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## Technical and economic assessment of a non-conventional HPGR circuit

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## ABSTRACT

In a recent publication (SAG 2015), we presented a non-conventional HPGR-Ball mill circuit as a lower capital cost alternative to the “standard” HPGR circuit. The circuit was designed for the treatment of a hard ore and relatively high tonnage (50,000 t/d). That paper provided details such as flowsheets, layouts, and equipment lists for the two options and compared their calculated capital costs demonstrating significant savings for the proposed circuit. This paper extends the analysis to a third option, a traditional SABC circuit, giving the same level of details and now including the operating cost estimates for all three options for a more comprehensive analysis. Moreover, this work also provides information about the strengths and weaknesses of the non-conventional HPGR circuit when compared to the “standard” HPGR option.

This study demonstrates that the proposed non-conventional HPGR-based circuit not only provides a lower overall capital costs for the project if compared to a “standard” HPGR circuit but also brings the capital cost to the level of the traditional SAG-Ball mill circuits. In addition, the innovative HPGR circuit provides similar operational cost savings of the “standard” HPGR and thus a significant advantage when compared to the SAG option. With the current capital cost sensitivity for most greenfield projects, the proposed alternative circuit should help make HPGR-based circuits more competitive and thus promote the utilization of a technology that enables higher energy efficiency and reduced greenhouse gas emissions.

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### 1. Introduction

The application of HPGR technology in comminution circuits is well established for the processing of cement, diamonds and iron ore (Broeckmann and Gardula, 2005), and over the past 10–15 years, this technology has slowly been applied to hard ores in high-tonnage precious and base metal operations. Unfortunately, under the current economic climate, the ability to finance large capital projects has become very difficult and companies tend to have an easier time securing funding if the capital expenditures are low with a proven process method. The traditional semi-autogenous grinding (SAG) mill/ball mill circuits easily fit into this mould, having been installed in countless plants around the world over the past 30 years with relatively low capital requirements. In contrast, it has been well-documented that HPGR-based circuits are capital intensive with complex material handling systems (Seidel et al., 2006). Although these circuits benefit from reduced operating costs with the increase in energy efficiency and the elimination of steel grinding media (Rosario et al., 2009), if the company is unable to secure financing to build the plant, these

advantages remain out of reach. With the current trend to retrofit existing SAG circuits with a secondary crushing circuit to achieve design throughput, the opportunity to circumvent this gross inefficiency by making HPGR-based circuits more capital friendly would greatly benefit the industry.

In this paper, we present an example of HPGR-based circuit which is designed for relatively high tonnage operation of 50,000 t/d. The design of the circuit focuses on reducing capital requirements by adopting the latest generation of process equipment and providing slight circuit modifications to reduce the need for ancillary equipment.

#### 1.1. The “Standard” HPGR circuit

Of the many possible flowsheets that have been proposed for HPGRs, those using HPGRs as tertiary crushers, in closed-circuit with wet fine screens, are expected to provide maximum energy efficiency (Jankovic et al., 2014). The fine screens classify out coarse material for circulation back to the HPGR while also ensuring an acceptable top-size for downstream processes such as ball milling. A safety coarse-screen, in closed circuit with secondary crushing, precedes the HPGR and prevents oversized material from

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damaging the rolls (Morley, 2006). This flowsheet configuration was selected for a number of high tonnage projects in the Southern Hemisphere, including Boddington (Fig. 1) Cerro Verde (Fig. 2), and most recently Sierra Gorda (Fig. 3).

Boddington has a design capacity of 35 Mtpa (approximately 96,000 t/d) and processes two very hard gold ores with average Bond ball mill work indices (BWi) of 15.1 and 16.6 kWh/t, Bond rod mill work indices (RWi) of 22.8 and 24.2 kWh/t, and JK Axb values of 27.9 and 25.5. The circuit is comprised of five 746 kW cone crushers, four 2.4 m diameter (D) × 1.65 m length (L) 5.5 MW HPGRs, and four 7.9 mD × 11.9 mL (26 × 39 ft) 15.6 MW ball mills (Dunne et al., 2007). The projected roll surface wear life was estimated to be 4250 h. A 2006 trade-off study showed that a preliminary semi-autogenous ball crushing (SABC) circuit would have 7% lower capital costs than the HPGR circuit, and that the HPGR circuit provided 12% savings in comminution operational costs. The study concluded that the lower operational costs of the HPGR circuit offset its higher capital costs (Seidel et al., 2006). Furthermore, after commissioning, the HPGR roller wear life was found to average 5000 h with expectations to achieve 6000 h with improved profile design (Hart et al., 2011).

Cerro Verde has a design capacity of 108,000 t/d of hard copper-molybdenum ore (average BWi of 15.3 kWh/t). The circuit is comprised of four 746 kW cone crushers, four 2.4 mD × 1.65 mL 5.0 MW HPGRs, and four 7.3 mD × 10.7 mL (24 × 35 ft) 12 MW ball mills. The projected roll surface wear life is 6000 h. Just prior to startup, Vanderbeek (2006) reported that although estimated capital costs were higher for the HPGR circuit than an equivalent SAG circuit, the estimated total comminution operational costs were 1.33 US\$/t and 1.70 US\$/t for the HPGR and SAG circuits respectively. The main contributors for this difference being the costs of power and grinding media. The estimated total comminution circuit specific energy for the SAG circuit was determined to be 20.1 kWh/t, as compared to 15.9 kWh/t for the HPGR circuit. In addition to operating cost savings, risk analysis conclusions and internal rate of return factors resulted in the decision to install an HPGR circuit instead of a SAG circuit.

Sierra Gorda has a design capacity of 110,000 t/d of hard copper-molybdenum ore (average BWi of 17.5 kWh/t). The circuit is comprised of four 933 kW cone crushers, four 2.4 mD × 1.65 mL 5.6 MW HPGRs, and three 7.9 mD × 13.4 mL (26 × 44 ft) 17 MW

ball mills (Pincock et al., 2011). The design of the circuit is similar to the Cerro Verde flowsheet and incorporates large surge bins and the operation of the secondary crushing circuit in reverse closed circuit.

In each of the above examples, a number of similarities can be observed:

- The primary crushing circuit remains a separate entity, with the coarse ore stockpile acting as a buffer between the gyratory crusher and the secondary crusher and HPGR.
- The secondary crushing circuit operates in closed circuit with screens to ensure a maximum top size of approximately 50 mm to each 2.4 m D HPGR.
- Plenty of surge capacity is provided between the ball mill and the HPGR to sustain constant feed to the ball mills while maintaining the secondary crushing and HPGR circuits. In the case of Boddington, four fine ore bins with a total live capacity of 20,000 tonnes are used, while at Cerro Verde and Sierra Gorda, 20,000 tonne and 24,000 tonne fine ore bins are installed respectively.

## 2. Objectives

The main objective of this work is to suggest an alternative HPGR-based circuit with reduced capital expenditures (CAPEX) to improve the chances of keeping these circuits viable in projects facing the current project financing hurdles. We believe that important benefits provided by the HPGR, such as energy savings and reduction in greenhouse gas emissions in hard or extremely hard ore processing, should be applied to a greater number of projects and in different regions around the world, including regions where indoor process plants are required. To assist in achieving this objective, the total capital cost of the comminution circuit must be lowered to a range similar to SAG mill circuit.

We have developed an alternative HPGR-based circuit for 50,000 t/d and will present the benefits and shortcomings of this non-conventional circuit when compared to the traditional HPGR and SABC circuits. The development of the alternative HPGR circuit targeted smaller footprint and less auxiliary equipment than the “standard” HPGR circuit. In addition, efforts were made to

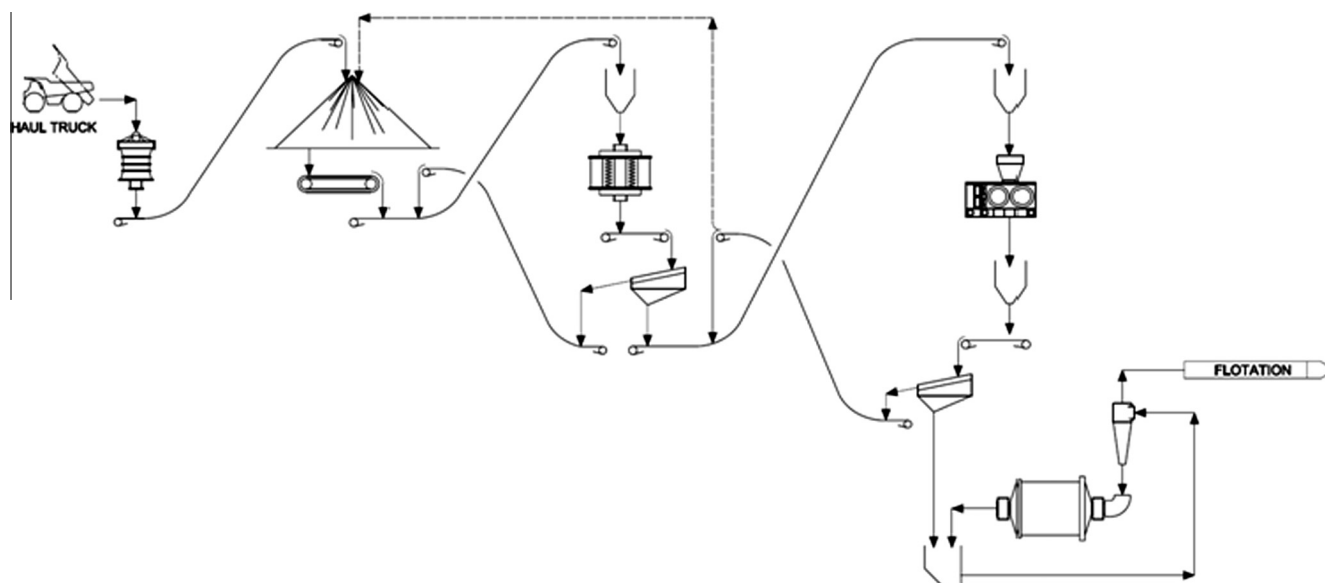


Fig. 1. Boddington comminution circuit (Dunne et al., 2007).

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