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Editorial

Editorial for Special Issue "Comminution in the Minerals Industry"

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Size reduction processes, which encompass crushing and grinding, represent a significant part of the capital as well as the operating cost in ore processing. Advancing the understanding of and improving such processes is worthwhile, since any measurable enhancement may lead to benefits, which may materialize as reductions in energy consumption or wear or improved performance in downstream processes.

This Special Issue [1–12] contains contributions dealing with various aspects of comminution, including those intended to improve our current level of understanding and quantification of particle breakage and ore characterization techniques that are relevant to size reduction, as well as studies involving modeling and simulation techniques.

The affiliations of the authors of the articles published in this Special Issue span 14 countries around the globe, namely China, Brazil, Italy, Korea, Sweden, Colombia, Saudi Arabia, Chile, Germany, Russia, South Africa, Canada and the United States, which attests to the highly international nature of research in this field. The themes of the manuscripts also varied widely from several that are more focused on experimental studies [1–5,9,10] to those that deal, in greater detail, with the development and application of modeling and simulation techniques in comminution [6–8,11,12]. Size reduction technologies more directly addressed in the manuscripts included jaw crushing, vertical shaft impact crushing, SAG milling, stirred milling, planetary milling and vertical roller milling. Ores involved directly in the investigations included copper, lead–zinc, gold and iron ores, as well as coal, talc and quartz.

The recognition that size reduction consumes significant amounts of energy has led to a fair amount of interest in methods of ore pretreatment over the years. Odewuyi et al. [4] critically reviewed the various methods that have been studied, ranging from the fairly well-researched thermal (conduction, microwave or radiofrequency), chemical and electric shock to the less studied magnetic, ultrasonic and bio-milling methods. The work shows that the most promising technologies, considering potential of energy reduction, safety, costs, stage of application and potential downstream benefits, are the microwave and electrical pretreatment methods, with important advances in recent years.

Comminution and liberation of minerals can benefit from a detailed knowledge of the structure and texture of rocks and ores. Optical microscopy, scanning electron microscopy and X-ray computed tomography are some of the leading tools that have been used in this task. Popov et al. [2] compared the results from X-ray computed tomography (CT) to those from optical microscopy using quantitative microstructural analysis (QMA) for selected rocks and ores. While recognizing the intrinsic advantage of the direct 3D measures obtained by CT and the ease in sample preparation, the challenges associated with discriminating minerals with similar densities limit its application. On the other hand, optical microscopy of three orthogonally oriented thin sections coupled with QMA offers detailed and precise textural information, including modal composition, grain size distribution and clustering, allowing to discriminate more effectively among minerals but demanding much greater sample preparation effort.

Baldassarre et al. [10] presented a case study of comminution flowsheet development for a high-grade mixed Zn-Pb sulfide sample. Ore samples were characterized through thin section observation and SEM analyses for estimating grain sizes and examining texture features, while X-ray powder diffraction analyses were performed for the definition of target mineral concentrations of comminuted product samples.

Quartz is one of the most common gangue minerals in several ores, occasionally being an ore mineral for glass production. In a study dealing with the investigation of fracture of quartz crystals, Martinelli et al. [9] found that the application of anisotropic stresses resulted in the formation of amorphous silica and, from it, cristobalite and tridymite in nanocrystalline form.

Recognizing the growing role of single-particle breakage in advanced comminution models, Bwalya and Chimwani [6] proposed an empirical breakage probability model that builds on previous works from the authors. The model, which takes into account the effects of energy input and number of impacts to compute the breakage probability, was applied to four different materials. The work also shows the existence of a size-dependent threshold energy for particle breakage.

Components in the feed of size reduction processes often present different breakage behavior; therefore, understanding the response of mixtures has attracted significant attention in the literature. With the aim of gaining insights into the performance of vertical roller (ball-and-race) mills when grinding mixtures of coals, Duan et al. [3] used an instrumented Hardgrove machine to grind anthracite and bituminous coals. The results indicated that the breakage rate and product fineness of the mixture decreased when increasing the proportion of hard anthracite in the mixture. When ground in conjunction with bituminous coal, the grindability of anthracite improved dramatically, while the opposite behavior was found for the former. Indeed, the interaction between the components resulted in a decrease in the specific energy of the mixture compared with the mass average value for separate grinding and, therefore, demonstrated a benefit of intergrinding.

Aiming to gain insights into the response of fine iron ore concentrates to size reduction under confined compression, such as that which happens in high-pressure grinding rolls, Campos et al. [5] investigated their breakage in a piston-and-die apparatus. The work showed that saturation of breakage of particles contained in the top size range occurred at a specific energy of approximately 2 kWh/t, whereas saturation in breakage of all sizes occurred at energies above approximately 6 kWh/t. An expression was proposed to characterize the propensity of a material to break under confined bed conditions. Such knowledge can provide important insights for descriptions of confined bed comminution processes in industry.

Barrios et al. [7] used a particle replacement method in the discrete element method (DEM) to simulate the breakage of a gold ore in a laboratory jaw crusher, demonstrating very good agreement between simulations and experiments. They also showed that the power demanded by the crusher and its throughput and product size varied sensibly with feed size, frequency of strokes and closed-side setting, demonstrating the potential of technology to be used as the basis of the development of improved crushing machines.

Vertical shaft impact (VSI) crushers have been used worldwide in producing crushed fines for construction and building as an alternative to natural sand, owing to the good aspect ratio and smooth surfaces of the crushed product. With the aim of assisting in assessing the suitability of the technology for any particular application, Grunditz et al. [11] proposed a modeling framework. The model, based on the theory of energy-based breakage behavior, also relies on particle collision energy data extracted from discrete element method (DEM) simulations, which are a function of rotor diameter and frequency. It was trained and validated on the basis of a dataset from 24 different sites in Sweden, demonstrating good robustness.

Application of stirred milling has been increasing steadily in the minerals industry, given its advantages in comparison to conventional tumbling mills in fine grinding. One key component of the mill that is directly responsible for media motion is the screw or stirrer. Esteves et al. [12] studied the wear of the screw liner used in a vertical stirred mill using a combination of industrial surveys and DEM simulations. The wear profile, metal loss, power consumption and particle contact information were used to gain insights into how screw wear affects grinding performance. Measurements of stirrer wear from a full-scale vertical stirred mill were then compared to predictions from simulations of a 1:10th scaled-down version of the mill, showing relatively good agreement as long as a proper scaled stirrer frequency was used in the simulations.

Ultrafine grinding also finds important applications in the size reduction of industrial minerals. Kim et al. [1] studied wet high-energy ball milling of talc, investigating the effect of ball size on its grinding response. It was shown that larger (2 mm) ball sizes resulted in faster size reduction and an increase in the specific surface area of the product, but at the expense of greater loss of crystallinity and increased agglomeration. In contrast, the use of smaller (0.1 mm) balls allowed for preserving the crystalline structure of the talc particles, with less tendency toward agglomerate formation, while still allowing for reaching particle sizes at the nanometer scale.

Geometallurgical information regarding ore breakage and grindability often populates block models. Unfortunately, such information is not always available and, even when present, may only have a limited temporal resolution to predict the performance of the comminution processes. Seeking an alternative to this approach and taking advantage of the richness of the data currently available in modern operating plants, Avalos et al. [8] proposed training long short-term memory, a deep neural network architecture, to predict operational ore relative-hardness. They then used the approach on the basis of real-time operational data from two SAG mill datasets, namely feed tonnage, spindle speed and bearing pressure, to classify a copper ore in “hardness” categories. The approach could reach over 80% accuracy in classifying the ore as either “hard” or “soft” type. The authors then proposed extending its application to other grinding and crushing machines to forecast categorical attributes that may be of relevance to downstream processes.

Although only a sample of the vast current research in comminution in the minerals industry, this ensemble of papers characterizes the lively scene of research in this area, which occupies a central role in the future and sustainability of the mining industry.

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