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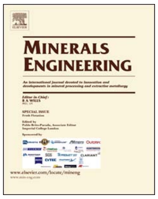

Existing opportunities for increasing metallurgical and energy efficiencies in concentrators

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ABSTRACT

A wide range of opportunities exist for greatly increasing the efficiency of concentrators, in their design and by retro-fitting existing concentrators, but exploitation of the opportunities will depend on the perceived urgency for this change within the mineral industry by companies. The industry has left behind a recent decade of unusually high product prices which resulted in an emphasis on "production at almost any cost" and which resulted in an emphasis on rapidly designing, constructing and operating new concentrators, reducing the scope for innovation in the concentrator and increasing reliance on some standardization of the designs.

For each deposit, the design and operation of a concentrator should be considered within the framework of optimisation of the total mining/processing sequence. It would be necessary to evaluate the potential for identification and rejection of low grade uneconomic portions of the mined material for each deposit. The evaluation would recognize those deposits for which the approach is applicable, resulting in an improvement of feed quality early in the mining/processing sequence. This aspect which at present often only receives cursory attention for most design studies can also be assessed for an existing mining/processing sequence for which retro-fitting is a possibility.

Within a new concentrator, important options giving improvements in metallurgical and energy efficiencies will be described. Some of these options may also be implementable for an existing concentrator.

Consideration of some important concentrator designs from the past will be undertaken briefly because of the instructive design approaches and because of their relevance for future designs.

1. Introduction

The industry has left behind a recent decade of unusually high product prices which resulted in an emphasis on "production at almost any cost", resulting in marked reductions in productivity in existing operations in the minerals industry in general. For new concentrators built during this period, it resulted in an emphasis on rapidly designing, constructing and operating new concentrators, reducing the scope for innovation in the concentrator and increasing reliance on some standardization of the designs. Such designs are likely to overlook some properties of the ore which can be exploited to provide opportunities for additional metallurgical and energy efficiencies.

To demonstrate means for recognizing opportunities for innovation in concentrator design, novel liberation data collected in a PhD thesis (Pokrajcic, 2010) have been used. The following conclusions were provided in a related paper (Pokrajcic et al., 2009) to achieve lowered energy consumption in concentrators, where energy consumption included energy consumed directly in the process and also indirectly e.g. for the manufacture of grinding media used in the process:

1. "The use of more efficient size reduction equipment and the return to autogenous grinding techniques where applicable based on ore properties.
2. The application of progressive ore upgrading strategies to remove liberated waste from the comminution circuit, to lower the throughput for grinding.
3. The selection of the coarsest target product size(s) based on improved knowledge of the liberation of the valuable and gangue minerals."

This paper addresses points 2 and 3 principally and it also notes the contributions from point 1, through the application of the more efficient stirred milling technology to regrinding in conjunction with concentrator circuits having an increased role for regrinding and a decreased role for primary grinding. Stirred milling technology has provided new options in design because of its increased energy efficiency and its compatibility with the use of inert grinding media. A higher proportion of the installed grinding power can be located in the regrinding section. Where warranted, finer regrinding product sizes can

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be considered.

Early in the twentieth century, one aspect of point 3, "selection of the coarsest target product size" was used in industry to improve the cost effectiveness of circuits for processing the low grade porphyry copper ores. This approach and the possibilities for application of this approach for other comparatively high grade base metal ores are discussed in this paper, along with other approaches arising from points 1, 2 and 3.

For each deposit, the design and operation of a concentrator should be considered within the framework of optimisation of the total mining/processing sequence. Alternatively, an approach could be taken in which the design facilitates retrofitting of processing steps into the total mining/processing sequence shortly after the start-up. Recognition of methods for productivity improvement early in the mining/processing sequence was the purpose for the Cooperative Research Centre for Optimising Resource Extraction (CRC ORE), established in 2010; its activities have been connected closely with the preceding listed point 2 which is described as grade engineering, with a summary in the next section.

The work by CRC ORE has produced relevant procedures for ore characterisation which are used to indicate if each of the sections of an orebody are amenable to grade engineering. For the amenable sections, some aspects of grade engineering can be included in the operation before and during the start-up while other aspects of grade engineering would require evaluation after the start-up.

A wide range of opportunities exist for greatly increasing the efficiency of the concentrator itself, by its design and by retro-fitting existing concentrators. Potential examples are included in this paper and they are connected closely with the preceding listed points 2 and 3. Ore characterisation by the wider use of liberation data and with various groupings of minerals allows the recognition of opportunities for rejection of gangue minerals; the size of the material being evaluated would be considerably finer than for the preceding grade engineering. For the concentrator, the objective would be to demonstrate that all sections of the orebody respond broadly in a similar fashion during the feasibility study phase, allowing the construction of the concentrator without further planned evaluation after the start-up i.e. unlike the situation which was described earlier for some aspects of grade engineering.

An important type of circuit was developed to assist improvement of the economics for processing porphyry copper ores, with Sutulov (1974) providing an example of this circuit (Fig. 1). The circuit in Fig. 2, provided as a common related current version 40 years after the book by Sutulov, differs principally because it has an open circuit structure for the tailing from cleaning.

The paper covers other flow-on effects from the described outcomes for amenable ores such as the production of coarser rougher tailings and the positive and negative effects arising for solid-liquid separation, the tailing storage system and the water system.

Ultimately, exploitation of the opportunities referred to in this paper will depend on the perceived urgency for such change within the mineral industry by companies. It must be noted that there are other types of approaches for improving the metallurgical and energy efficiencies for concentrators which are not included in this paper. Selection of the most energy efficient size reduction equipment in conjunction with the most appropriate primary grinding circuit configuration is clearly important. The following related opportunities can be recognized:

1. The use of more metallurgically efficient auxiliary equipment in grinding circuits where appropriate e.g. fine screening technology instead of hydrocyclones.
2. The use of a compact physical layout in terms of concentrator area, height and equipment positioning to minimize capital and operating costs including energy costs for pumping.

2. Methods for demonstration of liberated gangue rejection at coarse sizes in conjunction with mining

With suitable properties for an ore, the rejection of liberated gangue at coarse sizes results in an improved ore grade for further processing, a desirable outcome; of course, there will also be a small loss of the valuable mineral(s) which has to be evaluated on an economic basis. Selective mining, if possible, will also elevate the ore grade for further processing but this approach is outside the scope of this paper.

From industry practice, very good examples of the rejection of liberated gangue (often non-sulphide gangue) exist already in the literature. Some of these examples will be discussed in this section in a broader framework which has been established from the recent work of the Cooperative Research Centre for Optimising Resource Extraction (CRC ORE) which was established in Australia in 2010 and which was summarized recently (Pease et al., 2015). Recognition of methods for productivity improvement early in the mining/processing sequence was the purpose for CRC ORE. As a result, it has undertaken on-site studies at 27 operations in a range of countries.

For the deposit at each operation, the potential for identification and rejection of low grade uneconomic portions of the mined material was evaluated by studying the properties of the deposit using the developed characterisation tools. The evaluation allowed recognition of those deposits for which the approach was applicable technically. The business case for application of the approach was also evaluated for each case. Characterisation of the ore at each operating site may reveal nil, one or multiple opportunities for rejection of low grade uneconomic portions of the mined material. At a particular amenable deposit, only some of the identified ore zones in the orebody may be shown to be suitable for such grade engineering. For the amenable portions of the orebody, the effects may be an increase in the proportion of the deposit which can be directed to the concentrator (high recovery) instead of leaching (lower recovery). Other portions previously considered as waste may become transferable to leaching.

By rejection of low grade uneconomic portions of the mined material, improved productivity results from the improved feed quality achieved early in the mining/processing sequence. This method exploits heterogeneity within the deposit; such heterogeneity should not be lessened by ore handling practices up to the point in the mining/processing sequence at which the liberated gangue is rejected at coarse sizes.

From the viewpoint of the type of the necessary mineral separation equipment, four approaches to rejection of liberated gangue at coarse sizes will be discussed initially (Pease et al., 2015). It can be noted that two of these approaches (screening and gravity based separation) utilize old, proven technologies. The gravity based separation may be an absolute gravity separation e.g. a dense medium process on the Mount Isa zinc-lead ore (Munro et al., 1982) and on the McArthur River ore (Wallace et al., 2015) or a relative gravity separation method e.g. jig technology. Such gravity processes require that the gangue is sufficiently liberated for its rejection with minimal loss of valuable minerals and therefore they may need to be preceded by some crushing.

For the application of screening, two types of mined material can be recognized:

1. Mined material with an increased assay of the valuable mineral in certain size fractions as a result of its natural deportment after normal mining methods (often occurring in the fine fractions, allowing rejection of gangue in the coarse fractions during screening (Burns and Grimes, 1986)).
2. Mined material with an increased assay of the valuable mineral in certain size fractions from carefully designed differential blasting in mining. As an example, a blast can be designed to produce smaller fragments in the high grade regions and larger fragments in the low grade zones for the block being blasted, in preparation for the screening step (Pease et al., 2015).