Energy Efficient Comminution Circuits – A modified grinding strategy and the selection of a target product size

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Introduction

This paper describes two techniques that can be used in the design of comminution circuits for improved efficiency and a reduction in total energy consumption. They are:

- A modified grinding strategy where efficient grinding equipment is used and techniques employed to decrease grinding media consumption
- A more reasoned and thorough approach to the selection of target product size for a comminution circuit involving a better understanding and interpretation mineral liberation data.

Background

There has been much discussion about the energy intensive nature of comminution processes. It has been quoted several times that comminution processes account for 3%-4% of the global electrical energy consumption. However, the comminution process remains inherently inefficient. It is understood that 85% of the energy used comminution is dissipated as heat, 12% is attributed to mechanical losses and only 1% of the total energy input is used in size reduction of feed material (Alvarado et al. 1998).

Another aspect of comminution which contributes significantly to the energy intensity of the process is the consumption of media and mill liners. The quantity of energy necessary for the fabrication of the media and/or liners from extraction, to transport, to manufacture and assembly is considered part of the total energy utilisation of the comminution process. This is also quite an energy intensive process and opportunities to minimise steel consumption in comminution circuits should be realised.

The third factor which contributes significantly to the energy intensity of comminution circuit is the chosen target product size, or grind size. As the target product size decreases the energy required to achieve the product size increases significantly. As the particles become smaller their strength and therefore their resistance to breakage increases. For small particles as internal flaws are depleted, the observed strength approaches the high intrinsic strength of the solid.

This is the prospect facing all comminution design and operating engineers. Hence, there is an increasing need for more efficient grinding systems and innovative comminution technologies that not only increase the efficiency of the comminution process but also act to minimise the consumption of steel media and liners. This together with a new approach to choosing a target product size can significantly increase the energy efficiency of a comminution circuit.

Methodology / Experimental Technique

The two parts of this investigation were undertaken according to the following:

A modified grinding strategy

All of the modifications made to the configuration of an existing comminution circuit were undertaken using the modelling and simulation package JKSimMet. It is a valuable tool in predicting the performance of a comminution circuit, including the equipment power draw, product size distributions, classification efficiency, etc.

The aim of the eco-efficient modifications was to:

- Reduce the *direct* energy usage. That is, decrease the grinding power used in the size reduction process.
- Reduce the *indirect* energy usage. That is, decrease the consumption of comminution consumables such as steel media and mill liners.

The strategy used to achieve these aims involved better utilisation of the comminution energy. This can be achieved by purposely targeting the comminution energy at specific problematic size fractions such as the critical size material in the primary mill and the very fine fraction in the secondary mill. Through the use of more efficient comminution devices such as HPGR (high pressure grinding rolls) a product size distribution that is narrower in size range can be generated. This size distribution contains less material in the coarse fraction to aid overall mineral liberation and less material in the fine fraction to minimise the effects of slimes.

The strategy also exploited opportunities to minimise the load in grinding mills and in some cases employ autogenous grinding techniques to decrease indirect energy consumption.

Selection of a target product size

This concept was illustrated using a sample from of rod mill discharge from Mount Isa. Rod mill discharge can be equated to SAG mill discharge in terms of product size and product size distribution in SABC circuit (SAG mill with recycle crushing and a single stage ball mill).

The sample underwent staged grinding, using a laboratory scale rod mill and ball mill to produce samples of product sizes ranging from P_{80}=0.015μm to P_{80}=1.500mm.

Samples from each of the product sizes were analysed using MLA techniques to assess the extent of liberation of individual mineral components.

In order to maximise the potential target grind size and therefore minimise required energy input for the circuit, the following concepts were applied:

- minerals were grouped to form larger entities and therefore deemed liberated at coarser sizes
- particles were deemed *recoverable* in a flotation process, as opposed to liberated, when the particle contains greater than 15% mineral of interest

Together the above two points act not only to increase the target product size but it also enable the separation and rejection of material (typically liberated gangue) from the circuit. The rejection of gangue from the feed stream can limit the amount of over-grinding but more importantly it will reduce the mass of material proceeding to the next stage of size reduction and/or separation. This allows for more efficient separation and significantly lower energy requirements for downstream size reduction.

Key Results / Findings

A modified grinding strategy

Eco-efficient modifications were made to an existing SABC according to the following:

- A pre-crush stage using a HPGR was included to minimise the generation of critical size material in the primary mill. The aim was to reduce a portion of the feed material below critical size and generate more fines to decrease the load in the primary mill. Not all of the feed material was pre-crushed to allow for sufficient abrasion breakage in the primary mill.
- The SAG mill was converted to an AG mill and the ball mill was converted to a pebble mill to decrease liner and media consumption
- Existing mill sizes were reduced

When the performance of this new circuit, denoted ABC-HPGR-PM, was compared to the original SABC circuit, the following (based on JKSimMet and mass balancing predictions) was observed.

- The ABC-HPGR-PM circuit produced a both a finer and steeper product size distribution which promoted better flotation performance, approximately a 2% increase gold recovery
- Direct energy comparisons show that the ABC-HPGR-PM circuit had an operating work index of 15.9kWh/t compared to 24.3kWh/t for the base case SABC circuit. This is an energy saving greater than 8kWh/t for the whole circuit. Significant to say the least.
- Comparison of indirect energy consumption for the two circuits is showed that again the ABC-HPGR-PM out performed the standard SABC circuit with a 79% saving in indirect energy based on media and liner wear alone. The SABC circuit consumed 3535kW while the ABC-HPGR-PM circuit consumed 753kW. These figures are based on 6kWh/kg required to manufacture the grinding consumables.

Selection of a target product size

Analysis of the MLA data for the various product sizes to include liberated and recoverable particles, showed that:

- 70-80% of galena and sphalerite is liberated at P_{80}=76μm
- 70-80% of galena and sphalerite is recoverable at P_{80}=150μm
- When galena and sphalerite are combined and analysed as one mineral, 85% of this mineral is recoverable at P_{80}=150μm
- >95% of the sulphides (combined galena, sphalerite, pyrite and pyrrhotite) are recoverable at P_{80}=1607μm
- 45% of non-sulphide gangue is liberated at P_{80}=1607μm

These points can be used in the design a comminution circuit where product size is finer than 1.5mm.

The aim is to exploit the recoverability of valuable minerals and the rejection of liberated gangue in a separation step at the coarsest product size.

The separation step could be a flotation stage or a relative density separation stage. Ore properties will determine the most suitable method.
The chosen circuit may resemble that shown in Figure 1.

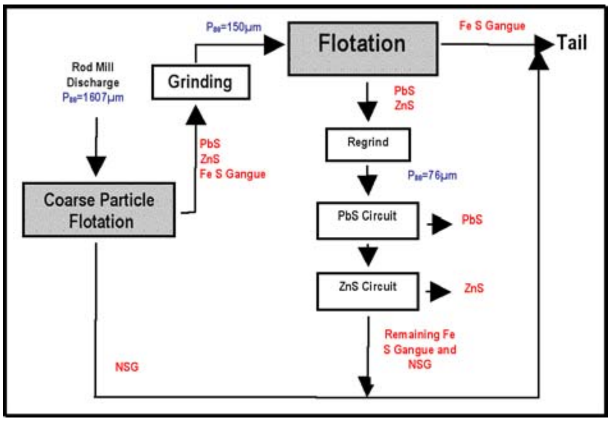

Figure 1: *Design of separation circuit post primary grinding.*

The circuit features a coarse particle flotation step to separate the liberated non sulphide gangue to tail from the recoverable sulphides. The sulphides then proceed to a further stage of grinding before being separated in to valuable sulphides (galena and sphalerite) and iron sulphide gangue which reports directly to tail. The valuable sulphides are then separated in the last grinding stage before proceeding to respective lead and zinc flotation circuits for concentrate recovery.
The effect on energy consumption resulting from the rejection of liberated non-sulphide gangue prior to the first stage of size reduction is shown in Table 1.

Table 1: *Energy saved by rejecting the liberated non-sulphide gangue at the head of the separation circuit.*

Direct Energy

		Original Circuit	Proposed Circuit
Rod Mill Discharge	tph	500	268
Bond Work Index	kWh/t	18	18
Feed Size	μm	1607	1607
Product Size	μm	75	150
Work Input	kWh/t	16.3	10.2
Power for total tonnage	kW	**8147**	**2733**
Potential Power Saving		**5414 kW 66%**	

Energy savings can be as high as 66% when removing almost 50% of the circuit feed material from further size reduction, the rejected material is primarily coarse (P80=1.607mm) liberated non-sulphide gangue.

Conclusions and Future Direction

Opportunities exist to improve comminution efficiency and decrease comminution circuit energy consumption by modifying the standard SABC circuit to include:

- a HPGR pre-crush stage
- autogenous grinding

The strategy is to target comminution energy at problematic fractions such as critical size material by decreasing re-circulating loads and employing autogenous grinding techniques.
It is also possible through a better understanding of mineral liberation characteristics of coarse stream (P80 ~1.5mm) in a comminution circuit to exploit opportunities to reject liberated gangue from the stream and therefore the comminution circuit thereby reducing the size and grinding energy requirement for downstream processes. These elements allow provision for a coarser grind product size based on the liberation and recoverability characteristics of minerals.

The combination of the modified grinding strategy together with a more reasoned approach to product size selection enabling the rejection liberated gangue from the circuit can decrease significantly total energy consumption of the circuit while improving the operating efficiency.

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