Original Article

Effect of screening media replacement on secondary crushing at Salobo mine

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Abstract

Screening plays a crucial role in the beneficiation process. This study investigated the replacement of a vibrating screen in the secondary crushing circuit at the Salobo mine, aiming to optimize particle size distribution and operational efficiency. Samples were collected before and after replacing the 75×150 mm screen with a 75×75 mm screen, analyzing the granulometry and its impact on the crushing process. The results indicated an increase in the amount of material passing through the 50 mm screen, a reduction in the maximum particle size, and a higher crushing rate, accompanied by an increase in electrical consumption. The modification improved circuit efficiency, contributing to the overall plant performance and highlighting the importance of classification screen control in mineral processing.

Keywords: Copper ore; Screening; Crushing; Particle size distribution.

1 Introduction

Copper is one of the oldest and most widely used metals by humankind, playing a crucial role in technological and industrial development throughout history. In Brazil, the demand for this mineral has historically exceeded production, with projections for continued global demand growth [1]. Nationally, the Salobo mine, located in the Carajás mineral province in Pará, is recognized for its strategic importance, being one of the largest copper reserves in the country [2]. The Carajás region, illustrated in Figure 1, is one of the world's richest mineral regions, with approximately 1.2 billion tons of ore and an average copper grade of 0.64% [3-5].

Discovered in the 1970s, the Salobo mine faces beneficiation challenges due to its geological complexity, so open-pit mining operations only began in 2010. The plant started producing copper concentrate in 2012, driven by technological advancements in mining and the development of efficient ore processing alternatives, particularly in flotation and crushing stages [2]. The copper deposit is classified as a world-class sulfide deposit, with an Archean origin and contemporary granite emplacement [3]. Salobo's mineralization occurs in shales with varying compositions, with magnetite being a key component in classifying the host rock. The main mineral units include the Magnetic Schist (XMT), with magnetite content above 10%, the Biotite-Garnet Schist (BDX) and the Garnet-Grunerite Schist (DGRX), with magnetite content below 10%. Each of these units have distinct structural characteristics and copper content percentages, adding complexity to the treatment of this ore [6].

The processing route was developed after several feasibility studies, particularly for the flotation stage, which was designed to achieve a copper recovery rate of 87.0% [2]. In addition to the mineral diversity in the deposit, the degree of liberation of the copper sulfides is very low, requiring grinding to 106 µm for flotation. Another significant feature of this material is its hardness, with technological characterization results showing a work index of 20,2 kWh/t for over 80% of the samples and a density of 2.8 to 4.2 g/cm^3, indicating a material with high grinding competency [7]. The copper ore from Sossego's mine is also associated with high levels of deleterious elements, mainly fluorine and chlorine, which can negatively impact production efficiency and lead to penalties for the company [6]. The challenges associated with exploring this reserve demands research into technological innovation and adjustments to the processing route.

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In this context, screening plays a crucial role in the efficiency of the beneficiation process, responsible for the ideal size classification of the material. The efficiency of this process can be defined as the degree of separation of material into fractions above and below the screen aperture, highlighting the importance of strict control over this stage for the success of the operation [8]. The metric can be calculated to determine screening efficiency, where an industrially ideal scenario is approximately 95%, though values in the 80–90% range are still considered acceptable [9,10]. Factors such as mineralogical variations, the presence of friable materials, and fine particles can negatively affect screening performance, requiring constant adjustments to the process [11].

Screening parameters can be optimized to improve efficiency, such as feed rate, type of motion, particle shape and screen aperture size [12]. This study focuses on the screen replacement of the Haver screen in secondary crushing, aiming to increase the amount of material under 50 mm. The research examined the impact of replacing the 75×150 mm screen with a new screen with a smaller aperture size. The results indicate that it was possible to increase the passing material rate at the proposed particle size, as well as increase the crushing rate in the secondary crushing circuit. The crushers' product became finer, as observed through top size analysis and dry screening results. This new particle size distribution generates productivity gains for the plant, optimizing grinding and other comminution stages. The proposal aligns with the ongoing pursuit of process improvements, reinforcing Salobo's position as a reference in innovation in the mining sector.

2 Methodology

The research collected samples at three points along the processing route of the mine to quantify the impact of the screen replacement. The processing route, illustrated in Figure 2, consists of two production lines (Salobo III). Initially, the material extracted from the mine undergoes

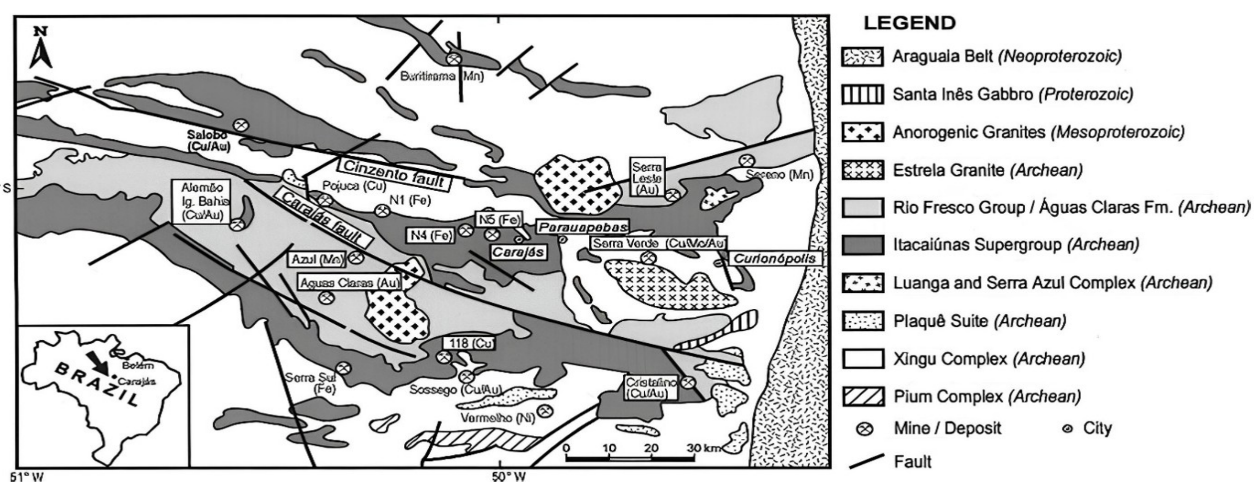


Figure 1. Simplified geological map of the Carajás region, including the location of major mineral deposits [3].

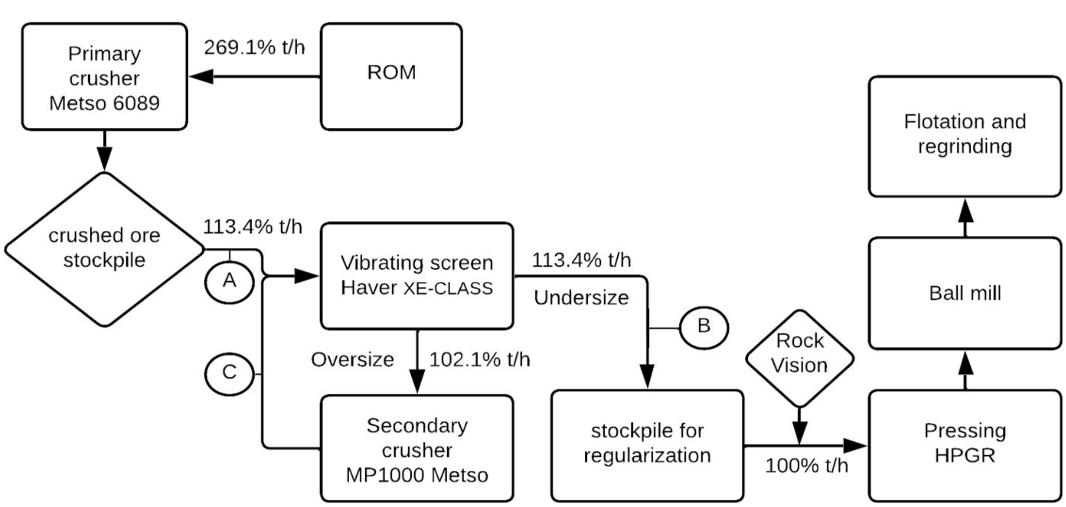
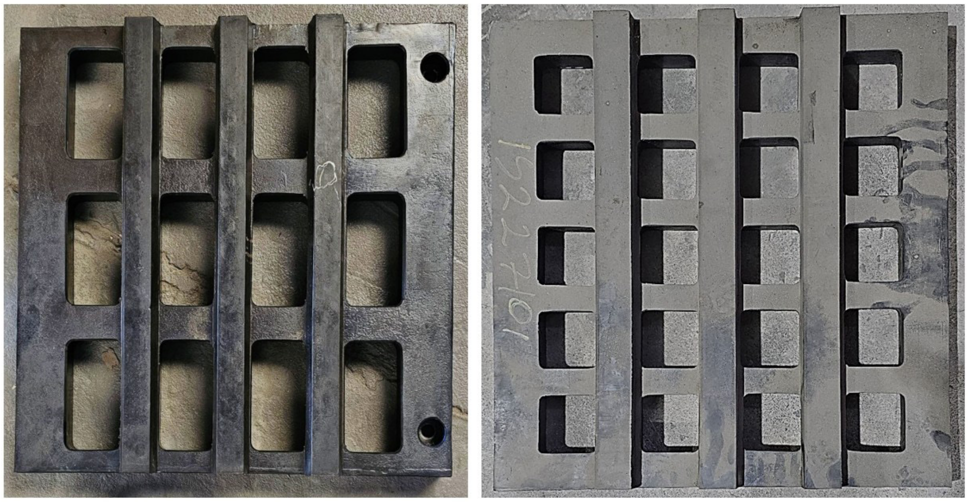


Figure 2. Processing route flowchart of Salobo's mine.



(a) (b)

Figure 3. (a) 75×150 mm screen pre-design and (b) 75×75 mm screen post-design of the Haver vibrating screen in the secondary crushing circuit.

primary crushing and is stored in a stockpile of crushed ore. It is then sent to the Haver XE-CLASS vibrating screens, which performs the size classification: the undersize material is directed to a regularization pile, while the oversize material proceeds to the Metso MP1000 cone crushers, forming the circulating load of the circuit. After the regularization, the ore moves to the pressing and milling circuit, aiming to achieve the proper size for the flotation stage. While the ore is transported from the regularization pile to the pressing circuit, Rock Vision conducts image analysis using cameras to determine the particle size of the material.

The collected samples were composed of material from three different points along the processing route: the first material from the crushed ore stockpile, followed by the undersize material from the vibrating screen and finally the material crushed by the MP1000 cone crusher, represented by letters A, B, and C, respectively, in Figure 2. The sampling stage was conducted along one meter of the conveyor belt, collecting a total of 200 kg of material in the periods of before and after the screen replacement, on November 11 and 27, 2024, respectively. The collected material was sent for dry screening to analyze its particle size distribution. The tests were performed using 10 screens, ranging from 1 mm to 203.2 mm, plus a bottom screen to collect the finer material.

The research also included statistical analyses of the mine's historical operation data, evaluating feed rate, crusher energy consumption and image analysis provided by Rock Vision. The dataset comprised historical data from the entire year of 2024, collected hourly. The analysis of this dataset included data cleaning, excluding values that were outside the normal operational regime of the plant, such as when crushers were operating under abnormal conditions, like during maintenance shutdowns or start-up phases. The resulting dataset was analyzed and illustrated in graphs that enable the assessment and measurement of the impacts of the modifications made to the system.

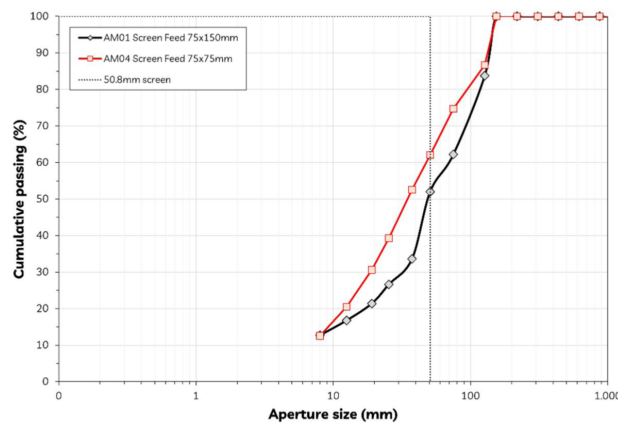


Figure 4. Comparative granulometric distribution for screen configurations before and after the project for the screen feed.

3 Results and discussion

The 75×150 mm of the Haver screen was replaced with a new 75×75 mm, as shown in Figure 3. Both screens have external dimensions of 590×920 mm, resulting in a total area of 542,800 mm^2. The key difference between the two screens lies in the ratio of open area to total area, a factor that directly influences screening efficiency. The 75×150 mm has an open area of 135,000 mm^2, resulting in an open area ratio of 24.87%, while the 75×75 mm has an open area of 112,500 mm^2, yielding an open area ratio of 20.73%.

The reduction in the size of the longitudinal openings led to a more uniform distribution of particles across the screen, thereby improving the efficiency of the secondary crushing stage by achieving a finer ore particle size. Figures 4, 5 and 6 present a comprehensive graphical representation of these findings, clearly delineating the differences in particle size distribution before and after the implementation of the optimized screen.

These figures provide both quantitative and visual evidence of the enhancements in screening performance achieved through the revised operational configurations, underscoring the critical role of screen design in optimizing mineral processing outcomes.

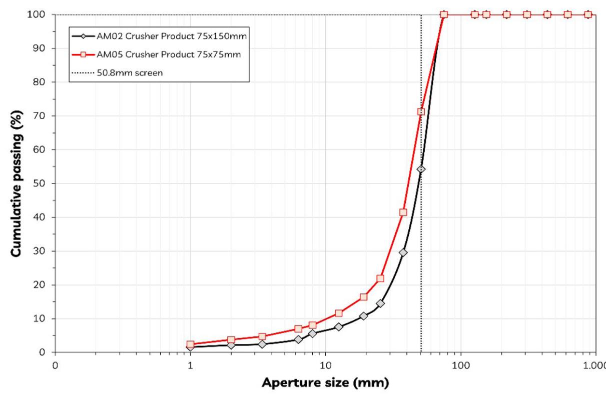


Figure 5. Comparative granulometric distribution for screen configurations before and after the project for the crushed material from the secondary crushers.

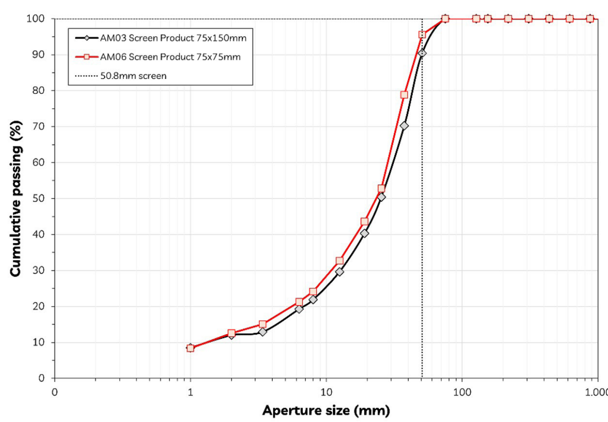


Figure 6. Comparative granulometric distribution for screen configurations before and after the project for the material passing through the screens.

The particle size distribution graphs clearly demonstrate a significant reduction in the granulometry of the processed material following the screen replacement. Transitioning from the 75×150 mm screen to the 75×75 mm screen resulted in a marked increase in the proportion of finer material passing through the screens. In Figure 4, it is evident that the screens were fed with finer material from the primary crushing stage. This occurrence can be attributed to fluctuations in the primary crushing process, as the sample collection was carried out 16 days apart.

The effect of the screen replacement is particularly noticeable in Figures 5 and 6, further supported by an analysis of Rock Vision's historical process data, presented in Figure 7. The Rock Vision system consists of a camera that measures the particle size of material passing from the regularization stockpile to the pressing stage. In Figure 7, the data illustrates the continuous monitoring of particle sizes in real-time, which provides the company with valuable insights into the material flow.

Given the sensitivity and importance of this data to operational efficiency, the values presented are normalized to the highest value recorded by the sensor, ensuring consistency and comparability.

The I-MR chart provides a clear visualization on the impact of changes in the material's top size. In the chart, Scenario A and Scenario B represents the consumption of the pre-formed pile using a 75×150 mm screen. The difference between the two scenarios is attributed to a calibration adjustment made to the Rock Vision's sensor, which accounts for the 3% increase in the values recorded by the sensor. The stabilization period reflects the time required for the operation to stabilize with the new 75×75 mm screen. Finally, the concluding phase represents the operation in a normalized state, using the screen proposed by the project, resulting in a reduction of the top size by at least 10% compared to the previous values.

In addition to achieving finer particle sizes, the project also aimed to sustain secondary crushing throughput. Figure 8 presents the density histogram of

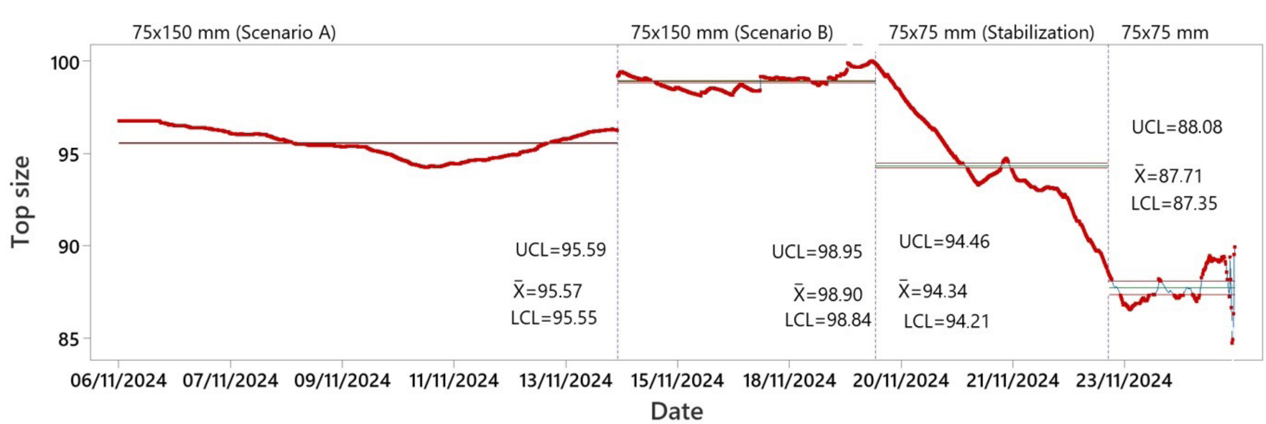


Figure 7. I-MR Chart of image data collected by Rock Vision regarding the top size material.

the secondary crushing rate, based on operational data spanning the entire year of 2024. This analysis provides a comprehensive overview of the crushing rate, before and after the screen replacement, offering further insights into the project's impact on the efficiency and consistency of the secondary crushing circuit. In the graph, the actual value of the crushing throughput is omitted, as the company classifies this data as sensitive information. Consequently, the values presented were calculated based on the nominal crushing rate, ensuring that the information remains protected while still providing meaningful insights of the process performance.

The histogram results show a notable increase in crushing rates following the screen replacement, which indicates successful process optimization and alignment with the project's objectives. The findings are consistent with expectations, as reducing the screen aperture also reduces the screen's open area ratio by 4.14%, from 24.87% to 20.73%, allowing more material to be retained on the screens, thereby increasing the amount of material processed by the crushers. This higher throughput resulting from the screen replacement places greater demands on the crushers, requiring them to process a larger volume of material. To evaluate this impact on crushers, the study examined the total electrical current consumed by this equipment in both configurations. The results are presented in Figure 9.

The histogram highlights a significant increase following the replacement of the screen from 75×150 mm to 75×75 mm. The notable rise in current consumption correlates with the higher volume of material processed by the secondary crushers and reflects a more intensive operation. While the increased energy demand suggests greater mechanical effort and potential equipment wear, this outcome was anticipated, as the new screen configuration aimed to process more material and achieve finer particle sizes. Importantly, the observed gains in throughput, illustrated in Figure 8, underscore the effectiveness of the modification in optimizing the crushing circuit to meet operational demands and enhance the overall process performance of Salobo's plant.

In summary, the study demonstrated that replacing the screen significantly improved the granulometric distribution of processed material, as shown in the figures above. The finer particle sizes achieved through this adjustment align with the project's primary objective of improving feed quality for downstream milling and flotation.

The increase in the crushing rate confirms the benefits of the screen replacement, while the higher current consumption observed in Figure 9 reflects the crushers' intensified workload, which was a necessary trade-off for achieving the desired outcomes.

Overall, the findings confirm the screen replacement as a crucial step in reducing particle size and enhancing the operational efficiency of the Salobo's plant.

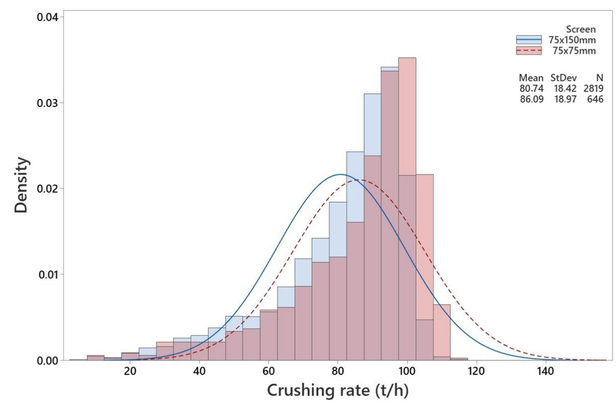


Figure 8. Histogram of secondary crushing throughput for both screen configurations.

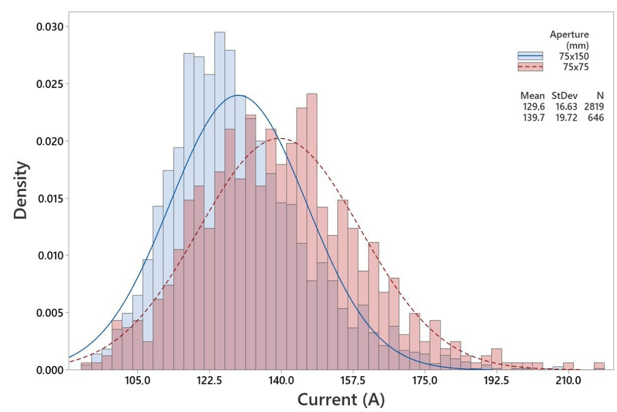


Figure 9. Histogram of total electrical current consumption for both screen configurations.

4 Conclusions

The replacement of the screen in the secondary crushing circuit at Salobo's mine was shown to be a highly effective intervention, delivering improvements in multiple operational parameters. By transitioning from 75×150 mm to 75×75 mm, the granulometric distribution of processed material was significantly reduced, achieving finer particle sizes that enhance the feed quality for the subsequent processes. The analysis of the throughput material revealed a clear increase in the secondary crushing rate, indicating that the screen replacement optimized this circuit efficiency and supported higher productivity.

While the project resulted in a notable increase in electrical current consumption by the crushers, this was an expected consequence of processing greater material volumes and achieving a particle size reduction. The findings highlight a successful balance between operational demands and equipment capacity, ensuring that the modifications yielded substantial productivity gains without compromising the reliability of the crushing circuit.

These results confirm the strategic importance of adjusting screen screens as a mean of optimizing the particle size in mining operations. The methodology and findings presented in this study can serve as a valuable reference for similar projects, demonstrating the potential of targeted interventions to enhance process efficiency and meet operational objectives. Additionally, future studies could focus on quantifying the impact of refined material on the grinding process, evaluating the gains achieved by this solution in terms of downstream efficiency, as well as assessing the wear and tear on crushers to better understand the long-term implications of this operational enhancement. These studies could not be conducted in the current research since the required data was not available.

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