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The Flowsheet of the Future: Optimizing Energy Efficiency and Minimizing Water Usage

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ABSTRACT

In response to the growing concerns over water and energy consumption in the mining industry, STM Minerals has collaborated with Weir Minerals and Eriez Flotation to develop an integrated solution, so called "the Flowsheet of the Future", for the modern mineral processing plant design, reducing carbon footprint and OPEX.

This partnership aims to optimize energy efficiency and minimize water usage by incorporating innovative technologies into a unified mineral processing flowsheet.

The proposed flowsheet includes the use of high-pressure grinding rolls (HPGR) and vertical stirred mills, as an alternative to replace conventional SAG mill and ball mill circuits, reducing substantially the total energy and water consumption during comminution process. Subsequently, coarse particle flotation and high-intensity flotation technologies are included to maximize the early rejection of coarse barren particles and the recovery of ultrafine mineralized particles while utilizing energy efficient stirred mills to prepare cleaner flotation feed.

The "Flowsheet of the Future" has the potential to increase the target metal recovery by reducing over-grinding loses for grinding-flotation process and by using inert grinding media against steel media on the grinding process for cyanide leaching plants.

Through collaborative research and testing, this paper demonstrates the potential water and energy savings achievable with this innovative 'flowsheet of the future' design, offering promising prospects for sustainable and efficient mineral processing practices.

INTRODUCTION

As mineral processing faces escalating operating costs, diminished head grades, and harder ores coupled with finer dissemination, the industry must explore sustainable and cost-effective solutions. However, the fundamental components of today's mineral processing flowsheets have remained largely unchanged for decades, relying on tumbling mills to achieve the desired grind size for subsequent recovery processes. In light of mounting concerns over water and energy usage in mining, Weir Minerals, STM Minerals, and Eriez Flotation have collaboratively introduced a forward-looking flowsheet concept, dubbed 'the Flowsheet of the Future'. This innovative approach integrates HPGRs, vertical stirred mills, and coarse particle flotation into a unified flowsheet, aimed at modernizing mineral processing plant designs and addressing sustainability concerns. This paper presents a conceptual copper-gold concentrator case study, providing a comparative analysis of flowsheet development, equipment sizing and selection, as well as mass-water-energy balances between the conventional grind-float design and the proposed 'Flowsheet of the Future'.

Technology Review

HPGR technology – Weir Minerals

High Pressure Grinding Rolls 'HPGR' become an industry standard in crushing and grinding of hard and competent ore applications with its energy efficiency, superior wear liner design and flexibility. Weir Minerals has more than 80 installations worldwide with their Enduron® HPGR design, making them the leading manufacturer of HPGRs in mineral applications. Enduron® HPGRs operate in both dry and moist applications and can accept a wide range of feed material sizes. The operations are mainly in closed circuit with dry/wet screening for product sizes up to around 2/3 mm or in closed circuit with air classification for fine product size in the range of 80-120 microns (Van der Meer et al., 2012. There are also variety of applications where the HPGRs are installed and operate in open circuit, such as pebble crushing, and operates with partial product recycling (recirculation without screening) where the screening is not needed or not practical, such as gold heap leaching and pellet feed applications (van der Meer et al., 2008). Enduron® design are well known with their high capacity, high availability and high flexibility. The roll surfaces of the HPGRs are covered with high abrasive resistance tungsten carbide studs, which allows to form an autogenous wear layer, formed by embedding the compacted material in between the stud profiles, protecting the rolls from the abrasive feed material and increasing the wear life time well beyond a year of operation. Figure 1, illustrates the internal components of Enduron® HPGR and the Studded roll surface.

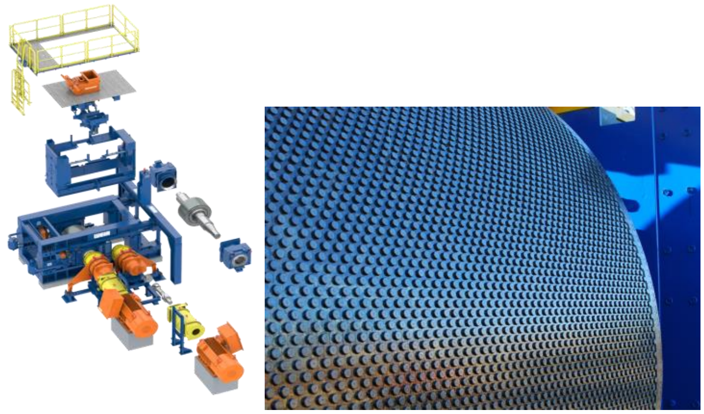

Figure 1 Enduron® Design and Roll Surface Lining

Stirred mill technology – STM Minerals

Swiss Tower Mill Minerals AG (STM Minerals) specializes in the design and manufacture of the state of art stirred milling technology, namely Vertical Power Mill (VPMill™) and Vertical Regrind Mill (VRMmill™), for the mineral processing industry (Zhmarin et al., 2023). Vertical Regrind Mills (VRMs) are well established for fine and ultrafine grinding of iron, copper, zinc, gold, molybdenum and platinum minerals throughout the global mining market, with many successful installations including AngloGold Ashanti's Sunrise Dam, Teck's QB2, and First Quantum's Cobre Panama. Vertical Power Mills (VPMs), a more recent innovation and development, are designed specifically for coarse grinding applications and offer a viable energy efficient alternative to traditional horizontal ball mills in primary and secondary grinding duties (Paz et al., 2023). Extensive testwork on coarse grinding has demonstrated the VPMs' ability to handle mill feed with a top size of 4 mm, making them suitable for processing product from a closed HPGR circuit (Vijfeijken et al., 2023).

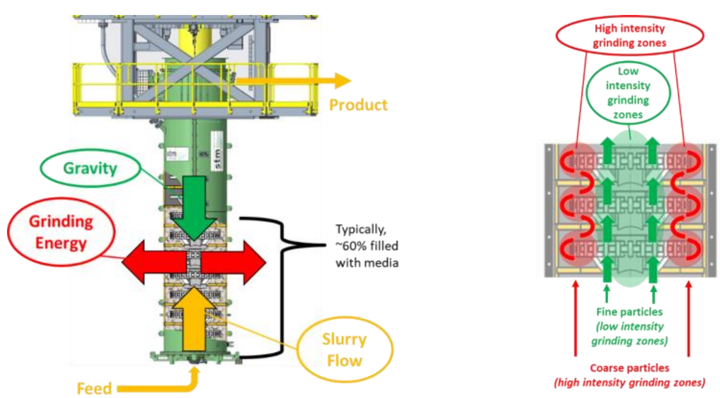

Figure 2 Principle of STM mill operation

Flotation technology – Eriez Flotation

Eriez Flotation is the world leader in coarse particle flotation with the HydroFloat® CPF technology, which has been established for more than 20 years as the standard flotation process for coarsely liberated minerals such as phosphate, potash, and lithium. There are several copper mining operations that already installed the HydroFloat CPF technology, including Newmont's Cadia Valley Operation (Vollert et al., 2019) and Anglo American's El Soldado concentrator (Arburo et al., 2022). Furthermore, the HydroFloat CPF technology is currently at various stages of evaluation for most of the largest copper mines in the world, including Rio Tinto's Kennecott Utah Copper operations (Hobert et al., 2023).

The HydroFloat is a fluidized-bed flotation technology that overcomes the turbulence and buoyancy constraints present in traditional flotation technologies, as summarized by Mankosa et al. (2016). The HydroFloat has been successfully implemented in the copper industry on an industrial-scale for Tailings Scavenging (TS), treating rougher/whole tailings, and for Coarse Gangue Rejection (CGR), treating a fraction of the primary mill recirculating load, to recover particles two to three times coarser in size than recoverable in conventional stirred-tank flotation cells. High-intensity flotation technology focuses energy input to enhance ultrafine particle recovery and improve flotation kinetics over the range of conventional flotation feed sizes. Through multiple full-scale installations and pilot-scale trials in base metals, Eriez' StackCell® high-intensity flotation technology has been proven to reduce flotation residence time requirement by 75 to 85 percent and increase fine particle recovery compared to conventional flotation cells (Wasmund et al., 2019). For example, an equivalent 600 m^3 of flotation capacity was added to Newmont's Red Chris concentrator rougher flotation circuit by installing two 65 m^3 StackCell SC-200 cells (Seaman et al., 2021). The novel, patented StackCell technology de-couples the particle collection process from the froth recovery process, thus allowing for optimization of each process independently.

Figure 3 Eriez HydroFloat CPF-300 (left) and StackCell SC-200 (right)

Project Background – Conceptual Case Study

For this study, the battery limits extend from the ROM feed to the rougher tailings and concentrate regrind product. Cleaning flotation, final concentrate handling, and final tailings management are excluded. To ensure a fair comparison between the two flowsheet designs, a summary of the key process parameters as the design basis is presented in Table 1, which is critical in determining the equipment sizing and selection for respective technologies.

Table 1 Summary of Key Process Design Criteria

Description	Unit	Values
Plant Throughput	tpd / tph	20,000 / 906
Drop Weight Parameter Axb	-	40
Bond Ball Mill Work Index	kWh/t	18
Primary Grind Size	microns	150
Conventional rougher mass pull	%	10
Regrind Size	microns	30

Flowsheet Development

The baseline flowsheet, employing conventional technologies and processes, is illustrated in Figure 4 (left), while the schematic of the "Flowsheet of the future" is presented in Figure 4 (right).

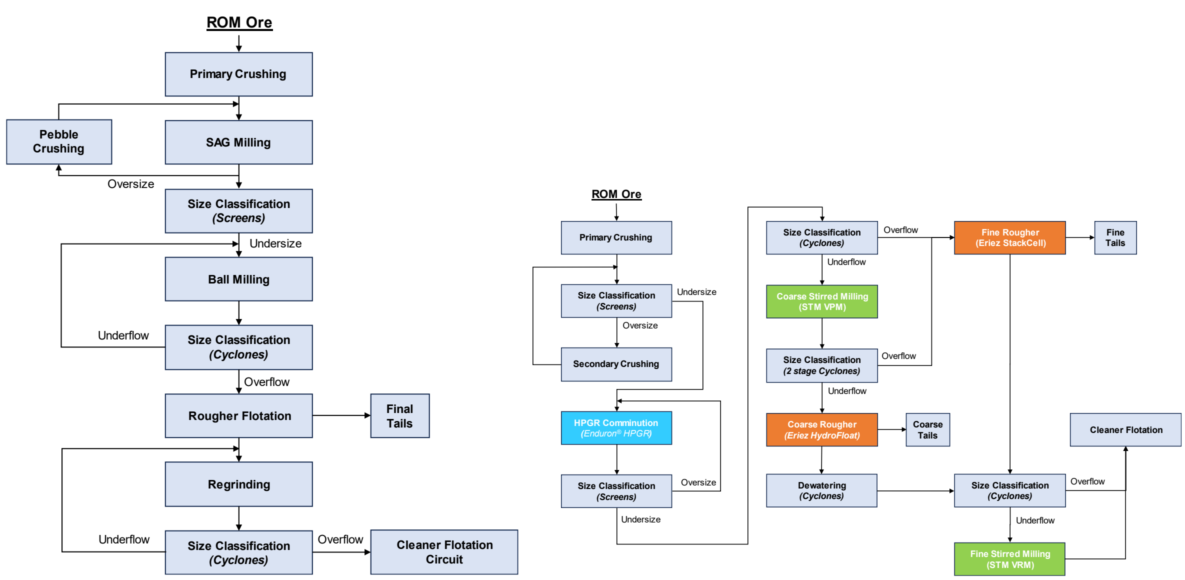

Figure 4 Left: Baseline flowsheet; Right: Flowsheet of the Future

Equipment Sizing and Selection

In addition to the base process parameters outlined in Table 1, the "Flowsheet of the future" would require additional process parameters. The updated process design criteria for the proposed flowsheet is shown in Table 2. Table 3 present a list of the major process equipment selected for the baseline flowsheets and the future flowsheet.

Table 2 Summary of Key Process Design Criteria - Flowsheet of the future

Description	Unit	Values	Remarks
HPGR SGE	kWh/t	1.80	Weir simulation
Coarse Stirred Mill SGE	kWh/t	4.5	STM database
Primary Grind Size	microns	300	Typical 2x baseline
CPF Coarse Rougher Mass Pull	%	30	Eriez database
Fine Rougher Mass Pull	%	10	Same as baseline
Regrind Size	microns	30	Same as baseline
Fine Stirred Mill SGE	kWh/t	18	STM database

Table 3 Major Equipment – Baseline Flowsheet vs. Future Flowsheet

Description	Baseline			Future Flowsheet		
	Qty	Installed, kW	SE, kWh/t	Qty	Installed, kW	SE, kWh/t
Primary Crushing	1x Gyratory	300	0.23	1x Gyratory	300	0.23
Secondary/Pebble Crushing	1x Cone	300	0.26	1x Cone	600	0.53
Primary Grinding	1x SAG mill	9,000	8.54	1x HPGR	4,000	3.66
Secondary Grinding	1x Ball mill	9,000	8.54	1x VPM50	5,000	4.50
Rougher Flotation	7x 100 m3 Tankcell	770	0.59	6x SC-50 (fine)	330	0.25
				2x CPF-200 (coarse)	75	0.06
Regrind	1x Ball mill	2,000	1.90	1x VRM23000	3,500	3.59

Water and Energy Balance

For the study, mass and water balances were developed for each flowsheet.

Table 4 shows that water consumption is notably reduced with the future flowsheet, decreasing from 0.48 m^3/t to 0.24 m^3/t, a 50% reduction mainly attributed to improved water recovery associated with coarse tailings. Regarding energy consumption, the future flowsheet yielded a 36% reduction.

However, detailed study of auxiliary equipment energy consumption has not been conducted for either flowsheet.

Table 4 Energy and Water Consumption – Baseline Flowsheet vs. Future Flowsheet

Description	Unit	Baseline	Future Flowsheet	Difference relative to baseline
Energy consumption	kWh/t ore	20.1	12.8	-36%
Water Consumption	m3/t ore	0.48	0.24	-50%

CONCLUSIONS AND RECOMMENDATIONS

Efforts to support sustainability in the mining sector are increasingly focused on reducing water and energy usage while optimizing resource utilization. The imperative to enhance energy efficiency and preserve water resources has intensified in recent years. Weir Minerals, STM Minerals, and Eriez Flotation are committed in developing innovative mineral processing flowsheet incorporating their core technologies to support industry-wide efforts to reduce carbon emissions and operational costs. In this paper, the proposed "Flowsheet of the Future" is compared to conventional SABC and flotation for a conceptual copper-gold mine, illustrating significant energy and water savings, along with the advantages of generating high-quality coarse tailings for enhanced tailings management. We are seeking collaboration with forward-thinking industrial leaders, to co-develop the proposed flowsheet. We acknowledge that there is further work needed to validate and quantify the anticipated benefits in comparison to existing plant operations. Consequently, a comprehensive business case needs to be developed in collaboration with operations and others to promote this innovative flowsheet concept widely across the industry.

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