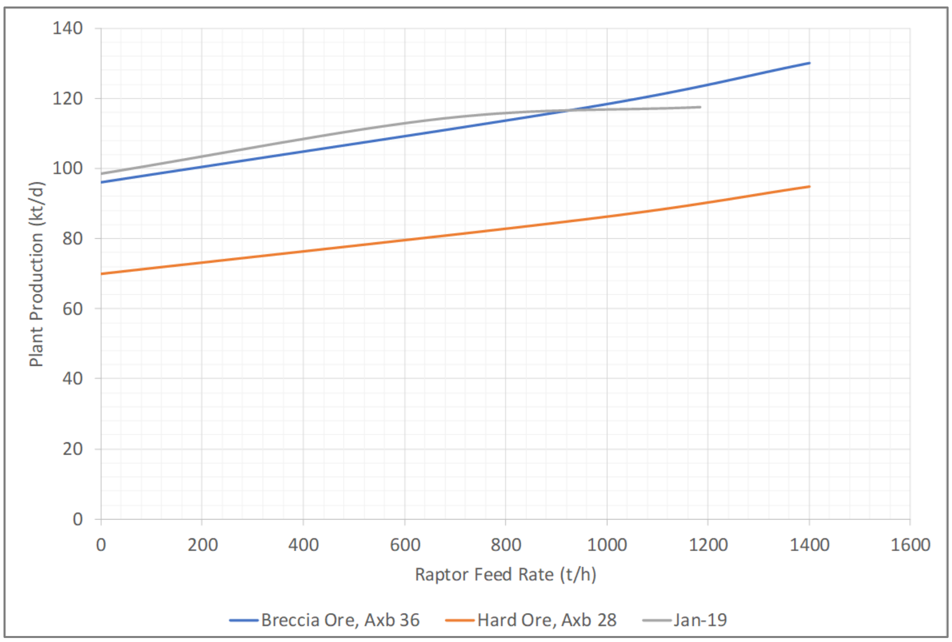

Figure 13 – Secondary Crusher Feed Impact on Total Plant Feedrate

Table 3 presents the relative circuit throughput differences when both HPGR and secondary crushers are switched on and off. The overall benefit of having both the secondary crusher and the HPGR operating is significant in the Peñasquito flowsheet; which highlights the importance of maintaining higher availability and utilisation of the crushing and augmented feed circuit. The reduction in throughput without the secondary crusher or HPGR could be higher if considering blends with more of the competent sedimentary ore as these have a greater impact on SAG throughput. Figure 14 highlights the plan view showing the relative location of the secondary crusher reclaim feeder at the COS. Due to its orthogonal position (relative to the two SAG mill feeders), feed availability to the secondary crusher is reduced (for a maximum feed rate of 1,500 t/h) when the COS drops below the 80% height level. At low coarse ore stockpile levels, the secondary crusher can typically only run for a short time before running out of available feed.

Table 3 – Relative Throughput Difference for Varying Operating Strategy

	HPGR OFF	HPGR ON
Secondary crusher ON	- 8%	Baseline
Secondary crusher OFF	-15%	-16%

Figure 14 – Secondary Crusher Feeder Arrangement at the Coarse-Ore Stockpile

As part of the strategy to maintain stable operations, control of the HPGR and pebble circuits was optimised, as shown in Figure 15. Before (LEFT chart) the crusher-control optimisation and implementation, the HPGR rolls speed was fixed, resulting in a frequent oscillation of the HPGR and pebble crusher feed bin levels. These bin level oscillations caused frequent pebble bypass to the stockpile, and at higher HPGR feed bin levels, a significant portion of crushed pebbles was bypassed to the SAG mills; further reducing the overall circuit throughput. Stabilising the HPGR feed bin level and optimising the HPGR control stabilises the pebble crusher feed bin level (RIGHT chart); therefore, minimising the pebble rejection to stockpile and bypass to the SAG mills. The overall control change to the HPGR operation aims to increase the feed to the HPGR; maximising the HPGR power draw and throughput.

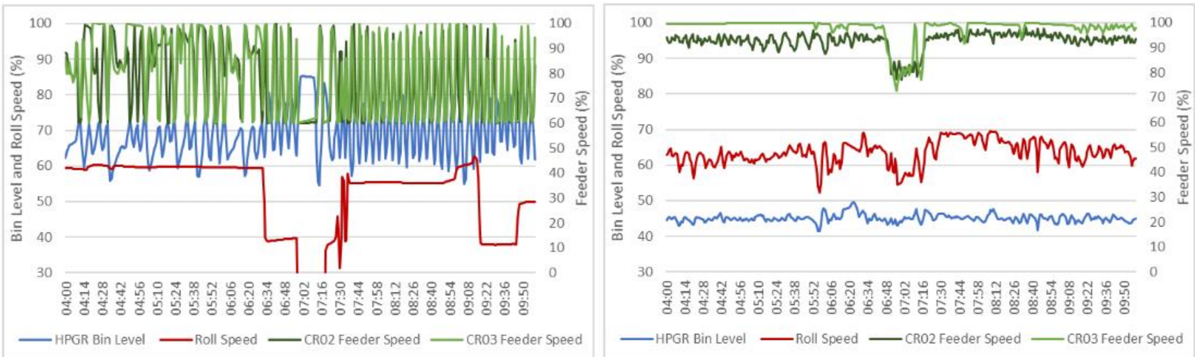

Figure 15 – HPGR and Pebble Crusher Control Optimisation

Temporary modifications were also made to the feed bin ahead of the HPGR feeder to reduce the significant size segregation of material across the feeder profile. Work is ongoing for permanent improvements to the bin to allow for sustained delivery of unsegregated feed to the HPGR.

Future Scope, Strategy, and Summary

The preliminary optimisation work conducted over six months demonstrated that the Peñasquito operations could achieve higher instantaneous feed rates if sustained feed were maintained through the secondary crusher, higher HPGR utilisation, and optimised SAG mill and pebble crusher operations. The key bottlenecks identified during the evaluation phase indicate that the circuit could operate more effectively through a combination of improved process control, operating parameters, and minor improvements to material handling equipment. For future years, more work is required to fully understand the variability within the various ore types and relationships to geometallurgical parameters. Achieving higher throughput with blends consisting of high proportions of competent sediment ore will likely require additional modifications to the comminution circuit.

Future work being considered:

- Addition of primary crushing capacity to maintain higher sustained levels on the COS. The current primary crusher will be throughput-limited for the future mine plan. Operating primary crushing with a smaller closed-side-setting (CSS) would allow the downstream comminution circuit to more consistently attain high throughput rates even with a higher proportion of competent sedimentary ore
- Evaluating replacement or upgrading of the current pebble crushers to maintain a tighter choke and smaller product size. The design and operation of the existing pebble crushers restrict the minimum allowable CSS, as the current crushers are not suitable to operate with a CSS less than 20 mm. A reduced CSS would improve the HPGR operation.

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