Mechano-grinding of platinum slags using stirred mills – key things to consider

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Abstract. The reprocessing of platinum-bearing slags presents significant opportunity for recovering residual platinum group metals (PGMs); however, the complex mineralogy and refractory nature of slag phases demand highly efficient comminution strategies. Smelting at high temperatures alters both the composition and grain structure of the material, significantly impacting their grinding response. In the reprocessing of platinum-bearing slags several technologies have been used. However, grinding of these slags using conventional ball mills have resulted in unresolved liberation challenges. Stirred milling technologies, with their capability for fine and ultrafine grinding, offer a promising alternative for processing these challenging secondary resources. This paper examines the grinding behaviour of platinum slags in stirred mills, focusing on key operational, mineralogical, and process-design factors that influence performance. A mechano-grinding approach is adopted to reduce activation energy and enhance particle breakage. Experimental studies were conducted on two platinum slags with different mineralogical characteristics sourced from platinum operations in South Africa. By integrating experimental findings with industry experience, this paper provides a practical framework for optimising stirred mill performance in slag reprocessing flowsheets, ultimately enhancing PGM recovery and improving the sustainability of smelting operations.

1. Introduction

The recovery of platinum group metals (PGMs) from secondary resources has become increasingly important due to declining primary ore grades and increasing pressure to improve the sustainability of metallurgical operations. Platinum bearing slags, generated during smelting operations, contain residual PGMs that are a potential economic benefit, but also present a processing challenge. These materials tend to have a complex mineralogy and often refractory nature [1], which results in poor liberation and inefficient downstream recovery.

Smelting at high temperatures alters the physical and chemical characteristics of the original concentrate, modifying the phase composition, grain size, and the textural association of PGMs within the matrix [2]. These transformations strongly influence the response of slags to comminution. Conventional milling has been applied in slag reprocessing circuits; however, such mills require a high energy input in order to achieve adequate liberation sizes. Thus, unresolved liberation challenges remain a key bottleneck in the effective treatment of platinum-bearing slags.

Stirred milling technologies, which have a high energy intensity and are more energy efficient at finer grinding sizes, are a promising alternative for processing challenging secondary materials. In particular, mechano-grinding approaches can promote enhanced particle breakage through increased stress intensity and potential mechanochemical activation, leading to reduced activation energy requirements. However, limited systematic studies have examined the grinding behaviour of platinum slags in stirred mills coupled with recovery of valuable minerals using froth flotation. This paper investigates the mechano-grinding response of two platinum-bearing slags sourced from South African operations, with the aim of identifying key operational and material-related factors that influence stirred milling performance in slag reprocessing applications and their effect on metal recovery downstream.

2. Methodology

2.1. Equipment and materials

Experiments were conducted using a laboratory-scale vertical stirred mill, shown in Figure 1. The mill is fitted with a pin-type impeller consisting of two layers of two pins, which generate high shear and impact forces within the grinding chamber. This configuration promotes efficient energy transfer to the media-particle system through intense stressing conditions.

The selection of this mill was guided by the need to carry out controlled tests on small platinum bearing slag samples. The pin mill would allow small quantities of slag material to be processed while still maintaining stress environments that can be scaled up to what is encountered in industrial size mills.

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Two platinum-bearing slags were sourced from South African operations. Prior to slag testing, platinum-bearing ore and flotation tailings were used in preliminary campaigns to establish an operational envelope and understand mill response across a broader range of conditions. Tests with slag material were performed in the operational envelopment that had promising results for both platinum-bearing ore and tailings samples.

Figure 1. Laboratory scaled vertical stirred media mill, showing the stirrer and bucket beside it. Taken at the University of Cape Town.

2.2. Operational Parameters

A parametric study was conducted to evaluate the influence of stirrer speed and grinding media size on milling performance and energy consumption. Stirrer speeds of 448 and 558 rpm were investigated, in combination with media sizes of 3.5 and 5 mm.

All experiments were conducted in batch mode, with grinding durations of 15, 30, and 45 minutes. At each sampling interval, particle size distributions were measured, and specific energy consumption was calculated based on power draw and grinding time.

To link the comminution performance with downstream recovery, flotation tests were conducted on each milled product. Mass pull and PGM recovery were used as indicators of liberation efficiency and process performance.

The experimental matrix enabled the identification of operating conditions that balance energy efficiency with sufficient particle size reduction for effective downstream recovery.

3. Preliminary Results

The study demonstrates a strong dependence of specific energy on both stirrer speed and media size. A minimum energy consumption was observed at a media size of 3.5 mm and stirrer speed of 448 rpm, indicating an optimal balance between impact frequency and stress intensity.

The signature plot for platinum-bearing ore (Figure 2) shows that increasing stirrer speed leads to higher specific energy consumption, along with finer product sizes. This suggests that at higher speeds, energy input may exceed the necessary energy threshold to process the material economically.

Similarly, the use of smaller media resulted in higher specific energy consumption. Although smaller media increase the number of contact points and enhance fine grinding, the reduced stress intensity per collision appears insufficient to effectively break the relatively hard and refractory slag phases.

Conversely, larger media (5 mm) provide higher stress intensity but reduce the frequency of collisions, limiting overall breakage efficiency. These findings are consistent with a mechano-grinding framework, where both energy efficiency and breakage effectiveness are governed by the interaction between operational parameters and material characteristics.

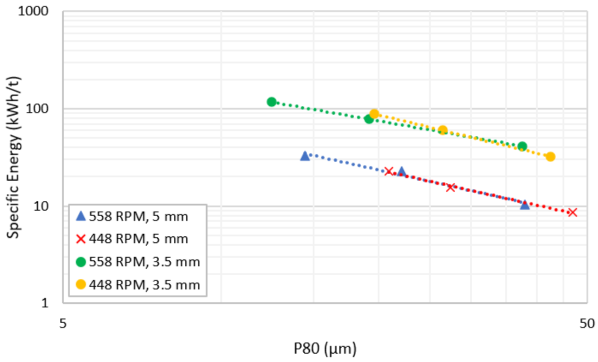

Figure 2. Signature plot showing specific energy as a function of particle size for different stirrer speeds and media sizes for platinum-bearing ore.

Tests conducted on platinum-bearing slags (Figure 3) within the identified operational window exhibited similar trends to those observed for the ore. In this case, the effect of media size was investigated at a fixed stirrer speed.

The use of larger media (5 mm) resulted in lower specific energy consumption at coarser product sizes; however, energy consumption increased more sharply as finer product sizes were targeted. In contrast the 3.5 mm media exhibited a more gradual increase in specific energy with decreasing product size.

This behaviour suggests that while larger media provide higher stress intensity suitable for coarser breakage, they become less efficient for grinding at finer product sizes due to reduced collision frequency. Smaller media, despite lower stress intensity, provide more frequent stressing events, making them more energy-efficient for achieving finer product sizes.

Froth flotation results for the ground slags are presented in Figure 4, highlighting the effect of media size used during feed preparation. Solids recovery increased with grind time for both media sizes, corresponding to increased energy input and finer particle sizes, which likely improved mineral liberation. This effect was more pronounced for material prepared with 5 mm grinding media, with little difference in solids recovery observed between 45 minutes and 60 minutes for the 3.5 mm prepared feed. This feed also yielded lower solids recovery while maintaining comparable water recoveries. The consistently high water recoveries observed for both cases suggest significant entrainment of fine particles. The similarity in water recovery, despite differences in solids recovered may not be entirely due to true flotation, but rather due to entrainment. This points to limited selectivity under the tested conditions and highlights the need to better control froth stability and fine particle recovery. Further tests are being conducted to characterise the solids recovered in the froth flotation tests.

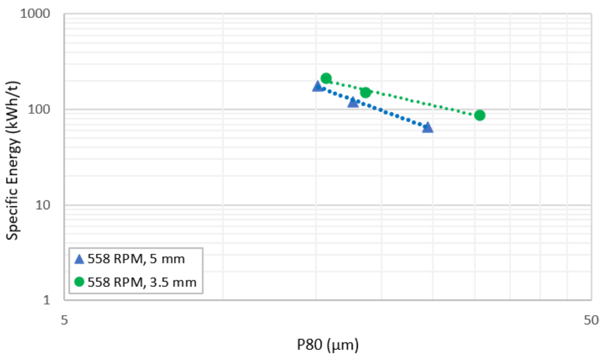

Figure 3. Signature plot showing specific energy as a function of particle size for optimal stirrer speed and different media sizes for platinum-bearing slags.

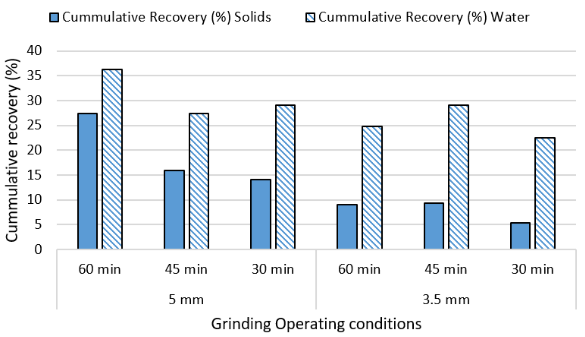

Figure 4. Cumulative recovery of solids and water in froth flotation tests for flotation feed prepared with 5 mm and 3.5 mm grinding media.

4. Conclusions

This study demonstrates stirred milling can be used in the comminution of platinum-bearing slags, particularly where conventional milling fails to achieve adequate liberation. The study highlights that both stirrer speed and media size play a critical role in determining grinding efficiency. For the pin mill size employed operating at a stirrer speed of 558 rpm and media size of 3.5 mm resulted in a higher specific energy, with limited corresponding gains in particle size reduction, indicating suboptimal energy consumption under these conditions. Froth flotation results showed consistently high water recoveries, suggesting significant entrainment of fine particles and consequently reduced selectivity. This indicated that improved control of particle size distribution and froth conditions will be necessary to enhance downstream recovery performance.

The study provides insights into the mechano-grinding behaviour of platinum slags and establishes a basis for further investigation into the links between mineralogy, stress environment, and downstream recovery. These findings contribute to the development of more energy efficient and sustainable slag reprocessing flowsheets for enhanced PGM recovery.

Acknowledgement

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