Process Optimization Through Innovation, Technology, Automation and Design

Abstracts

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Recent Modifications at the OSR Acid Plant

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Abstract

At OSR (Onahama Smelter & Refinery), SO_2 gas discharged from smelting process is treated by two acid plants, which started operation in 1960s. In 2002, one of them was expanded and renamed 3AP: a converter and heat exchangers (HEXs) were replaced, and absorbing process was changed from "double contact" to "single contact".

Since the expansion was carried out, two absorbing towers in 3AP had been operated in parallel to decrease pressure loss and reduce SO_3 load for each absorbing tower. However, the aged absorbing towers frequently had suffered from acid leakage from the bottom and the shell of the towers. Therefore, the two absorbing towers were replaced and unified into one new tower in 2015. At the same time, the acid distributor was changed from the pipe type to the open trough type to maintain absorption efficiency, and the packing material was changed from INTALOX saddle to Super INTALOX saddle which is characterized by lower pressure loss and higher contact area. As a result, absorption efficiency of the new tower maintained the same level as the previous one without increase in pressure loss. In addition, electric power consumption was decreased by reducing the number of circulation pumps. In 2018, SO_2 conversion ratio in 3AP dropped suddenly due to SO_2 gas leakage through into SO_3 side in the HEXs. Therefore, No.2 HEX was replaced in 2019. At the time, the tube material was changed from carbon steel to stainless steel to prevent high temperature corrosion.

Technology Enabled Operational Excellence in Mining Operations

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Abstract

There's a big opportunity to harness artificial intelligence (AI) to successfully overcome a very common yet, until now, unresolved problem in copper mining—truly breaking down the silos between mine and plant to manage both operations as one unit in real time. This groundbreaking approach can bring significant benefits to any site, and significantly increasing copper production in a sustainable way.

The key components of this silo-breaking approach are: i) optimization of the operating system via integrated operations using Artificial Intelligence, and ii) the evolution of the organization and management systems to drive operational excellence enabled by the new AI-powered operating system.

Operating system optimization through AI

The integration of AI optimization models throughout the value chain can solve the silo management practices. The integrated AI solution uses AI to trace ore characteristics across the value chain. It integrates this information with an optimization AI algorithm to provide recommendations to hundreds of variables across the mine and plant several times during the shift, to increase copper production.

Evolution of the organization and management systems

Management systems should also evolve through new working methodologies (for example, agile) and be adapted to capitalize on the insights derived from the AI-powered operating system.

Operators and leaders convene in an iROC (integrated remote operating center) and are reorganized into cross-functional squads with the mandate to maximize copper production. This arrangement groups several disciplines from across the value chain (for example, planning, mine dispatch, metallurgy, process control) and shift, for instance, the focus of a mine dispatcher from simply moving material to moving the best type of material that will maximize production in the processing plant.

The development of this approach has already been proven successful at several mining operations in different geographies, including Chile, and benefits go beyond the substantial additional copper production (which in itself is hugely significant) and the sustainability gains in terms of water and energy consumption: organizationally, the operation can enable a more motivated and empowered team, excited about their increased relevance and the enhanced role they could play in delivering better outcomes for the organization.

Shifting from mining silos to integrated operations: Solving a 100-year-old mining problem.

Ferran Pujol/ Alberto Hernandez/ Julio Gregorio, McKinsey & Company, Chile

Abstract

Historically in the mining industry, the mine and the plant have been operated in silos in a relatively isolated manner. The main objectives of both processes were not fully aligned, the mine looking for maximizing tons and the plant reacting to the incoming ore through the application of first principles recipes.

As mining companies take strides to adopt to the new digital revolution, many recognize a necessity to revisit their operating models in the mine and the plant and re-define how they add value in their operations. Competitiveness of many mining companies will be challenged, and those able to embrace the structural shift may emerge as industry leaders.

In this next-generation operating model, Integrated Operating Centers (IOCs) – which have been used in the industry traditionally as "surveillance and control" centers - have the potential to evolve to a fully integrative technology and operations centers where the mine and plant operations are synchronized and deliver significant value creation through the implementation of new technologies such as Advanced Analytics and process digitalization.

With these Advanced Analytics and digital technology, we have managed to connect the processes throughout the whole value chain (i.e. mine to mill). With the new technology and operating system of the IOCs, we have been able to generate an end-to-end visibility for decision-making that allows the maximization of metal production.

These new IOCs centers generate improvements in mining companies of between 3-5% increase in metal production thanks to a better command & control of integrated production operations, allowing to increase the competitiveness in an industry highly challenged by energy costs, water availability and reduction of mineral grades.

Measuring and Monitoring Refractory Lining for Peirce-Smith/Hoboken Converters and Teniente/Noranda Reactors

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Abstract

The safe and stable operation of converters and reactors in copper smelting depends significantly on the accurate understanding and monitoring of their refractory lining. Converters and reactors are cylindrical structures with two or three layers of the refractory lining in their cross-sections. The common practice for relining these vessels focuses on predicting refractory wear rates from previous campaign relines. In addition, thermal data for estimating refractory conditions is collected from the shell. This approach works well in some cases but can leave operators vulnerable to localized wear events and can also lead to poorly scheduled relines where refractory linings are removed before having worn to their minimum operational thicknesses.

In this paper, the authors review the available inspection and monitoring methods for converters and reactors and make recommendations based on the innovative strategies practiced at some operations. In the end, a definitive case study is presented on how to operate a vessel to its full value safely.

Measuring Matte and Slag Levels in Copper Smelting

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Abstract

The production of copper is typically done through the smelting of concentrate. During the primary smelting process, the concentrate is typically processed into a higher purity matte stream, and a waste slag stream, containing various impurities. The matte and slag phases separate via density differences and understanding the height of each layer in the furnace is valuable for process control, furnace integrity and operational reasons.

The most basic approaches for level measurement are mass balance calculations and the use of sounding rods. However, such approaches have accuracy and safety related drawbacks. For example, the physical inspection of sounding bars to determine levels is prone to human error and may change from operator to operator. This practice also may depend on operators on the furnace roof, unless automated. Further problems arise from the sometimes-fuzzy nature of the interface between furnace layers.

Currently, several techniques are available to determine matte and slag levels in operating furnaces. In this paper, we present the commercially available level measurement techniques. In addition, we introduce the new developments and approaches in level measurement techniques.

Artificial intelligence and integration of geotechnical data to improve early warning in monitoring systems

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Abstract

The remarkable advance in the use of artificial intelligence as a support tool to identify and anticipate potential instabilities has improved the performance of surface monitoring systems. On the other hand, there is a variety of relevant geotechnical information that could be incorporated in the monitoring data analysis. This makes it interesting to integrate this information into artificial intelligence algorithms in the search of optimal performance of geotechnical monitoring systems. Such information refers to geotechnical attributes that can influence the quality of the predictions of these algorithms, for instance: the quality of the rock mass, the orientation of discontinuities, the presence of water, and blasting damage.
This document shows the progress obtained by integrating information of potentially unstable blocks - generated by the structural arrangement present in the rock mass - into the A2V artificial intelligence algorithm. The information of the blocks was incorporated as a geotechnical-mathematical criterion in the A2V algorithm, allowing refining or modifying the "decision tree" of the algorithm to trigger a geotechnical alert. For the development of this study, historical records of geotechnical instabilities accumulated over a period of two years were used, contrasted with the structural database collected and processed in the same period.

The results indicate that by integrating information from preformed structural blocks into the artificial intelligence algorithm, the performance of monitoring systems - in charge of processing surface displacement data - is improved. This is because of an increase in the detection rate. The early warning results in a better quality, it is more reliable, and timely warning.

The results of the present study suggest that it would be interesting to continue with this line of work, incorporating other attributes or relevant information to achieve the best performance that a slope surface displacement monitoring system can deliver. Finally, it is worth mentioning that this study was carried out under a close collaborative relationship between E-Mining Technology S.A. (EMT) and Minera Los Pelambres (MLP) of the AMSA group.

Analysis of the reliability of underground short-term development scheduling based on simulation.

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Abstract

Short-term scheduling of an underground development operation is a difficult task to perform that is generally done manually with extensive use of spreadsheets. Only a few studies have applied optimization to handle this problem when considering operational contingencies. These contingencies generate unavailability of mining equipment or workplaces that occur during the execution of the plans. Therefore, short-term underground schedules with less deviation with their application are desirable to minimize the impact of these contingencies.

We propose a methodology that uses simulation and sensitivity analysis to minimize the deviation between plans and their application considering operational contingencies. The methodology considers the analysis of the operation data to characterize working times, moving times, and operational interruptions associated with various factors such as equipment failures, safety, among other operational issues. In the methodology, optimization methods provide short-term schedules, and a simulation model is run in such a way that each equipment in the fleet follows the fronts assigned by the initial schedule. If deviations caused by a contingency are too big, a new schedule is generated for the remaining time. Varying the input parameters, schedule times are compared to simulation times to analyse the reliability of the plans. This methodology has been applied to a panel caving mine development operation to improve the plans obtained with re-optimization only when the contingencies occur.

Technological Roadmapping methodology application in underground Chuquicamata mine

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Abstract

Technological Roadmap represents an important milestone for the development of engineering in Chuquicamata Underground Project. This exercise suggests and invites you to imagine an underground mine different from the one we know today and many challenges like this are likely to arise over the course of the next decade, so be prepared to face these challenges to build the mining of the future.
Cambridge Technology Roadmapping methodology was selected as the basis for development, and was adapted to the specific requirements of this project and underground Chuquicamata mine.

The technological roadmap process was carried out in two phases, according to Robert Phaal´s applied methodology. The first one called Strategic Plan or Plan S, where the first portfolio of technological solutions for technological roadmap was obtained and worked on by using divergent and convergent phases in group workshops and stages, the second phase is called Tactical Plan or Plan T technological surveillance. Technological surveillance corresponds to one of the sources that generates ideas and is defined as a tool to monitor development at a global level. According to the state of the art, the technological surveillance process must be accompanied by a competitive intelligence process, in such a way that decision-making is not based only on technological aspects, but also on competitiveness.

Technological roadmaping is a process of searching, analysing and using the "best" information on development, events and trends in the scientific and technological environment. It involves obtaining and analyzing information on activities or aspects that have a high value for the competitiveness of the organization, to guarantee its protection against external threats and to achieve optimal exploitation of the technology. The results of this process are directed towards technology in products and procedures, supporting efforts to acquire, develop, exploit and withdraw technologies. In general, it can be said that the objective is to anticipate and understand trends in science and technology in the competitive environment, to feed the strategic planning process.

To build the mining industry for the next decade, there are important innovation challenges for CODELCO, as well as costs, sustainability, security, autonomy, however, the greatest challenge is the transformation of knowledge and current human capital.

Cross-belt elemental analysis, stockpile blending optimization & waste bulk sorting in Copper using PGNAA.

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Abstract

The decline in grade of copper deposits around the world is impacting operating costs, energy and water consumption. To meet this increasingly complex challenge, reduce operating footprint and decarbonize new processes and technologies are now being used, including in-pit crushing, waste ore sorting, dry tailings, sensors, and drones to only name a few.

Only a few decades ago, on-line analysis for mineral slurries was used sparingly in mineral processing plants to measure grade, but today slurry elemental analysis is considered essential for process control and operational efficiency. Copper cross-belt elemental analysis is now available in real-time, with high accuracy on run of mine ores. Based on a predetermined economical copper grade cut off, the waste or ore classification can be achieved with confidence and in real time with PGNAA technology, while also monitoring of high level of impurities. Whilst PGNAA has been used successfully for several years in other industries, such as Cement, Iron Ore and Coal, its adoption rate into base metals applications like copper remains very slow despite a remarkably high accuracy even for low grade ores.

This paper will showcase practical and relevant copper applications using cross-belt PGNAA analyzer technology, including how cross-belt elemental analysis become a critical tool to achieve grade control, stockpile blending optimization, waste bulk sorting and downstream grinding and flotation efficiency in your mine.

Development of DRS digital twins to support mineral processing control strategies

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Abstract

Integration of geostatistical simulation within discrete event simulation (DES) is a basis to develop digital twins of mineral concentrators, thus to develop system-wide control strategies. Discrete rate simulation (DRS) is a type of DES that is well-suited for the early stages of digital twin development, since it supports dynamic mass balances and alternating modes of operations. Moreover it supports the detailing of critical unit operations such as rougher flotation, as demonstrated in the current paper; this is accomplished by incorporating a flotation kinetics model into a system-wide DRS representation that includes Monte Carlo simulation of mineralogical data. The resulting framework can rapidly simulate hundreds of operational days, applying different values for control parameters, thereby determining how these parameters should be adjusted in real-time. In practice, the extension of a DRS framework to include increasingly detailed unit-specific models can be the subject of continuous improvement, to enhance the global control of a mine and concentrator. Sample computations are presented that are based on publicly available NI-43-101 reports describing a well-known Chilean copper mine.

BioCobre® Technology; an improved process to leach mineral concentrates.

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Abstract

In Chile, copper oxides leachable mineral reserves are running out, diminishing local copper cathode production by SX- EW. New mining projects are mainly based on copper sulphide mineral concentrates production, mostly to be shipped overseas for its treatment by smeltering and refining. This has become a great threat to copper sustainability.

Hear we present a new sulphide mineral concentrate heap leaching process (BIOCOBRE® Tech), which uses plastic matrices as a support material to agglomerate concentrates, allowing the adhesion of those minerals in a stable form to be treated by leaching in packed bed or heap reactors. Biocobre® tech generate a copper sulphate PLS to feed SX–EW. Even more, the technology allows the later recovering of the unoxidized minerals Au, Ag.

The hydro processing of cooper concentrates allows the treatment of complex Cu-As concentrates that are environmentally risky and difficult to process, transport and the safe disposition of potential hazardous elements contained.

Results of Biocobre® tech pilot test, bioleaching 300 Ton of Chalcopyrite-Enargite concentrates shows Cu recoveries as copper cathodes up to 95% in 200-250 leaching cycle. The industrially tested technology allows the reuse of the plastic support matrix. Results demonstrate that Biocobre® tech can decrease C1 Cost between 5-15 USDc/Lb de Cu compared to pyrometallurgical process and generate environmental benefits, cutting SO_2 and GHG emission on copper productions.

Improvement and enhancement of facilities in the Mitsubishi Process at Naoshima Smelter toward contribution to the creation of a recycling and low-carbon society.

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Makoto Takagi, Mitsubishi Materials Corporation, Japan

Abstract

The current Mitsubishi process furnaces built in 1991 at Naoshima Smelter marked the 30th anniversary in 2021. Mitsubishi process is a copper smelting and converting process that is originally advantageous in terms of high reaction efficiency and environmental friendliness. In recent years Naoshima Smelter has improved and enhanced the facilities in order to increase the amount of E-scrap recycled and copper concentrate treated by taking advantage of the features of Mitsubishi process.

The new oxygen plant was constructed in 2016 to increase the concentration of the oxygen-enriched air blown into the S- and the C-furnaces, and the number of lance air compressors in operation was optimized. Subsequently, in 2017, the booster blower that transfers the exhaust gas of the furnaces to the sulfuric acid plant was replaced. The impeller size of the blower was increased and the control method was changed from non-contact hydraulic clutch control to inverter control to suppress the vibration. In 2021, preparing for further increase of the amount of E-scrap and copper concentrate, and with the aim of reducing fuel consumption by improving the reaction efficiency, the C-furnace electrostatic precipitator was replaced to improve the dust collection capacity. The S-furnace continuous feeding system was also introduced.

These strategic efforts have succeeded in expanding E-scrap recycling business and saving energy, in line with our desire to contribute to the creation of a recycling and low-carbon society.

Copper recovey optimization using advanced analytics

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Nicolas Tagle, Los Pelambres Mine, Chile
Cristian Ramos, Los Pelambres Mine, Chile

Abstract

Antofagasta Minerals has sought to increase productivity and competitiveness in the mining sector through digitization with a view towards a transformation to industry 4.0. One of the main drivers of digitization is data, which through Analytics can be converted into information, decisions, and actions to improve mining operations. This has proven to be a source of competitive advantages in other industries, but it presents a series of challenges to be properly enabled, mainly in terms of strategy, people, technologies, and processes.
To address those challenges, Antofagasta Minerals implemented an analytics operating model where a Chief Data Officer, at the corporate level, is responsible for the governance and use of information as an asset through data processing, analysis and extraction. In addition, Analytics teams are located by site work towards the operation, where there is a continuous process of data exploration to search for opportunities of value for the company.

One of the digital initiatives, using Analytics, being carried out at Minera Los Pelambres in collective flotation is SIRO (Integrated Optimized Copper Recovery System), a decision support system based on Machine Learning and Optimization Methods. The problem that drives this initiative is that despite having a high recovery rate, the lack of anticipated, standardized, and centralized information on the mineral that reaches the rougher flotation causes the operation to be reactive. Neither optimal recovery nor reagent dosage is achieved.

The system consists in four main components: A mineral tracking algorithm (mineral flow from mine to float), operating scenario detection using machine learning methods, operational recommendations (per operational scenario) obtained by optimization models and provided to the user by a real-time visualization dashboard. The system was released and implemented with a strong component of change management that ensures the tool's adoption.

System outcome is the optimization of operational variables such as foam speed, reagent dosage, pH and addition of water, generating an improvement in the decision-making process, which translates into a proactive operation given accurate and advance information.

The preceding has made it possible to capture improvements in the recovery and optimization of reagents. It is estimated that in situations where accepted recommendations, the impact on the progress was 0.6 points of recovery in the lines under test and a decrease in pH from 8.9 to 8.7. The next challenge is to implement SIRO in the total of the collective float.

Modelling of copper oxide reduction in a slag cleaning furnace.

Anton Ishmurzin, RHI Magnesita, Austria
Goran Vukovic, RHI Magnesita, Austria

Abstract

As environmental, energy saving and legislation considerations are becoming ever more important, there is evidently a demand for further improvement in slag handling and metal recovery practice. The metallurgical industry is initiating their actions into minimizing and processing of slags to achieve sustainable development and circular economy. Reduction of copper oxide is an important step of metal recovery and slag cleaning in copper production. This can be achieved by slag treatment with injected reducing agents. We present a computational fluid mechanics model of tuyere and purging plug injection of reductants into slag that considers a first order heterogenic chemical reaction to model copper oxide reduction. Using the model, it is possible to compare and optimize tuyere and purging plug arrangements in terms of time needed to reduce copper oxide content to a given value. Copper oxide reduction accomplished with injection of reducing media for several tuyere/plug arrangements in a slag refining furnace was simulated and the reduction performance was compared. We showed that purging plugs, which may be installed at the deepest position in the furnace, create an improved gas flow pattern that results in a higher copper oxide reduction rate.

Aurubis case study: development and evaluation of sensors to support industrial operations.

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Abstract

Aurubis is constantly looking to improve their operations. New technologies offer new opportunities and challenges, and R&D is the partner of technology suppliers to introduce sensors in the operation environment. Sensors support digitalization as well as process model and advisor development. In this respect, different detection principles are required matching the process conditions and materials. Treatment of the data became a sophisticated engineering task. This paper presents the recent Aurubis strategy on sensors and how our team of engineers, scientists, and technicians perform laboratory and field test activities for the evaluation of new technologies, impact on operators and data end users, maintenance, data processing and industrial implementation. This case study describes the collaboration with different suppliers, universities and technology centers for the development of different sensors. Finally, successful examples of sensor developments and new ideas are presented and discussed.

Automation and Technology Roadmap in a very low grade mine, severe climate and in high mountains

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Abstract

The incorporation of technology and leadership with digital transformation are some of the main mandatory enablers, so that people and processes can operate properly; safe, sustainable, continuous and stable, fostering to achieve design productions and maximizing installed capacity.
The empirical experience in this, accounts for the basic requirements, with new design criteria, high assets availability, skilled labor and robust training in:

1.- Energy and Communications Infrastructure in: improvements with Harmonic Filter of the SVC type; redundant and high-speed LTE 4 / 5G communications network; high availability and protection of physical and redundant Data Centers in the cloud.

2.- High Convergence OT&IT, with platforms organized as single data and "Situational Awareness", with strict cybersecurity surveillance and discipline with an Information Security Management System. (ISMS, ISO 2700).

3.- Control Systems and Optimization of Production Processes, through improvements in automatic, advanced and expert control, supported by platforms with AI, ML and Digital Twin in the cloud, to improve timely decision-making, maximizing production (here we will see particular experience with development of our own Chilean and Japanese personnel.

4.- Permanent remotization, aiming to minimize people's risk exposure and allowing them to manage the operation, the tactics and the strategy at normal and healthy geographical altitude levels.

Sensor technologies for optimized Copper furnace operations

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Abstract

Efficient and consistent copper furnace operations are difficult to achieve as the furnace operation is based on experience, a few process observations and mass balance calculations. Typical difficulties are found in the determination of furnace levels and in excessive metal losses.

Metal tapping should occur at a precise moment when the correct amount is available in the furnace and before overfilling. This moment can be difficult to determine without proper level monitoring.

Even for slag tapping, the right timing is difficult to assess and even worse, it often leads to metal value losses and represents a safety hazard.
RHI Magnesita offers modern and safe sensors technologies to help you control levels and detect metal losses. These are used for fact-based decision making ensuring optimized furnace operations and tapping procedures.
The paper will describe and discuss the technologies as well as how to implement them in copper furnace operations and what benefits can be achieved.

Methodology for monitoring Heap Leach freatic level for irrigation control and maximizing copper recovery.

Gerardo Olivares, TESRA S.A.
Miguel Yapura, TESRA S.A.
Víctor Olivares, TESRA S.A.

Abstract

It is essential to know and monitor the irrigation rate and the effluent recovery rate in the copper leaching process to determine its effectiveness. Likewise, it is essential to monitor other variables since the modules that make up the heap leaching need structural stability for the correct development of the process. The excessive accumulation of solution in the body of the pile increases the pore pressure to the point that it equalizes or exceeds the "effective pressure," reaching a condition of instability in the pile that causes its collapse and possible accidents. Therefore, it is essential to monitor the water table periodically and reduce irrigation within safety limits.

The mechanized drainage installation process developed by TESRA brings the opportunity to install piezometric sensors at the base of each module. These sensors protected against corrosion communicate remotely to a web server and data historian, allowing real-time monitoring and generating reports for correct operational decision-making. The proposed solution discussed herein to measure the water table and temperature continuously is the basis for building an irrigation control system that seeks to maximize the irrigation rate without compromising the stability of the pile or generating conditions that may cause an accident. It will allow the operation to maximize recovery and further comprehend the geo hydrodynamics of the leaching cycles.

Roasting Process Simulation combined with Digital Plant Solutions.

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Steffen Haus, Metso Outotec, Germany
Ralf Beyer, Metso Outotec, Germany
Joerg Hammerschmidt, Metso Outotec, Germany

Abstract

Process simulation and automatic control systems have a long history in Metso Outotec. Integrating the individual tools into the next generation ecosystem will be the future challenge in the industry. The seamless integration and implementation of new features into new and existing plant operations will be the key factor for success. With a large portfolio of different products in the digital field and a proven record of applications, the process simulation and process optimizers are one example of the continuous development to improve today's sustainable technologies to the next level of excellence. Metso Outotec has introduced in 2017 the Pretium Roaster Optimizer, which is a model based advanced process control (APC) solution. The Optimizer includes process understanding and simulation expertise directly in the daily plant operation. This paper describes both the active operational optimization, based on model-based controllers as well as the integration of process simulation in the economic production planning, with the example of a roasting process.

People as agents of change: How to improve productivity in Mining 4.0?

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Abstract

Despite the incorporation of different technological solutions to meet mining challenges around safety, productivity and sustainability, there are still losses and gaps in operational KPI's that strategically impact the day-to-day operations of the mining business, often going unnoticed by the operation, remote centers during Short Interval Control.

In the face of this, improvement efforts often focus heavily on process and asset management, but generally do not link the fundamental impact that human behavior, collaboration and empowerment can have on productivity.

Faced with this problem, INDIMIN creates Smart Mining Coach, an intelligent and personalized digital assistant to increase productivity in mining, with people as the engine change, collaborating online, in the field and remotely, to achieve higher performance in safety, productivity, and sustainability. This favors the development and empowerment of people, their learning, motivation and overall performance oriented to results with clear objectives and operational goals directed by advanced analytics.

The existing data in the mining industry gives us the opportunity to change the way we do things: question, correct and improve our processes. Human and Artificial Intelligence collaboration enables new analytics capabilities that support operation management and predictive decision making in a timely and reliable manner, integrating areas that usually work in silos.

New Generation Direct Bonded Magnesia Chrome Refractories for Copper Industry.

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Abstract

The pyrometallurgical processing of copper varies worldwide with respect to the copper concentrate, process, operating parameters. For optimizing the refractory consumption with minimum downtime and higher life judicious selection of refractory must be done. Direct bonded magnesia chrome refractories are widely used in copper industry for several years for its high stability against various environments and a high corrosion resistance against Fayalitic slag, calcium ferrite slag, sodium carbonate/hydroxide slags etc. Due to higher demand and deterioration of natural resources, copper manufacturer has to deal with more complex copper ore, less copper and higher amount of minor impurity like As, Sb, Sn etc. This minor impurity not only make the process more complex, but also have major impact on the refractory. To understand the wear mechanisms post-mortem study of the used bricks, lab-scale simulation and inspection of furnace lining is very much essential.

This paper shows the development of high-performance refractory for critical area of smelting, converting, and refining furnaces. We have developed new generation DBMC refractories that combine an effective infiltration barrier with a very good corrosion resistance and thermo-mechanical resistance by controlling the pore size distribution & formation of in-situ secondary spinel phases in the matrix. Suitable qualities of tailor-made and special refractories are also developed using high purity raw material like, fused Magnesia, Fused Magnesia-chrome clinker, DBM and chromite with spinel forming novel additives & adopting the state-of-the-art process technology. These products are being used in various furnaces globally with excellent performance which shows good agreement with stress analysis and simulation testing at our lab.

Mining 4.0 in Chile: Challenges and opportunities

Juan H. Rojas-Cortés, Jota2erre Innovaciones, Chile

Abstract

Chile supplies 28% of the global mine copper market and, therefore, its mining is living a crucial moment. Communications, electro mobility and green energy open it enormous opportunities for future growth. Critical success factors are operational excellence, intelligent mining, and environmental certification. Precisely, the mining 4.0 foundations.

The mere occurrence of fatal accidents does not meet the operational excellence requirements. Eradicating them is an ethical obligation. Fatal accidents are not regrettable, they are unacceptable. Secondly, intelligent mining leads us to Data Science. However, the utilization of data generated by digital 3.0 systems, such as Dispatch or PI, does not exceed 5%. International observers estimate that not even 1%. Finally, environmental certification is the eco-guarantee of the traceability of operational management.

To operate into these domains implies other paradigms. To persist in doing the same is not an option anymore; the priority is to configure an operational capacity that produces different, and more effective results. Mining 4.0 is green mining, more productive, more profitable with zero injuries. How do we get it? First, "back to basics": Let's look at the fundamentals of the mining business.

On-line monitoring of Cu concentration in molten copper matte by laser-induced breakdown spectroscopy

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Abstract

The elemental concentration of Cu is essential for processing control of copper smelting. Monitoring Cu concentration in molten copper matte is important for timely optimizing process control parameters, improving the utilization rate of raw materials and saving energy consumption. Due to the severe field conditions of copper matte, such as dust, fume, high temperature, melt level fluctuation and electromagnetic interference, it is difficult to on-line monitoring the composition of melt in the past.

In this paper, the long-term field application status of the GS-LIBS2200 Laser Composition Analyzer based on laser-induced breakdown spectroscopy (LIBS) is introduced. The online analyzer has been applied to monitor the Cu element content of copper matte melt for more than three years, and the online monitoring result compared with offline X-ray fluorescence(XRF) are also discussed. Among the comparison results of more than 3600, whose average absolute error is 0.58%, and the ratio of absolute error within 1.5% exceeds 95%. In addition to monitor the content of Cu element, the analyzer can also provide an evaluation factor of the slag content in molten copper matte at the same time.The results show that the GS-LIBS 2200 Laser Composition Analyzer has good measurement representativeness and stability, and has great potential in the on-line monitoring of copper melt elemental concentration.

Descriptive Analytics in Earth Movement Operation Data

Waldo Fishwick, Alaya Digital Solutions, Chile

Abstract

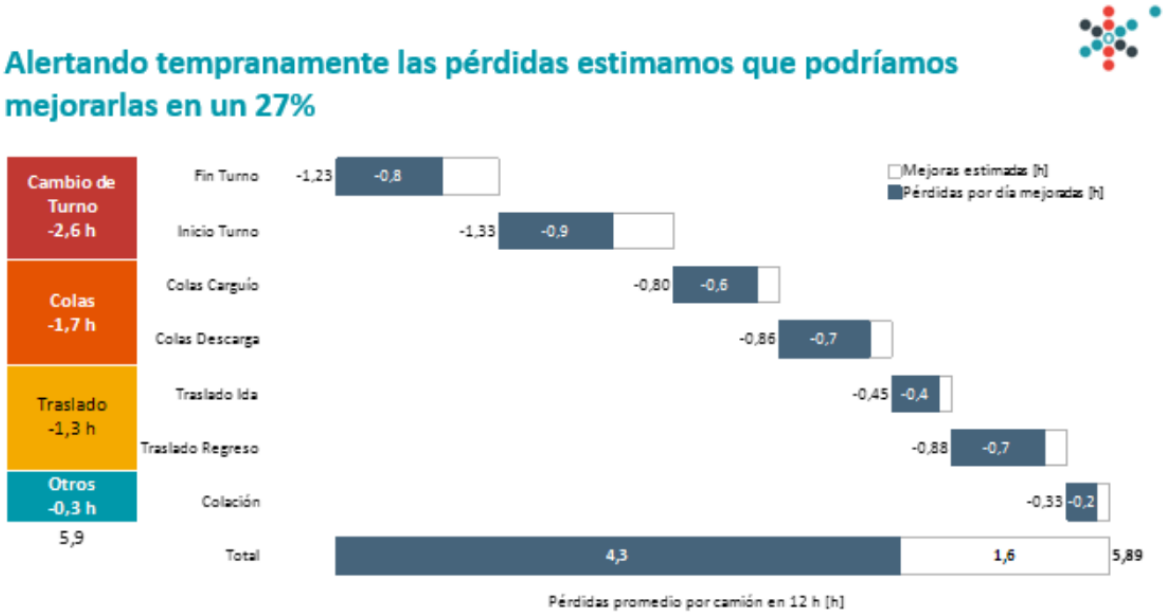
The application of technology in earthworks operations for the measurement of losses and productivity is typically not carried out, instead manual procedures are used that lead to errors and therefore poor decision-making. Considering this situation, OCU System (Operational Control Unit, in spanish known as UCO) was implemented, which consits in a platform that collects and stores data from GPS devices, CANBUS and Digital Hourmeters that are located in trucks and equipment.

Through the historical information provided by the OCU implemented in the Project 'VIII Etapa Tranque Talabre' a descriptive analysis of the data was carried out, in order to extract knowledge, patterns and insights from the process by estimating different metrics and KPIs such as: sub processes times (load, transport and unload), sub processes idle times, time lost at the start and end of shifts, collation times and frequencies, queue times and distances, approach events between equipment, advance area of unloading equipment (bulldozer and rollers), refueling quantities and times, performance, effective working time, etc. According to the information generated, the sources of loss were identified, then valued and finally given a weight, reaching an 18% of lost time associated with the beginning of shift, end of shift, lunch time and others, and even more important is the finding of losses within the production cycle, which reach an average of 33%.

Additionally, this information made possible to make a series of operational recommendations that take into account the complexities of the site and that seek to reduce losses for a new stage. This article presents the above mentioned, detailing each of the tasks carried out in the project.

The development of the project allowed, not only to be aware of losses that until that moment were unknown, but also to identify improvements for a new version of the OCU, which would provide better quality information and allow to implement a Predictive Analytics system with the objective of optimizing the transport of material while minimizing the losses of the process.

The simulation sample of improvements by focus category, at the level of 1 truck, is as follows:



For 1 Truck			
Focus category	Temporary Losses [h]	Improvement [%]	New Temporary Losses [h]
Start of Turn	1,33	35%	0,87
End of Turn	1,23	35%	0,80
Load	0,80	20%	0,64
Unload	0,86	20%	0,69
Back to B57	0,88	20%	0,70
Download site	0,45	20%	0,36
Lunch	0,33	30%	0,23
Subtotal	5,89		4,29

Online internal load, percentage of balls and Max Energy enable new and improved control strategies.

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Pablo Bustos, Codelco-Chuquicamata, Chile
Hector Carreño, Codelco-Chuquicamata, Chile
Ramón Farías, Codelco-Chuquicamata, Chile
Cristián Doerr, Codelco-Chuquicamata, Chile

Abstract

Codelco Chuquicamata is one of the largest copper mines in the world. The grinding plant has 2 SAG mills that process around 140k tons/day. Codelco's metallurgical engineers found an opportunity for improvement and optimization of the operation to bring the mills to higher processing capacity based on accurate estimations of the grinding parameters. These variables feed an existing model that was developed by Codelco.

Codelco's Innovation department and the Emerson team jointly developed the SAG Mill Optimization solution, which enables the plant to achieve new online parameters by delivering more accurate data and greater knowledge of the process, as well as providing tools to implement optimization strategies. The solution consists of 3 wireless sensors mounted in the shell of the mill that provides data related to operational features: ball hitting the shell and fines accumulation in the outlet. This data is integrated into the DCS and transferred to a PK controller that hosts the algorithm to process the data. This information and the process data from the DCS provide both online internal load level (Jc) and ball % (Jb).

The validation phase of the process showed less than 0,3% difference against physical real measurement on both parameters, and the direct measurement of the impact's peaks provided direct information of the energy of the internal ore, replacing indirect acoustic measurements.

As a result, Codelco has now access to online information which allowed to increase the SAG mill´s production, get additional throughput, and decrease SAG interventions and stoppages. This solution can be replicated and customized for other rotatory grinding equipment.

New in-line variables, i.e., internal load, % of balls, and maximum energy for better milling process control

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Pablo Bustos, Codelco-Chuquicamata, Chile
Hector Carreño, Codelco-Chuquicamata, Chile
Ramón Farías, Emerson, Chile
Cristián Doerr, Emerson, Chile

Abstract

The Chuquicamata Division of Codelco (DCH) is one of the largest copper mines in the world that recently changed from its open pit operation mode into a new underground mine operation mode for assuring the copper recovery from its copper porphids mineral in the mills and flotation plants. One of the grinding plants is featured by two SAG mills that process around 140 ktpd.

The plant and Innovation area engineers evaluated new available accurate measurements to estimate the grinding parameters to improve the current plant processing capacity. Thus, the Chuquicamata and Emerson team jointly implemented and evaluated the SAG Mill Optimization solution, which enables the plant to measure new online parameters and delivering data that are more accurate, besides allow a better understanding of the grinding process, which also might allow new optimization strategies for the milling process.

The evaluated solution consisted in three wireless sensors mounted in the shell of one of the SAG mill that provided data correlated to the operational features, i.e., ball hitting the shell and fines accumulation in the outlet. This information and the process data provided both online internal load level (Jc) and balls % (Jb).

The validation stage of the process showed less than 0.3% difference when compared with the Crush Stop and Grind out physical measurements for both parameters. Additionally, the direct measurement of the impact's maximum data that was collected provided direct information of the energy of the internal ore, which might also replace the standard indirect acoustic measurements.

Currently, the concentrator engineers continue to evaluate the information collected online of the SAG mill to confirm the preliminary positive evaluation obtained previously, that showed a slight increase in the production of the SAG mill, i.e., additional throughput, and might also allow eventually new control strategies for the SAG mill process.

This article presents a summary of the above industrial experience.

The use of MineSense Technologies' ShovelSense System at Copper Mountain Mine.

Stuart Sandler, MineSense Technologies, Ltd., United States of America
Miguel Carrera, MineSense Technologies, Ltd., Chile
Julio Cabeza, MineSense Technologies, Ltd., Peru

Abstract

MineSense® Technologies is a pioneer in digital mining solutions, providing real-time ore characterization and routing data analytics for mines using the ShovelSense® system after blasting. Using ore-characterization algorithms and digital models, ShovelSense provides mines with data that enables bucket-by-bucket ore and waste routing decisions at the mine face that maximizes profits and operational benefits by recovering ore from waste as well as reducing waste dilution in the ore feeding downstream processing.

The ShovelSense system predicts grade and other mineral elements using a system of proprietary hardware and software, along with data analytics. ShovelSense is installed in the bucket of existing shovels or loaders without the need for additional equipment or footprint. Real-time accurate ore and waste classification data allows smart routing decisions for each shovel bucket, improving haulage and downstream operational efficiency and profitability.

As the mining industry becomes more data intensive, disruptive technologies are taking digital form. Real and trended data, and the ability to organize, analyze and use this data for feed-forward and back mine control as well as predictive analytics are competitive differentiators. MineSense's ShovelSense system, with its data collection and analytical capability, has enabled the Copper Mountain Mine in Canada to increase its profitability through improved copper recovery and decreased dilution and extend its life of mine.

Electron Beam Smelting, Alloying, Refinery, and Purification of Special Metals and Alloys in Newly Constructed Production Units with Gas Discharged Electron Beam Guns

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A. F. Manulyk, Canada
P. P. Kucherenko, Canada
A. G. Melnyk, Canada
I. N. Grechanyuk, Canada
Yu. A. Smashnyuk, Canada
V.G. Grechanyuk, Canada

Abstract

We present the results of the electron beam equipment and technologies developed to produce metals and alloys coatings performed in Scientific and Production Enterprise "Eltekhmash" (Ukraine) from 2005 to 2017.

The presentation is about the result analysis of a new generation of electron beam equipment and technologies in this company over more than ten years. The company is intensively developing several directions of electron beam technology, including:

- *Development of experimental and industrial equipment for melting metals and alloys;*
- *Manufacturing high purity Re, Mo, Cu, Mo, Ta, Nb, Ni, Cr, Co and their alloys, used as seeds in growing single-crystal blades;*
- *Manufacturing high purity Re, Mo, Cu, Mo, Ta, Nb, Ni, Cr, Co and their alloys in ingot and billets form;*
- *Production of special titanium alloys for biomedical purposes;*
- *Master alloys productions;*
- *Manufacturing of quality ingots from a scrap of high–temperature alloys*
- *Manufacturing tubular billets-cathodes made off Ni-Cr-Al-Y. Ni-Co-Cr-Al-Y heat-resistant alloys for ion-plasma coating depositions*
- *Development of various laboratory and production electron beam equipment with different functional capabilities, which are currently realized in specialized units, allows saving time and money to develop a new technological process. L-2 unit belongs to this type of equipment. This unit capable of realizing four types of different technical methods:*

The company is also manufacturing different equipment types based on the mentioned development or equipment according to customer design and goals. The company opens for new materials development and research.

Development of high-performance alumina-chrome-zirconia brick for multiple application

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Kartik Khan, Trl Krosaki Refractories Ltd., India
Biswajit Ghosh, Trl Krosaki Refractories Ltd., India
Sunanda Sengupta, Trl Krosaki Refractories Ltd., India
Priyabrata Panda, Trl Krosaki Refractories Ltd., India

Abstract

Alumina-Chrome-Zirconia system is well known for its outstanding thermo mechanical properties and corrosion resistance towards various metals and slag. Phase diagram of alumina-chrome system shows a complete solid solution throughout the whole range without forming any eutectic phase which is mainly responsible for its excellent corrosion resistance property. Presence of zirconia in alumina-chrome system improves thermal shock resistance of the refractory by virtue of creation of micro cracks within the matrix. It also helps to enhance the thermo mechanical strength of the system. The present study describes the development of high performance- alumina-chrome-zirconia refractory having different percentage of chrome content (varies from 5 to 30% by weight) for application in Non ferrous smelters like Copper, Zinc ,Incinerators, pelletization furnace, glass tank furnaces etc. Depending upon the application requirement; various high purity raw materials like fused corundum, sintered corundum, reaction bonded chrome oxide, aluminosilicate synthetic aggregates and specially grade zirconia are being selected for designing of the products. The developed products are thoroughly characterized for physical properties, thermomechanical properties, and chemical analysis. The final product is characterized for X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), slag corrosion resistance and thermal shock resistance. Among these developed products, one product is put into operation in ISA smelting furnace in one of the leading copper manufacturing industries and the product is running successfully in the aforesaid area of application.

Instance rock lithological classification method based on hyperspectral images and deep learning

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Claudio Perez, Universidad de Chile, Chile
Pablo Estévez, Universidad de Chile, Chile
Martin Adams, Universidad de Chile, Chile

Abstract

The revolution of industry 4.0 is already a significant component of mining operations. New ways to control processes include the integration and analysis of various types of information to automate mining plants. The lithology of the ore is part of this information and provides data related to the chemical composition of rocks, and their physical properties. Hyperspectral imaging is an excellent tool to perform lithological classification. Additionally, the use of new techniques based on deep learning has yielded outstanding results in imaging analysis. Nevertheless, only few studies have presented new rock classification methods based on hyperspectral images and deep learning. We present a method based on hyperspectral images, within the short-wavelength infrared range of 900-2,500 nm, and deep learning, to perform lithological rock classification. Instead of a pixel-wise classification, we perform an instance segmentation which permits us to identify each rock and estimate its size. The method uses two deep neural networks. The first performs a reduction of the hyperspectral channels to obtain an RGB image, which in addition can be used for human interpretation. The second network segments and classifies the different rocks present in the image. The method was tested on our database of rock samples from copper mines in Chile, obtaining accurate results and demonstrating its potential use in mining plants.

Innovating In The Efficiency Of Vibrating Screens For Mining

Ivan Acevedo, ALVYAC,Chile
Vicente Ponce, ALVYAC,Chile
Victor Rocher, ALVYAC,Chile

Abstract

In the last century, the mining industry experienced a strong change that resulted in the gigantism of equipment, while in the present century it entered the digital age, breaking into new intelligent equipment, remote operations, expert systems, typical of the fourth industrial revolution. The continuous change of the industry, to obtain the greater efficiency in the processes of extracting and minerals beneficiation is observed in the permanent increase in the tonnages processed per day, something natural in an industry with high fixed costs. However, while the equipment evolved, already in the increase in size and automation, vibrating screening became the bottleneck of the comminution process. Traditional screens, considering the hard data, have low availability, ~70-80% compared to ~85-95% of the rest of the equipment in the plant. Traditional vibrating screens, product of their design for classification work, must withstand large high-frequency variable loads, so they tend to crack due to material fatigue, their gear systems usually present premature failures due to the same constant vibrations to which they are subjected and ultimately all these design features tend to cause multiple stoppages and generally have a short useful life.

ALVYAC, an engineering company, through long years of process optimization, failure detection analysis and repair of traditional vibratory screens, has accumulated a great deal of experience, so it decided to design and manufacture a screen that would break with the paradigm of a traditional screen with the following characteristics: An intelligent equipment, which by working near the resonant frequencies can achieve a better "performance"; with low energy consumption and without the need to apply large excitation forces, whose power requirement is ~40% of that required for a traditional screen; adaptable to the metallurgical needs of each plant; no gears; self-regulating, where the excess of load self-regulates the stroke and thus avoid the typical problems of overload and loss of efficiency.

The application of specific knowledge of the physical phenomena involved in the screening process, obtained from long years of work in bench test and in the field, has allowed ALVYAC to design a highly reliable equipment, whose result is reflected in minimal stoppages. This has different effects on production, which can be measured through the reduction of its OPEX, considering: Increase in processed tonnage, less recirculating load, decrease in energy consumed, greater availability of the equipment due to the decrease in failures, decrease in maintenance costs due to a considerable increase in the useful life of the equipment. At the CAPEX level, it is a very convenient cost equipment and because it is "customizable", it does not require special civil works or modify the existing infrastructure in the plant. Assembly is a simple exercise that reduces equipment change costs. It uses highly durable polyurethane or rubber meshes, both in dry and wet processes.

Using Big Data (BD) and Artificial Intelligence (AI), in addition to extensive experience, ALVYAC's objective was to design equipment tailored to the metallurgical needs of each plant to systematically accompany the process of increasing production, thanks to the greater screening capacity, reducing the recirculation load in the plant and providing greater availability.

The methodology for calculating the capacity of the screen that ALVYAC has developed, part of using the specific data of the plant and with the support of digital technology (BD & IA), allows you to take into account specific factors, typical of the metallurgical characteristics of the ore that will be screened, such as: The dynamics and rheological properties of the ore; flow velocity ; screening capacity, behavior of the mineral in the different granulometric borders of the fine and coarse, dry and wet product, depending on the work requirements; evaluation of the best efficiency point throughout the operating range. In general, this method looks for the efficiency of the screen, within a systemic process. Normally, the industry has been using the general recommendations of the "Vibrating Screen Manufacturer Association" (VSMA) as a guide for calculating the screening capacity, which includes a series of tabulated factors to estimate the required surface, whose results for many years have been a valuable guide to design. Nowadays, these tend to be general information in the design, since technological advances (BD & IA) allow the customization of screens, offering a better estimation of the real capacity and with better efficiency. On the other hand, the introduction of numerical calculation methods through the "Discrete Element Method" (DEM), have been a great contribution to the design of vibratory screens, especially for their good modeling of coarse grain size ranges. and dry ore.

The expected result of the vibratory screen designed and built by ALVYAC, presents significant energy savings, ~ 40% of that used in a traditional screen, where the lower impact forces to which it is subjected directly affect greater reliability and useful life. of the screen, being at least double the traditional screens.

The engineering and design, as well as its manufacturing, is totally domestic and the first screen that will work in CODELCO, Chuquicamata, is currently in the process of being manufactured.

The systematic improvement of a complex plant's metallurgical accounting – from locking out by-pass lines to installing accurate samplers and monitoring sample-preparation behaviours

Isaac MKandawire, Kanshashi Mining Plc, Zambia

Abstract

Metallurgical accounting sits at the heart of a successful and profitable mining venture. Success of an operating mine heavily depends on the layout, optimisation, maintenance and accounting of all valuable process products. The ability to accurately account for the process inputs and outputs are important for monitoring process performance, which is in turn critical for the optimisation, sustainability and profitability of a process. Resumption of operations at Kansanshi by First Quantum Minerals in 2006 was characterised by low capital injection favouring plant flexibility and production. Over the following years, the three concentrators, each processing different ore types, grew in a manner that allowed for flexibility in moving processing streams between the three circuits. This favoured production, but led to a plant layout that makes it difficult to avoid inter-circuit contamination. Furthermore, many streams were only equipped with low confidence samplers. Together, these factors led to low confidence in recoveries and significant metal accounting errors. Kansanshi Mining Plc is committed and determined to improve its metal accounting system to an auditable standard in line with the AMIRA code. This paper discusses the strides taken in the KMP metal accounting improvement plan over a three-year period, and demonstrates the validity of accuracy in metal accounting samplers, mass, moisture measurement equipment coupled with a stringent quality assurance system

On-line monitoring of Cu concentration in molten copper matte by laser-induced breakdown spectroscopy

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Junwei Jia, Hefei Gold Star Mechatronics Technical Development Co. Ltd, P.R. China
Rongsheng Zhao, Tongling Nonferrous Metals Group Co., Ltd Jinguan Copper Corporation, P.R. China
Bing Zhang, Hefei Gold Star Mechatronics Technical Development Co. Ltd, P.R. China

Abstract

The elemental concentration of Cu is essential for processing control of copper smelting. Monitoring Cu concentration in molten copper matte is important for timely optimizing process control parameters, improving the utilization rate of raw materials and saving energy consumption. Due to the severe field conditions of copper matte, such as dust, fume, high temperature, melt level fluctuation and electromagnetic interference, it is difficult to on-line monitoring the composition of melt in the past.

In this paper, the long-term field application status of the GS-LIBS2200 Laser Composition Analyzer based on laser-induced breakdown spectroscopy (LIBS) is introduced. The online analyzer has been applied to monitor the Cu element content of copper matte melt for more than three years, and the online monitoring result compared with offline X-ray fluorescence (XRF) are also discussed. Among the comparison results of more than 3600, whose average absolute error is 0.58%, and the ratio of absolute error within 1.5% exceeds 95%. In addition to monitor the content of Cu element, the analyzer can also provide an evaluation factor of the slag content in molten copper matte at the same time. The results show that the GS-LIBS2200 laser composition analyzer has good measurement representativeness and stability, and has great potential in the on-line monitoring of copper melt elemental concentration.

The use of data in setting sustainable development goals throughout the complete value chain from an industry and organizational perspective.

Malony de Ponte, Fraser Alexander, Brazil
Edgar Damasio – Fraser Alexander, Brazil
Juan Carlos Duarte – Fraser Alexander, Chile

Abstract

The life of copper is considered to be infinite as it has endless uses with no end phase. It is mined and can be recycled through complete value chains and in this manner drives a circular economy. Taking into consideration this important driver, how can organisations use data and data analysis in continued sustainable development throughout the complete value chain from individual and industry perspectives. A circular economy depends on the continuous benchmarking of such initiatives and the knowledge share the governing organisations provide. How can organizations feed into this use of data and contribute to the setting of these development goals and assure continued growth in this industry.

Mill Feed Stabilization of the Kansanshi Sulphide Milling Circuit during Emergency Feeding

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Abstract

The process of "Emergency Feeding" at the Kansanshi Sulphide milling circuit improves mill throughput by supplementing the main feed supply coming directly from the stockpile, particularly when there are disturbances affecting the main feed supply rate or material characteristics. The emergency feeding involves the use of ADTs to feed material on a belt running at an operator set speed. The advantage of this method is flexibility on feed assortment from the stockpile, however it has an adverse effect on the stability of the Milling process. The circuit has a nominal target milling rate of 1800 t/h, and the disturbance was found to be causing variation in feed rate with a standard deviation of 337 t/h based on error between Process variable (Pv) and Set point (Sp). In order to stabilize the combined mill feed rate, a controller was set up using an online laser-based volumetric measurement of Emergency fed material as an input to controlling the speed of the main feeder belt. Aided by Artificial Intelligence, an Advanced Process Control (APC) system was built on Model Predictive Control (MPC) with its ability to predict future events and take control actions accordingly. The results showed improved stability on Mill feedrate with a standard deviation of 134t/h on error between Pv and Sp, and an increased throughput of 71 t/h during emergency feeding.

Keywords: SAG mill, emergency feeding, batch process, Advanced Process Control, Model Predictive Control, process stability.

Avoiding and Eliminating Transfer Chute Bottlenecks: Principles of Design and Operation to Minimise Lost Production in the Mining Operation Due to Chute Problems

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Professor Michael S. A. Bradley, The Wolfson Centre for Bulk Solids Handling, University of Greenwich, United Kingdom
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Abstract

Transfer chutes are essential equipment handling hundreds of millions of tons of particulate copper ores and concentrates per year. In most cases they don't have a standby twin to be used in case of a failure, so an operational problem can stop the whole plant. Blockages, spillage, premature wear, degradation of the mineral and excessive dust emission are common problems that face operators every day. Belt mis-tracking and premature degradation are also commonly caused by chute problems. There are a variety of causes, including unsuitable geometry and lining materials, changes in the mineral properties, production conditions and requirements, poor maintenance, etc.

Most of these problems need not occur, because principles of good practice in chute design have been well established and thoroughly tested; but unfortunately, not as widely known as it should be. Consequently, many chutes are not designed as well as they could be. The purpose of this paper is to provide an overview of key design principles to avoid loss production due to flow problems and unplanned shutdowns.

Key principles include: The importance of flow properties characterization of the product handled, using a well proven scientific method that informs calculation of critical dimensions; the importance of calculating particle trajectory and velocity; the advantages of an adequate DEM simulation using real material properties; understanding types of chute design; and correct interfacing to belt receptor.

Capsule pipeline technology for transport of mineral slurries: a Chilean context

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Abstract

Recent global warming has caused drought on a worldwide scale, and more particularly in Chile with average rainfall dropping up to 60% of previous averages. This shortage of water imposes radical solutions to reduce water consumption associated with hydraulic transport of tailings and concentrates.

One solution consists of encapsulating filtered slurries and transporting them in a hydraulic capsule pipeline. The concept of hydraulic log pipeline was initially developed in the 1970's in Canada and further developed in the 1990's in the USA for transporting pressed coal logs. Recent research has focused on adapting the concept to sediment transport in recycled plastic capsules and on developing and improved design of the capsule launching system

Filtered concentrate or tailing with a moisture level as low as 11% is charged into the capsules. The concentrate never comes in contact with the water in the hydraulic capsule pipeline. The water can therefore be recycled without expensive wastewater treatment or returned to the mine. The hydraulic capsule pipeline achieves a fill ratio of 80%. When compared with slurry pipelines with a fill ratio of 30%, this converts into substantial reduction in needs for water. A comparison in water saving and power is presented. Challenges and opportunities are discussed in the context of Chilean mining operations.

Pressurized Lancing Injection System for Sulfurization of the EF Matte

Jyri Talja, Kopar Oy, Finland
Eero Lehtilä, Kopar Oy, Finland
Roni Jahila, Kopar Oy, Finland

Abstract

Kopar Oy is acknowledged for engineering and manufacturing of robust systems for powdery material handling at power plants, chemical industry, EV batteries, and in non-metal ferrous smelters. We have over thirty years of experience with systems specifically designed for hot and abrasive conditions, aiming at low cost of ownership, low operational expense and high availability. Our core competence is pneumatic conveying applications, also at the copper & nickel smelters. Pneumatic conveying applications typically comprise pressure conveying, blower conveying and pressure injection. Several materials are conveyed pneumatically at the smelter: concentrate, feed mix, WHB dust, ESP dust, BHF dust and crushed slag among others. To improve conditions for enhancing the recovery of valuable metals, sulfur addition is favorable into the electric furnace. One approach herein is to accomplish the required sulfurization by a unique application of pneumatic conveying in which injection of high sulfur containing concentrate is directed underneath the molten bath. This is carried out using a pressure injection system which consists of a storage vessel, pressure vessel, rotary valve, partially flexible conveying piping and injection lance. This injection process will be described in detail, including full material flow, key components, feeding system, operation of the adjustable height lancing system and the expandable steel lance. Practices and challenges are discussed in the paper in detail.

BlueMetals Technology – Efficient solutions in WEEE recycling

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Rolf Degel, SMS group GmbH, Germany
Timm Lux, SMS group GmbH, Germany
Nikolaus Borowski, SMS group GmbH, Germany
Frank Kaussen, SMS group GmbH, Germany

Abstract

The demand of electrical and electronic equipment has increased dramatically with technological progress over the past years. Innovations on the technology of electronic devices has resulted in a shorter usage and lifespan and thus boosted the generation of Waste Electrical and Electronic Equipment (WEEE). WEEE is one of the fastest growing waste streams, growing with an average of 2 to 4 % per year worldwide and it is expected to reach approximately 75 million tons per year by 2035.

The focus for treatment usually lies on the highest qualities such as printed circuit boards, low-grade materials are hardly considered for recycling. The collected WEEE is processed in mechanical pre-treatment plants using shredding and sorting facilities and / or manual dismantling. Medium to high scrap qualities, such as copper-enriched fractions, are often utilized in the conventional copper industry while special solutions are applied for some materials. Low to mid-grade fractions are often landfilled or incinerated/processed by the informal sector.

Our solutions in WEEE recycling – the so-called BlueMetals plants - allows the recycling of the complete range of PCBs and thereby provides a solution also for low grade PCBs. The plants are designed for an annual capacity of 3,000 - 100,000 tons of e-scrap concentrate. It can be installed as a complete greenfield plant, or as a supplement to existing copper or nickel smelters using the infrastructure and equipment already installed in the existing plant. Our concepts are subdivided into pyrometallurgical pre-treatment followed by hydrometallurgical refining to recover base metals such as copper and nickel, as well precious metals such as gold, silver, platinum and palladium.

The central component in the pyrometallurgical treatment of the WEEE is either the BlueSmelter and / or the Top Blown Rotary Converter (TBRC). Compared, the BlueSmelter can also handle lower grade WEEE concentrates with higher organic shares. The concept of the BlueSmelter was successfully demonstrated on an industrial scale and resulted in a new generation of bath-smelting technology, which applys the supersonic SIS-injector. In these industrial scale trials, various WEEE concentrate mixes of different qualities were treated.

SMS group successfully commissioned a PCB recycling plant with a TBRC as primary smelter near Moscow, Russia. This plant has been designed to process about 6,000 tons of

printed circuit boards and 6000 tons of copper scrap every year to LME / LBMA grade metals, such as copper, cobalt, nickel, silver, gold, and platinum and palladium. Up to 98% of these metals are completely recovered and converted to high quality and pure products. SMS also received the contact for the expansion of the plant that will triple the overall capacity. Furthermore, SMS supplies the core equipment based on TBRC technology for a recycling plant in the US with an overall capacity of 60,000 tons of PCB's per year. Commissioning is planned for the year 2024.

Trends and solutions in primary and secondary non-ferrous metals production lines

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Rolf Degel, SMS group GmbH, Germany
Timm Lux, SMS group GmbH, Germany
Nikolaus Borowski, SMS group GmbH, Germany
Frank Kaussen, SMS group GmbH, Germany

Abstract

The non-ferrous market faces several future challenges in carbon constrained environment. Therefore, the tighter environmental restrictions, shortage of high quality raw materials, demand for higher recycling rates and remaining high demands of copper quality results in the need of new technological and process related solutions. SMS group developed intensively in providing sustainable solutions for these challenges. Our strong international set-up supports us, securing a reliable project execution, wherever possible even in these troubled times. Our BlueTechnology philosophy assures environmentally balanced technology taking the equally important awareness / consciousness for ethical aspects of the human society into account.

Over the past decades, SMS developed several furnaces and plants for the primary (ore/concentrate based) and secondary (scrap based) non-ferrous metals production. Our concepts focus on environmentally balanced CO_2-neutral metal production processes with minimized waste accumulation, maximized metal yields with a minimized resource consumption. Our product portfolio includes various furnaces for smelting, converting, refining, slag cleaning, metal casting, slag granulation and leaching and we have expanded our competencies, from the smelting of the ore or other metal-containing sources right up to a variety of different LME-grade metals.

Additionally, we actively participate in the new age of digitalization, which will play a game changing role in the future for the copper, nickel, zinc, lead, PGM and other non-ferrous producing industry. Understanding the process is a fundamental requirement when it comes to designing reliable and efficient metallurgical plants. This ensures the correct and optimized dimensioning of pyrometallurgical furnace for new non-ferrous metal facilities. Moreover, a clear definition of process and boundary conditions provides the fundamental data, understanding, and information needed for all auxiliaries and surrounding units, such as the offgas system, raw material handling, product handling, or cooling systems. It is also possible to integrate the process simulation models into the automation system used for predictive operation of the unit. We developed a process simulator – the "so-called BlueControl", providing assistance for the furnace control and operation of metallurgical furnaces.

Development of the PyroLIBS system: direct and real-time molten material composition in the Peirce-Smith converter

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Abstract

The PyroLIBS system is part of the next generation of technologies in pyrometallurgy, capable of direct, continuous, and real-time measurement of molten material composition. Based on the principle of laser induced breakdown spectroscopy, the system is being developed in collaboration between Hatch and the National Research Council of Canada. An overview of the technical roadmap to-date is presented, with a focus on continuous measurement in the Peirce-Smith converter.

Selecting sulfuric acid technology to maximize copper production

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Abstract

Copper smelter sulfuric acid plants capture and treat dirty sulfur dioxide bearing off-gases and produce by-product sulfuric acid. Sulfuric acid plants are also used at copper leach operations to produce sulfuric acid from sulfur. The safety, efficiency and reliability of the gas cleaning and sulfuric acid plant at either operation plays a critical role in achieving sustainable, low cost copper production. This paper reviews critical areas in the plant design which have major impact on the plant operation and reliability for the life of the plant as well as technologies that can be used to expand the capabilities of existing acid plants. It further provides real-life examples where these design solutions have contributed to the long-term reliability of the plant thus ensuring that copper production is maximized.