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Influence of Process Mineralogy on Improving Metallurgical Performance of a Flotation Plant

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Mineral Processing And Extractive Metallurgy Review, 2011, Vol. 32(1), pp. 30-46

In this study a sampling survey was carried out in JSC Madneuli copper flotation plant to improve metallurgy by using process mineralogy. Size-by-size mineralogical analyses were performed for some critical streams around rougher, scavenger and cleaner banks by optic image analyzer system. With quantitative data, it was possible to indicate the reasons of dilution in the final copper concentrate and copper loss in the tail. It was found that 18.2% of total copper was lost from tail particularly from finest size as chalcocite. Also, batch flotation tests of some critical streams were performed during and after the sampling survey to evaluate the efficiency of the operating conditions in the plant. These tests showed that increasing the residence time and adding extra collector will result in an increase up to 20% of copper recovery improvement in scavenger bank while it will be 95% in cleaner bank without any decrease in grade. Based on the mineralogical results, regrinding was proposed for particularly cleaner tail as it consisted of mostly coarse and locked particles.
10.1080/08827508.2010.509678

ToF-SIMS-derived hydrophobicity in DTP flotation of chalcopyrite: Contact angle distributions in flotation streams

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International Journal of Mineral Processing, Volume 98, Issues 1–2, 17 January 2011, Pages 35-41, ISSN 0301-7516, http://dx.doi.org/10.1016/j.minpro.2010.10.003.

Particle hydrophobicity has been derived from Time of Flight Secondary Ion Mass Spectrometry (ToF-SIMS) measurements and its impact on the flotation behaviour of chalcopyrite investigated. Batch flotation tests were performed using a dithiophosphate-type of collector in different concentrations. Three flotation regimes were studied using particle size ranges of 20–38 μm, 75–105 μm and 150–210 μm. The individual particle contact angle, and hence, the distribution of contact angles of chalcopyrite within feed, concentrate and tail flotation samples has been determined using ToF-SIMS secondary ions. The effects of particle size and

hydrophobicity on the flotation behaviour have been investigated using this new approach. The hydrodynamic effects of the particle size were highlighted by the different distributions of contact angles obtained for each concentrate size fraction, with fine and coarse sizes requiring higher average contact angles to float. This effect was overtaken by hydrophobicity when a high collector concentration was used. The broad distribution of contact angles observed in all samples, i.e. heterogeneity in hydrophobicity, has significant consequences for interpreting flotation behaviour. The methodology of analysis conducted in this study was applied to real ore and can be used as a quantitative, diagnostic tool for examining surface chemical factors affecting hydrophobicity. This new technique has promise and may advance the understanding of mechanisms, which may lead to better control strategies for improving flotation performance. Furthermore, any mineral–collector system can be targeted, provided appropriate calibration is performed.

Weathering of phlogopite in simulated bioleaching solutions

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International Journal of Mineral Processing, Volume 98, Issues 1–2, 17 January 2011, Pages 30-34, http://dx.doi.org/10.1016/j.minpro.2010.10.004.

The purpose of this study was to examine structural alterations of finely ground phlogopite, a trioctahedral mica, when exposed to acid, iron- and sulfate-rich solutions typical of bioleaching systems. Phlogopite suspensions were supplemented with ferrous sulfate and incubated with iron- and sulfur-oxidizing bacteria (*Acidithiobacillus ferrooxidans*) at 22 °C. As bacteria oxidized ferrous iron, ferric iron thus formed partially precipitated as K-jarosite. K-jarosite precipitation was contingent on the preceding ferrous iron oxidation by bacteria and the release of interlayer-K from phlogopite. This chemically and microbially induced weathering involved alteration of phlogopite to a mixed layer structure that included expansible vermiculite. The extent of phlogopite weathering and structure expansion varied with duration of the contact, concentration of ferrous iron and phlogopite, and the presence of monovalent cations (NH_4^+, K^+, or Na^+) in the culture solution. NH_4^+ and K^+ ions (100 mM) added to culture suspensions precipitated as jarosite and thereby effectively prevented the loss of interlayer-K and structural alteration of phlogopite. Additional Na^+ (100 mM) was insufficient to precipitate ferric iron as natrojarosite and therefore the precipitation was coupled with interlayer-K released from phlogopite. When ferrous iron was replaced with elemental sulfur as the substrate for *A. ferrooxidans*, the weathering of phlogopite was based on chemical dissolution without structural interstratification. The results demonstrate that iron oxidation and the concentration and composition of monovalent ions can have an effect on mineral weathering in leaching systems that involve contact of phlogopite and other mica minerals with acid leach solutions.

A thermogravimetric study of refractory clays chlorination

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International Journal of Mineral Processing, Volume 98 (3–4), 9 March 2011, Pages 195-201, http://dx.doi.org/10.1016/j.minpro.2010.12.004.

The chlorine effect on different samples of refractory clays has been studied within a wide temperature interval. The isothermal and non isothermal calcination assays were carried out in currents of N_2 and a mixture of Cl_2/N_2 (1:1), using a thermogravimetric system designed in our laboratory and masses of approximately 300 mg. Isothermal assays were also performed with masses of 2 g, using a fixed bed reactor with horizontal dynamic flow. The initial samples of refractory clays and the residues resulting from thermal treatments were characterized by X-ray fluorescence (XRF), X-ray diffraction (XRD), scanning electron microscopy (SEM), electron probe microanalysis (EPMA), specific surface area analysis (BET) and CIELAB colorimetry. The thermograms in N_2 and Cl_2/N_2 showed two mass losses, between room temperature and 650 °C, due to the elimination of the mineral hydration water and the transformation of kaolinite into metakaolinite. A third mass loss was observed over 750 °C in Cl_2/N_2 due to the chlorination and elimination of the iron contained in the samples. The X-ray diffractograms of the residues from the different thermal treatments showed that the calcination produced the total transformation of kaolinite and other phases contained in the mineral. The XRF analysis of the residues resulting from the isothermal assays in Cl_2/N_2 permitted to determine that the iron contained in the samples might be completely removed by chlorination at 900 °C for 2 h. The colorimetric analysis of the chlorination residues indicated that the discoloration and bleaching of samples were caused by the deferrification of the mineral. The results of the characterizations using SEM and EPMA supported the previous observations.

The influence of the density of a gas-solid fluidized bed on the dry dense medium separation of lump iron ore

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A gas-solid fluidized bed was used for dry dense medium separation of lump iron ore particles based on their floating and sinking in the fluidized bed. The density of the bed was adjusted to different values using mixtures of zircon sand and iron powder as the fluidized media. Float-sink experiments using 30 mm diameter density adjusted spheres in the range of 2100-4500 kg/m(3) in density increments of 100 kg/m(3) were carried out to determine the partition curves, the density of the bed and the probable error (Ep). It was found that the density could be adjusted in the range of 2500-4200 kg/m(3), when the bulk volume fraction of iron powder and the fluidizing air velocity were varied. The Ep values were less than or equal to 0.05, if suitable fluidizing air velocities were chosen. The density of the bed determined

using the spheres floating-sinking corresponds to that measured using the height of the fluidized bed. The float-sink performance of lump iron ore particles in the size range of +25-31.5 mm agrees well with the spheres' float-sink performance. The partition curves, separation density and the Ep values were determined for the lump iron ore particles. The Ep value for the ore particle separation was around 0.03. The theoretical Fe-grade recovery (washability) curve for the ore was determined for separation densities between 2500 and 4200 kg/m(3) from the density distribution and Fe content of the lump iron ore particles. The actual Fe-grade and recovery were calculated from the partition curves of the ore particle separation and compared to the theoretical maximum obtainable Fe-grade and recovery. (C) 2010 Published by Elsevier Ltd. 10.1016/j.mineng.2010.10.010

Slurry flow in a tower mill

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Minerals Engineering, JAN, 2011, Vol. 24(2), pp. 152-159

Tower mills are a commonly used device for fine grinding in the mineral processing industry and can be used for dry or wet-grinding applications. In wet grinding, the nature of the slurry flow plays an important role in transporting feed rock and ground fines inside the mill and also assists discharge from the mill. Operating conditions and impeller design can affect the slurry distribution within the mill with some regions of the charge potentially being drier and others saturated. To help understand the slurry distribution and transport we use a two stage modelling process. The Discrete Element Method (DEM) is used to characterise the motion and distribution of the grinding media in the tower mill. The averaged voidage distribution and steady velocity field from the DEM model is then used to define a dynamic porous media in the fluid model. The Smoothed Particle Hydrodynamics (SPH) method is used for modelling the fluid flow because of the free surface and the moving impeller. The one way coupled DEM/SPH model is then used to assess how the fluid distribution and flow pattern of the slurry in a tower mill are to variations in the slurry viscosity. 10.1016/j.mineng.2010.11.002

Comparison of different 2D image analysis measurement techniques for the shape of talc particles produced by different media milling

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Talc, which is an extremely versatile industrial mineral, has found increasing number of uses in various industries such as paint, paper, plastic, ceramic and cosmetic. As it is well known, the particle shape is one of the main properties affecting the behavior and properties of mineral particles, especially for the bubble-particle attachment in flotation. In this study, shape characteristics of talc particles

produced by laboratory ball and rod mills were determined by automated image analysis using Malvern Morphologi (R) G3 instrument. The results were compared by previous studies on the same samples that used other shape characterization techniques namely Scanning Electron Microscope (SEM) (Yekeler et al., 2004; Hicyilmaz et al., 2004) and Clemex image analysis system (Ulusoy, 2008). About 10,058 particles for ball milled product and 7086 particles for rod milled product were measured for the shape analysis by the Malvern Morphologi (R) G3 instrument. They were expressed in terms of Aspect ratio, HS Circularity and Elongation and compared by applying t-test using the software Statistical Package for Social Science (SPSS) with a 0.05 significance level. t-Test revealed that, the difference between the image data group for different mill products are significant with a 95% confidence level. Although lower sample population was used for the SEM and Clemex analysis techniques than for the new technique Malvern Morphologi (R) G3, there is a clear difference in the particle shape obtained by different grinding methods for the talc mineral used. The determined shape property depends on the measurement technique applied. However, the results are in good agreement with each other by this study. i.e., more elongated talc particles were obtained by rod mill product. 10.1016/j.mineng.2010.05.011

Is media shape important for grinding performance in stirred mills?

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Models for understanding the basic concepts of fine grinding and how they apply to the design of stirred media mills have not yet matured. While spherical media in tower mills has previously been studied, real grinding media shape in stirred mills can range from spherical (steel/ceramic balls) to highly non-spherical (sand or slag) resulting in very different media and grinding dynamics. Handling the contact mechanics of non-spherical particles is a challenge for numerical models, and very few studies dealing with non-spherical particle shape exist in the literature. Discrete Element Method (DEM) simulations of dry media flow in a pilot-scale tower mill are performed for four cases with different shaped grinding media, in order to understand how flow and energy utilisation within a stirred mill depend on media shape. Differences in media transport, stress distribution, energy dissipation, and liner wear were observed in the tower mill for the spherical and non-spherical cases. A significant departure from sphericity of the media leads to strong dilation of the bed, reduced bulk density, and a reduction in active volume and collisional power levels leading to a reduction in power draw for the mill. In addition, highly non-spherical media tend to pack tightly near the mill walls forming a near solid layer around the inside of the mill shell which results in poorer transport and mixing, as well as increased wear rates on the screw impeller. Grinding performance in stirred mills appears to deteriorate strongly when using highly non-spherical media.
10.1016/j.mineng.2010.10.016

Computational study of the multiphase flow and performance of dense medium cyclones: Effect of body dimensions

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This paper presents a numerical study of the gas liquid solid flow in 1000 mm dense medium cyclones (DMCs) with different body dimensions, which includes the spigot diameter, cylinder length, cone length and inlet size by means of a computer model which we recently proposed. In this model, mixture multiphase model is used to describe the flow of the dense medium (comprising finely ground magnetite contaminated with non-magnetic material in water) and the air core, where the turbulence is described by the well-established Reynolds Stress Model. The stochastic Lagrangian Particle Tracking method is used to simulate the flow of coal particles. It is found that the spigot size is very sensitive to the performance. The operational head and medium split reporting to overflow, decrease dramatically as the spigot diameter increases. The density differential decreases rapidly, and then passes through a minimum and increases slowly. The long body including cylinder and cone is helpful to particle separation, particularly for fine and heavy particles. The inlet size plays a remarkable role on the performance on DMCs. The operational head, the density differential and the medium split increase dramatically as the inlet size decreases. Both the upward flow and the downward flow become very strong in the DMC with a small inlet when medium feed rate is constant, which results in a very low Ep. 10.1016/j.mineng.2010.09.003

Effect of magnetic field orientation on high gradient magnetic separation performance

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The magnet has a dominant role in a high gradient magnetic separator; it provides the passage for the magnetic field and the working space where the matrix is placed to produce magnetic gradients and magnetic forces high enough to capture magnetic particles from the slurry. The effect of the magnetic field orientation of the magnet on high gradient magnetic separation (HGMS) performance has been comparatively investigated on a pilot pulsating HGMS separator with vertical and horizontal magnets respectively. The results of the investigation indicate that the magnetic field orientation has a significant effect on the performance. It was concluded that a properly designed magnet in a HGMS separator greatly improves the performance.
10.1016/j.mineng.2010.09.019

Stability analysis of a copper tailings dam via laboratory model tests: A Chinese case study

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The upstream method is a popular method for raising tailings dams. Currently in China there are more than 12,000 tailings impoundments and almost 95% of them use the upstream method for the construction of the dam. Statistical data has shown that the tailings impoundment is one of the main sources of risk in the mining industry. Failures of tailings impoundments have resulted in the loss of many lives, considerable property damage, and irreversible pollution in downstream areas. Therefore, the safety of tailings management facilities has been of increasing concern to governments and local communities. The management of a conventional tailings storage facility requires the maintenance of a high level of structural stability. Therefore, according to the relevant mine Acts, the mine operators are required to conduct stability analyses for all types of tailings facilities, whether they are new, active, or decommissioned. For the stability analysis of tailings dams, the accurate profile of the tailings dam is very important. The profiles are easily obtained for both active and decommissioned tailings facilities because their data can be collected through field investigations. However, collecting basic data from newly constructed tailings facilities is difficult. In this paper, a laboratory physical model test has been performed. The construction process for new tailings impoundment has been physically simulated in the laboratory, where the tailings particle composition and distribution below a beach, the change of phreatic surface of the dam, and the engineering properties of the tailings of the dam profiles have been measured. A new tailings facility. Yangtianqin tailings impoundment, owned by Tongchang copper mine of Yuxi Mine Co., was used as a case study to illustrate the physical modeling of the tailings dam. In the model test, the geometrical model of pond area was constructed according to the scale factor, lambda(L), of 1:200 (model:prototype), and the tailings discharge system was also established, the tailings slurry then being discharged based on the design data. Finally, on the basis of the model test results on profiles, the stability analysis of the tailings dam at different heights was conducted under different conditions. The model test results and stability analysis show that the height of the tailings dam should be less than that originally planned. The original design of Yangtianqing tailings impoundment should therefore be revised for the safety of the tailings impoundment. 10.1016/j.mineng.2010.10.014

Impact of tunneling on regional groundwater flow and implications for swelling of clay-sulfate rocks

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Engineering Geology, Feb, 2011, Vol. 117, pp. 198-206

Tunnels play a key role in many transportation concepts. The swelling of clay-sulfate rocks leads to serious damage to many tunnels crossing such rock, producing great difficulties and high extra costs in tunnel engineering. The swelling is caused by the transformation of the sulfate mineral anhydrite into gypsum, entailing a 60% volume increase. The transformation involves anhydrite dissolution in water, transport of the solution with groundwater flow, and gypsum precipitation at a different location. Therefore, the knowledge of groundwater flow systems at the tunnel and adjacent areas is essential to better understand the swelling processes. The present study investigates the groundwater flow systems at the Chienberg tunnel in Switzerland before and after the tunnel excavation, based on numerical flow modeling. The models include faults and the hydrostratigraphic layering in the subsurface to assess the role of the hydrogeological setting. The results of this study indicate effects on groundwater flow caused by the tunneling, which may trigger rock swelling by favoring anhydrite dissolution and gypsum precipitation, including (1) increase of flow rates around the tunnel, (2) broadened, shifted and more distributed capture zones leading to a change in origin and age of groundwater, (3) access of groundwater from preferential flow paths (e.g. faults) due to the drainage effect of the tunnel, and (4) change in geochemical equilibrium conditions because of decreased pore water pressures in the tunnel area. 10.1016/j.enggeo.2010.10.018

Size-Dependent Bioavailability of Hematite (alpha-Fe2O3) Nanoparticles to a Common Aerobic Bacterium

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The size-dependent bioavailability of hematite (alpha-Fe2O3) nanoparticles to obligate aerobic Pseudomonas mendocina bacteria was examined using the natural siderophore-producing wild type strain and a siderophore(-) mutant strain. Results showed that Fe from hematite less than a few tens of nm in size appears to be considerably more bioavailable than Fe associated with larger particles. This increased bioavailability is related to the total available particle surface area, and depends in part on greater accessibility of the Fe to the chelating siderophore(s). Greater bioavailability is also related to mechanism(s) that depend on cell/nanomineral proximity, but not on siderophores. Siderophore(-) bacteria readily acquire Fe from particles <10 nm but must be in direct physical proximity to the nanomineral; the bacteria neither produce a diffusible Fe-mobilizing agent nor accumulate a reservoir of dissolved Fe in supernatant solutions. Particles <10 nm appear to be capable of penetrating the outer cell wall, offering at least one possible pathway for Fe acquisition. Other cell-surface-associated molecules and/or processes could also be important, including a cell-wall associated reducing capability. The increased bioavailability of <10 nm particles has implications for both biogeochemical Fe cycling and applications involving engineered

nanoparticles, and raises new questions regarding biogenic influences on adsorbed contaminants. 10.1021/es102922j

Processing of coal fines in a water-only cyclone

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FUEL, FEB, 2011, Vol. 90(2), pp. 834-837

It is reported in the literature that a water-only cyclone (WOC), a centrifugal gravity concentrator, is an alternative to froth flotation to treat coal fines (below 0.5 mm). This unit overcomes the inherent limitations of froth flotation and the dense-medium cyclone techniques as it requires no chemicals or artificial medium. The literature dealing with WOC performance to treat coal fines is also limited and as a result it is not well established how the design variables affect the performance of a WOC while treating coal fines. Therefore, an attempt has been made to develop regression models based on factorial design of experiments to quantify the effects of major design variables of a WOC on the beneficiation characteristics of a typical coal fine sample. Further attempts have been made to provide possible explanations on the observed trends of the data based on simple hydrodynamic analyses. 10.1016/j.fuel.2010.10.038

Status of Some Soil Trace Elements and Their Potential Human Health Risks Around a Coal Beneficiation Plant

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International Journal of Coal Preparation And Utilization, 2011, Vol 31(2), pp. 61-77

The entire coal beneficiation process, starting from unloading the raw coal to the loading of processed coal, liberates particulate matter, which would ultimately settle on the soil at varying distances. This is likely to affect soil quality and possibly the health of the inhabitants. Soil samples collected from the sites of two coal beneficiation plants (CBPs), located in Dhanbad, India, and a control (CNT) site were analyzed for some trace elements like Cr, V, Co, Ni, Cu, Zn, Ga, Rb, Zr, Ba, Th, and U. The results showed that the CBP soils were enriched in Cr and Ni. In the absence of other sources of industrial pollutants, the enrichment of Cr and Ni is attributed to their input from the CBPs. However, the accumulation of Cr and Ni did not appear to reach health-risk levels, as the calculated lifetime human intake levels through different exposure pathways from the soil are within the USEPA's reference dose (RfD). Multivariate analyses like principal component analysis (PCA) and cluster analysis showed that the association between the trace elements in CBP soils is distinctly different than the CNT, thereby suggesting a different origin of some of the trace elements in CBP soils. 10.1080/19392699.2010.534746

The Application of the Coal Grain Analysis Method to Coal Liberation Studies

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Emerging coal markets such as the use of coal for conversion to liquid fuels and its use in fuels cells and as coal water slurries in diesel engines require coal products with different coal quality specifications than those applicable to traditional coal markets of coke making and conventional power generation. As well as quantifying coals in terms of their chemical and physical properties, detailed knowledge of the mineral inclusions within the coal particles is required to identify coals that are suited to economically produce the low-ash value coals required for these markets. Hence, it is necessary to understand the associations of the minerals and macerals in individual particles as these give a particular coal not only its chemical attributes and utilization performance but also its washability (density distribution) and contribute to its surface chemistry characteristics. These attributes pinpoint the coals that are suited to beneficiation techniques that can be employed to produce economic amounts of low-ash value products for these new markets. After mining and processing, some particles can consist of essentially pure components of a single maceral or mineral phase whilst others are composite particles that are comprised of varying amounts of macerals and minerals. The proportion of particles that are present as pure components or as composites will be a function of the characteristics of the coal and the particle size. In general, it is considered that size reduction will result in liberation and hence increased yield. The amount of liberation that occurs during crushing or grinding a coal is however coal specific. Particle characterization information provided by an optical microscopic-imaging method, Coal Grain Analysis, was used to identify coals that might benefit from additional crushing to improve recovery of clean coal by new density separation techniques and by flotation. As expected, the results of these studies suggest that the degree of liberation that is obtained is coal specific, and, hence, yield improvements are also coal specific. Hence a quantitative method of investigating this issue is required. 10.1080/19392699.2010.537995

Cadmium adsorption by coal combustion ashes-based sorbents-Relationship between sorbent properties and adsorption capacity

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Journal Of Hazardous Materials, Mar, 2011, Vol. 187, pp. 371-378

A very interesting possibility of coal combustion ashes reutilization is their use as adsorbent materials, that can also take advantage from proper beneficiation techniques. In this work, adsorption of cadmium from aqueous solutions was taken into consideration, with the emphasis on the intertwining among waste properties, beneficiation treatments, properties of the beneficiated materials and adsorption capacity. The characterization of three solid materials used as cadmium sorbents

(as-received ash, ash sieved through a 25 mu m-size sieve and demineralized ash) was carried out by chemical analysis, infrared spectroscopy, laser granulometry and mercury porosimetry. Cadmium adsorption thermodynamic and kinetic tests were conducted at room temperature, and test solutions were analyzed by atomic absorption spectrophotometry. Maximum specific adsorption capacities resulted in the range 0.5-4.3 mg g(-1). Different existing models were critically considered to find out an interpretation of the controlling mechanism for adsorption kinetics. In particular, it was observed that for lower surface coverage the adsorption rate is governed by a linear driving force while, once surface coverage becomes significant, mechanisms such as the intraparticle micropore diffusion may come into play. Moreover, it was shown that both external fluid-to-particle mass transfer and macropore diffusion hardly affect the adsorption process, which was instead regulated by intraparticle micropore diffusion: characteristic times for this process ranged from 4.1 to 6.1 d, and were fully consistent with the experimentally observed equilibrium times. Results were discussed in terms of the relationship among properties of beneficiated materials and cadmium adsorption capacity. Results shed light on interesting correlations among solid properties, cadmium capture rate and maximum cadmium uptake.
10.1016/j.jhazmat.2011.01.029

Theory and Applications of High-Power Nanosecond Pulses to Processing of Mineral Complexes

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Mineral Processing And Extractive Metallurgy Review, 2011, Vol. 32(2), pp. 105-136

This paper reviews current research in high pulsed power technologies for processing of precious metals containing refractory ores and natural mineral aggregates. This is a branch of experimental engineering physics that critically depends on national priority research projects for its dynamic development. The aim of the manuscript is to show progress in the study of nanosecond processes involved in the disintegration and breaking-up of mineral complexes with fine disseminated precious metals. The manuscript presents results of theoretical and experimental studies of the mechanisms of the nonthermal action of high-power electromagnetic pulses with nanosecond leading edge, pulse duration, and high electric field strength on natural mineral media. Experimental data are presented to confirm the formation of breakdown channels and selective disintegration of mineral complexes as a result of pulse irradiation. This makes for efficient access of lixiviant solutions to precious metal particles and enhances precious metal recovery into lixivia during leaching. The paper shows the advantages of high-energy pulse treatment that provides a stable gain in valuable components recovery (5-80% gain for gold and 20-50% for silver) and at the same time helps to reduce energy consumption and cost of products in the processing of resistant gold-containing ores and beneficiation products from Russian deposits. X-ray photoelectron spectroscopy

was used for determining the relationship between electromagnetic pulses energy and the surface chemical composition for pyrite and arsenopyrite. It has been concluded that impulsive treatment influences oxidation and hydrophobicity of the minerals and, therefore, it allows for the control of the hydrophobic-hydrophilic mineral surface balance. 10.1080/08827508.2010.530722

Beneficiation of high-ash, Indian non-coking coal by dry jigging
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Minerals & Metallurgical Processing, FEB, 2011, Vol. 28(1), pp. 21-23

Indian coals, which are of Gondwana origin, contain high amounts of mineral matter, wherein the extraneous material was intimately mixed in the coal matrix during the formation stage, causing a high level of impurity in the run-of-mine (ROM) material. These coals possess difficult to very difficult washability characteristics. Beneficiation of high-ash non-coking coals of India has become the prerequisite for improving the overall economics and efficiency of power generation. The use of dry cleaning systems in India for beneficiation of non-coking coals has gaining renewed interest recently The benefit of the dry beneficiation process is to exploit the given resources while providing a more reliable and consistent quality fuel with a low operating cost. M/S Allmineral has introduced a technique for the dry beneficiation of coal, which is being tried in India for the treatment of high-ash non-coking coals. The first commercial air jig of 50 t/hr capacity was installed and commissioned to beneficiate high-ash coals of 40 x 5 mm feed with an ash content of 40%; a clean coal product of 33% ash was produced and is being used for a sponge iron plant.

A comparative study between cone crushers and theoretically optimal crushing sequences
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The supply of minerals, ores and aggregates are crucial for the continuous development of today's society. With a rising world population, growing urbanization, and increasing standards of living, the performance and efficiency of existing crushers must be improved in order to meet the escalating demand on these products. The current paper thus presents a comparative study between existing cone crushers and theoretically optimal crushing sequences. Full scale experiments are conducted in order to examine the effects of Closed Side Setting (CSS), stroke, and eccentric speed on crusher output. The performance of the examined cone crusher is then compared against what is considered as theoretically optimal. The subsequent analysis shows that significant gains can be made in terms of both product yield and overall capacity by adjusting crusher operation depending on the conditions at hand, e.g. increasing the CSS while maintaining the same stroke or decreasing the eccentric speed. It is also shown that a mixture of

breakages modes is more optimal than the sole application of one optimized breakage mode. (C) 2010 Elsevier Ltd. All rights reserved.
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A preliminary investigation into the feasibility of a novel HPGR-based circuit for hard, weathered ores containing clayish material

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The paper reports the progress of a research project using rock samples from a large copper-gold mining project. The orebody contains a mixture of hard rock, softer material, and clays (sericite), in proportions that are expected to vary throughout the mine-life. The feasibility of a novel comminution circuit, using an autogenous (AG) mill/scrubber and parallel trains of cone crushers and high-pressure grinding rolls (HPGR) is being investigated. The process enables the application of energy-efficient HPGR to base and precious metal hard-ores containing clay, which are usually processed using SAG mill circuits. The work presented in this paper involved laboratory testwork including pilot HPGR testing, and modelling and simulation of both the HPGR-based circuit and an equivalent SAG-based circuit. The preliminary analysis reported herein includes a comparison of the energy consumption of both circuits: complete operating and capital cost comparisons will be reported in a future paper. (C) 2010 Elsevier Ltd. All rights reserved. 10.1016/j.mineng.2010.09.011

CFD-DEM modelling of particle flow in IsaMills - Comparison between simulations and PEPT measurements

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The IsaMill (TM) is a high speed stirred mill with a horizontal configuration that offers advantages such as energy efficiency and an inert grinding environment. A combined computational fluid dynamics (CFD) and discrete element method (DEM) approach was developed to investigate the particle and fluid flows inside a simplified IsaMill (TM). The configuration of the mill was simpler than that of an actual IsaMill (TM) and no feed flow or rotor was considered. The CFD-DEM model is a progression from earlier DEM only models of "dry" systems which did not account for the fluid phase. The properties of flows at a macroscopically steady state, such as velocity field, distributions of particle velocity and acceleration in the radial direction and power draw, were analysed. Detailed comparisons were carried out between the simulation results and Positron Emission Particle Tracking (PEPT) measurements under similar conditions. The comparisons showed reasonable agreements, confirming that both techniques can capture the key features of the

flow. The discrepancies between simulated and measured results were discussed. The findings indicated that the proposed model can be used to generate microdynamic information that is useful in leading to a better understanding of the underpinning physics of flow inside mills. (C) 2010 Elsevier Ltd. All rights reserved. 10.1016/j.mineng.2010.07.011

Comparison of open and closed circuit HPGR application on dry grinding circuit performance

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A conventional cement grinding circuit is composed of a two compartment tube mill, a mill filter which collects the fine material inside the mill and a dynamic air separator where final product with required fineness is collected. In general the material fed to the circuit has a top size of 50 mm which is very coarse for the ball mill. For this purpose, later in 1980s. high pressure grinding rolls (HPGR) has found applications as a pregrinder which increased throughput of the grinding circuit at the same fineness. In early applications, HPGR was operated in open circuit. But later as the operating principle of the equipment based on the compression, some portion of the HPGR discharge recycled back to improve efficiency of the mill or operated closed circuit with classifiers. Within this study effect of open and closed circuit HPGR applications on dry grinding circuit performance was examined. For this purpose sampling studies around three different cement grinding circuit were completed. In the first study, a circuit including open circuit HPGR, ball mill and air separator was sampled and chosen as the basic condition. As the final product size distribution is important for grinding circuit, model structure of each equipment was developed. The second and third surveys were carried out around closed circuit HPGR operation with V and VSK separator to develop models for the separators. Finally the separator models were used in basic condition to simulate closed circuit HPGR application. It was understood from the studies that closed circuit HPGR operation improved the overall circuit efficiency at the same final product fineness by reducing the specific energy consumption. 10.1016/j.mineng.2010.08.024

Investigation of the breakage of hard and soft components under high compression: HPGR application

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In the cement industry, high pressure grinding rolls (HPGR) has been used since 1985. At the first applications, this equipment has been installed in the existing cement grinding circuits as an open circuit precrusher in order to crush clinker especially. The cement factories produce different type of cement by using basically

clinker, gypsum and additives like limestone and trass. The additives generally are not precrushed before ball mill circuits. In this study, three different mixed feeds were prepared with clinker, gypsum, limestone and trass to evaluate the performance of an industrial scale open circuit HPGR. The results of the tests show that due to the stress concentrates on soft and fractured material, the performance of HPGR becomes worse when the relatively hard material (clinker) is fed together with soft and weak materials (i.e. gypsum, limestone, trass). In addition to the industrial tests, the piston die tests have been also performed with narrow size fractions of the mixed and unmixed materials. (C) 2010 Published by Elsevier Ltd.
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Modeling breakage of monodispersed particles in unconfined beds

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Mathematical models of grinding mills and crushers are undergoing significant advances in recent years, demanding ever more detailed information characterizing ore response to the mechanical environment. In a mechanistic model of a comminution machine, the type of characterization data used should cover, as much as possible, the conditions found inside the size reduction machines. This applies to the particle size, the stressing energy and rates that particles are subject to, the breakage mechanism and the level of interaction of the particles during stressing, which all must be described appropriately. Whereas, a very large number of experimental techniques and published data exist that allows understanding and quantitatively describing the response of single particles to stressing, comparatively little information exists on the breakage of particles contained in beds. The present work investigates breakage of particle beds impacted by a falling steel ball in unconstrained conditions, such as those that are likely to be found in tumbling mills. The influences of particle size, impact energy, ball size and bed configuration are investigated for selected materials and a mathematical model is proposed that describes the influence of all these variables. The key element of this model is that it allows predicting breakage in monolayer unconfined particle beds with a combination of single-particle breakage data and functions that describe energy partition and volume of material captured in the bed. This model has been calibrated and validated using data from quartz, granulite, limestone and a copper ore, with good agreement.
10.1016/j.mineng.2010.09.018

Optimisation of the secondary ball mill using an on-line ball and pulp load sensor - The Sensomag

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The ball load and pulp load have a significant influence on the ball mill product size and production capacity. To improve the circuit performance at industrial scale these variables must be tweaked to levels where the plant can get grind and capacity benefits. In most grinding circuits the influence of these variables are not quantified because it is difficult to obtain precise measurements of the pulp load for an industrial scale mill and the conventional method of obtaining ball load measurements that involves crash stops is not attractive. A comprehensive investigation was performed on an industrial scale mill to quantify the effects of both ball and pulp load. A wide range of ball and pulp loads were tested and the findings are reported in this paper. The Sensomag, a sensor developed by Magotteaux, was used to obtain ball and pulp load measurements during the experimental work. 10.1016/j.mineng.2010.10.011

Studies of the effect of tracer activity on time-averaged positron emission particle tracking measurements on tumbling mills at PEPT Cape Town

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Minerals Engineering, JAN-MAR, 2011, Vol. 24(2), pp. 261-266

The statistical uncertainties associated with time-averaged positron emission particle tracking (PEPT) measurements of the position, velocity and acceleration of a small tracer particle have been investigated. Experiments were undertaken using the ECAT 'EXACT3D' PET scanner recently installed at the facilities of PEPT Cape Town at iThemba LABS, South Africa. Small "button" sources of (68)Ga were attached to the outer shell of a small mill and PEPT data were recorded over several half-lives, for the cases of the mill being empty and entirely filled with steel balls. The effect of tracer activity on the statistical uncertainties in the positions, velocities and accelerations derived from the measurements was investigated, as a first step towards fully quantifying the uncertainties associated with tracking particles via PEPT in laboratory-scale tumbling mills.
10.1016/j.mineng.2010.08.020

Special issue: Comminution Foreword

Powell, M
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10.1016/j.mineng.2011.02.007

Towards a mechanistic model for slurry transport in tumbling mills

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A new modelling approach to slurry transport in dynamic beds based upon combining space and time-averaged Navier-Stokes equations with a new type of cell model is described. The resulting Ergun-like equation is used to correlate pressure drop with time-averaged distributions of the porosity, superficial fluid velocity and solids velocity for data derived from positron-emission-particle-tracking (PEPT) experiments in a scaled industrial tumbling mill fitted with lifter bars, pulp lifters and a discharge grate and run with particles and re-circulating slurry. 10.1016/j.mineng.2010.08.010

Understanding fine ore breakage in a laboratory scale ball mill using DEM

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DEM models of fine grinding in ball and stirred mills have to date almost entirely focused on the motion of the media and their interaction with the mill configuration. For SAG mills, a large fraction of the feed material can now be accurately represented in DEM models. However, for other mill types with much finer feed materials, such as the second chamber of a cement ball mill, the vast numbers of feed particles makes their explicit inclusion in the models prohibitive. However, it is now feasible to model a periodic section of a laboratory scale ball mill and include the coarser end of the ore size distribution directly in the DEM model. This provides the opportunity to better understand the effect of media on the interstitial bed of powder and of the effect of the powder on the media. The effect of the powder fill level, which is varied between 0% and 150% of the pore space in the media charge, is explored. The distribution of the powder, its effect on power draw and the way in which it contributes to the pattern of energy utilisation is assessed. The simulation results are compared with experimental results from a test at similar ball loading and rotation rate and for several size fractions of ore at a range of powder fill fractions. Tracking the collision histories of specific ore particles within the charge allows estimates of the probability (per unit time) of collision between media and ore particles (the "Selection" function) and of the intensity of each collision which can be used to estimate the severity of breakage using the JKMRC breakage model (the "Breakage" function). The energy spectra indicate that for a typical ore, only very few collisions are large enough to cause damage to the body of each particle. This provides an estimate of the energy efficiency which is less than 10% at even the best operating conditions. 10.1016/j.mineng.2010.12.013

Influence of particle size and contact angle on the flotation of chalcopyrite in a laboratory batch flotation cell

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The flotation response of chalcopyrite has been characterized as a function of particle size and advancing contact angle. The advancing contact angle of individual particle size fractions was controlled to different values. Flotation experiments were carried out under constant hydrodynamics and feed particle size distribution. A two-component kinetic model was used to fit the experimental flotation data. The maximum recovery increased with advancing contact angle for each size fraction. Particles within the same size fraction and within the same contact angle range displayed similar flotation behaviour, within experimental error, in different tests. Evidence of a distribution of advancing contact angle values within each particle size fraction was found, and it was assumed that particles in the non-floating fraction had advancing contact angle values below the critical contact angle required for stable bubble-particle attachment. The flotation results were used to model the maximum recovery and the critical contact angle as a function of particle size, assuming a statistical distribution of contact angle values about a measured mean. The recovery and rate constant data were collated into master curves as a function of particle size for different contact angle ranges. These master curves, together with the critical contact angle, may be used to benchmark the flotation response of chalcopyrite and to infer an effective operational contact angle in natural ores.

Full-text Papers available in NML Eprints (http://eprints.nmlindia.org)

Das, Avimanyu and Singh, Ratnakar and Bhattacharyya, K K (2011) *Split Processing of High Ash Indian Coking Coal Fines Using Jameson Flotation Cell.* Mineral Processing and Extractive Metallurgy Review, 32(1) (0.611 (SCI)). pp. 17-23.

The processing of two samples of high ash Indian coking coal fines (-500m) has been studied. Mechanical cell flotation of two coal samples resulted in poor recovery of combustibles at a specified ash content of 17%. The use of Jameson Cell for flotation was also found helpless in improving the performance. The poor recovery of combustibles was attributed to low recovery of coarse particles (300m). Split processing involving spiral concentration of the coarser fraction (-500+100m) and Jameson Cell flotation of the -100-m fraction resulted in an improved overall performance. Substantial improvement in the yield of clean coal at the same target ash (17%) could be achieved in split processing. http://eprints.nmlindia.org/3001/

Vijaya Kumar, T V and Rao, D S and Gopalakrishna, S J (2011) *Mineralogical and separation characteristics of iron ore fines from Bellary – Hospet, India with special emphasis on beneficiation by flotation.* Journal of Mining and Metallurgy, 47A (1). pp. 39-49.

The depletion of high grade iron ore and increased generation of fines during mining and handling and demand for high grade iron ore fines for pellet making and

export has necessitated the processing of low to medium grade fines. Physical separation methods were found to be inadequate to process fine sized ores due to reduced selectivity of separation. An attempt has been made to understand the intricate associations between different mineral phases of iron ore fines from Bellary- Hospet area, India from XRD, as well as Electron microscopy studies. XRD studies indicated that hematite and goethite are the iron bearing minerals in order of abundance and quartz and kaolinite form the gangue. EPMA studies on these ores show the presence of gibbsite as the only alumina bearing phase and apatite as phosphorous bearing mineral. Traces of alumina, present as solid solution in the iron oxide minerals has also contributed Al2O3 to the ores. Electron microscope studies indicated that gibbsite grains are in the range of 10 to 50 microns and are intimately associated with the iron oxide phases. Particle Size Analysis and Heavy Medium Separation (HMS) tests on different size fractions provided the insight into the liberation and separation characteristics of the material. d80 of the material was found to be 40.5 microns. 20.6% by weight of the material can be treated as fairly liberated and obtained as a concentrate assaying 66.29% Fe, 2.15% SiO2 and 1.17% Al2O3 from the feed assaying 60.43% Fe, 6.88% SiO2 and 3.26% Al2O3. This defines the lower bench mark for theoretical recovery and grade of the concentrate. Further, scope exists for increase in recovery of iron values from the partially liberated particles without diluting the concentrate grade in terms of allowable limits of alumina (not more than 2.5%) for pellet making. Considering all these factors, flotation appears to be the only industrially viable process to recover these iron values with acceptable grade, recovery and alumina in the concentrate.
http://eprints.nmlindia.org/4436/

Prabhakar, S (2011) *Column Flotation for the Beneficiation of Iron Ore Fines.* In: International Conference on Iron and Steel Industry : Emerging Trends (Steelrise 2011), Feb. 1-2. 2011, National Metallurgical Laboratory, Jamshedpur.

Iron ore is more integral to the global economy than any other commodity" perhaps except oil. Indian iron ore industry is one of the world's largest and growing at a rapid pace. Optimum utilization of iron ore resources have become a national priority. As per the recent national steel policy, our country will be producing about 110 millions tons of steel per annum by 2020 requiring around 42 million tons of iron ore. The iron ore exports are projected to a level of 114 million tones and it amounts to total production of 300 million tons by 2020. In the present steel boom, many global steel producers have projects in states of Chattisgarh, Jharkhand, Karnataka and Orissa. Research on utilization of low grade iron ore to produce quality raw material would play a key role in future which is a fact acknowledged by the iron and steel industry. http://eprints.nmlindia.org/4248/

Rao, D S and Vijaya Kumar, T V and Bhaskar Raju, G and Prabhakar, S (2011) *Effect of the particle size on flotation performance of a siliceous limestone sample.* Journal of Mining and Metallurgy, 47A (1). pp. 37-49.

Laboratory tests were conducted to decipher the effect of the particle size of minerals that influenced the concentration of limestone in terms of grade and recovery by flotation. Both direct as well as reverse flotation experiments were conducted on five different mean particle size ranges on a low grade siliceous limestone sample having CaO 43.09% and SiO2 18.24% from Jayantipuram mine of Andhra Pradesh, India. Direct flotation experiments were carried out using sodium silicate and sodium oleate as depressant and collector respectively. Reverse flotation process was adopted where silica containing minerals of the gangue (quartz) are floated using cationic collector SOMU Sokem 565C. The direct flotation process using sodium oleate as a collector was found to yield better weight percentage as well as distribution than reverse flotation. http://eprints.nmlindia.org/6105/

Bhagat, R P (2011) *Modeling of air flow through sinter mix bed.* In: Proc. : Inter. Conf. on Mathematical Modelling and Application to Industrial Problems (MMIP-2011), Org. by Dept of Mathematics, March 28-31, 2011, National Institute of Technology, Calicut , Kerala .

The present work relates the flow of air through a packed sinter mix bed to the pressure drop using the Ergun's Equation. The velocity of air infiltration across the sinter mix charged into a pot was measured at different suction pressures. The parameters, void fraction and equivalent spherical diameter were calculated using the pressure drop and air velocity relationship. These have been interpreted in terms of the process variables vis-à-vis the mix permeability The validity of the Ergun's equation was checked while comparing the observed pressure drop with the computed one obtained by fitting the above parameters in the equations. http://eprints.nmlindia.org/4583/