HIGmill OPEX optimization at Ero Brazil's Concentrator

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ABSTRACT

Ero Copper Corporation has been expanding rapidly and been dedicated to achieving a growing sustainable mining resource from 2017 after its acquisition of Mineração Caraíba (now Ero Brazil).

The concentrator plant is being sequentially debottlenecked, expanded and optimized for a future 4.2 MTPA. The HIG2300 has undergone multiple improvement measures to lower the HIGmill OPEX, such as upgrading to a 3.5 MW motor, trialling better performing ceramic grinding media and reconfiguration of the castellated and non-castellated HIGmill rotors. The larger installed motor power allows for greater HIGmill throughput and greater flexibility due to higher torque availability. Laboratory tests on media of same density and size shows wear rate of the new high-quality media is 34% lower than the previous media. A plant scale trial of the new media with same topping up size and initial size grade was performed. The trial proves the media wear rate decreased by 26.8% from 8.73 to 6.39 in terms of g/kWh, and results indicate that the media roundness also influences the life of HIGmill parts. Roundness of seasoned new type ceramic media below 7.0 mm is 0.93 to 0.98, which is higher than previous media's 0.61 to 0.93. Rounder ceramic grinding media lowers the wear of HIGmill rotors by 28.7% and the liners by 43.3%.

Due to higher wear on liners of the transition zone, 3 smaller rotors replaced the original large rotors and 2 castellated rotors were added. The new rotor design also promotes the HIGmill performance by achieving better grinding intensity distribution along the mill chamber, benefits of 41.1% increase to the liner life are achieved.

This paper will focus on the details of the improvements mentioned above, and the resulting positive results which lead to more stable HIGmill performance, and lower HIGmill OPEX, and stable feed streams to downstream rougher flotation circuit.

Introduction

Ero Copper is a high-growth, clean copper producer with operations in Brazil and corporate headquarters in Vancouver, B.C. Mineração Caraíba S.A. ("MCSA"), owner of the Caraíba Operations, which is comprised of the operations located in the Curaçá Valley, Bahia State, Brazil.

The Caraíba Operations consist of fully integrated mining operations and processing facilities, including the Pilar and Vermelhos underground mines and the Surubim open pit mine. Typical feed grades vary between 1.25% and 1.54% copper resulting in a high-grade, clean concentrate grading approximately 32% to 35% copper.

In mid-2018, the Company initiated an optimization program aimed at improving metallurgical recoveries and overall plant performance. Studies on mineralogical characterization and liberation analyses paved the way for the introduction of HIGmill technology. The HIGmill was supplied by Swiss Tower Mills Minerals via Metso and commissioned in August 2020, with ramp-up and optimization through to December 2020. In 2023, to increase the maximum torque limit and reduce the operational shaft speed, a 3.5-megawatt (MW) motor replaced the existing 2.3 MW motor.

During 3-year operation, severe deformation was found among used grinding media, the shape change was significant as the media wore down - the smaller media became triangular or multi-faceted. High and uneven wear to the liner was experienced in the transition zone, and the rotor closest to the transition media level accelerated liner wear. To reduce the wear on the transition zone, smooth rotors were installed in the transition zone instead of the castellated rotors, even with smooth rotors the operation experienced high wear in the transition zone.

In August 2023, a new ceramic media of same size and density from different supplier (King's Beads) was introduced to the HIGmill, and a 4-month plant trial was carried out to justify if it had better wear rate performance in terms of the media consumption per se and the wear to the mill spare parts. To further reduce the wear on the mill parts, a newly rotor configuration setup by mill manufacturer STM was installed in the HIGmill in December 2023, and significant wear decrease was also achieved on mill spare parts. This paper will mainly focus on the results of above improvement campaign.

Mill Operation with King's Media

In 2022, a laboratory campaign was initiated to determine the optimal ceramic media selection for the HIGmill. The mechanical characteristics of then ceramic media (incumbent media) and a media from King's Beads (TA-380) were compared. The wear tests of the 2 media products were conducted by grinding abrasive silica flour slurry in a lab-scale vertical stirred mill in open circuit. To better reflect the wear resistance of ceramic media products, the fresh silica flour slurry was continuously fed into the test mill with the ground product overflowing from the mill top for a certain length of time. Some of the results of the test work performed by King's Beads are shown in Table 1.

Table 1 – Physical Property and Wear Performance Comparison

	Ceramic Media Density (g/cm³)	Average Size (mm)	Wear Rate (g/kWh)
Incumbent media	3.8	9.02	22.9
King's media (TA-380)	3.8	9.06	15.1

The results indicate that the King's media has similar density and size compared to the incumbent media yet 34.1% better wear rate, meaning that the likelihood of causing HIGmill operational issues by replacing the incumbent media with King's media was very low, should the same size grade be used. Better wear resistance will also contribute to reduced wear to HIGmill spare parts.

After the motor replacement in April 2023, the HIGmill operating parameters with incumbent media such as power draw, speed, torque, feed slurry parameters, media consumption rate were recorded to create a benchmark, and a total 2,181 hours' operation data was recorded. After that, a manually graded initial charge of King's media was loaded in the HIGmill in August 2023 and the same sized media (9 mm) was used as topping up, to make sure the only variable in the plant trial was the ceramic media type. The trial on King's media lasted for 2,109 operation hours till December 2023. The same dataset was collected for the 2 ceramic media products during the 8-month plant trial period, and Figure 1 illustrates the HIGmill operation parameters of the 2 ceramic media products.

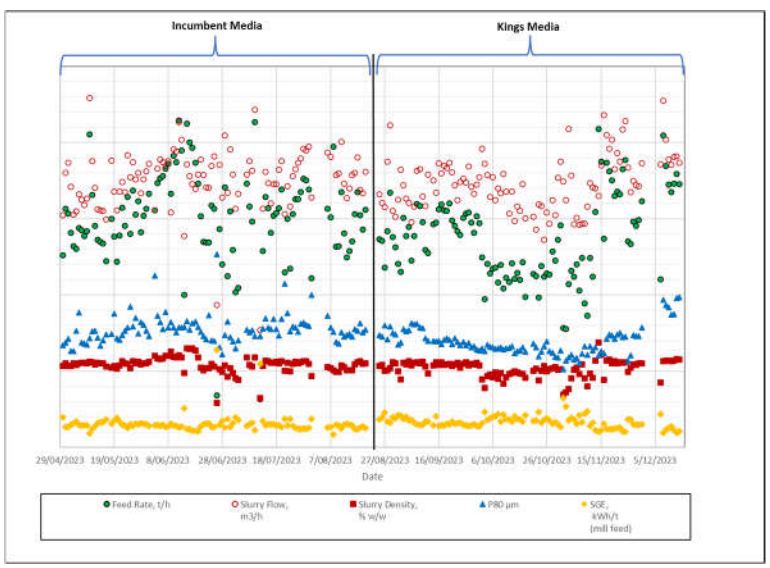


Figure 1 – HIGmill Operation Parameters in Plant Trial Period

The HIGmill feed solids averaged 54.3%w/w and 51.6%w/w for the incumbent media and King's media, respectively, which resulted in difference in HIGmill throughput (151.1 MT/h and 137.3 MT/h for the incumbent media and King's media respectively), although the flow rate was similar (176.1 m^3/h and 173.4 m^3/h for the incumbent media and King's media respectively). The operational speed slightly reduced from 91% to 86% for the incumbent media and King's media respectively.

The P80 of HIGmill ground product averaged at 69.7 microns for King's media and 77.7 microns for the incumbent media. The respective specific grinding energy to reach their P80 values were 16.65 and 15.45 kWh/MT, respectively. The resulting media consumption were 8.73 g/kWh and 6.39 g/kWh for the incumbent media and King's media, respectively. This means a 26.8% media wear decrease was achieved with King's media in the plant trial.

Table 2 – Wear Rate Comparison in Plant Trial Period

	Total Media Consumption (MT)	Grinding Energy (kWh)	Media Wear (g/kWh)
Incumbent media	41.70	4,774,223	8.73
King's media (TA-380)	29.60	4,631,757	6.39

Note that although the feed density and flow rate were set a bit lower with King's media, during the trial, the average HIGmill operation power for the incumbent media and King's media were almost the same (2,324 kW and 2,337 kWh, respectively). The ~4% lower media fluidization in the HIGmill combined with higher specific grinding energy subjected the King's media to harsher wearing conditions.

Media Wear and Roundness

The on-going media wear analysis is shown in Figure 2. Since it is hard to estimate the remaining media charge in the mill chamber accurately, the operating team measured the discharged media quantity during each maintenance inspection to calculate the accurate wear rate and corresponding media filling ratio. Figure (a) and (b) are comparisons of media wear rates and media filling ratios in the plant trial period.

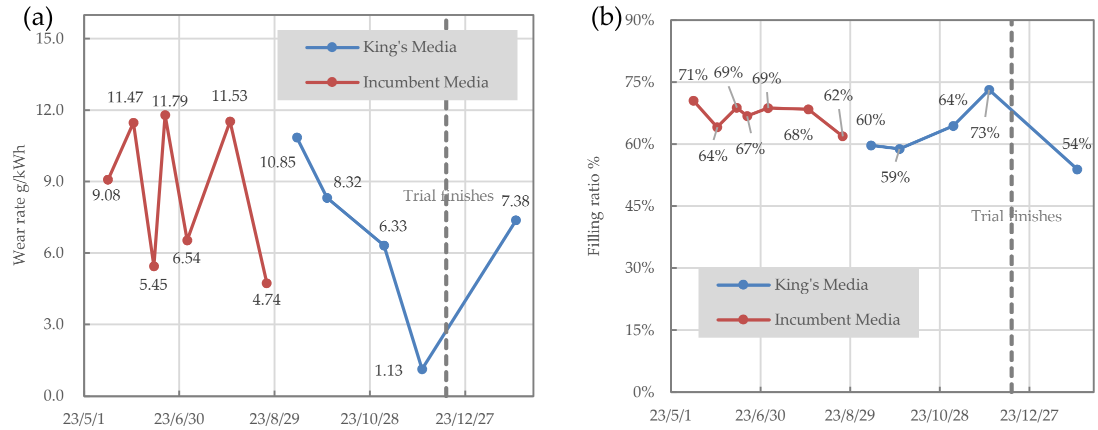


Figure 2 – Comparison of Wear Rates (a) and Media Filling Ratios (b) in Plant Trial Period

Figure 2 indicates that, the wear rate of incumbent media ranged from 4.74 to 11.79 g/kWh, while King's media was 1.13 to 10.85 g/kWh. The filling ratio during the whole trial period was around 54% to 73%. It is obvious that the media consumption rate with King's media was significantly reduced leading to a reduced OPEX of the HIGmill circuit.

During the HIGmill shutdown maintenance in August and December 2023, the operators collected seasoned incumbent media and seasoned King's media, respectively. It was theoretically assumed that the first several MTs of the discharged seasoned media were only from the HIGmill bottom zone, and the following several MTs were from the middle zone while the last several MTs were from the top zone of the HIGmill. Then the seasoned media were carefully sampled from the jumbo bags to minimize sampling discrimination and rotary sample splitter was used to get the final representative seasoned media. Two seasoned media samples were sent to King's lab and another lab in University of São Paulo. The morphology of seasoned media in different size ranges and the detailed roundness data are listed in Figure 3, Figure 4, Table 3 and Table 4, respectively.

Table 3 – Roundness of Seasoned Incumbent Media Collected in August

	< 4.5 mm	4.5 – 5.5 mm	5.5 – 7.0 mm	> 7.0 mm
Top	0.653	0.834	0.931	0.968
Middle	0.627	0.817	0.933	0.964
Bottom	0.605	0.840	0.885	0.956

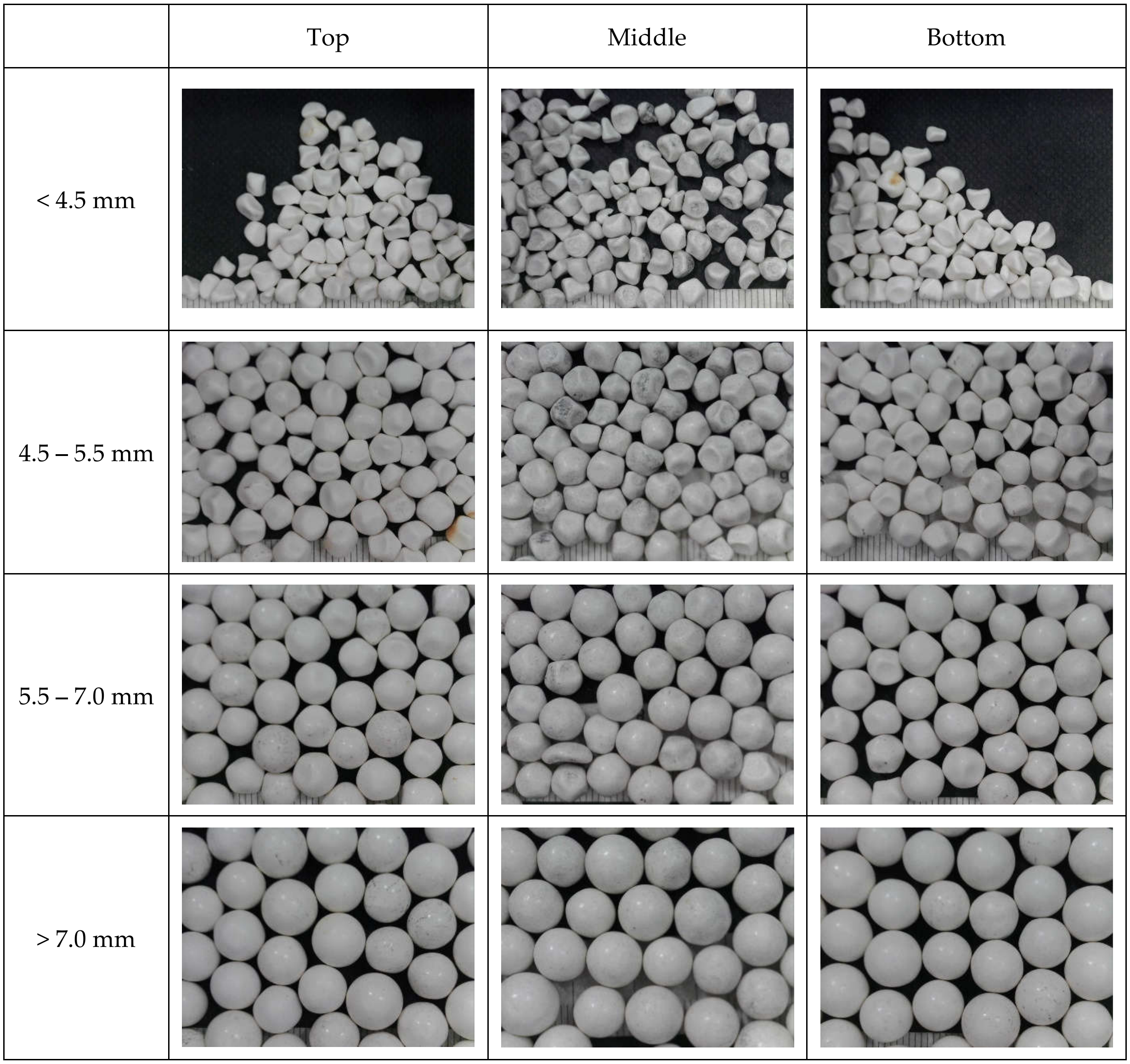


Figure 3 – Morphology of Seasoned Incumbent Media Collected in August

Table 4 – Roundness of Seasoned King's Media Collected in December

	< 4.5 mm	4.5 – 5.5 mm	5.5 – 7.0 mm	> 7.0 mm
Top	0.984	0.970	0.949	0.989
Middle	0.984	0.970	0.965	0.987
Bottom	0.984	0.962	0.941	0.985

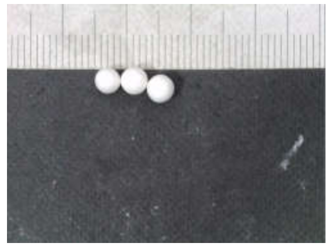
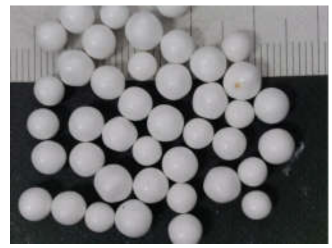
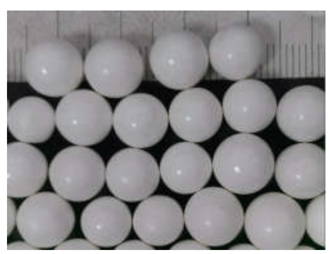
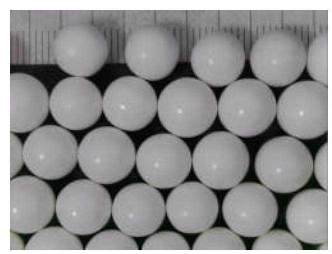
	Top	Middle	Bottom
< 4.5 mm			
4.5 – 5.5 mm			
5.5 – 7.0 mm			
> 7.0 mm			

Figure 4 – Morphology of Seasoned King's Media Collected in December

Among the seasoned incumbent media, only a small portion of the beads are in the sub 4.5 mm size range, while most of the beads are in >7.0 mm size range. As the wear on the incumbent media increased, the beads lost their original shape and generated sharp edges and multiple facets and the roundness of the beads decreased to 0.61.

As for seasoned King's media sample, the analysis of roundness showed that even the smallest beads still maintained its original shape and the roundness was much higher (0.984).

No significant sharp ceramic edges or corners were found among the seasoned King's media, indicating it has better mechanical properties. It was also found that with rounder media, wear on the mill parts such as rotors and liners were also decreased. Roundness of grinding media could be one of the key factors of extending the life of mill parts, more research and studies are needed to further explore the quantitative relationship between media shape and wear to the mill parts.

Wear of Rotor and Liner with King's Media

"A" shaft was used from April 26th to August 22nd, with total running time 2181 hours. During the reline on the August 22nd it was observed that the two segments of the shell liners were 100% worn, several stators were 100% worn and the first rotors were 100% worn. From these observations we can conclude that the shell liner is the wear limiting component governing the reline interval.

"B" shaft was used from August 22nd to December 16th, total 2103 hours. During the reline on the December 16th it was observed that the one segment of the shell liner was 100% worn, and one stator was 97% worn and the heaviest worn rotor was 80% worn. From these observations we can conclude that the shell liner is still the wear limiting component governing the reline interval.

The wear pattern across the mill shaft improved significantly with a step change drop in the rotor material loss, from an average 124.6 mm wear for the incumbent media to 85.7 mm wear for King's media, indicating a significant wear improvement.

The wear pattern across the liner improved significantly with a drop in the material loss, from an average 10.3mm wear for the incumbent media to 5.6 mm wear for the King's media, almost doubling the liner life.

The wear performance for the media trial is summarized in Table 5, the increase in rotor life is 28.7% and the increase in liner life is 43.3%, as can be seen in Figure 5.

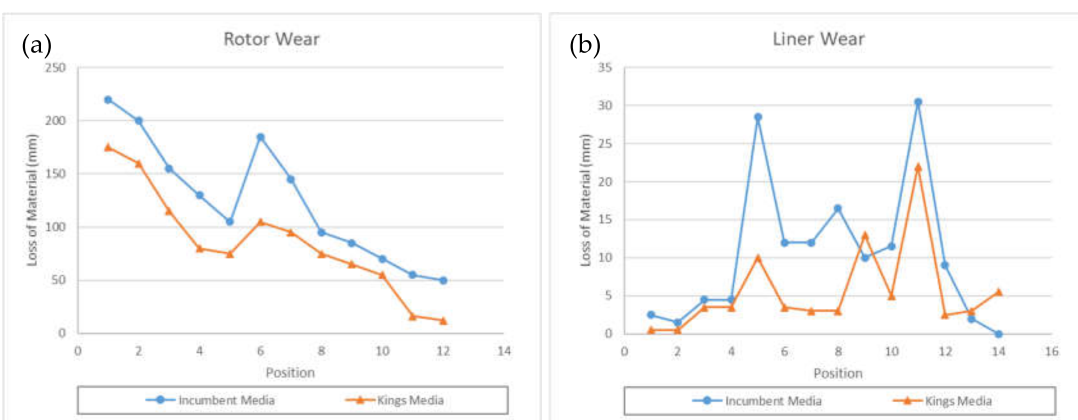


Figure 5 – Rotor (a) and Liner (b) Wear Profile

Table 5 – Rotor and Liner Wear Performance Comparison for Media Trial

	Average Rotor Wear Rate (mm/h x10^3)	Average Shell Liner Wear Rate (mm/h x10^3)
Incumbent media	57.09	4.70
King's media (TA-380)	40.74	2.67

Figure 6 shows the rotor appearance before and after use. It can be clearly seen that new rotor installed in April (a) and August 2023 (c) are all relatively new. After 2181 hours of operation, rotor with incumbent media got severely worn, and bottom rotor was worn away (b). After 2109 hours of operation with King's media, the bottom discs were worn, yet no serious damage or rotor framework detachment was found (d).

Figure 6 – New and Worn Rotors in Plant Trial Period

Wear of Rotor and Liner with New Shaft Configuration

After analysis of the operational data Swiss Tower Mills Minerals recommended to change the rotor configuration to a more optimal design. Figure 7 shows the difference in the shaft configuration selected for operation (shaft B) up to December 16th, 2023, and the configuration (shaft A) from December 16th, 2023, to April 22nd, 2024. New design has some changes on the size and arrangement of the rotors. The new shaft A has 2 more castellated rotors (no. 13, 14), rotors no. 3, 4, 5 were enlarged from 1360 mm to 1550 mm. To reduce the wear in the transition zone, rotors no. 12, 13, 14 were changed from 1500-1550 mm to 1360 mm. The number of castellated rotors was increased to allow higher media filling levels, to share the load over more rotors.

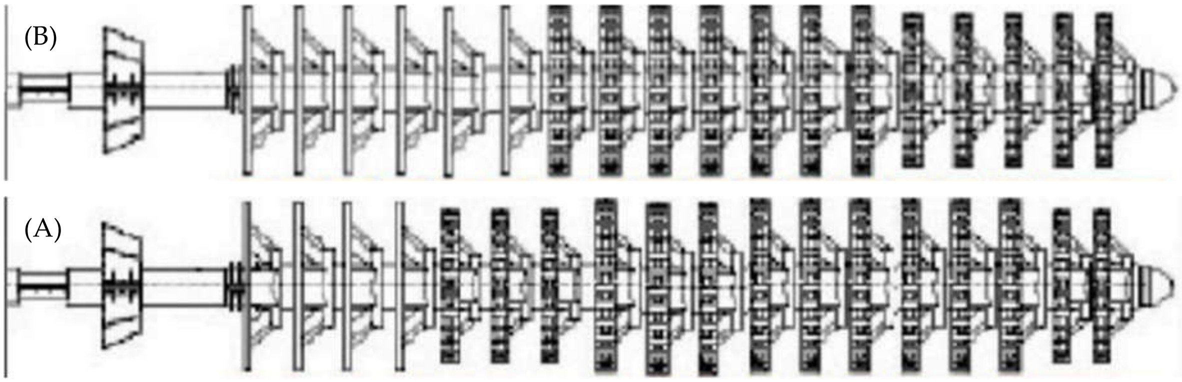


Figure 7 – Shaft Configuration Changes for Shaft A and B

"A" shaft was used from December 16th, 2023 to April 22nd, 2024 total running time 2046 hours. During the reline on the April 22nd, it was observed that the heaviest worn stators was 72% worn and heaviest worn rotors were 70% worn. From these observations we can conclude that the shell liner is no longer the wear limiting component governing the reline interval, and the focus shifts to the rotor.

The wear pattern across the mill shaft changes with an increase in rotor wear in the first half of the mill but reduces in second half of the mill, the overall shaft wear increased slightly from an average wear 85.7 mm wear for shaft B to 94.6 mm wear for shaft A. This can be directly linked to the use of larger rotor diameter for positions 3, 4, 5, and smaller rotor diameter in position 12.

The wear pattern across the liner improved significantly with a drop in the material loss, from an average 5.6 mm wear for shaft B to 3.2 mm wear for the shaft A.

The wear performance for the media trial is summarized Table 6, the reduction in rotor life is 13.5% and the increase in liner life is 41.1%. Although there is a reduction in rotor life, if we compare it to the incumbent media the overall increase in rotor life is still 19.0% higher. Similarly, if we compare the shell wear to the incumbent media the overall increase in liner life is 66.6% higher.

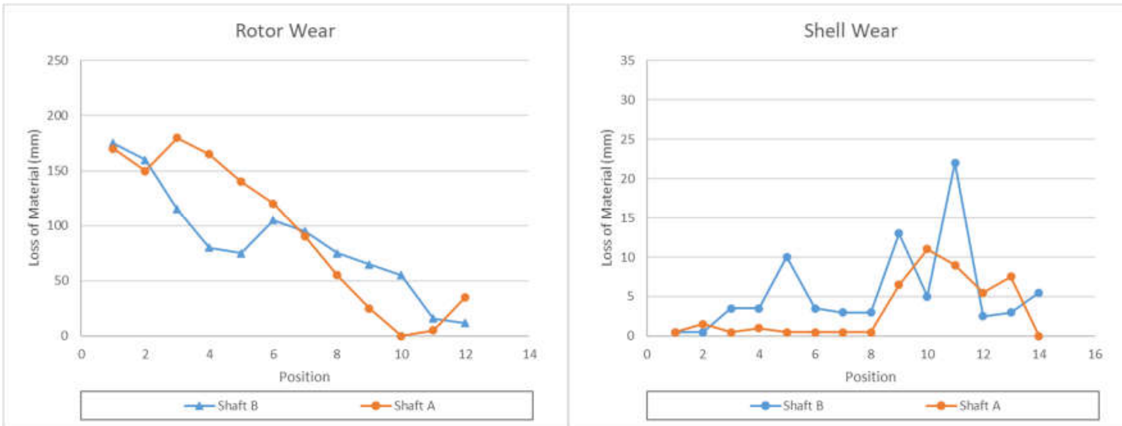


Figure 8 – Shaft (B) and Shaft (A) Wear Profile

Table 6 – Rotor and Liner Wear Performance Comparison for Rotor Configuration Change

	Average Rotor Wear Rate (mm/h x10^3)	Average Shell Liner Wear Rate (mm/h x10^3)
Rotor B	40.74	2.67
Rotor A	46.23	1.57

Improvements on operation parameters were found by changing to new shaft configuration, the feed rate was increased from 137.3 MT/hr to 148.7 MT/hr with lower power draw 2337 kW to 1998 kW. Specific grinding energy and P80 size were similar (16.65 kW Vs. 16.60 kWh/t and 69.5 microns Vs. 70.2 microns for shaft B and A respectively). The operational speed reduced from 86% to 72% for shaft B and A respectively. The media wear rate decreased further from 6.39 g/kWh to 3.67 g/kWh. This means a further 42.5% media wear decrease was achieved. All these evidence points to a fact that the new shaft configuration achieved consistent grind efficient milling with lower OPEX due to lower wear parts and media consumption.

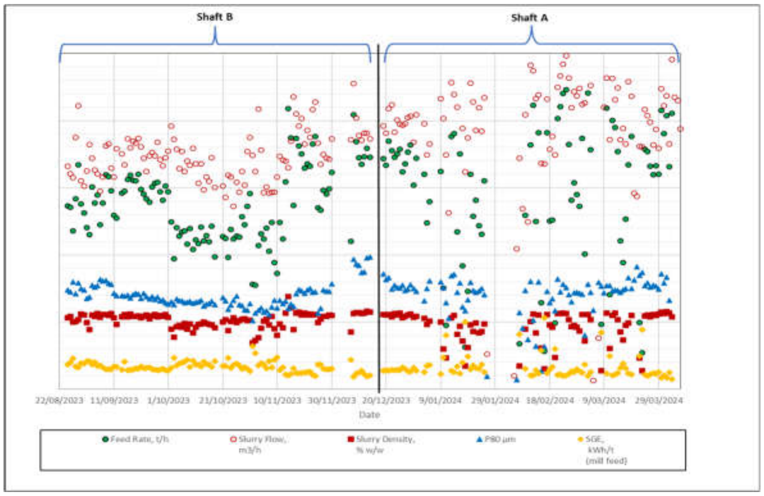


Figure 9 – HIGmill Operation Parameters with New Shaft Configuration

Conclusions

1. By using a better-quality grinding media, the consumption rate of King's media was 26.8% lower than the incumbent media. HIGmill operation parameters such as P80 size were also improved.
2. King's media kept its original shape after wear. Rounder ceramic media shows better grinding efficiency and was beneficial to reduce the HIGmill spare parts. The averaged rotor wear and shell liner wear were reduced by 28.6% and 43.2%, respectively by using King's media.
3. Based on the wear patten of the mill shaft, new shaft configuration was designed, and the new shaft further lowered the averaged wear on the shell liner by 41.1 %.
4. New shaft configuration with King's media jointly improved the HIGmill performance with a higher throughput but lower power draw and media wear rate. The specific grinding energy and P80 size remained similar, indicating the OPEX of the HIGmill circuit was reduced and there were no adverse effects to the downstream process.

Acknowledgments

The authors would like to thank the Ero Brazil Project for allowing publishing this work, and their on-site HIGmill operational team's professional work, and Swiss Tower Mills Minerals (STM) and King's Beads' technical support to this improvement campaign.

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