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Assessing the amenability of a free milling gold ore to coarse particle gangue rejection

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A R T I C L E I N F O

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A B S T R A C T

Coarse particle gangue rejection is highly topical due to the potential benefit in removing a significant fraction of gangue prior to fine grinding, thereby creating significant potential savings in energy, water, reagents (and consumables) and significantly reducing fine tailings deposition requirements. The research presented here focusses on characterising and evaluating liberation and separation of gangue from a gold bearing sulfide ore in the −2 mm +0.3 mm size range (associated with post tertiary crushing). This particle size range was chosen from a materials handling perspective, focussing on material that can be transported by pumping an ore slurry. This paper will review the procedure and results of an in-depth assessment of the amenability of a gold ore to gangue rejection in the pumpable size range. The liberation of the non-sulfide gangue of crushed gold ore is evaluated by proxy using sequential sink-float analysis for various size fractions. SPT (sodium polytungstate) and LST Fastfloat® (comprising of lithium heteropolytungstates) were used as heavy liquids. The results establish the deportment of gold to the sink and float products yielding a recovery versus mass pull relationship. Liberation patterns were investigated as produced by various crushing technologies such as vertical shaft impact (VSI) crushing, cone crushing, SelFrag®-based comminution, and high pressure grinding roll (HPGR) crushing. The gangue liberation behaviour, using a sink-float proxy, was dependent upon the mode of crushing and varied for different size intervals. The results of the Gangue Rejection Amenability Test allow for the determination of the grade and mass splits that are achievable for a given crushed product. The method is applicable to a wide range ores with varying mineralogies. Significant variation in the amount of barren rejectable gangue for a given gold ore and a given gold loss to rejects was observed for the various crushing technologies at the same 100% pass size, even though the particle size distributions were fairly similar.

1. Introduction

Continuous coarse particle gangue rejection holds much potential to significantly reduce the costs and improve upon sustainability measures if a large proportion of suitably barren material can be liberated and separated from the metal/mineral values, without significant value loss.

This aim of this research is an attempt to quantify the potential for coarse particle gangue rejection (or preconcentration) for a free milling gold ore. The particle size range investigated has been restricted to the pumpable size fraction of 0.3–2.0 mm from the perspective of keeping the streams suited for hydraulic transport and classification, though the range in investigation is now being extended to particles as coarse as 4.75 mm. This size range offers particular process benefits related to slurry based materials transport and low cost separation methods, including screening (for mineral differentiation rather than size classification only) and gravity separation (using jigs, classifiers, coarse particle flotation, dense media separation, etc.), can then be employed.

Preconcentration has been defined as unit operations prior to the main recovery process targeting removal of waste by exploiting the physical properties of the material (Shirley 2009). Similarly, one can describe coarse particle gangue rejection (CPGR) as removing as much deleterious or low specific gravity (SG) waste material as possible, without compromising significant recovery. For gold ores, these processes are most attractive when evaluating a low grade, sub-economic ore where a loss in recovery is mitigated by upgraded feed and extra metal units to production (Grigg and Delemontex, 2014). In order to understand gangue rejection opportunities in this area it is advantageous to first identify and define the attributes which make some ores amenable to gangue rejection of a significant component of the feed mass to tailings at a coarse liberation size. Characteristics such as ore type, mineralogy, breakage pattern, particle shape and liberation characteristics can all influence amenability to gangue rejection techniques and prospective recovery flowsheets. Typically, gravity devices have been the most common method for preconcentration (Smit and

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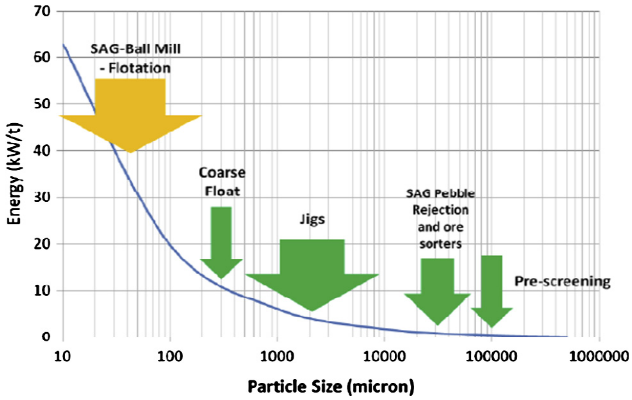

Fig. 1. Specific electrical energy consumption versus particle size on a kWh/ton of ore basis (Wang and Forssberg, 2007).

Coetzee, 2012) and in this way, the presented research can be differentiated from other gangue rejection/preconcentration processes such as those performed by automatic ore sorters at the mill feed size range.

Comminution in general, and comminution by grinding in tumbling mills in particular, is an energy intensive and, therefore an expensive step in liberation of the targeted metal from the host rock. For example, the relative cost to liberate to P_{100} of 500 µm for the VSI is ~$1.30 USD/t, for HPGR it is ~$1.50 USD/t and for SAG/Ball mill circuit is its ~$2.95 USD/t, assuming 15 kWh/t at $0.10/kWh, media 1 kg/t at $1.20 and liners at $0.25/t (Gray et al., 2014, Grigg and Delemontex, 2014). In Fig. 1 (Wang and Forssberg, 2007) it is demonstrated that eliminating or reducing the requirement for particle size reduction below 1 mm for entire feed streams leads to substantial energy and cost savings and thus coarse particle gangue rejection for amenable ore types in the pumpable size range offers improved processing economics.

Data collected from the AMIRA P420E Industry Practices Survey on mine production, gold production and cyanide consumption can also be used to demonstrate the potential of preconcentration and coarse gangue rejection for gold ores (Eksteen, 2015). Fig. 2 plots the energy consumption per unit of gold produced against head grade. The specific energy requirement increases exponentially as grade falls below 1 g/t for the sites surveyed. Ballentyne and Powell (2014) developed similar curves for copper and copper-gold ores through a benchmarking study. This trend highlights the potential for coarse particle gangue rejection to convert previously uneconomic waste to ore through significant processing cost reduction.

The energy cost savings realised by opting to use a fine crush and rejecting gangue material prior to milling is not the only benefit of a gangue rejection strategy. Fig. 2 also demonstrates a significant increase in cyanide consumption per unit of gold produced as a function of declining head grade and thus gangue rejection offers potential to decrease both energy and reagent cost per ounce produced for low grade ores where it is feasible.

Other than reduced reagent costs as well as decreased energy requirements during grinding and leaching, a significant savings in water demand and grinding media consumption may be achieved and the generation of fine tailings (with commensurate environmental risk and water loss) may be minimised.

One example of the potential for gangue rejection is given in recently published Grade Engineering ® work by CRC ORE at Newcrest's Telfer mine in Western Australia. Grade Engineering is the term defined by CRC ORE to refer to the operational techniques to exploit intrinsic grade variability to remove low grade uneconomic ore prior to energy intensive and inefficient grinding (Carrasco et al., 2016). It was found that screening of the primary crusher product at 20 mm yields 80% of the gold and copper in less than 40% of the mass in the undersize stream (Sakuhuni, Tong et al.).

However, one of the main challenges of any research program on gangue rejection, as was the case in the Telfer example previously mentioned, is to understand the cost saving by rejecting the discard fraction (i.e., the liberated barren gangue) versus the potential loss in value. In other words, is the discard fraction truly barren (or sufficiently barren in economic cut-off grade terms), will the stream be stockpiled and treated at a later time (end of mine life or when mill feed is low) or will the ore undergo a different extraction process (heap leach)? This research has aimed to understand the deportment of valuable material into each stream as a function of size, crush type and efficiency of gravity recovery, recognising that the quantification of liberation at the crusher product level is very difficult however and may vary with different crushing modes.

2. Determination of amenability to gangue rejection

2.1. Development of a gangue rejection amenability test

Shi et al. (2015) indicated that the establishment of an ore characterisation test to determine the amenability of an ore, as well as a fundamental study of preconcentration mechanisms, will allow for a better understanding of the intrinsic qualities of an ore to influence it's amenability to gangue rejection. In addition, it will allow a prediction of the recovery behaviour in a preconcentration/gangue rejection circuit. The authors originally referred to high voltage pulsed comminution, but the need for this research exists for all comminution methods if

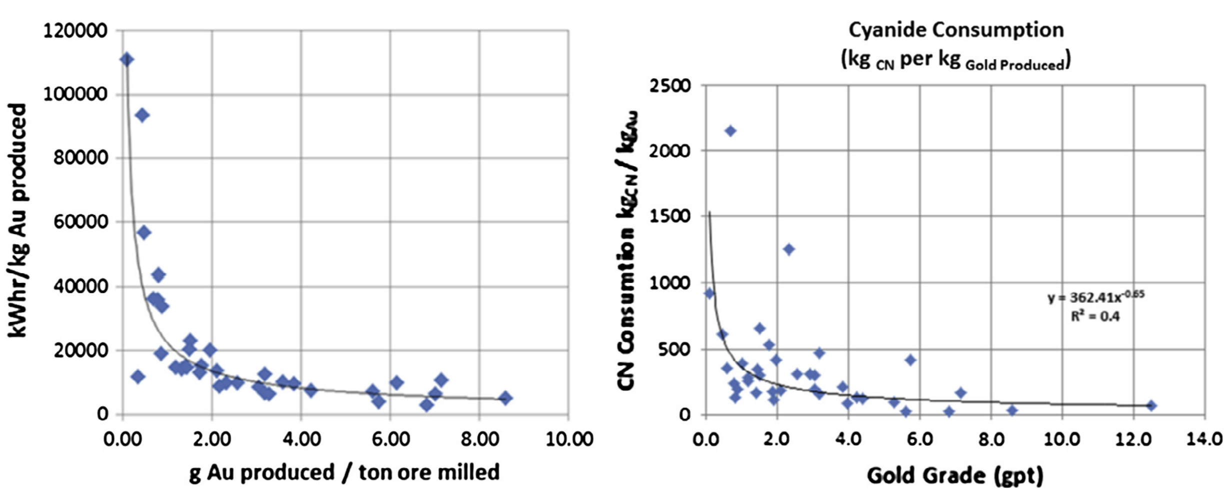

Fig. 2. Specific electrical energy consumption versus gold grade in ore on a kWh per kg gold produced basis (left) and cyanide consumption versus gold grade per kg of gold produced basis (right) (Eksteen, 2015).