Mineral Processing

Abstracts

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Estimation of Aggregate Density in Batch Flotation Testing

Marco Vera, Universidad Técnica Federico Santa María, Chile
Nahir Tapia, Universidad Nacional Andrés Bello, Chile
Carmina Quintanar, Solvay, Chile

Abstract

Flotation is most used separation process worldwide. The driving force of the separation is air injection as a bubble size distribution. Flotation air metric combined with particle size distribution, physico-chemical conditions and type of flotation cell defines separation performance. Batch flotation testing needs to comply with the requirements of operating this type of reactor, i.e., to keep volume constant during the flotation time for the separation. When ore kinetic flotation process is studied, kinetic order transition occurs. The latter was determined through the aggregate density which is indicative of bubble loading throughout the test. This comprehensive analysis of the batch flotation testing allows a deep understanding of the flotation mechanism to be established and helps study different operating conditions thoroughly. It is believed that this new proposed approached will help reconsider batch flotation testing and revalue its used.

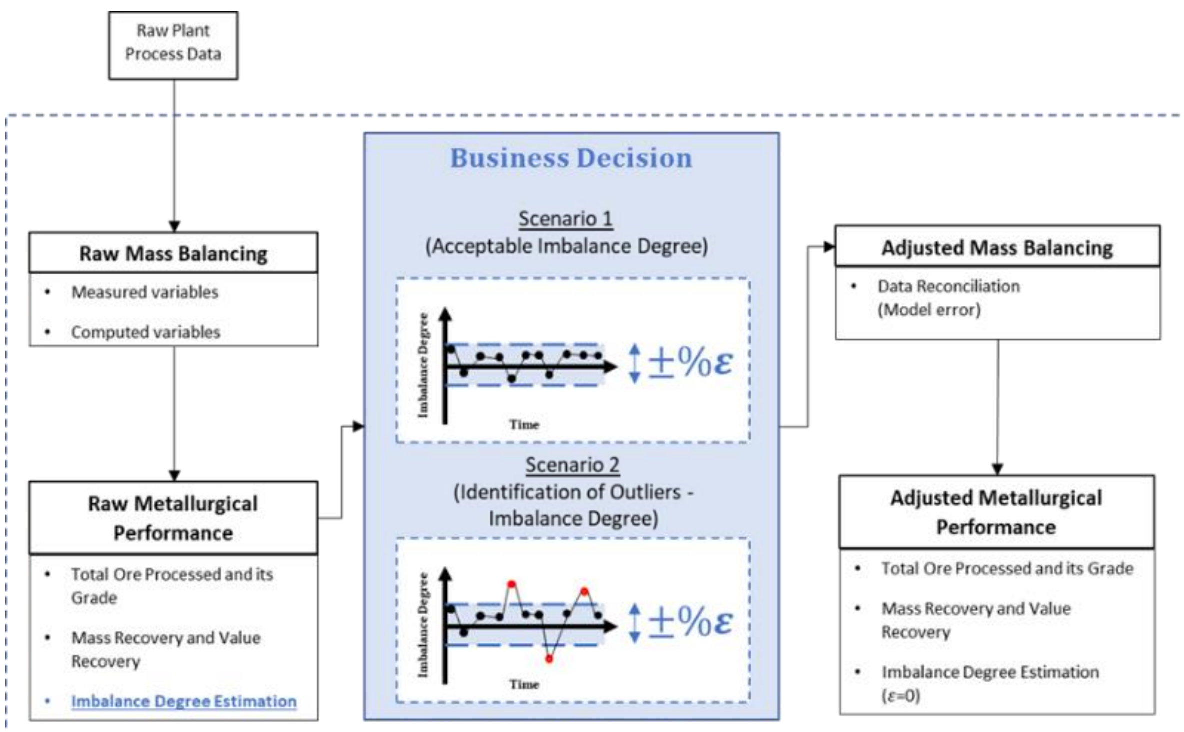
Practical Metal Accounting To Determine Metallurgical Imbalance Degree – A Case Study

Marco Vera, Universidad Técnica Federico Santa María, Chile
Diego Arteaga, Independent Consultant, Chile

Abstract

Mineral processing data are usually not consistent around separation units within a circuit. An assessment of circuit metallurgical performance requires a set of numerically consistent data. All measurements are subject to statistical variation. Knowledge of the degree of variation allows best estimate to be determined. Self-consistent data can be used to assess and compare performance. As well, mathematical models of the process can be established. The analysis of raw data allows the degree of imbalance (% ε) to be determined. In general terms, mineral processing operations have % ε that oscillates between 2% to 10%.

This paper provides a robust methodology to quantify Imbalance Degree and identifies mitigation strategies on a Copper Concentrator in Chile. Metallurgical performance is determined considering the imbalance degree and depending upon its magnitude, a reconciliation approach is also proposed (see attached figure).



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Retrofit design modifications for the pulp-froth interface: the effect of feed size distribution on flotation performance and froth stability.

Joel Kelion, Imperial College London, United Kingdom
Diego Mesa, Imperial College London, United Kingdom
Pablo Brito-Parada, Imperial College London, United Kingdom

Abstract

Higher demand for copper and decreasing ore grades has resulted in the increased need for innovation in mineral processing. In froth flotation, retrofit design modifications are a potentially effective option to consider for improving separation efficiency. With turbulence in the pulp zone destabilising the froth and fast-moving flows near the walls of the cell that tend to carry more water (increasing entrainment of fine particles especially), the flotation process is far from optimal. Retrofit designs may be able to reduce these phenomena, hence improving recovery and concentrate grade.

This study considered the effects of variations in the feed size distribution on the flotation performance of a cell, with pulp-froth interface retrofit designs. The designs assessed were inverted semi-conical funnels of different lengths and geometries, which were installed at the pulp-froth interface. The funnels aim to minimise turbulence at the interface and designed to redirect the pulp flows near the walls towards the centre of the tank. Tests were carried out using a four litre continuously overflowing bench-scale flotation tank, with a two-species system (synthetic ore of chalcopyrite and quartz). The impacts these retrofit designs have on entrainment for different particle size distributions in the feed were analysed and discussed. As an additional optimisation strategy, different air flowrates were also assessed to determine changes in froth stability, measured via air recovery.

A novel Cu sulfide and pyrite depressant as a safer and efficient alternative to NaSH in Cu-Mo Separation.

Arinaitwe, Esau, Solvay, USA
Santana, Alfredo, Solvay, USA
Zapata, Julio, Solvay, Chile
Quintanar, Carmina, Solvay, Chile

Abstract

In Cu-Mo separation, Cu sulfides and pyrite are depressed using inorganic reagents such as NaSH and Nokes while floating molybdenite selectively. However, these inorganic depressants have serious safety and health hazards due to potential formation of toxic H_2S gas during use. Solvay previously introduced AERO® 7260 HFP depressant several years ago as a safer alternative to NaSH. This technology is in commercial use globally, but it is only able to replace up to 60% of the NaSH. Solvay's latest innovation is AERO® NR-7361 depressant, which replaces 70-100% of the NaSH. This technology is chemically stable and safer to apply under a wide pH range, with air or nitrogen, without concern for product degradation or H_2S formation. This paper presents results of commercial application of AERO® NR-7361 at a large Cu-Mo operation in North America, which achieved 100% NaSH replacement at an overall consumption in the range of 1-2 kg/t of molybdenum plant feed compared to 11.5 kg/t NaSH dosage. Metallurgical results indicated that AERO® NR-7361 provided advantages in terms of better Cu and Fe depression resulting in higher Mo concentrate grades, more efficient removal of Pb impurities from the final Mo concentrate, and overall stable Mo plant operation.

Ore Comminution Efficiency Improvement at the Assarel Concentrator Plant in Bulgaria

Iv. Vasilev, Assarel-Medet, JSC, Bulgaria
Iv. Cholakov, Assarel-Medet, JSC, Bulgaria
G. Matanov, Assarel-Medet, JSC, Bulgaria
T. Pakov, Assarel-Medet, JSC, Bulgaria

Abstract

Assarel-Medet JSC is a leading Bulgarian mining company for copper ore open pit mining and processing which invested 75 mln. Euro in a project aimed at more efficient comminution and achieving 15 mln. tonnes of annual throughput at the Assarel Concentrator Plant.

Three (3) ore types are fed to the Assarel Concentrator Plant which differ in terms of their particle sizes and mineral composition. The ore blend contains secondary quarcites, propylites and strongly eroded argillites. The finely disseminated valuable mineral particles are another ore feature which imposes that the coarse clayey pieces shall be crushed at the first comminution stage of the mining operations immediately after primary crushing. Prior to the implemented modernization, the material used to be disintegrated by five (5) AG mills and fed to the grinding circuit. The AG mills are equipped with a pair of trommel screens which split the particles into three sizes: coarse fraction (which later undergoes secondary and tertiary crushing), ready to grind material and fine size fraction later classified at the Ball Mill Area.

The implemented modernization project involves expanding the AG Sector area where a sixth MMC 7,0x2,3 AG mill and the largest in the Balkan mining industry ball mill of a throughput of 650 tonnes per hour are installed. It is METSO 6.71m x 10.21m and will grind all the 5-0 mm product size from the AG mills. New routes are being built to a new preliminary classification pump station which will separate the product to be fed to flotation. The equipment is managed by a currently unique in Europe OCS-4D™ expert control system. The Medium and Fine Crushing Sector optimization involves the installation of another HP800 secondary crushing cone crusher and a MF 3073 DD MULTI-FLO screening system which ensures the designed throughput achievement.

The detailed modernization result analysis, achieved grinding and classification indices show improved process efficiency summarized below:

- *Achieving an annual throughput of 15 mln. tonnes of ore while propylites are increased to about 55%*
- *Increased throughput of the AG sector in an AG mode*
- *Optimized operation at the Medium and Fine Crushing Sector with an efficient processing potential of 45% of the ore fed from the AG Sector*
- *Increasing the throughput at the Ball Mill Area and improving the flotation slurry particle size distribution*
- *Utmost state-of-the-art ore milling process management by an expert automated system.*

The impact of clays on froth stability for copper sulphide ore flotation.

John Morley, Imperial College London, United Kingdom
Diego Mesa Pena, Imperial College London, United Kingdom
Pablo Brito-Parada, Imperial College London, United Kingdom

Abstract

Demand for copper continues to grow due to many factors such as increasing human population and the green energy transition. Mining and processing of complex copper sulphide ores, that are low grade, highly disseminated and contain troublesome gangue minerals such as clays, is becoming more common. Clays are fine to ultra-fine phyllosilicate particles which have a deleterious impact on the flotation of copper sulphide ores. The impact of clays on the pulp phase during flotation has been widely studied. However, a lesser focus has been put on the impact of clays on the froth phase during flotation. Clay particles reduce the grade and recovery of copper sulphide concentrates due to their high levels of entrainment, formation of slime coatings and absorption of chemical reagents.

This work studied the impact of different clay types on froth stability during the flotation of copper sulphide ores. Synthetic ores, containing quartz and chalcopyrite, were spiked with two different clays: kaolinite, a non-swelling clay and montmorillonite, a swelling clay. Two proxies for froth stability were calculated: (i) air recovery using a lab scale flotation tank where the concentrate was constantly recirculated back into the pulp to allow steady-state to be reached and (ii) dynamic froth stability in a column. The relationship discovered between clays and froth stability can be used to improve the efficiency of flotation cells at mines where copper sulphide ores are enriched in clays.

Predicting the HPGR Throughput by Using a Piston Press Test.

Giovanni Pamparana, The University of British Columbia, Canada
Bern Klein, The University of British Columbia, Canada

Abstract

Sizing a High-Pressure Grinding Rolls (HPGR) requires a large quantity of material, making it not attractive and costly to be considered for new mining projects. Ongoing efforts are being made at the University of British Columbia to predict the behaviour of the HPGR using a low quantity of material on a piston-and-die press apparatus. Although the energy requirements and size reduction predictive models are already developed, there is still a need to predict the HPGR throughput on a small-scale test. This paper aims to present a new model to predict the HPGR throughput based on the previously developed model to predict the operational gap. The throughput model was developed using machine learning techniques, and it is calibrated using pilot-scale HPGR tests and piston press tests. The resulting model has an $R^2 = 0.87$ *with a prediction error of ±5% on average. The developed methodology shows to have potential to fill the gap of the missing throughput model. Further pilot-scale HPGR testing is required to continue validating the model.*

Copper Oxide Flotation Optimization of a Tajikistan Copper-Bearing Gold Ore.

Songtao Yang, Zijin Mining Group Corporation Ltd., State Key Laboratory of Comprehensive Utilization of Low-grade Refractory Gold Ores, China
Haibin Lin, Xiamen Zijin Technology of Mining and Metallurgy Co. Ltd., China
Jinghe Cheng, Zijin Mining Group Corporation Ltd., China
Laichang Zou, Zijin Mining Group Corporation Ltd., China
Qiankun Wang*, Zijin Mining Group Corporation Ltd., State Key Laboratory of Comprehensive Utilization of Low-grade Refractory Gold Ores, China

Abstract

Refractory copper-gold ore from transitional zone of Tajikistan Taror mine contains 3.5-5.0g/t gold, 0.45-0.65% copper and 1.5-2.5% sulfur, in which oxide copper is 0.12-0.33%. The oxidation rate of copper minerals in the ore is relatively high, i.e., 27-51%. We propose applying "flotation - flotation concentrate to sell - flotation tailings to cyanide carbon-in-leaching (CIL)" process to comprehensively recover gold and copper. In current flotation operation, copper grade in flotation tailings is generally higher than 0.30%, and annual average copper flotation recovery is only around 50%. A large amount of sodium cyanide, i.e., 5-10kg/t, is required if using CIL to leach gold from the flotation tailings. In order to economically recover gold, how to optimize and improve flotation recovery of copper, especially to improve copper oxide flotation, becomes a key technical issue that needs to be resolved. To this end, by adding copper oxide flotation reagents (Na_2S and a Cytec collector), soda ash, slime depressant, and optimizing flotation pulp density, the copper grade in flotation tailings could be reduced to 0.14-0.20%, in which 0.05-0.11% Cu was cyanide leachable copper. The required sodium cyanide dosage for flotation tailings CIL was reduced to 2.5-3.1kg/t. The copper flotation recovery was improved up to 70-75%, and the overall gold recovery from flotation and CIL was as high as 90-94%.

Mill throughput improvement via crusher throughput stabilization, at Kansanshi Mine.

K. Ngosa, First Quantum Minerals, Solwezi, Zambia.
Z. Gangaidzo, First Quantum Minerals, Solwezi, Zambia.
L. Gurieff, First Quantum Minerals, Solwezi, Zambia.
M. Malambo, First Quantum Minerals, Solwezi, Zambia.
I. Simwawa, First Quantum Minerals, Solwezi, Zambia.
C. Johnson, Partner in Performance, Bryanston, South Africa,

Abstract

With the mills achieving their maximum instantaneous throughput and as well as mill run hours being maxed out, Kansanshi mine took a step in conducting a diagnostic to explore further throughput increase opportunities and implement an alignment process to realize and sustain those opportunities. The diagnostic highlighted that the largest unplanned downtime element on all three crusher circuits at Kansanshi mine was due to feed supply inconsistencies and material quality. This inconsistent feed through the crushers was impacting milling performance as it resulted in erratic operating parameters for the milling circuits resulting into virtual downtime on the mills due to consistent variations in mill feed PSD. To debottleneck the crushing circuits, gaps in operations between mining and processing were explored and key performance drivers identified. To close gaps and address key drivers of inconsistent ore supply, key alignment and communication elements were implemented. This included alignment and agreement on SOPs, alignment and agreement on performance metrics, streamlined communication channels and maximized visibility of progress and actions being taken. Clear improvements have been realized across all performance metrics on both crushing and milling. This paper give details of the implementation methodology and the performance of the plant after implementation.

Keywords: Throughput, ore supply, stabilization, alignment, virtual downtime, crushing, milling, communication

Implementation of paste thickening technology for slag tailings

Juan Carrasco, Glencore – Altonorte, Chile
Cristian Fritis, Glencore – Altonorte, Chile
Karen Mendez, Glencore – Altonorte, Chile

Abstract

Altonorte is a copper concentrate Smelter with a permanent development of continuous improvement with support in technological innovation, framed in the path outlined to achieve the vision of becoming a World Class Smelter.
Altonorte has a slag flotation plant since 2001 to process the slag produced in the smelter as part of the treatment of concentrate in the Noranda Reactor, this slag flotation plant has a capacity of 900.000 tons per year producing 150.000 tons of concentrate and 750.000 tons per year of tailings.

This document describes one of these technological developments, which consists of implementing a paste thickening process for copper slag tailings, it is a pioneer project in copper slag tailings, which have approximately 30% more specific gravity than copper ore tailings where the implementation of the first paste tailings operations began.

This technological improvement of the process also makes possible to reduce the plant's water consumption and increase the useful life of the tailings dam as the Cp was increase from 60% from the conventional deposit up to 78-80 % in the new technology.

With this project, Altonorte seeks to provide sustainability to the operation of the complex, allowing the deposit of approximately 17.2 million tons of paste tailings, which allows extending the life of the complex's operation more than 25 years.

Capture characteristics of matrix to chalcopyrite and molybenite particles in pulsating HGMS.

Jianwu Zeng, Faculty of Land Resource Engineering, Kunming University of Science and Technology, Kunming,China
Luzheng Chen, Faculty of Land Resource Engineering, Kunming University of Science and Technology, Kunming,China

Abstract

China is abundant in molybdenum resources, but more than 50% of the molybdenum occurs in the porphyry Cu-Mo deposits with chalcopyrite ($CuFeS_2$) in the form of molybdenite (MoS_2). Chalcopyrite and molybdenite may be easily co-floated, but the selective flotation of chalcopyrite from molybdenite is difficult. Just recently, the industrial application test for the high gradient magnetic separation (HGMS), an environment-friendly separation method, has been realized successful for the copper-molybdenum separation. In this work, the capture characteristics of matrix to chalcopyrite and molybenite particles in the pulsating HGMS process were theoretically and experimentally described, to improve the separation performance of HGMS for copper-molybdenum separation. It was found that the matrix obtained a much higher mass weight for chalcopyrite particles, in comparison with the molybenite particles. And, the matrix was able to achieve a high capture selectivity for the chalcopyrite particles to molybenite particles, under the high magnetic induction and pulsating frequency. For instance, under the magnetic induction of 1.5 T and the pulsating frequency of 250 r/min, the pulsation HGMS process produced a copper concentration assaying 28.35% Cu and 0.46% Mo, at a high recovery of 89.37% Cu, from a copper-molybdenum mixed pure mineral. This investigation will provide the theoretical foundation for the application of the HGMS technology in separation of fine copper and molybdenum, and will provide a new approach for the high-efficient and environment-friendly utilization of porphyry copper molybdenum ore.

Keywords: Pulsating HGMS; Matrix; Chalcopyrite-molybdenite separation; Capture characteristics

Direct Flotation Reactor at Copper Mountain Mine

Koichiro Takatsugi, Mitsubishi Materials Corporation, Japan
Jaime Weber, Copper Mountain Mine (BC) Ltd, Canada

Abstract

The Concentrator at Copper Mountain Mine, located in southern British Columbia, Canada has been improving its operation and production since it was commissioned in May 2011. As a result of a series of operational improvements and upgrades, the Installation of three 1.7m x 2.9m Direct Flotation Reactors (DFRs) was successfully completed in July 2020. The DFR currently being supplied by Woodgrove Technologies is classified into the next generation of the Staged Flotation Reactor (SFR) where the various components of the flotation process were partitioned out and can be optimized. The cells of DFR are fully enclosed with the concentrate grade being controlled by the concentrate flow rates, resulting in a small footprint and low operational cost. The present paper will discuss on the results of pilot plant test, operational improvement and fine-tuning after the commissioning.

Estimation of Cu and Mo recoveries of five type ores composite in seawater flotation

Yoshiyuki Tanaka, Sumitomo Metal Mining Co., LTD, Japan
Tsuyoshi Hirajima, Sumitomo Metal Mining Co., LTD, Japan
Hajime Miki, Kyushu University, Japan
Gde Pandhe Wisnu Suyantara, Kyushu University, Japan

Abstract

The copper-molybdenum ores are typically mined from various spots in the mine, thus the mineral composition, oxidation degree and grade vary. Generally, these ores are blended according to the production plan for further process using flotation. However, the variety of these ores make it difficult to predict the flotation performance. Thus, a method should be developed for predicting the flotation outcome based on the mineralogical analysis of each ore. In this study, five types of ores with different degrees of oxidation were collected from an operating mine. A flotation kinetics model for a blended ore was proposed based on the blending ratio and Cu and Mo minerals composition. The floatability tests of each ore and a blended ore were performed in seawater. The flotation kinetics of each Cu and Mo minerals in these various ores were calculated by Mineral Liberated Analysis (MLA). The flotation kinetics of the blended ore were calculated and then the results were compared with the estimated flotation kinetics based on the proposed flotation kinetics model. It was found that the recovery of Cu and Mo of ores in seawater decreased with increasing the degree of copper oxidization. Moreover, the recovery rate of Cu and Mo minerals of a blended ore could be estimated by the blending ratio of each ore and the flotation kinetics parameters (i.e., the terminal recovery rate (R_{max}) and the flotation rate coefficient (k)) of each mineral in each Cu-Mo ore.

Investigation of flotation conditions for recovery of high-arsenic concentrate and copper concentrate from arsenic-bearing copper ore

Atsushi Shibayama, Akita University, Japan
Kazutoshi Haga, Akita University, Japan
Genta Sato, Akita University, Japan
Altansukh Batnasan, Akita University, Japan
Sambalkhundev Delgermaa, JX Nippon Mining & Metals Corporation, Japan

Abstract

Enargite (Cu_3AsS_4) is one of the arsenic-bearing minerals associated with copper sulfide minerals such as chalcopyrite, chalcocite, and covellite. The separation of arsenic-bearing minerals from copper sulfide minerals in copper ore using the flotation process is significant because of the environmental risks related to the emission of arsenic through copper smelting.

Based on the difference between the natural floatability of enargite and copper sulfide minerals, a two-stage flotation process consisting of enargite flotation and cleaning flotation of copper sulfide minerals was proposed to produce both the enargite concentrate and the clean copper concentrate from the enargite-bearing copper sulfide ore.
The effects of various operating parameters, namely collector dosage, pulp pH, and particle size, on the selective separation of enargite from copper sulfide minerals by flotation were investigated.

The results showed that in the first-stage flotation, the maximum recovery for enargite was about 90 % at pH 12 when a collector dosage was less than 10 g/t. In contrast, the loss of copper sulfide minerals as chalcopyrite was lower than 30%. It implies that collector dosage and pulp pH in the flotation process are important parameters resulting in improved enargite floatability than copper sulfide minerals. Furthermore, in the second-stage flotation, a clean copper concentrate containing <0.2 % arsenic and about 20% copper was produced from the tailings/middling of the first-stage flotation.

Keywords: Enargite, Chalcopyrite, Flotation, Floatability, Copper concentrate

Development and application of a machine learning model for ore sorting in Hishikari Mine

Kensuke Seno, Sumitomo Metal Mining Co., Ltd., Japan
Yuji Aoki, Sumitomo Metal Mining Co., Ltd., Japan
Jun Sugihara, Sumitomo Metal Mining Co., Ltd., Japan
Shungo Hobo, Sumitomo Metal Mining Co., Ltd., Japan
Yuki Yoshimoto, Sumitomo Metal Mining Co., Ltd., Japan

Abstract

The Hishikari Mine is an epithermal gold-silver deposit located in northeastern Kagoshima Prefecture, Kyushu, Japan. Gold grade of the ore is over 20 grams per metric ton. The gold mineralized white quartz veins of the deposit are hosted by black basement sedimentary rocks of the Lower Shimanto Group. The ore is proceeded to crushing, screening and sorting process, in which a color sorting technique is employed, using an automated sorting machine and handpicking to produce white concentrate.

The automated ore sorting machine utilizing image processing consists of an ore scanning step with a line camera, an image converting step into a 0-255 grey scale and a classifying step into concentrate and waste based on a predetermined grey level threshold. The threshold is finely tuned several times in an operating day manually for suitable sorting because of fluctuation of the milled ore type. It is necessary to improve efficiency of operator's work and to standardize the manual fine tuning.

Machine learning technology was applied to meet the requirements. In the first trial, a basic model was developed using input data of about 3000 images of liberated concentrate/waste and locked concentrate/waste. The results showed that a logistic regression model is suitable using ore brightness and size and the model ensured 93% of accuracy for sorting them. In second trial, plant trial has been conducted to evaluate the developed model in comparison to the current sorting technique.

Mineral Processing Study for Improving Gold Recovery in Flotation Plant at Atacama Kozan Copper mine.

T. Saito, Nittetsu Mining Co., Ltd., Japan
Y. Okamoto, Nittetsu Mining Co., Ltd., Japan
Y. Ebisu, Nittetsu Mining Co., Ltd., Japan
J.V. Satur, Nittetsu Mining Co., Ltd., Japan
K. Mitsuhashi, Nittetsu Mining Co., Ltd., Japan
T. Kawasaki, S.C.M. ATACAMA KOZAN, Chile

Abstract

Atacama Kozan copper mine, located at the northern part of Chile, is classified into IOCG type and its mineral processing is froth flotation for recovering chalcopyrite which is also associated with gold and silver. These precious metals are hosted mainly in electrum mineral and recovered with chalcopyrite, but their recoveries in the flotation plant are lower compared to copper and therefore require improvement. As preliminary surveys, we analyzed material balance in the flotation circuit to comprehend where these precious metals are lost, and observations using MLA (Mineral Liberation Analysis) to determine the minerals` morphology (size, shape, and associated minerals). It was consequently found that electrum associated with pyrite as well as liberated fine electrum particles were not recovered and were lost in the cleaner tail.

In this study, we investigated flotation conditions as follows to improve gold recovery: addition of gold collector to recover electrum associated with pyrite; and, injection of microbubbles to recover fine electrum particles. As results, the combination of thionocarbamate and mixed thiophosphate collectors showed a significant improvement on gold recovery. Injection of microbubbles in cleaner flotation also exhibited potential to improve it. Furthermore, we verified and discussed the effect on Atacama Kozan using a process simulator. The simulation results showed that the final recovery is greatly influenced by the improvement in the rougher.

Can pyrite be successfully depressed in copper flotation using sea water?

Yufan Mu, School of Chemical Engineering, the University of Queensland, Australia
Yongjun Peng, School of Chemical Engineering, the University of Queensland, Australia

Abstract

In copper flotation, copper ions emanating from copper minerals can activate pyrite, leading to difficult depression of pyrite. Normally, high pH and oxidizing flotation conditions are used to depress pyrite. However, when sea water is used, pyrite activation by copper ions is stronger due to a stronger galvanic interaction between copper minerals and pyrite, which generates a higher amount of copper ions, and a reducing condition, which promotes copper activation on pyrite. The buffer pH of sea water also rules out the use of high pH to depress pyrite. Plant managers and metallurgists often ask: can pyrite be successfully depressed in copper flotation using sea water without the need of desalination? This question is answered in this paper by conducting flotation tests on a Chilean copper ore using fresh water and saline water. In fresh water, pyrite depression was maximized by high pH and oxidizing conditions while in sea water, copper activation was minimized at neutral flotation pH.

Application of a new sulphidisation technology to improve the flotation of oxidised copper ores

Tiisetso Moimane, School of Chemical Engineering, The University of Queensland, Australia
Yongjun Peng, School of Chemical Engineering, The University of Queensland, Australia

Abstract
The practice of ore stockpiling leads to oxidation and alters the intrinsic surface properties of the copper sulphides in the ore, which renders them unamenable to thiol collector flotation and the net effect is poor flotation response. The current sulphidisation process for flotation of oxidised ores, which supposes to form a metal sulphide phase on the surface, has proven to suffer from low efficiency and difficulty to improve flotation of oxidised ores. We herein report on a new sulphidisation technology that shows great potential as the remediation strategy for flotation of oxidised copper ores. For the oxidised ore containing both primary and secondary copper minerals in this case study, the application of the new sulphidisation technology yielded a copper recovery improvement of 16% with an increase in copper grade as well. The ore mineralogy, flotation tests and the surface science underpinning the traditional sulphidisation and the new sulphidisation will be discussed in detail in the paper.

Application of microencapsulation technique for improving flotation separation of chalcopyrite and molybdenite

Ilhwan Park, Hokkaido University, Japan
Uchida Dai, Hokkaido University, Japan
Kosei Aikawa, Hokkaido University, Japan
Sanghee Jeon, Hokkaido University, Japan
Mayumi Ito, Hokkaido University, Japan
Naoki Hiroyoshi, Hokkaido University, Japan

Abstract

Porphyry copper-molybdenum deposits, the most important sources of copper (Cu) and molybdenum (Mo), are processed by flotation in which sodium hydrosulfide (NaHS) is commonly used to depress Cu minerals selectively. Although effective, the use of NaHS is not free from health and safety issues because it readily emits toxic hydrogen sulfide (H_2S) gas when the pulp pH decreased to < 8. In this study, thus, microencapsulation (ME) using ferrous (Fe^{2+}) and phosphate (PO_4^{3-}) ions to selectively depress the floatability of chalcopyrite by forming hydrophilic ferric phosphate ($FePO_4$) coatings on its surface was investigated as an alternative to the process using NaHS.

The ME treatment of chalcopyrite using 1 mM Fe^{2+} and PO_4^{3-} showed about 80% of coating agents were precipitated for 1 h, whereas they were precipitated < 20% for the case of molybdenite. Moreover, X-ray photoelectron spectroscopy (XPS) analyses of ME-treated minerals indicated the amount of $FePO_4$ coating formed on the chalcopyrite surface was substantially larger than that of molybdenite. Flotation of untreated chalcopyrite/molybdenite mixture showed both minerals were well recovered (i.e., 83% Cu and 92% Mo); however, after ME treatment, only Cu recovery decreased to 20–30%, and thus the separation efficiency was improved from 10% (w/o ME) to 67% (w/ ME). These results imply that ME treatment can be applicable for improving flotation separation of chalcopyrite and molybdenite without using NaHS.

Arsenic removal from arsenic containing copper concentrate with heat treatment and magnetic separation.

Hajime Miki, Kyushu University, Japan
Tsuyoshi Hirajima, Sumitomo metal mining Co.,LTD, Japan
Hiroki Fukuda, Kyushu University, Japan
Gde Pandhe Wisnu Suyantara, Kyushu University, Japan
Keiko Sasaki, Kyushu University, Japan
Yuji Aoki, Sumitomo metal mining Co.,LTD, Japan

Abstract

It is continuing issue to removal arsenic from arsenic containing copper concentrate. Current process of removal of arsenic from copper concentrate is copper concentrate roasting. However, this method needs to treat arsenic containing roasting steam dust and it is difficult to recover completely. Considering these situations, this research tried to improve heat treatment with lower temperature such as 400ºC followed by wet and dry magnetic separation. Primary copper sulfide minerals such as chalcopyrite and bornite contains iron in chemical formula then heat treatment can make magnetize these minerals. On the other hands, arsenic containing copper minerals such as enargite and tennantite does not contain iron in their chemical formula then it kept non-magnetic property. Magnetic separation after these heat treatments can separate primary copper minerals as magnetic product and arsenic containing copper minerals as non-magnetic minerals. Both wet magnetic separation and dry magnetic separation has been carried out and results shows that arsenic removal from copper concentrate can be achieved with high separation efficiency.

Froth zone design optimisation – the key to enhancing recovery in large flotation cells.

Diego Mesa, Imperial College London, United Kingdom
Pablo Brito-Parada, Imperial College London, United Kingdom
Rodrigo Grau, Metso Outotec, Finland
Diego Davoise, Atalaya Mining, Spain
Angel López, Atalaya Mining, Spain

Abstract

The froth zone in flotation cells plays an important role in determining metallurgical performance. This is even more critical as cell size increases, since larger bursting surface areas can easily result in poor froth transport and even stagnant froth zones, which are detrimental to recovery. Generating additional overflowing lip length by adding internal launders and reducing surface area (while also directing the froth to the overflow) by adding crowders, are well-established design strategies to enhance froth mobility. However, comparative experimental studies of froth zone design modifications at industrial scale are scarce and often lack detailed froth characterisation.

In this work, we present the results of two experimental campaigns that were carried out at Atalaya's Riotinto concentrator in order to determine the effect of a new froth zone design on the flotation performance of a TankCell® e300 cell that operates as the first cell of the rougher bank. These campaigns provided a unique opportunity to assess froth phase phenomena and metallurgical performance before and after changes in design. The original cell design had an internal launder and a central crowder, while the new launder technology includes a doughnut launder and an adjustable doughnut crowder. The new froth zone design significantly enhanced flotation performance, allowing copper recoveries in the TC300 cell to increase dramatically. In addition, radial profiles of froth height and froth velocity at the surface were determined, which provide valuable insight into the effect of design changes on froth stability and mobility.

The effect of iron content in zinc sulfide for depression of sphalerite in copper ore

Kazutoshi Haga, Akita University, Japan
Reona Sato, Akita University, Japan
Atsushi Shibayama, Akita University, Japan
Refilwe Sandra Magwaneng, JOGMEC, Japan
Tatsuhiro Ono, JOGMEC, Japan
Tatsuru Takahashi, JOGMEC, Japan
Kazuya Sunada, JOGMEC, Japan

Abstract

In recent years, copper ores containing zinc derived from sphalerite have been increasing in some copper mines. In flotation, zinc mineral surface to be covered with copper (activated) undergo a redox reaction with copper ions present in the solution, and zinc mineral was floated with the copper mineral. As a result, the zinc grade in the copper concentrate becomes high, and zinc removal technology is required during the flotation stage.

This study investigated the effects of flotation conditions and sphalerite properties in flotation to understand sphalerite's suppression mechanism in copper ores during flotation. In this paper, the effect of iron content in the zinc sulfide on the adhesion to air bubbles was investigated using simulated Fe-bearing sphalerite sintered by adding a certain amount of FeS to ZnS. An induction timer (MCT-100) was used to evaluate the adhesion to bubbles. In addition, X-ray photoelectron spectroscopy (XPS) was used for surface analysis.

From the results, the flotation probability of the sphalerite decreased with increasing iron content. These results suggest that iron hydroxide formed on the zinc sulfide surface, and it inhibited activation by copper for the zinc sulfide to adhere to air bubbles.

Commissioning HydroFloat in a Copper Concentrator Application

Karina Arburo, Anglo American, Canada
Jaime Zuniga, Anglo American, Canada
Adrian McDonald, Anglo American, Canada
Felipe Valdes, Eriez Flotation, Canada
Jose Concha, Eriez Flotation, Canada
Eric Wasmund, Eriez Flotation, Canada

Abstract

There are great demands on miners to reduce their environmental footprint. Currently, more than 3% of the world's electricity is consumed in the grinding process to liberate valuable minerals, much of that produced from non-renewable sources. The fine gangue from these processes requires large tailings facilities for waste storage and represents the largest water loss in mining, and an existential threat for mining companies and local communities. The competition for water resources puts miners in conflict with agricultural users and local populations, especially in metal-rich mining regions. As demand for a wide variety of metals for the green economy is rising, new and existing resources have lower grades. This is leading to four main drivers for reducing footprint and resource intensity; improving energy efficiency, reducing the consumption of water, increasing the long-term safety of tailing facilities, and minimizing losses of valuable pay-metals. A number of technologies are being developed to address each of these drivers individually, for example, more efficient grinding technologies, improved techniques to de-water and minimize evaporative losses, and better designs and maintenance for tailing facilities, such as dry-stacked tailing. One technology that can potentially improve all of these is coarse particle recovery (CPR).

Coarse Particle Recovery (CPR) can be used in any flowsheet that requires flotation, and it provides an opportunity to improve recovery and reduce energy and water consumption by recovering minerals at a particle size 2-3 time coarser than conventional flotation processes. As new technology, the first applications of CPF commercialized in sulphide flotation applied the technology to scavenge coarse losses from flotation plant tailings. This demonstrated the suitability of CPR for harsh, 24/7 mining applications. The next step is to use this technology to reject gangue earlier in the process, where the benefits of energy efficiency (less energy in grinding and less energy in de-watering) and water reduction can be achieved.

The successful introduction of innovative new technology requires a close multidisciplinary and collaborative approach to pilot, scale-up, design, de-risk and operate. In the present paper, we will discuss the close collaboration that has led to the demonstration of CPR in a coarse gangue rejection in a copper application. Anglo American, in collaborative partnership with technology partner Eriez have developed the world's largest HydroFloat® unit and applied it in an early gangue rejection mode at its El Soldado operation in Chile, South America. The plant was commissioned in Q1 2021. Results of the El Soldado module are presented.

The partnership between a mining company and a technology partner has a number of interesting facets that will be explored in the paper. For example, the mining company has intimate knowledge of processing flow-sheets and the interaction of all of the unit operations including the sensitivity to inputs and process dynamics. They are also expert in the economics of the mine planning, capital investments, operations and tailing management.

This paper will detail the CPR flow-sheet, design considerations that were the basis of increasing the size and reducing the height of the module for suitability in high seismic regions, issues around integration of a CPR circuit into an existing copper concentrator, and the impact on global recovery, plant throughput, and operability. Finally, there will be a brief discussion of Anglo American's plans to deploy the optimized technology across other similar sites

Cobre Las Cruces radically changes the selective flotation of polymetallic sulphides

Carlos Frias, Riotinto Proyectos S.L., Spain
Joaquin Gotor, Cobre Las Cruces S.A., Spain
Jorge Blanco, Cobre Las Cruces S.A., Spain
Edward Vera, Cobre Las Cruces S.A., Spain
Pedro Soler, Cobre Las Cruces S.A., Spain

Abstract

Selective flotation of polymetallic sulphides to produce separate copper, zinc and lead concentrates is often a difficult operation due to the complex mineralogy of the bearing-metal sulphides. This is the case of the massive sulphide ores of the Iberian Pyrite Belt, where producing qualified commercial concentrates of Cu, Zn and Pb implies sacrificing the recovery of those metals to a great extent. As a result, the metals flotation efficiency in produced concentrates yield 60-70% Cu, 40-50% Pb and 70-80% Zn. It means that a great proportion of the metals value is lost and wasted in flotation tailings. The radical change that Cobre Las Cruces technology brings to improve the profitability of the selective flotation process is recovering a significant amount of the metals currently deported to tailings into a low-grade bulk concentrate capable of being treated through CLC´s PMR process (Poly Metallurgical Refinery). Consequently, overall Cu, Zn and Pb metal recovery will increase 15-20% in the flotation process.

Centinela, challenges in the concentration of complex ores

Luis Pizarro, Minera Centinela, Chile
Raul Bahamondes, Minera Centinela, Chile
Miguel Catalan, Minera Centinela, Chile
Felipe Bello, Minera Centinela, Chile

Abstract

Minera Centinela (ex Esperanza) is a deposit of low grade copper with complex gangue and also having a high variability in pyrite content. These mineral characteristics represent a constant challenge as they affect the performance of the flotation stage (metallurgical recovery and concentrate grade). In addition to the above, a new sulphide based open pit has recently started operation together with successfully implemented projects focused on achieving increased throughput in the concentrator plant. These changes address new challenges to achieve optimal results in the metallurgical indicators of the flotation stage.

In the search for alternatives focused on increasing performance, a series of experimental campaigns have been carried out at the laboratory and pilot level with different technologies on the market, specifically pneumatic flotation. The results have been encouraging in terms of enrichment, including those considering feeds of low copper grades (flotation tailings).

Considering the difficulties of the ores that will be processed in the future and the existing challenges in the industry, starting in 2020, a series of specific studies focused on the use of the Jameson Cell as an additional stage for the current cleaner circuit were developed. In April 2021, an industrial test was carried out in the collective flotation stage considering feed of complex ores (low copper grade and high pyrite content). This test made it possible to identify opportunities for improvement associated with recovery by increasing the efficiency of the current flotation circuit and to endorse the theory of adding a cleaning stage to improve the final concentrate grade.

From the final concentrates obtained from this industrial test, a series of additional tests were developed with a pilot Jameson Cell to understand the maximum potential that could be obtained with this technology. Considering the positive results obtained, the design bases were generated for a future implementation of Jameson Cells in the Centinela collective flotation circuit.

Investigation of sodium sulfite as a selective depressant in the flotation of chalcopyrite and enargite

Gde Pandhe Wisnu Suyantara, Department of Earth Resources Engineering, Faculty of Engineering, Kyushu University, Japan
Tsuyoshi Hirajima, Department of Earth Resources Engineering, Faculty of Engineering, Kyushu University, Japan
Hajime Miki, Department of Earth Resources Engineering, Faculty of Engineering, Kyushu University, Japan
Keiko Sasaki, Department of Earth Resources Engineering, Faculty of Engineering, Kyushu University, Japan
Yoshiyuki Tanaka, Sumitomo Metal Mining Co., Ltd., Japan
Yuji Aoki, Sumitomo Metal Mining Co., Ltd., Japan

Abstract

The potential of sodium sulfite as a selective depressant in the flotation of chalcopyrite and enargite was investigated in this study. Micro flotation tests were conducted using single and mixed minerals. The flotation results showed that sodium sulfite exhibited a depressing effect on the floatability of chalcopyrite and enargite in the absence of potassium amyl xanthate (PAX). However, sodium sulfite demonstrated a selective depressing effect on the floatability of chalcopyrite in the presence of PAX and enargite remained floatable under a similar condition, indicating a potential use of sodium sulfite as a selective depressant. Surface analysis using X-ray photoelectron spectroscopy was performed to explain the selective depressing effect of sodium sulfite.

Development of mineral processing techniques for arsenic removal from copper raw material

Hisatoshi Furuya, Japan Oil, Gas and Metals National Corporation, Japan
Taro Kamiya, Japan Oil, Gas and Metals National Corporation, Japan
Tatsuhiro Ono, Japan Oil, Gas and Metals National Corporation, Japan
Refilwe Magwaneng,Japan Oil, Gas and Metals National Corporation, Japan
Kazuya Sunada, Japan Oil, Gas and Metals National Corporation, Japan
Taisuke Sakakibara, Japan Oil, Gas and Metals National Corporation, Japan
Koichi Hashimoto, Japan Oil, Gas and Metals National Corporation, Japan
Shuichi Miyatake, Japan Oil, Gas and Metals National Corporation, Japan

Abstract

In recent years, the concentration of impurities, particularly arsenic in copper concentrate has been increasing as the grade of copper ore decreased. An increase of arsenic in copper concentrate results in an increased arsenic concentration in the slag generated by smelters therefore posing a major threat to the disposal and recycling of the slag. Against this backdrop, the Japan Oil, Gas and Metals National Corporation (JOGMEC), together with Japanese mining companies, research institutes and universities, have been conducting research on reduction of arsenic concentration in copper concentrate at mineral processing stage since 2017. The focus is on developing flotation processes that can effectively separate arsenic-bearing copper sulfide minerals (e.g., enargite) which do not differ significantly in flotation behavior compared to non-arsenic copper sulfide minerals (e.g., chalcopyrite). From the results of previous experiments, it has been confirmed that arsenic-bearing copper sulfide minerals can be selectively recovered as froth by modifying the mineral surface prior to flotation. In addition, the effect of grinding by HPGR (High Pressure Grinding Roll) on the liberation of each mineral in ores and the possibility of separating arsenic-bearing minerals by high gradient magnetic separation are also investigated.

ReAK- Reduction of arsenic in copper concentrates WP 3.3.3: Electrochemical oxidation

Anna-Lisa Bachmann, Fraunhofer IWKS, Germany
Dr. Gert Homm, Fraunhofer IWKS, Germany

Abstract

ReAK (Reduction of arsenic in copper concentrates) is a project build of German and Chilean partners. The aim of the project is the optimization and further development of process steps in copper production, which deals with the treatment of ore fractions that are particularly rich in arsenic.

The project focuses on different process steps and tries to find the most cost-efficient and environmentally friendly way for arsenic separation and disposal. One of many tasks is to oxidize the arsenite from the arsenic-rich wastewater of the gas scrubbers to arsenate in order to precipitate it subsequently as scorrodite. This iron arsenate compound is more stable and can therefore be landfilled in a more environmentally friendly manner.

In work package 3.3.3 an electrochemical oxidation method is investigated which uses a special diamond electrode. So far, the principal capability has already been demonstrated within the project. Also, high concentrations of arsenite could already be oxidized to arsenate in a relatively short time. The presence of other ions such as copper and iron in the solution has also already been investigated.

The next research steps are now the optimization of the parameters, the application to realistic solutions and the final precipitation as a scorrodite. In addition, the method will be subjected to a cost comparison with the conventional oxidation method using hydrogen peroxide.

Converting A Self-Air Induced Sparger Flotation Cell into A Higher Shear Forced Sparger System.

Joseph Sakala, Kansanshi Mining PLC, Zambia
Barnabas Ng'ambi, Kansanshi Mining PLC, Zambia
Patricia Mankubwa, Kansanshi Mining PLC, Zambia
Andre Prinsloo, Kansanshi Mining PLC, Zambia

Abstract

This project was aimed at enhancing a self-air induced flotation cell's performance through retrofit with higher shear forced are sparger system. With the crucial need of improved concentrate quality at reduced tonnes that would free up the currently constrained Kansanshi smelter capacity. Excess concentrate produced is exported at $175/tonne to other smelters for processing. Laboratory test work indicated that the change would enhance separation efficiency giving an improved concentrate grade at equivalent recovery, this was followed by retrofitting of the ten feeding medium density polyethylene channels into stainless steel channels that would cope at higher operating pressures. Circuit surveys around the modified unit were conducted to determine size class recoveries, cell recovery and concentrate grade improvements. Results showed improvements in fines and ultra-fine recovery accompanied with better flotation kinetics. Implementation led to a concentrate grade improvement of 3% total copper with no loss in recovery, which equated to a payback period of approximately 2 months.

A larger cyclone cluster for improved PSD control at a coarser grind

Lucy Little, Kansanshi Mining PLC, First Quantum Minerals LTD, Zambia
Doctor Mucheche, Kansanshi Mining PLC, First Quantum Minerals LTD, Zambia
Patricia Mankubwa, Kansanshi Mining PLC, First Quantum Minerals LTD, Zambia
Warren Little, Kansanshi Mining PLC, First Quantum Minerals LTD, Zambia

Abstract

The Sulphide circuit at the Kansanshi copper mine in Zambia had a design throughput of 1350 tph at a target grind of 150µm. Since 2008 various projects have helped with increasing the throughput to the current target of 1900 tph. In 2019, the design specifications of the cyclone cluster were identified as one of the root causes of grinding product instability due to pressure swings associated with opening and closing one of six active cyclones in an eight cyclone cluster. This was linked to cyclones frequently roping when targeting high mill rates (>1600 tph at the time). A project to replace the cyclone cluster with a larger one was initiated to improve cyclone control, at the same time targeting a more efficient separation at a coarser target grind size. A coarser grind size was deemed acceptable because detailed mineralogical analysis indicated that most chalcopyrite losses in the flotation tails were in the fine fraction and were well liberated. The new cluster was installed in July 2021, by which time the target mill rate had increased to 1900 tph with a coarser, more variable grind and more roping events leading to significant downtime. This paper will discuss the key cyclone optimisation challenges and how they were addressed to achieve the project's initial objectives of improved stability and separation efficiency at a coarser grind and higher throughput target.

Agitation intensity impacting Controlled potential sulphidisation effectiveness

Mulenga Chibesa, Kansanshi Mining Plc, Zambia
Lucy Little, Kansanshi Mining Plc, Zambia
Patricia Mankubwa, Kansanshi Mining Plc, Zambia

Abstract

Kansanshi Mine is a Copper and Gold producing company situated in North Western province of Zambia. It's Copper concentrator is composed of 3 circuits, namely; the Sulphide, Mixed and Oxide circuits. The Oxide circuit incorporates both flotation and leaching to recover copper from both sulphide and oxide minerals occurring in the ore. However routine mineralogy consistently showed fine grained copper sulphides as a major component of the float-leach copper losses. Laboratory test works, coupled with plant surveys indicated that increased agitation intensity during the two Controlled Potential Sulphidisation (CPS) stages would improve recovery of these minerals. The motors and impellers of both the Oxide CPS tanks and subsequent SIBX conditioning tanks were upgraded to triple the specific power (KW/m3). The upgrade coupled with optimisation of CPS control led to improved flotation recovery of copper sulphides and consequently improved float-leach recoveries.

The use of Integrated Metallurgical Process for Sustainable Production of Copper, Iron and Cobalt at Minera Santo Domingo, Chile

Romke Kuyvenhoven, Minera Santo Domingo, Chile
Fernanda Solís, Minera Santo Domingo, Chile
Giancarlo Daroch, Capstone Mining, Chile

Abstract

Capstone Mining is a base-metals producer with two producing copper mines: Pinto Valley in the US and Cozamin in Mexico. Capstone also owns 100% of Santo Domingo, a large scale, fully permitted, copper-iron-gold project in the Atacama Region, Chile. Santo Domingo is a top quartile copper-iron-gold project with an opportunity to build a low-cost, vertically integrated battery-grade cobalt business. The Santo Domingo project considers a concentration plant designed for 65 ktpd, treating an IOCG ore with a LOM grade of 0.30% Cu, 28.15% Fe and 0.04 g/t Au. The project is located at 1000 m.a.s.l. at about 7 km from the city of Diego de Almagro, in Chile's Atacama region.

The selected process route consists of a SAG/ball mill comminution circuit, copper concentration through flotation and magnetite recovery on copper tailings through wet magnetic separation, to obtain separate copper and iron concentrates. The option to recover cobalt is at preliminary economic assessment (PEA) level and will allow for cobalt recovery from the copper cleaner tailings through oxidation of Co-rich pyrite concentrate, followed by leaching, purification, and precipitation of cobalt sulphate as final cobalt product. The copper concentrate will be the most relevant source of revenue for Minera Santo Domingo for the first five years of operation; after year five, magnetite concentrate will take over as the most relevant source of revenue. Byproducts are gold contained in the copper concentrate, in addition to sulphuric acid and energy (from steam), the latter two from the pyrite oxidation process.

Given the high intrinsic ore variability and the interdependence of the individual metallurgical circuits (for Cu, Fe and Co), a geometallurgical strategy was chosen that focuses both on overall geology-mine-plant integration and optimization of the grade/recovery for the minerals of economic values: chalcopyrite, magnetite, and Co-rich pyrite.