can be depressed by using either CMC or guar as depressants, for different dosages of either guar or CMC in a study of an ore sample from the Merensky reef.

One of the unintended consequences of depressing the NFG through the use of depressants is that the amount of solids reporting to the froth is significantly reduced and this has negative consequences in terms of the stability of the froth. This can be partially overcome by increasing the frother dosage or by using a stronger frother.

The recoveries of NFG at different dosages of CMC or guar were always higher when copper sulfate was present. This has been shown to be due to significant inadvertent activation of gangue minerals such as pyroxene. It has also been shown in the case of the Platreef ore that the addition of copper sulfate reduced recoveries of the tellurides from >90 percent to about 50 percent. It was also shown that the recovery of NFG decreased as the ionic strength increased.

One of the most significant gangue minerals present in the ore bodies is chromite, which when present in the concentrate at concentrations in excess of about 5 percent can have negative effects on the downstream smelting process. Increasing froth depth and depressant dosage (in cases where the chromite is talc rimmed) and reducing superficial gas velocity all resulted in reduced chromite recovery. However, at high depressant dosages all the NFG is depressed, and in so doing negatively affects the stability of the froth, which may then affect the amount of chromite recovered by entrainment.

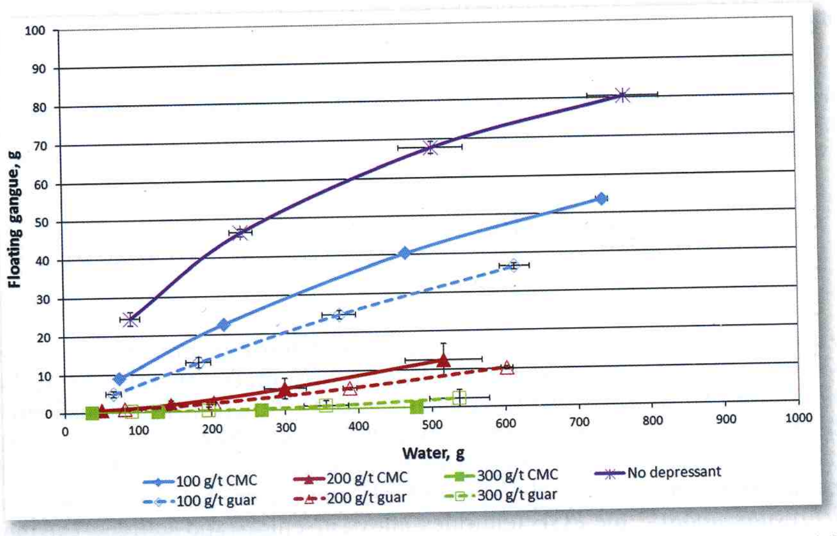

Fig. 1 Naturally floating gangue (NFG) recovered as a function of water recovered for Merensky ore using different dosages of CMC or guar as depressant.

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Grinding and flotation optimization using operational intelligence

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To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

In recent years, metal-producing companies have increased their investment in automation and technological innovation, embracing new opportunities to enable transformational change. Transformation to a digital plant can fundamentally revolutionize how industrial complexes operate. The abundant and growing quantity of real-time data and events *collected in the grinding and flotation circuits in a mineral processing plant can be used to solve operational issues and optimize plant performance. A grade recovery model is used to identify the best operating conditions in real time. A strategy for increasing the value of instrumentation in current plants is reviewed. An optimal Gaudin size distribution model provides augmented information from traditional sensors to find the optimal grind cut size to reduce metal losses in the flotation circuits. Sensors in flotation circuits enable an estimate of the recovery and determination of the optimal froth depth and aeration using an air hold up flotation model. A strategy of classifying data for online generation of insights to using operational intelligence tools is described. The implementation of a recovery/grind strategy with industrial examples in nonferrous mineral processing is presented.*

Background

The abundant and growing quantity of real-time data and events collected in the grinding and flotation circuits in a mineral processing plant can be used to solve operational issues and optimize plant performance [1]. To maximize the metal recovery and operating profit, the mill has to be operated at the optimal mill production target. Using data validation and classification algorithms enables an estimate of the rougher flotation metal recovery in real time [2].

Digital plant template. A unit data object is created to define a process unit containing the key attributes and analytics to detect the operating states of each of the process units in the mineral processing plant [3]. The object has estimate five operating states to classify the operating modes of all process units and to aggregate the production and consumable variables for analysis.

The Running OK state is defined for a unit running at a current production above a minimum triggering limit, which is above 10% of the schedule. Trouble state is defined as unit performance below the desired planned operational target. These are usually the hidden or invisible losses that have been very hard to detect in the past. Idle state is defined as the unit being OK in term of equipment health but no production feed is available. Down state is defined as the unit being run below a minimum production limit or stopped due to an unscheduled event. Maintenance state is defined as the unit being stopped for scheduled maintenance.

The digital plant object model is configured using target data for all of the desired elements derived for the unit template. Because the base template is not equipment or process specific, the real value of this approach comes with its scalability if applied across the organization to render a high-level overview of plant throughputs, consumables and recoveries.

Key results

Online overall production effectiveness. This is the most important result, where all of the process units are automatically analyzed by the system. The event frames subsystem aggregates the production and consumable variables for each of the operational states. This enables sharing of these results to the operational staff and management to look for improvements to eliminate the losses in the trouble, idle and down times states.

Online grinding particle size shape estimations. The sag mill feed particle size distribution and the cyclone overflow particle size distribution are modeled using the Gaudin Schumann model to obtain the D_{max} and the slope of the particle size distribution using an online least-squares estimator. The slope is termed the particle size distribution shape (PSDS). An online grinding particle size soft sensor is obtained by using the key operating variables of the grinding circuit. All measured disturbances, manipulated variables and observed variables become available to use machine-learning tools to derive a grinding model for predicting the grinding particle size output. The model variables used are in accordance with the dynamic process models available in the literature [4].

Online flotation recovery calculation. The Running Ok state and validation of the operational data for each of the elements (crushing, grinding, rougher flotation, scavenger flotation, cleaning flotation, dewatering and filtering) can be used to estimate the mass balance for each area. For example, the X-ray metal assays and the production flow rate are used with the two product formula (R = Recovery % = $100c(f - t)/f(c - t)$). The concentrate and tailing flows are estimated from the mass balance.

Online flotation bank air hold up estimation. The importance of the air hold up in managing the flotation performance is well known. Bascur's [5] correlation air hold up correlation is used. The air flowrate, cell pulp/froth area, cell power, pulp level, frother flow rate operational variables provide an estimate of the cell air hold up.

Online rougher metal recovery predictive analytics. Having the rougher metal assay, particle size, PSDS, air hold up, flotation cell power, froth height, feed flow and reagent flow operating variables, a predictive model is derived using machine-learning tools. Using the MS Studio Machine Learning tool a multiple linear regression can be obtained and used online when the unit is in Running Ok state. The disturbances, manipulated and observed variables can be used to find the best set of operating conditions for a given ore type.

Conclusions

The integration of grinding and flotation operational strategies is necessary for optimal metal recovery. Using the digital plant template simplifies the configuration of the data model, and the metal recoveries for all flotation banks are calculated. The critical part of the presented methodology is the classification of operational data into running mode. The Running Ok operating condition state enables use of a basic mass balance to estimate the metal recovery, concentrate flow and tails flow in each of the flotation banks. The particle size distribution shape can be used to model metal flotation recovery and optimize the water additions to the grinding and flotation circuits in order to improve recovery and operating profit.

The ability to have a good recovery performance estimate allows development of a flotation recovery correlation with the enhanced particle size squared, PSDS soft sensors and the operational derived variables such as air holdup, energy intensity, and flotation bank profile of variables.

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Updated look at the DCFC: the fuel cell technology using solid carbon as the fuel

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To read the full text of this paper (free for SME members), see the beginning of this section for step-by-step instructions.

Special Extended Abstract

Whatever the social, political and environmental implications, carbon remains the world's primary energy carrier and energy source. Coal, petroleum and natural gas, all sources of carbon, are extracted, refined and transported — energy carriers (carrying their energy) — to the electric power and transportation industries that use them as their energy source or fuel. The chemical energy of carbon is transformed through energy conversion networks (ECNs) into other energy forms, such as electricity, kinetic energy, heat, light, other fuels and energy carriers. For example, coal is combusted to make steam for steam turbine generators, which provide electricity. Fuel cells are one type of ECN that can operate directly on hydrogen, ammonia, methanol, methane and other fuels or energy carriers. In a fuel cell, most of the chemical energy in these fuels is directly, electrochemically converted to electrical energy. Most fuel-cell development has centered on developing fuel cells that operate on hydrogen or reformed methane. Most of the world's hydrogen comes from the steam reforming of methane into hydrogen and carbon dioxide. This steam reforming process is only 85 percent efficient. The hydrogen fuel cell itself is theoretically only 80 percent efficient in extracting the chemical energy of hydrogen into electricity. The overall efficiency is 65 percent. It would be much more efficient to directly convert solid carbon to carbon dioxide in a direct carbon fuel cell (DCFC). The maximum intrinsic efficiency of the solid carbon to carbon dioxide is nearly 100 percent. This would be a 40 percent fundamental improvement in thermal efficiency if fuel cells could directly operate on carbon (see Fig. 1).

Role of particles

Particle processing is the key to using solid particles in fuel cell applications. Selectivity with regard to reactivity, impurities and so on is an important feature, and the treatment of particle surfaces could have a great impact on the performance of direct carbon fuel cells. Solid fuel particles will become increasingly important in the future. Present energy conversion systems for solid fuels are too inefficient. New energy conversion systems for solid fuels with higher energy conversion efficiencies are possible. Fuel cell technology is a key technology in these new conversion systems.

The DCFC operates on carbon particles obtained from a variety of solid fuel feedstocks. The DCFC is the only fuel cell designed to directly oxidize carbon particles in a special anode chamber. The particles are generally graphite structure with high purity. The electrolyte used is high-temperature solid oxide (SOFC), molten carbonate (MCFC) or hydroxide electrolyte. As a pure stream of carbon dioxide is produced, the stream can easily be sequestered and disposed. Pure carbon dioxide produced as a byproduct would also have a market in many industries. A well-defined technology roadmap identifying key research and development issues is necessary to provide a framework for the development of these systems and to prevent entrenchment in inherently inefficient technologies. This review paper describes the direct carbon fuel cell and its system, how it works, the developmental status, the characteristics of the carbon particles needed, and the research and development issues for the technology.