Pirometallurgy

Abstracts

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Isasmelt and Electric Furnace Campaigns at Kansanshi Copper Smelter

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Abstract

Kansanshi Copper Smelter which is part of Kansanshi Mining Plc, jointly owned by First Quantum Minerals and ZCCM Investment Holdings, commenced operation in March 2015. The smelter features a single Isasmelt furnace for smelting concentrate, one 6-in-line electric furnace for matte-settling and slag cleaning duties, four Peirce-Smith converters and two rotary anode furnaces. The Isasmelt furnace was operated for 1.4 years after commissioning before a premature failure of the refractories in the kettle section. A partial repair was performed to enable the furnace to operate for another year before a full reline in August 2017. A number of process changes, together with enhanced bricks wear monitoring were implemented during the next campaign that has lasted for four years. The matte settling electric furnace was partially relined in 2017 and has been in operation for four years. This paper outlines the challenges faced during most recent Isasmelt and electric furnaces campaign with a description of the process changes performed that enabled the nameplate capacity of 1.2 million tonnes per annum of copper concentrate to be exceeded.

Isaconvert™ design, commissioning, and initial operation

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Abstract

Kansanshi Smelter is part of Kansanshi Mining Plc, jointly owned by First Quantum Minerals (FQM) and ZCCM Investment Holdings, started operation in 2015. The smelter nameplate capacity was 1.2Mtpa of copper concentrate produced at the Kansanshi and Kalumbila mines. In 2019, the Kansanshi Smelter completed the construction and commissioned the ISACONVERT™ top-submerged lance continuous converting furnace.
Peirce-Smith converting has been the accepted standard as copper converting technology for the last century. Despite continual improvements to the efficiency of the Peirce-Smith converters, compared to its predecessors, it has struggled to maintain environmental standards in the modern world. FQM has embarked on a new continuous secondary smelting furnace, the ISACONVERT™, as an economical and environmentally friendly path forward to increase matte converting capacity should it be decided to expand the existing Kansanshi smelter. To date, the ISACONVERT™ process technology has not been used elsewhere as a production line and had only been proven on a small pilot plant scale. This posed a significant risk for the company when considering the construction of a large scale furnace in future expansion scenarios. Therefore, FQM invested in a smaller scale “demonstration” ISACONVERT™ plant, designed to treat 12tph of matte, as a proof of technology that would reduce the operational and technical risks prior to the planned larger smelter expansion.

This paper provides a description of the plant and process design, as well as a summary of the commissioning and initial operation of the much awaited ISACONVERT™ furnace.

Integrated Experimental Phase Equilibria and Thermodynamic Modelling Research and Implementation in support of pyrometallurgical copper processing

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Abstract

Copper feed streams chemistries continue to be increasingly complex due to the growing metal demand, corresponding shortage of primary sources and increasing recycling. Improvement of industrial processed requires accurate prediction of high temperature chemistry. Integrated experimental and thermodynamic modelling research program on characterisation of the complex multi-component multi-phase gas-slag-matte-speiss-metal-solids system with the Cu_2O-PbO-ZnO-FeO-Fe_2O_3-CaO-Al_2O_3-MgO-SiO_2-S *major and As-Sn-Sb-Bi-Ag-Au-Ni-Co minor elements is under way to support major copper primary and recycling pyrometallurgical industry. The experiments involve high temperature equilibration in controlled gas atmospheres, rapid quenching and direct measurement of equilibrium phase compositions with quantitative microanalytical techniques including electron probe X-ray microanalysis and Laser Ablation ICP-MS. The thermodynamic modelling is undertaken using FactSage software package with advanced thermodynamic solution models. The continuing development of research methodologies has resulted in significant advances in research outcomes. Implementation of the results of fundamental studies involves ongoing collaboration of researchers and industry technologists and advanced professional training. An overview of recent progress in research, implementation and applications in industrial practice are given in the paper.*

Experimental study of the reactions between "FeO"-SiO_2 slag and magnesia chromite fused-grain refractories.

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Abstract

Experimental studies have been undertaken to characterise the reactions taking place between synthetic fayalite slags and magnesia chromite fused-grain refractory bricks. The experiments were carried out under controlled laboratory conditions using a synthetic "FeO"-SiO_2 slag system at a controlled oxygen partial pressure of 10^{-8} atm. at 1250°C. Detailed microstructural examination has been undertaken. The phases present at the slag/refractory interface, in the slag infiltration zone and in the original refractory materials, have been identified and their compositions measured using electron probe X-ray microanalysis.

It has been shown that, as a result of reaction between the slag and the periclase MgO grains, the olivine phase $(Mg,Fe)_2SiO_4$ formed preferentially in the refractory pores adjacent to the magnesiowustite grains, replacing the original monticellite, $CaMgSiO_4$ phase. Although secondary spinel was formed at the slag/chromite and slag/magnesiowustite interfaces at the slag/refractory interface, this low-Cr phase did not appear to strongly bind the primary chromite $(Fe,Mg)(Cr,Al,Fe)_2O_4$ grains to the interface. The study has provided useful information on the various reaction mechanisms taking place in this reaction system with a view to further improving refractory life in these and related systems.

Experimental Investigation and Thermodynamic Modelling of the Cu-Cr-Fe-Si-O-S system.

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Abstract

Stability of Cr-based refractories is of crucial importance in Cu smelting involving Cu-Fe-Si-O slag and Cu-Fe-S matte. Chemical interactions at the slag-refractory interface depend on the solubility of Cr in these oxide and sulphide liquids.

High-temperature experimental study of the Cr-Fe-Si-O (slag-metal-solids and slag-solids-fixed pO_2*), Cu-Cr-Si-O (slag-metal-solids), and Cu-Cr-Fe-Si-O-S (slag-matte-metal-solids) has been conducted. The compositions of the quenched phases are directly measured with electron probe X-ray microanalysis (EPMA). Experimental study is integrated with thermodynamic reoptimisation of the multicomponent Cu-Cr-Fe-Si-O-S system within FactSage software package.*

Thermodynamic behaviour of Ni in copper smelting and converting processes

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Abstract

Nickel (Ni) can enter primary and secondary pyrometallurgical copper production with the concentrates, recycled materials and by-products of other metal processes. An economic analysis for potential recovery of Ni can be greatly assisted with the use of predictive tools for the distribution of Ni among main process streams: slag, matte, metal, solid spinel, etc. Prediction of potential impacts of Ni on phase equilibria and energy balance for major process units is also important. Thermodynamic database developed using integrated experimental and modeling approach can provide a foundation to develop such predictive tools.

Experimental research methodology used in the present study involved high-temperature equilibration at controlled conditions, quenching of the samples and accurate measurement of the phase compositions by electron probe X-ray microanalysis. The data on Ni distribution between fayalite- or calcium ferrite-based slags, matte, metallic copper and spinel have been obtained. Phase equilibria for the important Ni-containing oxide systems in equilibrium with copper or nickel (Cu_2O-NiO-SiO_2, NiO-"FeO"-Fe_2O_3-SiO_2) have been characterized as well. All these new experimental data combined with the literature information were used for the development of the thermodynamic database.

Experimental and thermodynamic modelling study of the phase equilibria in the Cu-As-Si-O system

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Abstract

Multicomponent thermodynamic database for prediction of As behavior in pyrometallurgical copper production is being developed and constantly improved at Pyrometallurgy Innovation Centre (PYROSEARCH). Critical assessment of available literature data revealed a lack of experimental information necessary for the correct modeling of arsenic oxide in the liquid slag phase. The integrated experimental and thermodynamic modeling methodology allows to use phase equilibria studies together with distribution data to obtain the missing interaction parameters between $AsO_{1.5}$ *and* $CuO_{0.5}$ *in slag. For that purpose, an experimental series within the Cu-As-Si-O chemical system has been undertaken.*

Experimental procedure involved high-temperature equilibration at fixed conditions on the primary phase substrate, i.e. SiO_2*, quenching of the samples and accurate measurement of the phase compositions using the Electron Probe X-ray Microanalysis (EPMA). New data on As distribution between copper and* SiO_2*-based slag have been obtained. Also, liquidus projection of the Cu-As-Si-O system has been constructed. All these data combined were used for the re-assessment of quasichemical model parameters in the slag solution.*

Experimental Investigation and Thermodynamic Modeling of Leachability of Elements from the Pb-Cu-Fe-Si-O Slag

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Abstract
Understanding of the pH-dependent leaching behavior of heavy elements is critical to use of the copper metallurgical slags as value-added materials (slag valorization). Review of earlier research on leachability analysis of hazardous impurities, and parameters used in different standard leaching tests is undertaken in the present study. New experimental results on leachability of major elements (Fe, Si) and heavy elements (Pb, Cu) for the laboratory-synthesized slag are presented. The slag samples were prepared in controlled conditions representing industrial processes followed by rapid quenching or cooling with control rate, and characterization using the Electron Probe X-ray Micro Analyzer (EPMA). In leaching tests, the pH-static test method (EN 14997, 2015) was used. Special focus was given to the quantitative analysis of the slag-aqueous solution interface after leaching. The final goal of the present research project is to provide a link between the chemical and phase composition of slags at high temperature, the cooling regime and leaching phenomena. Improved thermodynamic modeling of solid crystalline phases, slags in a vitreous state (with Modified Quasichemical Model) and aqueous solution pertinent to leaching (with Pitzer framework) within the FactSage computer package was used for both slags and aqueous solutions.

Experimental study of distribution behaviour of Au and Ag in the Pb-Cu-S system by quantitative microanalysis techniques

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Abstract

The distribution behaviour of Au and Ag between the metal and sulphide phases in the Pb-Cu-S system has been experimentally studied at temperatures between 400°C and 1000°C. The samples were equilibrated in a vacuum sealed silica ampoule and then quenched for quantitative microanalysis by an electron probe X-ray microanalysis. It has been found that both Au and Ag preferentially partition to the metal phases rather than the sulphide phases at all temperatures investigated. Challenges in accurate measurement of trace levels of Au and Ag in the sulphide phase are discussed. Advanced analytical methods including utilizing LA-ICP-MS with matrix-matching standards for accurate trace elements analysis in matte, speiss and metal phases are being developed at PYROSEARCH as a part of integrated experimental and thermodynamic study aimed to development and optimisation a thermodynamic database for copper- and lead-containing systems of non-ferrous metallurgy.

Phase equilibria in ‘$CuO_{0.5}$’/PbO/ZnO-MgO-SiO_2 systems for characterization of MgO-based refractory-slag interactions

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Abstract

New experimental phase equilibria data for the ‘$CuO_{0.5}$’-MgO-SiO_2, PbO-MgO-SiO_2 and ZnO-MgO-SiO_2 systems were obtained to characterize the MgO-based refractories – slags interactions in Cu processing reactors. The experimental technique involved high-temperature (750-1740°C) equilibration of the synthetic mixtures with predetermined compositions on an appropriate substrate/crucible, quenching and electron probe X-ray microanalysis (EPMA) of the compositions of the equilibrated phases. The results for the ‘$CuO_{0.5}$’-MgO-SiO_2 and PbO-MgO-SiO_2 systems showed that the presence of silica in high-copper slags leads to the formation of olivine (Mg_2SiO_4) and pyroxene ($MgSiO_3$) phases on the surface, increase the solubility of MgO in slag, and weaken the performance of the MgO-based refractories. In contrast, wide ranges of solid solutions were identified for periclase (Mg,Zn)O, zincite (Zn,Mg)O, olivine $(Mg,Zn)_2SiO_4$, willemite $(Zn,Mg)_2SiO_4$ and pyroxene $(Mg,Zn)SiO_3$, indicating possible stabilization of the refractory in the presence of ZnO in slag. The experimental results for the systems investigated were used to optimize the parameters in a thermodynamic database that is subsequently used to describe the Cu-containing multi-component multi-phase system for characterization of slag-refractory interactions.

Laser OES - How pinpoint process control for pyrometallurgical copper production can lead to significant efficiency boosts

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Abstract

Pyrometallurgical copper production is not only producing the cupper, but also slags. In order to monitor these processes, a wide variety of parameters are monitored. Among other things, samples of copper and slag are taken from the melt and then being analyzed. Analysis of the solidified copper samples is often performed directly on the furnace platform and is usually available within one minute. The analysis of the slag, however, used to be much more time-consuming. Due to the necessary sample homogenization, in some cases far more than 10 individual steps were necessary to analyze one slag sample. This is particularly dramatic because the slag contains precise information about the process condition. If this information is missing, the slag analysis result can only be used "post-mortem" for process optimization. As an alternative in large parts far less precise process condition evaluations have been established. The new laser OES technology, on the other hand, can accurately analyze slag and other heterogeneous materials in 1-2 minutes and in just one instrument, directly on the furnace platform. This results in closer process monitoring and increased efficiency through in-situ process optimization. Thus, in addition to a precise in-situ adjustment of the input materials, the end point of the treatment can also be accurately determined. Therefore, among many other advantages, energy and other resources are saved and efficiency is increased accordingly.

Principles and first industrial results of a radiometric probe to monitor the flame of a Flash Smelting Furnace

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Abstract
The radiometric measurement of the spectrum emitted by chemical reactions can be used to monitor the advance and some physical-chemistry characteristics of such reactions. These features have been especially applied to control fossil fuel combustion in different types of burners. An opportunity for a technological transfer was identified with the flash oxidation of copper sulphides concentrates during the smelting stage in the classical pyrometallurgical Cu production. This idea was first developed at laboratory scale where previous flash oxidation studies were complemented by the use of a high temperature probe allowing the collection of the VIS-NIR spectrum during the oxidation. The results validated the concept and an industrial campaign was started.

This paper summarizes the first results where the temperature and radiation measured by the probe were incorporated as process variables. These two new variables combined with others of the production process allow the design of support tools to improve the operational control of the furnace.

Data analytics for prediction of chemical characteristics of matte and slag from the data of a radiometric probe to monitor the flame of a Flash Smelting Furnace

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Abstract
The application of radiometric sensors has been validated in different process industries. The application on pyrometallurgical process is in a nascent stage of development where the use of a probe for the monitoring of a flash furnace flame is a first example. The spectra emitted by the combustion flame and the temperature calculated from this information are new and complementary variables to the database that the monitoring of the operation of a flash smelting furnace produces.

This article discusses the first results of the combined use of the traditional process variables of a smelting flash furnace and the spectral information collected by the probe. The first advance for the control of a flash smelting furnace was the validation of models by using different data analysis techniques that allow predicting the quality of the matte and the magnetite content in the slag, as well as the dynamic of the change of the charge fed to the FSF.

Zero waste – zero emissions: An integral process for copper concentrates.

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Abstract

The University of Concepción is developing a novel process for copper concentrates that recovers virtually all metals contained in the concentrate as anodic copper, metallic iron or magnetite concentrate, molybdenum (as salt or trioxide) and a silica concentrate.
The process considers an initial oxidation roasting step of the concentrate at 800-850°C followed by a reduction of the calcine with hydrogen at 700-750°C. The separation of the valuable products from the calcine considers wet magnetic separation for the iron or the magnetite, and flotation or gravimetric separation to obtain a nearly pure product of metallic copper and precious metals for further electrorefining and a silica concentrate. No slag or fugitive emissions are generated, and the metals recovery can be above 99% for copper and above 95% for iron, silica and molybdenum.

The process has a negative carbon footprint and generates over 86% of the water requirements and a surplus of energy. Both CAPEX and OPEX are competitive with the conventional smelting-converting processes complying with present and future restrictions in terms of both emissions and carbon print, as well as waste generation.

High Temperature Direct Dearsenifying – Smelting: an alternative to dearsenifying roasting – blending – smelting for high arsenic copper concentrates.

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Abstract

A high-temperature process and reactor have been developed at a pilot scale to direct smelting high arsenic copper concentrates to generate matte or white metal. The process uses dry concentrate and technical oxygen in a derivation of a cyclonic-type reactor mounted on a settler for matte/slag separation. The reactor, with six vertical water-cooled concentrates/oxygen injectors, allows reaching temperatures up to 1600°C.
For 3-4 wt-% arsenic in the copper concentrates, operating the reactor with 50 – 100% oxygen at 1500-1600°C a 60-80% copper matte/white metal can be produced with 0.2-0.5% arsenic and slag with 6-8% copper.

This process and reactor could be a more economical and direct technological alternative to conventional dearsenifying roasting-blending-smelting for high arsenic concentrate both in terms CAPEX and OPEX, since in a single step can generate an acceptable matte or white metal for conventional converting. In addition, the matte or white metal produced could be ground and converted to blister copper in a separate reactor, operating at 1500-1600°C with technical oxygen.

This could permit to have a continuous combined smelting-converting unit with no gaseous emissions.

Experimental investigation of CaO, Al_2O_3 and MgO influence on Continuous Bath Converting Process Salgs

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Abstract

Experimental information regarding the effect of CaO, Al_2O_3 and MgO on the liquidus lines of Cu-Fe-Si-O based slags was investigated at the conditions of copper converting processes in which matte-copper-slag condensed phases would coexist. For the experiment, the starting materials corresponded to high purity SiO_2, CaO, Al_2O_3, MgO and Cu, using tridymite (SiO_2) and spinel (FeO_X) substrates to support the samples. The substrate/sample was positioned in a vertical electric furnace at a temperature of 1250 °C, then PO_2 and S_2 partial pressures were fixed by means of a mixtures CO, CO_2 and SO_2 flow of gas. After a holding time of six hours at the experimental conditions, the samples were quenched in cold water, mounted in epoxy resin and polished. Using Energy Dispersive X-Ray Spectroscopy (EDS)/Scanning Electron Microscope (SEM), the elemental composition of the observed phases in the samples were acquired. The attained information provided insights regarding a suitable slag composition for a continuous bath converting process.

Stabilization of arsenical toxic residues by the GlassLock^{TM} vitrification process.

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Abstract

Copper concentrates contain an increasing amount of arsenic, as the sources of cleaner ores are becoming depleted. Pyrometallurgical treatment of the concentrates to about 700℃ will remove significant amounts of the arsenic in the form of As_2S_3 or As_2O_3. Due to arsenic toxicity, countries have legislation limiting arsenic level in air, water and soils and post-treatment of the toxic arsenic waste generated need to be an integral part of the operations.

Vitrification provides a convenient method for immobilizing toxic metal waste and it has been considered as a Best Demonstrated Available Technology (BDAT) by the US-EPA for arsenic containing waste. In situ vitrification of soils has been applied in some contaminated sites in the US and vitrification is used in several facilities worldwide, including France and Japan, to immobilize the slag and ashes from municipal waste incineration.

In the present work, GlassLock^{TM}, a batch vitrification approach is applied to sequester and stabilize various arsenical residues of different forms including arsenic trioxide dust (As2O3), arsenites and arsenates such as hydrated ferric arsenite (As2Fe2O6.Fe2O3.5H2O), ferric arsenate (FeAsO4.2H2O), calcium arsenite (AsCaHO3), calcium arsenate (Ca3(AsO4)2), sodium arsenite (AsNaO2) and sodium arsenate (Na3AsO4) or a mixture thereof. DST arsenic glass essentially contains As, Si, Na and/or Ca and Fe as oxide. The levels of the constituents are adjusted based on the specific nature of the arsenic containing material to be vitrified. The mixture is then melted into a homogenous liquid oxide mixture which is then rapidly cooled to favorize the formation of amorphous solid solution (glass) and avoid crystallization of the constituents. The glassy material is a solid-state system that presents a broad continuous X-Rays pattern, typical of single-phase non-crystalline material confirming that a stable arsenic glass material is formed incorporating the arsenic in the silicate glass structure. The stabilization of the As in the glass is further confirmed by acceptable EPA TCLP 1311 and other environmental characterization results which can only be achieved with As bonding in the glass structure. Lastly, differential scanning calorimetry (DSC) was used to help provide additional information on the glass long term chemical durability and thermal stability of the glasses containing arsenic.

Refractory issues in the copper furnaces

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Abstract

Copper smelting furnaces are typically lined with magnesia-chromite refractories, which are exposed to complex wear phenomena. This paper evaluates the common refractory wear mechanisms observed in the copper anode furnace. The chemical factors include corrosion by fayalitic slag and sulfur, which roots at the difference in basicity/acidity between refractory species and atacking compounds. The high SiO2 supply results in "forsterite bursting" combined with volume expansion. Furthermore, increased temperature level respectively changes in the temperature during the furnace operation (thermal-shock) are further wear phenomena. Mechanical factors include erosion, caused primarily by the movement of the metal bath, slag and charging material, as well as stresses in the brickwork due to punching. Finally improper lining procedures can also effect the service life. All these wear parameters lead to severe degeneration of the brick microstructure and a decreased lining life. Thus, a deep understanding of the wear mechanisms through "post mortem studies" including (1) chemical analyses, (2) mineralogical investigations, (3) thermochemical calculations by FactSageTM and (4) corrosion evaluation by the application of the Dietzel's field strength is a prerequisite for the refractory producer. New refractory brick candidates are identified by this method to improve upon the current solution and support the customer with candidates, whose properties surpass those of the materials currently in service.

ILTEC Technology – New applications for the safest way of cooling

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Abstract

The use of water - today's standard cooling medium - has major drawbacks as it can cause problems during furnace start up and operation, namely hydration problems, corrosion and explosion. Not to forget the severe personal as well as economic damage in case of a malfunctioning water cooling systems.

ILTEC is a patented cooling technology, developed by Mettop GmbH in Austria, to overcome the disadvantages of water by using an alternative cooling medium, namely the ionic liquid IL-B2001. IL-B2001 is non-flammable, non-corrosive, non-toxic and minimizes explosions due its low vapor pressure. It also has a wide liquidus range and operating temperatures between -15 and 200 °C. These properties all contribute to the safe use of IL-B2001 in various cooling applications in the metal processing industry where there is a risk of cooling water explosions.

Within this paper, the newest developments and applications will be presented. Lance cooling for improved operation mode because of lowering the lance as well as heat removal with an under bath cooling in zinc melts are just two examples of how ILTEC cooling can contribute to a better operational result.

IonicLife cast technology – copper in copper cast for superior copper cooler quality

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Abstract

Mettop and WeCo have developed an innovative casting process enabling the only real copper-in-copper pipe cast by cooling with ionic liquid. The result is excellent metallurgical bond between copper tube and copper casting which leads to both long lifetime and recyclability of the copper cooler. Mettop and WeCo joined forces to develop this new safe production method for copper coolers aiming for improved thermal and mechanical properties and consequently extended lifetime.

As the cooling with gases is not sufficient and the use of water is extremely dangerous in presence of liquid metals - the only viable option keeping work safety in mind, is to cool with an Ionic Liquid. These liquids can be tailored in their characteristics in order to fit the application.

With the Know-How and control of the manufacturing process combined with the capabilities to design, simulate and optimize coolers for critical applications, Mettop and WeCo started the development towards the perfect cooler. Different examples are shown where the service life of the coolers has been multiplied.

Preparing the ISACONVERT™ for Commercial Production at the Kansanshi Copper Smelter

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Abstract

The first commercial production scale ISACONVERT™ furnace was commissioned at the Kansanshi Mining Plc (KMP) copper smelter in Zambia in early 2019. KMP is jointly owned by First Quantum Minerals Limited and ZCCM Investment Holdings. The initial purpose of the furnace was to prove the technology on a commercial scale, reduce the operational and technical risks, and provide scale-up data for the design of a larger ISACONVERT™ furnace. KMP is currently evaluating a smelter expansion to treat 1.6 million tons of copper concentrate per annum. The existing ISACONVERT™ furnace will be an integral part of this expansion to increase matte treatment capacity. A total of four short operating campaigns were performed since commissioning. Challenges faced included blister tapping and slag skimming, furnace and waste heat boiler accretions, blister casting, bath temperature and lance positioning control, slag chemistry and blister level measurement. A number of these challenges were overcome successfully while others remain to be resolved completely. The average treatment rate for the first two weeks of operation was only 35 tonnes of matte per day. A consistent throughput of 245 tonnes per day of matte at 66% availability was achieved during the last week of operation before the ISACONVERT™ was placed on care maintenance in anticipation of the smelter expansion. This paper provides a summary of the ISACONVERT™ operation in preparation for commercial production.

Improvement of Cu recovery from Noranda Reactor slag at Altonorte by a new slag cooling in pots process

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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 treats copper concentrates using a Noranda Continuous Reactor, which generates copper slag with a Cu content of ~7%. The recovery of this copper involves the cooling and feeding to a flotation plant, obtaining tails with Cu content of ~0.7 % (this make up the main loss of Cu in the overall Altonorte process). Two operations were evaluated at bench scale in order to increase the recovery in the flotation plant: regriding and slow cooling of slag in pots. The economic evaluation showed that the slag cooling in pots process is the most attractive to proceed with its implementation.

The tails obtained in initial pilot-industrial tests included the feeding of slag cooled in pots under different operational parameter, they showed that Cu content in tails were reduced to 0.52% and the water consumption for cooling from 1.36 m^3/slag ton to 0.42 m^3/slag ton with a low water cooling flow of 5 lpm.

Since February 2020, 27 cooling stations were implemented and incorporated to the current operation of the flotation plant, obtaining operational results consistent with previous tests. The main difference between this project and others in the Copper Smelting industry is the low water consumption with this new process. The execution stage of the project started in June 2021 and is expected to be fully operational at the third quarter of 2022.

TPID – A novel "Tuyere Push-In Device" for anode furnaces

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Abstract

Many producers are seeking for a new concept for inserting the tuyeres to increase work safety, a possibility to reduce the steel consumption and decrease the damage of refractory material. However, the state-of-the-art process for the worn tuyere pipes to be mechanically driven it into the anode furnace with the help of a sledgehammer, is not favorable for this.

The, currently heavy, physical work in a danger zone and in the hot environment is exhausting and dangerous for the workers. At the same time, the process is also uneconomical and resource-intensive due to the idle time.

With the developed TPID (tuyere push in device) and automated and yet customer tailored device has been developed allowing a hydraulic driven device to do the work. In terms of further safety, the hydraulics medium is an ionic liquid.

The paper will highlight two different versions of the TPID, ready to be installed or further developed for our customers needs.

Review of Operational Data of Two Matte Burners: CJD Burner and Cyclone Burner at Rio Tinto Kennecott Utah Copper

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Abstract

Rio Tinto Kennecott Utah Copper (RTKC) installed a new cyclone matte burner supplied by XGC in the Flash Converting Furnace (FCF) in July 2020. RTKC became the first smelter in North America to have successfully commissioned this burner technology. The matte burner facilitates mixing of feed and oxygen-enriched process air then injects the mixture into the furnace reaction shaft. Prior to adoption of the XGC burner, RTKC employed a different design based on Central Jet Distribution (CJD) technology developed and patented by RTKC in conjunction with Outotec. The CJD burner introduced feed in the center and the process gases in the periphery, while the cyclone burner has the process air in the center and matte in the periphery. The CJD burner utilized distribution air for dispersing the feed in the reaction shaft. The cyclone burner eliminates the need for distribution air and uses the oxygen-enriched air on the sides to create swirl motion that disperses the fluidized feed evenly in the reaction shaft. The plume geometry control differs significantly in both burners. The cyclone burner offers a fixed plume while the CJD burner allowed online alteration of the plume geometry by manipulation of distribution air. In this paper, key operational data such as oxygen consumption, reaction shaft temperature and heat loss, slag chemistry, blister quality, online time, maintenance frequency, and furnace availability are presented and discussed for both burners.

Process intensification of the Teniente Converter with BBA's proven sonic injection technology – One more step towards carbon footprint reduction

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Abstract

At the 2015 Conference of Metallurgists (COM2015), Kapusta, Larouche, and Palumbo presented a comparative study of the capacities and process intensities based on process simulations with METSIM for three bath smelting technologies, namely the Noranda Reactor (NR), the Teniente Converter (TC), and the Chinese Bottom Blowing Smelting Furnace (SKS-BBS). To avoid any bias, the study used published data on the NR operated at the Altonorte smelter in Chile, on the TC operated at the Caletones smelter in Chile, and on the SKS-BBS operated at the Dongying Fangyuan smelter in China. In spite of the skepticism surrounding the SKS-BBS that prevailed in the pyrometallurgical community at the time, the study showed that the SKS-BBS furnace, even though it was the smallest of all three smelting units evaluated, had both the highest process intensity level and production rate per unit volume of furnace. The SKS-BBS furnace, operating at ultra-high oxygen enrichment levels, could achieve this feat by diluting its feed concentrate so as to overcome the industry accepted oxygen enrichment upper limit of 38 to 48% typical of autothermal processing of "higher grade copper concentrates". In light of the major successes with the testing and commercial implementation of BBA's sonic injection technology in the years following COM2015, we believe an update of our study is warranted, particularly focusing on the Teniente Converter as the 11th International Copper Conference, or Copper 2022, will be held in Chile. Our objective in this paper is to revisit our 2015 simulations and discuss several possible scenarios to increase the smelting intensity and reduce the carbon footprint of the Teniente Converter compared to its current operating conditions in Chile.

Effect of solids on the rheology of secondary copper smelting slag

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Abstract

Viscosity is one of the most important physicochemical properties during slag processing. With process feedstocks becoming more complex, accurate predictions of the viscosity are key for optimal process operation. In the sub-liquidus regime, an important factor is the presence of suspended solid particles. This work aims to determine the influence of spinel particles on the rheology of a multiphase synthetic $PbO-SiO_2-ZnO-Fe_2O_3-CaO-Al_2O_3$ slag at 1473 K. By working in the spinel primary phase field, the amount of these crystals can be varied while keeping the characteristics of the remaining liquid slag constant. This aids to examine the sole influence of spinel crystals on the slag viscosity. An Anton Paar FRS 1800 rheometer was used, which can perform both rotational and oscillatory measurements in a wide-gap Couette-type set-up. Microscopical and EDX analyses of the quenched slag indicates the present phases, their morphology, phase composition and dissolution of ceramic crucible materials. The viscosity determined for solid-free melts was verified against the quasi-chemical viscosity model. Furthermore, the applicability of several solid-liquid mixture viscosity models was assessed by comparing the experimental heterogeneous viscosity data to the model results. The findings of this work contribute to a better understanding and model prediction of the contribution of spinel crystals on the slag viscosity.

Sustainable Copper Production based on Fluid Bed Roasting Technology

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Abstract

Fluid Bed Technology is a key pyro-metallurgical process for a vast number of ores and concen-trates. Over the past 50 years considerable research and development efforts have been made by Outotec GmbH & Co. KG (part of Metso:Outotec Group) to expand the application window of Fluid Bed Technology. Their versatility has manifested itself in the treatment of minerals including solid fuels for metallurgical processes. Process applications have ranged from roasting, calcining, combustion and charring of coals. The most important applications for the fluidized bed technology are zinc-, pyrite-, copper- and gold roasting and fluid bed calcination of alumina-, lithium- and phosphorus- materials.

The reduction of CO2 emission is one of major reason of increase of world's demand for copper. The recycling and secondary raw materials will be very important in the future, but these sources of copper are not sufficient to cover expected needs. The processing of the primary raw materials is and will be critical for further development of global societies.

This paper shall show the different copper processing routes, where the fluid bed technology plays an important role in the production of the copper. The used fluid bed processes are partial roasting, sulphate giving roasting and finally the dead roasting. The focus of this paper will be on the dead roasting of copper concentrates. This "zero waste" process can provide the copper oxides, steam, electrical power, and sulfuric acid for the existing SX-EW copper production plants. Because these operations are running slowly out of cheap oxidic ores and concentrates the fluid bed roasting can be applied to close this gap and provide again the required copper oxides on the sustainable way.

Fluidized-bed roasting of high arsenic copper concentrates – a Mitsubishi's view

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Abstract

Arsenic content in copper concentrate have gradually increased as the clean ores have been depleted, while environmental legislations having been stringent globally. Under such tough situations, technology for removing arsenic from the concentrate on mine sites is quite attractive for copper smelters. Although plenty of emerged technologies for arsenic removal have studied and suggested, conventional roasting using a fluidized bed reactor seems to be the most realistic measure, so far. The authors, therefore, conducted both stationary and kinematic studies simulating physico-chemical conditions in fluidized-bed roasters. Stationary experiments focused on the equilibrium and rate aspects of the roasting of enargite concentrate. The results were used in the kinematic studies based on chemical reaction engineering to obtain optimum parameters for operation and design of fluidized-bed roasters. Innovative roasting concepts of Mitsubishi technology will also be discussed in comparison with conventional roasting operations.

An experience of using sintered Mg-Cr bricks in Converting furnace of Mitsubishi Technology of Copper manufacturing

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Abstract

Mitsubishi continuous copper making technology consists to Smelting, Cleaning and Converting furnaces. Converting furnace uses fused cast magnesia – chrome refractory brick in hearth by design due to superior infiltration resistance to slag and copper. These bricks are manufactured through electro fused process and have closed pore distribution. These bricks are very costly and lead time is 1 year. A very critical decision was taken in the year 2011 at Birla Copper Mitsubishi copper smelter, India to replace conventional fused cast bricks with cheaper magnesia – chrome sintered bricks which was having similar physical and chemical properties. Issues faced during initial campaign of fused cast bricks were thoroughly analyzed and new refractory design with sintered bricks was developed. The behavior of sintered bricks was closely monitored in 2 consecutive campaigns (2011-2016 and 2016-2021) . This paper describes reasons for original fused cast bricks replacement, alternate brick quality selection and sintered brick performance throughout the campaign.

Improvement of SO_2 converter operation at Toyo Smelter & Refinery

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Abstract

The Toyo Smelter & Refinery of Sumitomo Metal Mining Co., Ltd. (SMM) produces approximately 4,000 tons a day of sulfuric acid as by-product using two parallel plants. The electricity consumption cost of the SO_2 blower is a large percentage of the acid plant operating costs. For that reason, reducing the electricity consumption of the SO_2 blower is an important issue. In order to reduce the electricity consumption of the SO_2 blower, decreasing the pressure drop in the catalyst layers of the SO_2 converter is effective. The catalyst changes must be considered carefully because it affects not only the pressure drop but also the SO_2 conversion ratio. Study was carried out to evaluate the SO_2 conversion reactivity and the pressure drop of the catalyst by a laboratory-scale converter. The experiment result shows that the amount of the SO_2 conversion reaction is influenced by the amount of V_2O_5 in catalyst. According to the result of the study, catalyst renewal work is carried out to maintain the SO_2 conversion ratio and to reduce the pressure drop every regular maintenance.

Direct observation of the copper concentrates ignition and combustion reaction with a lab-scale experiment

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Abstract

Copper consumption has increased because of high demands for electronics like electric vehicles. Although copper production has also increased, copper smelting companies face many problems, such as deterioration of copper quality in copper ore with harmful impurities, physical and chemical copper loss in slag, and harmful contaminations. Flash smelting furnace refines approximately forty percent of smelted copper in the smelting process in the world. In a flash-smelting furnace, copper concentrates and flux are thrown into the furnace mix with the reaction shaft to burn with heavy oil. In this process, the surrounded refractories prevent us from observing them directory. In our research, we built a lab-scale experimental setup to simulate the flash smelting and observed the ignition and combustion reaction, and clarified that the amount of magnetite in the slag decreased with much addition of pyrite.

Influence of slag chemistry and oxygen blowing condition on removal rate of silicon and iron from molten copper: Concentration of gold and silver in copper bath

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Abstract

The combinatorial effects of slag composition and O_2-blowing conditions on silicon (Si) and iron (Fe) removal from molten copper as well as gold (Au) and silver (Ag) enrichment in copper bath were investigated to optimize the copper converting process employing waste printed circuit boards (WPCBs) as raw materials. Regardless of the experimental conditions, the removal rate for Si and Fe was approximately 100%, except in slag-free operation. The Si removal rate was generally higher than the Fe removal rate at a given reaction time irrespective of experimental variables because the O_2 affinity of Si is higher than that of Fe in molten copper, thermodynamically. The removal rate of impurities was clearly dependent on blowing conditions and slag composition, and a combinatorial operation of bottom-blowing and highly fluid slag favored the efficient removal of impurities. The maximum enrichment ratio of Au and Ag was about 10% and the possession rates of Au and Ag were greater than 96%. The loss of Au and Ag can be minimized by stopping O_2-blowing before metal droplets are physically entrapped by molten slag, because metal droplet's entrainment is affected by slag viscosity, which contributes to the settling velocity of metal droplets. Consequently, it is very critical to appropriately control not only the slag composition but also O_2-blowing conditions for both impurities removal and maximizing precious metals enrichment and possession.

CFD and ROM Modeling of an Industrial Waste Heat Boiler for Primary Copper Smelting

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Abstract

The flash smelting furnace (FSF) operates with a waste heat boiler (WHB) for the recovery of heat from the copper production process from the gas phase. Due to the high SO_2-content in the process gas, formation of SO_3 is likely. Formation of sulfuric acid in cooled areas of the system can lead to corrosion, equipment failures and extended downtime. The SO_3 formation reaction can proceed homogeneously in the gas phase, but also heterogeneously-catalyzed by among others copper and iron oxides in the flue dust. Due to the limited accessibility into the WHB, experimental studies regarding this phenomenon are challenging. Therefore, Computational Fluid Dynamics (CFD) simulations are a promising alternative for investigating the SO_3 formation and concentration in a three-dimensional set-up, making the evaluation of risk areas and the influence of process parameters observable. While various researchers for numerous geometries have already investigated gas flow and heat transfer within a WHB, the reaction kinetics and mechanisms of SO_3 formation have not yet been studied with the help of a CFD simulation to date.

This study describes the setup of a CFD model of the WHB, which includes the oxidation of SO_2 to SO_3 using reaction kinetics based on literature data. In addition, because of the large calculation time of the CFD model, a simplified Reduced-Order-Model (ROM) is derived, thereby reducing the calculation time to seconds. Using the ROM, time-efficient parameter and sensitivity studies as well as comparison of different reaction kinetics become possible and will be discussed. The models are validated with industrial data as well as a dust sampling campaign. Finally, operational recommendations for minimizing SO_3 formation are derived and suggested.

Continuous converting and refining of copper matte in packed bed reactors

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Abstract

The new process of continuous converting and refining of copper matte in a packed bed reactors is an attractive option due to its very low investment cost, flexibility of operation with a liquid, solid or liquid and solid copper matte charge. Based on fluid dynamics concepts, heat and mass balances, fundamental measurements of the rate of matte and copper oxidation and copper reduction the technology in a ceramic packed bed has been developed. In 2018, ENAMI in a join agreement with the Chinese company NERIN, a semi-industrial integrated pilot plant of 5 t/h was built in the vicinity of Nanchang. The results of tests, mathematical models and heat and mass balances processing copper matte 74 % are shown. Likewise, details of the integrated industrial pilot plant.

Theoretical study of the synergy effect of temperature, basicity and carbon on the obtaining a Fe-rich phase from copper slag

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Abstract

Currently, economic and environmental issues along with metals consumption have imposed the development of effective and inexpensive method for the recovery of valuables metals from secondary sources. Chile produces more than 3.5 million ton/year of copper slag containing Fe and Cu in the range 43–48% and 0.8–1.2% respectively. Therefore, copper slag exhibits an economical potential for recycling by using metal extraction processes. Thermodynamical calculations were made using the ThermoCalc softaware to study the condition for obtaining a Fe-rich phase from copper slags. The effect of temperature, slag basicity and coke addition on the reduction of fayalite, magnetite and silica was studied. The ranges studied were, temperature between 1300 – 1700 °C, basicity between 0.8 – 1.7 and coke addition between 0.3–1.6 of stoichiometric ratio. The best results were obtained at a temperature range of 1400–1600°C with an iron recovery over 94%.

A parametric CFD study of a Top Submerged Lance Reactor

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Abstract

Refractory This paper addresses the typical design parameters of a Top Submerged Lance (TSL) type of reactor, using URANS CFD simulations. This type of reactor consists of a vertical lance that is vertically submerged, blowing air into a three-phase bath, composed by slag and matte. Parameters investigated include bath level, mass flow and lance penetration and injection. Results allow better understanding of bath agitation, large bubble dynamics, phase mixing, and the effect of lance design. Bath frequencies are obtained from simulations and compared to experimental values to validate a base case. Then, a quantitative relation is made for agitation and submergence, and another for agitation frequency and lance design.

Effect of microstructure on the properties of Magnesia-Chrome refractory Bricks

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Abstract

This study reports the results of a study on magnesia-chrome refractories used in the pyrometallurgy section of NICICO-Sarcheshmeh. Microstructure observation and chemical composition analysis was carried out by using SEM, X-Ray map analysis, and spectral analysis, respectively. Results indicated that, however, the amount of SiO_2 and CaO were higher than standard, the ratio of SiO_2/CaO was lower than 2 and standard, and Chromate deficiency was also observed in the samples. X-Ray map analysis detected Fe and Mg in the same area led to the formation of magnesia-ferrite strengthening spinel. Also, the Observed simultaneous presence of Si and Ca caused the weakening of stability of refractory bricks by the formation of silicate phases. In addition, the chance of formation of magnesia-alumina spinel was decreased by the concurrent presence of Cr and Al.

An innovative process of roasting copper concentrates – commissioning of an industrial installation to increase the efficiency of the flash furnace

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Abstract

The industrial installations and research applied in the world focused on roasting sulfur and arsenic present in raw materials, to obtain metals in the oxides form. This does not solve the problem of roasting copper-bearing concentrates containing other compounds. In 2019 at Głogów Copper Smelter KGHM Polska Miedź S.A., a new, innovative fluidized bed roaster was launched. The innovativeness of the installation results from the need to adapt it to the unusual nature of Polish copper-bearing deposits, i.e. low iron and sulfur content, but significant amounts of organic carbon. The purpose of roasting a mixture of copper concentrates at the Głogów Copper Smelter is to remove organic carbon and convert sulfur from sulphide to sulphate form. The roasted mixture of concentrates is part of the feed to the Flash Smelting Furnace. Changing the nature of exothermic to endothermic material is crucial in the case of furnace operation with design productivity. The work presents the innovative and hybrid nature of the roasting process and the experience gathered during 3 exploitation campaigns.

Production of copper by KGHM – flash furnace process at Głogów Copper Smelter

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Abstract

Głogów Smelter is one of the biggest copper smelters in the world and has an excellent reputation thanks to:

- *large-scale production of copper, above 400.000t/year and silver at the level of 1300t/year*
- *the highest quality of the produced copper and silver*
- *compliance with the global standards in the field of environmental protection.*

Production of copper by the Smelter is realized with application of flash process with direct production of blister copper accordingly to Outotec technology. Two flash furnaces are operating in the Smelter: the first one – started up in 1977, the second one – started up in 2017.
In comparison to the shaft furnace process used by Legnica Copper Smelter the application of flash process makes it possible to achieve a number of effects, such as:

- *lack of costly briquetting of the concentrates with application of expensive, imported binder, such as sulphite lye*
- *complete recovery of S*
- *complete recovery of heat from gases coming from the flash furnace*
- *no need to conduct wet purification of gases, and at the same time avoiding of the shaft slimes and their difficult processing*

The II furnace installation is an improved version of the installation I, with application of new solutions, especially in the following aspects:

- *copper removal from the slag in the electric furnace and system for purification and utilisation of gases from the furnace*
- *new type of steam dryer*
- *processing of Cu – Pb – Fe alloy to increase recovery of lead using lead slag which is directed to production of lead in Dorschel furnaces*

The presentation shows technological and technical parameters of both flash furnaces. An essential innovation is a technology for processing of Cu-Pb-Fe alloy from the electric furnace with achievement of lead slag directed to lead production.

Production of copper and by-product metals by KGHM – shaft furnace process at Legnica Copper Smelter

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Abstract

KGHM's copper production is based on the own concentrates from Rudna, Lubin and Polkowice mines, as well as imported materials and copper scraps.
Two following technologies for production of copper are used:

- *Shaft furnace process at Legnica Copper Smelter*
- *Flash furnace process at Głogów Copper Smelter*
-

The presentation concerns shaft process which is focused on smelting of copper concentrates after briquetting (with addition of sulphite lye) with coke. This technology is used from the beginning of Smelter activity, i.e. since 1953, with many improvements which have been made so far. The process is characterized by good efficiency, low Cu losses in the slag, good recovery of Cu, Pb and precious metals.
However, the problems are:

- *Briquetting costs (imported sulphite lye)*
- *Coke which is a reducer*
- *Wet dedusting*

Gas dedusting is carried out with application of Venturi scrubber, with afterburning of gases in power plant, next purification of gases from SO2 in the Solinox installation, and direction of gas stream of increased SO2 content to Sulphuric Acid Plant.
Legnica Copper Smelter is undertaking a series of actions aimed at improvement of shaft furnace process, i.e.

- *Introduction of dry purification of gases with application of their afterburning in the waste-heat boiler aimed at heat recovery, and then dedusting of gases in a bag filter*
- *Additional installation for purification of gases from As and Hg*
- *Smelting of copper scraps together with concentrates and WEEE*
- *Attempts to change a form of charging to the shaft furnace, with exclusion of binder*

Investigation of the solubility of hydrogen and oxygen in liquid copper

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Abstract

For the usage of hydrogen as a reducing agent as well as a fuel in industrial sized metallurgical processes, the knowledge about the hydrogen solubility in the process phases is necessary. The soluted hydrogen could outgas in further steps and form with oxygen an explosive atmosphere. To avoid this, knowledge about the hydrogen solubility is essential. The amount of hydrogen, which can be soluted in a liquid copper phase, is investigated under different conditions such as temperature and phase composition. In a first step, the planned experiments are simulated using FactSage™ to evaluate the expected results of the experiments and for comparison with previous studies. This study focuses on the influence of temperature as well as the hydrogen partial pressure on the hydrogen solubility. In the next step the obtained results of the modelling should be confirmed in experiments using an equilibrium furnace.

Other studies indicates that the amount of soluted oxygen in the liquid phase has influence on the hydrogen solubility and vice versa. For this reason, the solubility of oxygen in liquid copper is also considered in this study.

keywords: copper, FactSage™, hydrogen, modelling, solubility

Process stability to increase flash furnace campaign life at BHP Olympic Dam operation

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Abstract

In 2017 the Olympic Dam Smelter underwent major maintenance with the intention of running a four year campaign. However by late 2019 lower side wall refractory temperatures began to indicate risk of the flash furnace not reaching the next major maintenance milestone in 2021. During 2020 a new operating philosophy was employed to promote a more consistent and stable operation. As a result of these changes furnace runtime increased and refractory temperatures, cooling jacket heat flux, and hearth growth stabilised. This enabled confidence to make the next major maintenance window and increase campaign life to six years. The approach involved systemising the target feed rate to the furnace, and a renewed focus on process control, to limit variation in the process and the production schedule.

Industrial Slag cleaning of Reduced Iron Silicate Slag – Effect of Process Parameters and Slag Modification

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Abstract

During primary copper sulfide smelting and converting, one of the main copper losses is to the slag, which decreases the overall copper recovery. To decrease the copper losses, which are mechanically entrained or dissolved, a slag cleaning route can be used. At the Boliden Rönnskär smelter in Sweden, the slag from the smelting furnace is treated under reducing conditions in a fuming furnace and then tapped to an electric settling furnace where the copper is separated from the slag under the action of gravity. An industrial trial was conducted in the settling furnace at the Rönnskär smelter to increase the knowledge of the copper content in slag and how the process parameters temperature and settling time influence the final slag copper content. The slag was also modified with CaO, to enhance the slag properties for an increased settling rate and thus decreased copper content. The trial was evaluated by collecting multiple samples on the ingoing and outgoing slag and then compare the slag copper content in the samples. The results showed that the copper content increased with increasing temperature and decreased when the slag was modified with CaO, both parameters had a more pronounced effect compared to the settling time. The slag was also characterized showing that copper was associated with spinels and bubbles, which hinders the settling.

Stabilization of Reactants and Development of Sumitomo Type Concentrate Burner at Toyo Smelter

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Abstract

In order to achieve competitive advantage, Toyo Smelter & Refinery of Sumitomo Metal Mining Co.,Ltd has been charging copper concentrate of around 4,000 tons per day, which is one of the highest levels of smelting capacity with a single flash smelting furnace (FSF). Sumitomo type concentrate burner has mainly two features. One is long life of the reaction shaft of the FSF due to low damage to the refractory bricks. And the other is very low dust generation ratio of approximately 3% because of comparatively compact reaction zone in the reaction shaft and more frequent collision of the concentrate particles. However, the rapid increase of the FSF throughput caused a decrease in the reactivity of concentrate and oxygen in the reaction shaft. This resulted in an increase of magnetite and copper content in slag.

To reduce the copper content in slag, the influence of zinc on slag was investigated. As a result, it was found that zinc induced magnetite formation and affected the viscosity of slag. With the intention of overcoming these problems, optimizing the concentrate burner dimension and introducing equipment to prevent the flushing phenomenon on material powder enabled an improvement in its performance while maintaining an advantage of the Sumitomo type concentrate burner.

Recovery of Palladium and Platinum Particles Suspended in the Al_2O_3-CaO-SiO_2 Slag Using Copper-based Extractants at 1723 K

Takashi Murata, Waseda University, Japan
Katsunori Yamaguchi, Waseda University, Japan

Abstract

Platinum group metals (PGMs) are rare precious metals mined only in a few regions of the world. Recycling PGMs used in automotive catalytic converters is of utmost importance to meet increasing global demand. The Rose process is the main recycling process used in Japan to recover PGMs from spent automotive catalytic converters. The recycling process involves smelting a ceramic structure, in which PGMs are supported, with Cu, Cu_2O, reductants, and fluxes such as CaO and SiO_2.

This study compared the Pd and Pt recovery capability of Cu or Cu_2O as extractants. Pd and Pt particles were simultaneously suspended in Al_2O_3-CaO-SiO_2 molten slag, and the extractant Cu or Cu_2O was added. The concentration of Pd and Pt in the slag as a function of processing time was investigated at 1723 K of the operating temperature in the Rose process, under carbon saturation. The results show that the suspended Pd and Pt particles were combined by collisions in the slag, and the recovery ratio and recovery speed of Pd and Pt suspended particles were higher when using Cu_2O than when using Cu. The Cu_2O dissolved in the slag was reduced to metallic Cu in the slag and alloyed with the suspended PGMs particles to form Cu-PGMs alloys. As a result, the particle size of the PGMs increased and sedimentation motion in the slag is promoted.

Failure Analysis on Waste Heat Boiler Tube used in Khatoon Abad copper smelting complex

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Mohammad Khorasani, National Iranian Copper Industries Company, Iran

Abstract

In this Studies the microstructure and chemical composition of waste heat boiler tube of Khatoon Abad copper smelting complex was investigated. SEM, EDS and line scan for microstructure observations and spectral analysis for chemical composition analysis was carried out. Results show that the steel in the sample was ASME-SA210-A1 plain carbon steel with a ferrite matrix with 30±6.3µm grain size. The structure of the steel was homogeneous without any impurities and inclusions. It seems corrosion in this sample occurs because of operational parameters such as the applied heat regime and the geometry of the tubes and no stress corrosion cracking was observed.

Advanced Analysis of Flash Smelting Furnaces

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Abstract

Assessment of concentrate smelting within a flash smelting furnace is available with the use of Computational Fluid Dynamics (CFD). Over the past 2 decades, Hatch has developed various CFD models and techniques which have been used to assess the multi-phase combustion of concentrate under different process and operating conditions. The assessments have provided valuable input into, furnace sizing, dimensional benchmarking, and the development of new technologies and upgrades. Hatch couples CFD type assessment with industry experience and furnace industry benchmarking to improve process understandings and mitigate risks associated with major smelter upgrades and process changes.

Complexity: Evolution and Value Creation in Copper Smelters

Prof. Dr. Gerardo R.F. Alvear Flores, Technical Marketing Manager, Rio Tinto Copper, Adjunct Professor, University of Queensland, Singapore

Abstract

Primary and secondary sources of base metals are gradually increasing complexity. This complexity in expressed in terms of lower grade materials, increase in concentration of minor metals and slagging elements. This pattern has clearly affected the non-ferrous metal production, increasing operating costs and investment required to ensure a sustainable production of metals.

This pattern, place smelters in a constant questioning of their competitiveness and with the need of a regular evaluation of cost-effective measures to remain competitive. It is in here, where producers are facing the most critical question: How to differentiate from each other in a business that have been traditionally regarded as a commodity business with commodity technologies used for this purpose.

This paper discusses relevant aspects associated with raw materials complexity and reviews some of the technological response of smelters to manage complexity and improve competitiveness.

Efforts to Improve the Weight, Sampling, and Moisture Determination Process at Oyu Tolgoi

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Gerardo R. F, Alvear Flores, Technical Marketing Manager, Rio Tinto Copper, Adjunct Professor, University of Queensland, Singapore

Abstract

The final price for Copper Concentrate must be agreed between the seller and the buyer based on an agreed specification of the product delivered. Due to product variability and "customer specific" sampling approaches, agreement on specifications can be a contentious and costly issue if effective processes are not in place.
The Weighing, Sampling and Moisture Determination (WSMD) process consists of taking representative physical samples and measurements for moisture and chemical analysis – to determine wet and dry weights (WMT, DMT), and chemical assays of the payable and penalty elements of a product.

In order to achieve "win-win" outcomes from the WSMD process, aspects associated with sampling, understanding of copper concentrate gradual oxidation during the supply chain process from the mine to the smelter, consistent approaches to improve assay service providers' procedures and qualifications, development of systematic analysis of an assay data and reporting process for exchange, and regular round robin tests are used to evaluate accuracy of the sampling process and proper determination of assays.

This paper describes the efforts conducted by Oyu Tolgoi to improve the WSMD process to ensure the price of the product is representative of the agreed specification with their clients.

Application of XGC cyclone burner in the flash converting furnace of Kennecott Smelter

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Abstract

The XGC cyclone burner is a key equipment independently researched and developed by China for flash copper smelting and is essentially different from Outotec's central jet-distribution burner in structure and in reaction mechanism. In 2020, the XGC cyclone burner was successfully applied to the renovation of the flash converting furnace in Rio Tinto Kennecott Smelter in the United States to replace Outotec's central jet-distribution burner. The XGC cyclone burner has solved long-standing problems such as matte segregation, excessive heat in reaction shaft, and high failure frequency in the flash converting furnace of Kennecott Smelter. After the replacement, the flash converting furnace gets much better oxygen utilization and availability. The XGC cyclone burner now has been successfully used in 5 copper flash smelters around the world and will be soon applied in additional 2 flash smelters, which are now under construction. The XGC cyclone burner is the new development direction for the flash smelter.

Key words: XGC cyclone burner, flash converting furnace

CO_2 emission reduction by optimized process control

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Abstract

Copper is considered as an enabler to a greener future and, therefore, the carbon dioxide emissions of its production are of high interest. A short-term opportunity for existing sites to lower unit CO_2 emissions is to optimize the process performance. To enable continuous process optimization Metso Outotec has developed an advanced process control system that include high level metallurgical knowhow in a unique tool called Metso Outotec Process Advisor. It is an expert-level control system that is based on dynamic mass and heat balance model and can be automatically calibrated with process measurements and laboratory assay information. The beneficial effects are seen as optimized energy balance and lower metal losses. Also, simulation-based environmental footprint analysis was conducted to evaluate the effect of process optimization on carbon footprint. The analysis was carried out using HSC Chemistry software to build a relevant flowsheet and to quantify the input and output streams. OpenLCA software was utilized for the life-cycle assessment (LCA) using Ecoinvent 3.5 database. Data from real smelter site operations was taken to verify the calculated cases. The effect of process optimization on CO_2 emissions of unit processes is discussed.

Continuous copper converting with ISACONVERT™ - Technology Update and Applications

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Abstract

The ISASMELT™ furnace technology is recognised worldwide as the leading modern, flexible, environmentally friendly, and low capital cost smelting technology. Batch smelting and converting of copper feeds has been performed successfully in the ISASMELT™ plants of Umicore Precious Metals, Belgium, and Aurubis Lünen, Germany, for over 20 years. When applying the ISASMELT™ technology to continuous converting it is referred to as the ISACONVERT™ process, developed and patented in the 1990s. Kansanshi Mining Plc, part of First Quantum Minerals Ltd, were the first company 'bold and driven' enough to build and successfully commission the first industrial-scale ISACONVERT™ furnace in July 2019 at their Kansanshi Copper Smelter in Solwezi, Zambia. Since installation, the operating team has overcome a number of technical challenges associated with operating the equipment that supports the ISACONVERT™ technology package. The next evolutionary step for the ISACONVERT™ is to directly challenge the need for copper smelting and converting to be co-located.

This paper will describe the current status of the ISACONVERT™ furnace technology. It will review how an ISACONVERT™ furnace and anode casting unit could centralise matte processing duties for a cluster of matte-producing smelters, whilst reducing fugitive emissions. This would provide an opportunity for smelters currently operating with a range of furnace technologies (including the Flash, ISASMELT™, Noranda, or El Teniente reactors) to increase capacity whilst making significant cost reductions via the decommissioning of multiple converting units.

Peirce Smith Converter Blow-by-Blow and Heat Balance Optimization Model for Glencore's Pasar Smelter

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Abstract

Glencore's PASAR Cu smelter in the Philippines uses traditional Peirce Smith Converter process to process Cu matte from its Flash Furnace and produce Blister Copper. The converting cycle includes three slag blows and one Cu blow and in addition to receive furnace matte, the recirculating load of cold charge must be processed. The reverts include matte skulls, spills and other streams as well as high Cu grade stream such as reject, scrapped or spent anodes. It is important for the smelter to maximize its capacity to consume all the high grade reverts as well as matte reverts. To achieve this goal, a thermodynamic-based converter blow by blow model was built to look for opportunities to improve overall heat balance and optimize the reverts processing capabilities.

This article describes the setup and results of the steady state model used, the different optimization cases considered and the impact of the model in the converter aisle operation at PASAR's smelter.

In addition, this model lays the foundations of a dynamic, real-time model for each converter. The possibility of using such model as a digital twin of the converter's at PASAR and its implication in as an advisory tool for the operators is discussed.

Copper, the metal - reserves, demand and production technology needed for the climate change era

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Abstract

Will the world have sufficient copper and will production match projected demand? Reports of searing summer temperatures and climate change in North American and Europe and the call to renewable energy fills the news. Copper is the one important metal that will be key to expanding renewable energy- copper is vital for electrical vehicles, hydrogen electrolysis, wind and solar power and more. This paper discusses copper resources, demand, and production technology – now and into the future.

Valorisation of copper slag: Zero-Waste Production of Pig Iron and Glass Fibers

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Abtract
This study demonstrates a way to valorize a fayalitic copper slag through carbothermic reduction (CTR) into a pig iron phase and a secondary glassy phase.

The latter is used for glass fiber production.
CTR is realized with graphite, petrol coke, and high fixed carbon alternative reduction agents in pelletized form at 1400°C and 1500°C. A magnesia-chromite lining (typical for copper smelters) in a SiC-crucible within an induction furnace is used. Experiments are realized under an argon atmosphere. To improve the quality of the resulting pig iron phase, a first step with only "slight reduction" is introduced. A separation of the copper together with some iron can be realized, which can be recycled to the copper process. While this reduces the total amount of produced iron phase, it allows for copper lean pig iron production.

The secondary glassy phase is directly used for fiber production. We also investigate the mixture with additives (e.g. B2O3, MgO, Na2O, CaO), to adjust the viscosity vs. temperature dependence. The properties of the glass fibers are characterized and evaluated in respect to their applicability as insulation or for construction materials.
Our future aim is to show the transferability of this process to a TRL-5 scale, using a Top Submerged Lance (TSL) furnace of 15 kg melt capacity. If implemented, this process could produce high quality construction materials without waste out of the ~25 Mt of copper slag produced annually.

Blister Tapping: increasing production with CFD

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Abstract

Tenova South Africa (Pty) Ltd, operating as Tenova Pyromet, in partnership with BHP Billiton Olympic Dam Corporation Pty Ltd, have used computational fluid dynamics (CFD) analysis to determine to what extent the service life of a taphole on an Electric Slag Furnace (ESF) can be safely increased.

Improvements related to tapping operations are a high priority for BHP and reducing the amount of downtime is a focus area. In support of this goal, Tenova Pyromet was approached, as part of a larger engineering collaboration, to analyse the existing taphole design and modify the design to safely increase production throughput. Multiple CFD analyses were completed to characterize the existing tapping operation, develop a benchmark model and use this as the comparative basis against which design changes were measured.

A sensitivity study was completed to test the responsiveness of the models, evaluate the impact of proposed material changes and to evaluate the suitability of proposed instrumentation additions to monitor the tapping operation. The results of this investigation are presented and discussed.

Measurement of minor elements in the black-copper smelting process by microanalysis techniques

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Abstract

Slags are a major product in metallurgical processes, which use becomes more and more important in terms of saving natural resources. Deep knowledge on the production process and the effect of process parameters on the products allows active value engineering. New techniques are an important tool to achieve this goal. Minor elements in the samples collected from an industrial trial for black-copper smelting were determined by quantitative microanalysis technique, combining Electron Probe Microanalysis (EPMA) and Laser-Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS). Major factors affecting analysis accuracy, including analysis precision, detection limits, background correction, beam damage and standard selection were discussed. The minor elements distributions determined in present study were compared with available literature data and FACTSAGE thermodynamic calculations. It was demonstrated that minor element distributions could be obtained with precision close to that of laboratory studies by direct measurement of industry samples upon careful sampling, microstructural examination and applying customized analytical routines. The advantages and limitations of using microanalysis techniques for industry slag assay were also discussed.

An update of Boliden Harjavalta copper smelter

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Juha Järvi, Boliden Harjavalta, Finland

Abstract

Copper smelter, today owned by Boliden, has been operated in Harjavalta since 1945. The first commercial flash smelting process was commissioned here in 1949.

This paper describes current operations and experiences since latest process modifications executed in 2019 as the concentrate throughput was debottlenecked by 20% to 620 kt per annum. The main modification included concentrate drying, dry charge feeding, flash furnace, and heat recovery boiler. Also, an update on new acid plant's operation is described.

Hydrogen reduction of entrapped metal oxides from fayalitic copper slags

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Bernd Friedrich, Institute of Process Metallurgy and Metal Recycling (IME) RWTH Aachen, Germany

Abstract

The avoidance of CO_2 emissions is also leading to a rethinking of processes in non-ferrous metallurgy which were previously carried out with carbon. A popular solution at the current time is substitution by the use of hydrogen. In this study, metal reduction from slags will be investigated using liquid copper slag as an example within the framework of the EU project HARARE. The aim is to reduce the amount of carbon used in copper production and to increase the copper yield. Thermochemical observations with FactSage™ show that the valuable metal content of Cu, Sn, Ni, Pb and Zn can be significantly reduced. The experimental implementation gives hope that the innovative process can be used to reduce copper and other heavy metals with hydrogen. The influence of the hydrogen content in the reduction gas is being investigated. The results will be evaluated for scale-up and for the use of the slag as an iron carrier.

Temperature and oxygen partial pressure effect on arsenic condensation and reaction mechanisms in Flash Smelting off-gas line conditions

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Abstract

Arsenic is a common impurity element in sulphide concentrates and it tends to accumulate in the flue dust of the Flash Smelter (FSF) due to its high volatility and internal circulation of the flue dust in the smelting-converting process chain. The only outlets, in addition to minor partitioning to the off gas, for arsenic are anodes and discard slag. A separate flue dust treatment for arsenic removal is possible but it creates an additional process for the smelting plant with an influence on CAPEX and OPEX of the processing.
The aim of this study is to find out the influence of temperature and gas composition on the condensation reaction mechanisms of arsenic compounds in the FSF off-gas line conditions for better understanding of the partition of the arsenic between dust and cooled off-gas.

Arsenic condensation has been studied with a newly designed set-up with a filter at temperatures below 500 °C where the gas atmosphere was controlled by the gas mixture of SO_2*/Air/*N_2*.*

The amount of evaporated arsenic was measured and subsequently condensed arsenic dusts on the filter were collected and characterized to determine the mineralogical phases, particle sizes, and chemical speciation. Based on these experimental results, the formation mechanism of the arsenic-containing dust and the influences of temperature and atmosphere on the process was compared and discussed.

Experimental Study of the (Cu_2O)-FeO-Fe_2O_3-SiO_2 Slag System at fixed pO_2

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Abstract

The phase equilibria of the Cu_2O-FeO-Fe_2O_3-SiO_2 slag system in equilibrium with metallic copper and the FeO-Fe_2O_3-SiO_2 slag system were investigated at fixed pO_2 between 1200-1700 °C. High temperature equilibration of synthetic slag/metal mixtures, followed by quenching and the direction measurement of the phase compositions with the electron probe X-ray microanalysis (EPMA) was used to determine the liquidus temperature, and liquid slag and solid oxide compositions at equilibrium conditions. The experimental work extended the range of temperatures that the Cu_2O-FeO-Fe_2O_3-SiO_2 slag system in equilibrium with metallic copper was studied at fixed pO_2 to 1400 °C. Additionally, the liquid slag compositions at the two liquids miscibility gap over cristobalite in the FeO-Fe_2O_3-SiO_2 system was experimentally measured for the first time. The present study was an important continuation of previous investigations by the authors into the Cu-Fe-Si-O multicomponent slag system, aimed at providing information for improving the thermodynamic models for all phases in this system.

Current Peirce Smith Converter Practice At Kansanshi Copper Smelter

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Abstract

The greenfield Kansanshi Copper Smelter is part of Kansanshi Mining Plc, a company jointly owned by First Quantum Minerals and ZCCM Investment Holdings. Nameplate copper concentrate treatment capacity is 1.2 million tonnes per annum. Concentrate is supplied from the Kansanshi mine and Kalumbila Minerals Limited mine.

The smelter has four Peirce Smith Converters with a capacity to treat 350 tonnes of matte and produce 250 tonnes of blister per cycle. The operating scenario is "two in stack at any one time, one on hot standby or holding metal for scheduling purposes, and one on turnaround maintenance".

Matte treatment currently averages 77,000 tonnes per campaign with a maximum of 87,000 tonnes. Corresponding blister production averages 57,000 tonnes per campaign with a maximum of 65,000 tonnes. In excess of 250 cycles per campaign can be achieved, but for scheduling reasons, some campaigns are closed earlier.

Smelter and Peirce Smith Converter operations in the period from hot commissioning to 2019 have been described in previous publications.

This paper describes general Peirce Smith Converter practices at Kansanshi Copper smelter with focus on production scheduling, ladle management and main aisle crane operation.

Review and thermodynamic analysis of As (arsenic) in solids, liquid mattes, metals, slags and speiss phases

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Viktoria Prostakova, University of Queensland, Australia
Evgueni Jak, University of Queensland, Australia

Abstract

Increasing concentrations of As (arsenic) in mined ores remain problematic for the pyrometallurgy of copper. Many approaches were proposed to eliminate it from the process streams: partial roasting of concentrates before smelting; eliminating to the gas phase during the smelting followed by the processing of dust; chemical fixation of arsenic in the slag phase; additional refining steps for blister copper in the anode furnace. Thermodynamic database developed in the Pyrometallurgy Innovation Centre (PYROSEARCH) contains the phases for the pyrometallurgical processing of copper: gas, liquid matte, metal, slag, speiss, as well as solid sulfides and arsenides. The database is continuously improved using the integrated experimental and thermodynamic modeling approach and can be used for process optimization through computer simulation of individual units and complete flowsheets. Present study provides a critical review of available literature data and recent experimental results obtained in PYROSEARCH for the thermodynamic properties, phase equilibria and distribution of arsenic among these phases. A set of diagrams is used to explain the effect of process conditions, i.e. slag composition, on the distribution of arsenic. Also highlighted, are areas where the lack of experimental information still exists. Kinetic factors affecting the achievement of thermodynamic equilibrium for arsenic distribution are discussed.

Development and Industrial application of "SBF + MTC" Continuous Copper Smelting Technology

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Abstract

"Side-blown Smelting and Multi-lances Top-Blown Converting" is referred to as "SBF+MTC" continuous copper smelting technology. As a new continuous copper smelting technology independently developed by China, it has the advantages of short process flow, low investment, low energy consumption, clean and environmental protection. The technology has developed rapidly in recent years, with three large smelter complexes in China and DRC, with throughput of over 3.7 million tons of copper concentrate per year, and several more plants using this technology are under construction now.

This paper introduces the process flow, process characteristics and engineering design of "SBF+MTC" continuous copper smelting, and introduces several typical industrial application references, and the future development of this technology is prospected.

Keywords: Side-blown smelting, Multi-lances Top-blown converting, "SBF+MTC" Continuous smelting technology, Industrial Application.

Controlling accretions formation in the waste heat boiler off gas intake of the Isasmelt furnace at Southern Peru Ilo Smelter

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Abstract

The Ilo Smelter of Southern Peru has been operating since 2007 with an Isasmelt furnace as a single smelting unit (1,200,000 tpy of copper concentrates) which is associated with a large waste heat boiler. Depending on the operational performance of the Isasmelt furnace lance, large accretions can be formed at the WHB intake, which seriously affects the smelter productivity. This paper describes the modifications and improvements carried out at Ilo Smelter in order to reduce the lance splashing and increase its oxygen utilization efficiency in order to minimize the formation accretions in the WHB intake.

New Approach to Continuous Development of Thermodynamic Databases for Applications in Copper Production

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Abstract

Accurate prediction of complex chemistry in modern copper production requires the use of multicomponent multiphase thermodynamic databases. Pyrosearch has been continuously developing a database now containing 20 elements using the integrated experimental and modeling approach. Targeted experiments are selected to fill in the gaps in literature data, and the results are used to improve the model. It is an iterative process. The time and effort spent into constant development and maintenance of a multicomponent database grows exponentially with each added element.

A new modelling approach has been developed which greatly alleviates the efforts on the database maintenance and allows to continuously update the whole database when new experimental data become available. The overall optimization procedure has been formalized and many of its parts have been automated. Strict quantitative criteria have been developed to judge the quality of optimizations and overview the overall quality of a database. Introduction of first derivative matrices of target values as a function of model parameters allows real-time sensitivity analysis throughout the database, finding optimal combinations of model parameters and their values.

Examination of reaction mechanism by in-situ observation of combustion behavior of copper concentrate granules

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Abstract

In the flash smelting furnace shaft, molten sulfide (matte, Cu_2S-FeS) and molten oxide (slag, 2FeO-SiO_2) are formed from copper concentrate and silica sand. Due to the reasons such as a decrease in the concentration of copper in the concentrate, it has become difficult to improve only from the conventional theory and experience of actual operation. Therefore, in this study, in-situ observation of copper concentrate combustion behavior was carried out for the purpose of elucidating the detailed reaction mechanism of copper concentrate particles that undergo a wide temperature and composition range in the flash smelting furnace shaft, and suspended copper. The temperature of the concentrate particles was measured at the same time.

A combustion tests were carried out by forming samples into a columnar shape under conditions in which the gas temperature, oxygen concentration, and gas flow velocity were controlled to be uniform. Samples are chalcopyrite ($CuFeS_2$), pyrite (FeS_2), and several types of concentrate.

As a result, combustion behavior accompanied by various gas generation was observed depending on the mineral species, concentrate species, and oxygen concentration.

This report describes some of the results.

Expanded Opex Comparison of Modern Copper Smelting Technologies and Related Downstream Processes

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Mari Lindgren, Metso Outotec, Finland

Abstract

Operational cost efficiency is a critical success driver to smelters, but operators lock down most of the parameters already when they choose the core smelting technology. This paper focuses on comparing different copper smelting options available in the market and estimating via HSC-SIM simulation which technology offers the best chances for profit maximization under different scenarios. We chose to have a closer look at Flash Smelting (FSF)-PS-Converting (PSC), Flash Smelting (FSF)-Flash Converting (FCF), TSL Smelting (TSLS)-PS-Converting (PSC), TSL Smelting (TSLS)-TSL Converting (TSLC), Mitsubishi Smelting Process (MSP), Bottom Blowing Reactor (BBR)-Bottom Blowing Continuous Converting (BCC), and Side Blowing Furnace (SBF)-Top Blowing Converting (TBC) since these seem to be the main state-of-art technologies now being applied in many recent copper smelter projects around the world.

This is a continuation to the authors' previous article on the topic, presented at Copper 2019. The methodology has been revisited and developed further to include also wet gas cleaning, acid production, copper fire refining, anode casting and tankhouse electrorefining, along with carbon pricing for Scope 1 and 2 emissions. With these additions, the majority of the operational costs are now captured, allowing an even better comparison to real world references. Furthermore, a cost graph is generated based on geographical differences to illustrate how much location may affect the cost structure.

Freeport-McMoRan Miami ISASMELT – Operational Improvements

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Abstract

Freeport-McMoRan Inc. (FCX) uses ISASMELT™ TSL technology for the primary smelting of copper concentrates at the Miami Smelter. The furnace was installed in 1992 as an energy efficient primary smelting alternative to an electric smelting furnace. Oxygen enriched air and natural gas are injected through a vertical lance partially submerged in a molten bath. Blended concentrate, flux and secondary materials are added through a port in the furnace roof and then react in the slag layer of the turbulent molten bath. The furnace is a semi-continuous operation with a tap hole being opened / closed at certain bath heights. Lance tips commonly fail due to high-temperature oxidation and / or contact with corrosive matte. Lance failures increasingly reduced the furnace availability, becoming the predominant cause for smelter downtime. The Miami Smelter assembled a cross-functional agile team to identify the root cause of lance failures with the goal of increasing furnace availability to maximize smelter throughput. Inconsistent bath temperature and chemistry, along with lance immersion operations were determined to be the main factors affecting lance life. Process targets and improvements were implemented to improve the consistency of bath temperature and chemistry. A key improvement developed was a novel furnace temperature controller based on cooling system heat losses that automatically adjusts the natural gas flow rate. Lance life was improved to exceed the industry standard, contributing to Miami Smelter setting an annual concentrate throughput record in 2020.

The study of the effect of SO_2 gas formation at the matte/magnetite interface by in-situ observation

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Sakiko KAWANISHI, Tohoku Univ., Japan
Sohei SUKEGAWA, Tohoku Univ., Japan
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Abstract

During copper smelting using a flash furnace, the solid magnetite (Fe_3O_4) phase that stagnates at the slag/matte interface inhibits the absorption of the suspended matte in the slag into the matte, resulting in copper loss. However, the phenomena that occur at the magnetite/matte interface are complex, and the effect of gas formation at the interface on the removal of magnetite has not been studied. In this study, we elucidated the effect of gas formation on the dissolution of the magnetite phase into the matte by directly observing the high-temperature reaction interface through the magnetite thin film. In contrast to the rapid dissolution of magnetite into FeS in the absence of gas formation, magnetite dissolution was strongly inhibited at the Cu_2S/magnetite interface by the generation, agglomeration, and accumulation of SO_2 gas bubbles. A quantitative analysis of the dissolution rate of the magnetite phase into Cu_2S indicated that the mass transfer rate of Fe in the matte is extremely low. We also discuss the contribution of the generated SO_2 gas to the inhibition of the interfacial reaction.

Experimental phase equilibria study and thermodynamic modelling of the "$CuO_{0.5}$"-$AlO_{1.5}$-SiO_2 ternary system in equilibrium with metallic copper

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Abstract

The "$CuO_{0.5}$"-$AlO_{1.5}$-SiO_2 system in equilibrium with metallic copper is an important part of copper smelting, converting and recycling slags in use by industry today. Silica (SiO_2) is present in copper concentrates and is the main flux in slags used in the pyrometallurgical production of copper. Alumina (Al_2O_3) is usually introduced into the process with concentrates or recycled wastes from electrical and electronic equipment (WEEE) and it is known to lower copper solubilities in fayalite slag in equilibrium with matte.

Phase equilibria studies were undertaken on the "$CuO_{0.5}$"-$AlO_{1.5}$-SiO_2 system in equilibrium with metallic copper with the use of equilibration and quenching technique followed by electron probe X-ray microanalysis (EPMA). The liquidus of the "$CuO_{0.5}$"-$AlO_{1.5}$-SiO_2 system, including the two 2-liquid miscibility gaps as well as the cuprite (Cu_2O), corundum (Al_2O_3), delafossite ($CuAlO_2$), tridymite and cristobalite (SiO_2), and mullite ("$3AlO_{1.5}\cdot SiO_2$") primary phase fields has been determined. The alumina and copper oxide solubilities in tridymite and cristobalite (SiO_2) have been measured for selected temperatures. These impurities stabilize cristobalite (SiO_2) over tridymite (SiO_2) at low temperatures that was confirmed by electron probe X-ray microanalysis (EPMA) and X-ray powder diffraction (XRPD). The experimental results were used for the improvement of the existing thermodynamic database used to describe pyrometallurgical multi-component multi-phase systems.

Review of Global Slag Cleaning Furnace Practices

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Isabelle Nolet, Hatch, South Africa
Lucy Rodd, Hatch, Canada
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Abstract

Slag Cleaning Furnace (SCF) operations are of paramount importance to further treat metallurgical slags, achieve reliable base metal recoveries, and produce waste streams that can be safely disposed. However, there is limited information available in the public domain regarding the operating philosophy, efficiency of base metal recovery and equipment design. Hatch has therefore conducted a survey of various Cu-Ni smelters with the objective of collecting information regarding SCF operations and practices such that all industry stakeholders may benefit from this comparative information. The survey contains information such as furnace configuration and key design features, operating practices, process metallurgy including feed and product characteristics, furnace campaign life, and key drivers for slag cleaning including metal recovery and environmental considerations.

Design, construction and performance of the copper cooling system installed in the first ISACONVERT™ copper converting furnace.

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Isobel Mc Dougall, Tenova Pyromet, South Africa
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Stanko Nikolic, Glencore Technology, Australia
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Abstract

The first ISACONVERT™ copper converting furnace was commissioned at Kansanshi Mining Plc in 2019 and a number of successful operating campaigns have been completed since. The furnace was built to operate as a demonstration unit prior to becoming a production vessel for the site. Industry experience indicated that an aggressive slag combined with a high sidewall heat load would be anticipated and so Glencore Technology contracted Tenova Pyromet to design and supply a copper cooling system for the slag bath sidewall. Tenova Pyromet selected its high intensity MAXICOOL® copper cooling system due to the expected operating temperatures and heat loads of the furnace. The hot face of each cooling element was initially coated with a sacrificial monolithic refractory layer. To date no wear has been detected on the MAXICOOL® copper coolers and a stable slag freeze lining is maintained on the hot face of the cooling elements. In this paper, we review the design of the copper cooling system, its installation, and its performance during the initial pilot campaigns. In particular, we compare the measured operating heat fluxes and cooling element temperatures to that calculated during the design phase. Finally, we explore potential improvements for future installations.

Reaction State Improvement in Flash Smelting Furnace

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Abstract

Flash smelting furnace in Saganoseki smelter is currently treating various kinds of raw materials. In recent years, the alumina content in slag is increasing due to the increase of gangue components in concentrates and the increase in treatment of secondary materials. In addition, some of the feeding materials are difficult to react due to their coarse particle size. The changes would cause an increase of solid spinel and unreacted substances in the slag. As a result, the slag fluidity deteriorates, and the copper loss in slag increases.

The smelter examined the reaction state improvement in the flash smelting furnace to mitigate the above situation. By achieving more uniform reaction state in the reaction shaft by adjusting the balance of the solid-gas reaction, it was expected that the amount of excess spinel generation and unreacted substances would reduce. CFD techniques were utilized to predict the improvement in reaction state. The effect of operational parameters' adjustment on reaction state was investigated. A quantitative evaluation method for reaction state was also established based on sample analysis of reaction products falling in the shaft. Several ideas were planned and tried in the commercial furnace, and the reaction states were evaluated. In this way, the smelter is continuously trying to improve the reaction state in the flash smelting furnace and to treat various kinds of raw materials.

Heat Recovery Steam Dryer, a novel concept to utilize low calorific heat sources to increase drying efficiency

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Abstract

Kumera Steam Drying Technologies with Kumera Steam Dryer and its energy upgraded heat recovery -based solutions offer remarkable savings in energy and environment basis. Energy efficiency of Steam Dryer is more than 30 % better than a conventional drying process meaning the smallest carbon foot print and avoidance of harmful environmental emissions. Kumera Steam Dryer has given solution for advanced smelters during the last decades. Further research and development have announced a Steam Dryer with Heat Recovery system. This Kumera Heat Recovery Steam Dryer represents the latest development in targeting highest energy efficiency and lowest emissions.

Kumera Heat Recovery Steam Dryer is lifting energy efficiency into a new level. Heat Recovery Steam Dryer can utilize low calorific heat sources. Heat Recovery Steam Dryer can win the common challenges in concentrate drying. It can handle complicate chemical compositions and it is tolerating corrosion. The fuel consumption, off-gas generation, dust emission and environmental impact have been minimized.

Kumera Heat Recovery Steam Dryer boosts environmentally friendly operation in non-ferrous smelting processes. Increasing environmental requirements and emission limits, force industries to find energy efficient and fewer polluting solutions and move from conventional drying furnaces into energy efficient steam-based processing.

Replacing a fossil fuel heated dryer with the Kumera Heat Recovery Steam Dryer, thermal efficiency is taken to a completely new level for drying of concentrates, minerals, lignite, bio-mass and other materials. Kumera Heat Recovery Steam Dryer uses exhaust vapour from Steam Dryer, or other waste heat sources. Heat Recovery Steam Dryer CO_2 emission reduction is remarkable compared to any direct fired drying process utilizing primary fossil energy. Alternatively, the Heat Recovery Steam Dryer can be used to increase the existing drying capacity by up to 40 % without any additional use of primary energy or steam. Energy is limited to utility power, only. Waste heat for the Heat Recovery Steam Dryer is recovered from an existing Steam Dryer or other waste heat source of the smelter. This solution is extremely viable when a limited amount of steam is available.

Steam Dryer has high number of advantages to improve the smelter process. High availability and a low level of maintenance are boosting smelter process. While the dryer has higher availability than the main process, it allows full flexibility for the main process. Steam Dryer has opportunity for water recovery, which is vital at dry areas with limited water reservoirs. It captures even the moisture from the concentrate.

The dust emission rate is low, due to a low gas flow rate inside the dryer and in Heat Recovery Steam Dryer the steam recovery system is also part of the dust recovery process. Gases are purified in-between the Steam Dryer and Heat Recovery Steam Dryer when the dust is separated.

The Kumera Heat Recovery Steam Dryer can be installed into a new production line or to modify an existing one. There are 30 installations (2021) of Kumera Steam Dryers in the last twenty years, and newest reference is the Kumera Heat Recovery Steam Dryer with a feed capacity of 61 t/h that replaces an oil-fired rotary dryer in a smelter in Finland. This Heat Recovery Steam Dryer utilizes the steam energy coming from the exhaust gases of the existing Kumera Steam Dryer. The Kumera Heat Recovery Steam Dryer is benchmark technology for energy-efficient water removal and an answer for tightening environmental and energy requirements.

As a summery, Kumera Heat Recovery Steam Dryer represents the latest development, increases drying efficiency to a higher level than ever before. It can utilize low calorific heat sources, exhaust vapour from Kumera Steam Dryers or other waste heat sources. Dryer minimizes fuel consumption, off-gas generation, and dust emissions. with it, the CO_2 *emission reduction is significant compared to any direct fired drying process utilizing fossil energy sources and operation cost is limited to utility power. Heat recovery Steam Dryer has high capacity of concentrate feed rate at 100 t/h and high capacity of water evaporation rate at up to 10 t/h with temporary steam boost. Its superior energy efficiency is answer for tightening environmental and energy requirements.*

Silver Solubility and Effect of Copper Concentration on the Activity Coefficient of Silver Oxide in the FeOx-SiO2 slag system at 1573K

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Abstract

There is an increasing trend in the copper smelters to recycle electronic materials, which contain relatively high concentration of silver. Silver lost in the slag is increasing with increasing of treated scrap amount. To determine the portion of the silver chemically dissolved in the slag will be a key factor to improve the recovery of those metals.

An experimental study was carried out to determine the solubility of silver in the FeO_x-SiO_2 *slag equilibrated with a pure liquid silver and the molten Ag-Cu alloys at 1573 K in the range of oxygen partial pressure from* 10^{-9} *to* 10^{-6}*. The solubility of silver in the slag tends to increase with increasing oxygen partial pressure and the activity of Ag in the alloys. Therefore, lower oxygen partial pressure and lower concentration of silver in the metal phase tend to lower silver dissolution in the slag. Based on the measured silver solubility and the oxygen partial pressure, activity coefficients of silver oxide in the* FeO_x-SiO_2 *slag were derived. The activity coefficients of* $AgO_{0.5}$ *in iron silicate slag show a constant value regardless of the oxygen partial pressure and the copper concentration in the slag.* $AgO_{0.5}$ *and* $CuO_{0.5}$ *in the slag are known to be neutral oxides. We found that* $AgO_{0.5}$ *and* $CuO_{0.5}$ *in the slag behaved as ideal solution from the derived activity coefficient of* $AgO_{0.5}$*.*

Metso Outotec Flash Smelting technology – development together with the customers

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Abstract

Thanks to over 70 years of operating history of the Outotec Flash Smelting process, feedback from the numerous operating sites is available and development work is often carried out in co-operation with our customers. Metso Outotec is continuously working on developing its portfolio of equipment to better suit the needs of our customers in the continuously changing operational environment. Orebodies are getting more challenging and processing of recycled materials becomes even more important. Some of the newest innovations are related to optimizing process gas distribution to the Flash Smelting furnace, feed distribution to the furnace and feed rate stability. In order to reach long term optimal process results, not only the equipment design has been considered, but also the monitoring and control of the equipment and furnace operation in order to upkeep the performance. The general goals for the development work have been to improve equipment performance and to prolong its lifetime, thus realizing savings in smelter plant operation costs. Digitalization has already allowed new opportunities to improvements in equipment and furnace monitoring and control. This paper highlights the latest developments in furnace feed system and new digital products and shows their effect on the improved process performance.

Miami Smelter - Top Submerged Lance Furnace Cooling System Performance

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Abstract

The Freeport-McMoRan Miami Smelter processes copper concentrates and metal-bearing recycle materials in Claypool, Arizona. Blended concentrate, flux and secondary materials are smelted in an ISASMELT^{TM} TSL furnace. The furnace was upgraded in May 2017 with additional and upgraded cooling elements to extend the refractory's campaign life. Included in the upgrade were novel lintel shelf coolers installed in the freeboard section of the furnace. The ISASMELT^{TM} furnace has been relined twice since the initial 2017 install as part of planned turnaround work; it has yet to be operated to failure. Recent developments for the system include improvements in alarm monitoring and lintel cooler design, along with the external replacement of damaged lintel coolers. Operating data and refractory wear measurements from the two furnace campaigns were analyzed to assess the cooling system's performance. Operating campaign life has nearly doubled since the 2017 upgrade. Performance data from the two campaigns were used to project campaign life.

Operation and improvements of the first industrialized bottom blowing continuous furnace

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Abstract

Commissioned in March 2014, the first bottom blowing continuous (BBC)furnace at YuChuan copper smelter in China has been running for more than seven years. Compared with the traditional PS converter, it shows great environmental and production advantages. In the seven years until now, the other 5 BBC furnaces were built and in operation in other plants.
Although Its capacity and reliability have improved over time in these years, but compared with other BBC furnaces, some Factors is still not good enough, such as Spray gun life, copper content in slag, splashing at feeding port and so on. So, in May 2021, some modifications were completed during minor overhaul.

This paper presents an overview of the main operation conditions of BBC furnace in YuChuan copper smelter, the improvements that have occurred since its commissioning and the effect of the modifications of the vessel.

Integrated Experimental Phase Equilibria and Thermodynamic Modelling Study of the PbO-ZnO-$CuO_{0.5}$ Slag System in equilibrium with metal

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Evgueni Jak, Pyrometallurgy Innovation Centre (PYROSEARCH), School of Chemical Engineering, The University of Queensland, Australia.

Abstract

The phase equilibria of the PbO-ZnO-$CuO_{0.5}$ slag system in equilibrium with metallic copper solid and/or lead-copper liquid alloy was investigated between 700-1000 °C. High temperature equilibration of synthetic slag/metal mixtures on copper or iridium substrates, followed by quenching and the direct measurement of the phase compositions with the electron probe X-ray microanalysis (EPMA) was used to characterize the a) Massicot (PbO), b) Zincite, c) Cuprite, and d) Copper plumbite (Cu_2PbO_2) primary phase fields of the system. Experimental data obtained from the present study were used to produce a self-consistent set of parameters of the thermodynamic models for all phases in this system using the FactSage computer package. The present system was part of a broader study of the 18-element PbO-ZnO-Cu_2O-FeO-Fe_2O_3-CaO-SiO_2-Al_2O_3-MgO-S-(As, Sn, Sb, Bi, Ag, Au, Ni, Cr as minor elements) multicomponent system for the ***nonferrous metal smelting and recycling industries.***

Peirce Smith Converter test with metal fibre reinforced ceramic composites

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Abstract

In copper conversion furnaces there are areas of high wear due to mechanical, chemical and thermal influences. In general, areas such as tuyere line and charge mouth are the ones that present the greatest wear. Magnesia chrome bricks or refractory castables generally line these areas.

This document shows the post-use results of the use of refractory silica alumina and chromium alumina castable with the addition of metallic fibers as internal matrix (30% weight) in the format of pre-shaped pieces, which were tested in the charge mouth and tuyere line. The application of these materials in converter furnaces had different results and behaviors in the different zones. In the tuyere line it failed to show any difference in wear rate, but it did show a different wear behavior. In the area of the mouth he managed to go from 6 months to 14 months, finding less wear, but different from each other depending on the type of material used. All of these tests were performed without changing any operational variables. The traditional installation of these materials had to be changed to support these pre-shaped pieces.

Methodological investigation of a four-electrode electrical conductivity setup in a binary SiO_2-PbO system

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Abstract

As a result of the globally increasing consumer use of electronic devices, it is expected that serious pressure will be put on the supply chain of precious metals including copper. Hence, recycling of these electronics becomes increasingly important, as well as optimizing the current processes. One major issue in copper production is the amount of metal that is lost to the slag. This metal loss is inherent to the production process and therefore, additional processing steps such as slag cleaning may be required. Slag cleaning can be done in electrical resistance furnaces in which heat is produced using the Joule effect, making the slag's electrical conductivity an important operating parameter. However, conductivity data for secondary copper smelting slag containing PbO and/or FeO_x are scarce. As a first step for this project, a conductivity measurement setup was constructed based on a four-electrode configuration using Pt wires and a potentiostat to record the impedance. The methodology was then determined via a set of experiments in a binary SiO_2-PbO slag system. Conductivity data and impedance spectra were then compared to literature data to confirm the validity of our setup and methodology.

Reduction Smelting of Copper Oxide Concentrate Containing High Silicon and Low Iron

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Abstract

A copper smelting blast furnace at the COMMUS smelter in DRC is used for treating copper oxide concentrate using reduction smelting. The equipment and operation parameters of the traditional copper smelting blast furnace are optimized to suit the characteristic of high silicon and low iron of the concentrate. By increasing the height of the feed column, both the electric heating of the furnace settling bath and the feed drying system are removed. The operation rate of the equipment is increased with the installation of new type of blower. The slag composition is optimized according to the composition of concentrates. The copper recovery is improved, and the coke and limestone consumption per ton of copper is greatly reduced, lowering operating cost. The operation performance in COMMUS smelter shows that the reduction smelting process for treating high silicon and low iron copper oxide concentrate is profitable and displays high efficiency and provides a reference for treatment of similar oxide ore flotation concentrates.

Soluble Copper Losses in Copper Smelting Slags at Different %Fe/SiO_2 and Different %Fe in Matte

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Mika Muinonen, XPS Expert Process Solutions, Canada

Abstract

The present work focused on the impact of temperature, %Fe in matte and %Fe/SiO_2 in slag on the soluble copper losses in Cu smelting. In these preliminary trials, it was found that temperature and the %Fe/SiO_2 in slag had a minor impact on Cu soluble losses in slag.

The %Fe in matte was found to be the most important factor influencing the soluble copper losses. In the measurements, it was shown that minimal Cu losses were obtained with 8-10% Fe in matte. At 8-10% Fe in the matte, the soluble copper losses were measured at 0.44% by weight.

When the %Fe is lower in matte, the %Cu increases rapidly and theoretically, extrapolates to approximately 5-7% Cu in slag when the %Fe in matte approaches 0 (Cu_2S converting to Cu). This is mainly due to an increase in oxygen potential which raises the Cu_2O level of the slag.

The results of this experimental work show that operation of the smelting furnace, of the slag settler, is optimal at a %Fe of 8 to 10% and a temperature of 1200 to 1250°C. When the %Fe in matte is over 6%, the %Cu in slag is under 0.5% by weight. Depending on the efficiency of settling in the slag cleaning furnace, Cu levels in the range of 0.7 to 1.3% in the discard slag are generally obtained.

Sulfidation for Copper Mineral Processing, Impurity Management, and Slag Recycling

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Abstract

Decreasing ore grades, growing water scarcity, and renewed focus on the sustainability of copper extraction motivates the search for technologies to manage impurities and increase the recovery of copper and valuable byproducts during smelting. An attractive avenue is pyrometallurgical sulfidation, in which a copper-containing slag or mineral is roasted with elemental sulfur or pyrite to favorably alter the anion chemistry of the material. Herein, we develop a new thermodynamic framework to control the selectivity of sulfidation for copper minerals and slags, enabling improved recovery of copper and byproduct elements such as selenium and tellurium, management of oxygen content, and removal of impurities such as arsenic. We then experimentally demonstrate sulfidation of chalcopyrite concentrate, copper smelter slag, and copper selenide, confirming sulfidation as a viable materials pretreatment for use with economically-competitive and environmentally-benign copper electrowinning via molten sulfide electrolysis. The sustainability and applicability of sulfidation are discussed in the context of greenhouse gas emissions, environmental acidification, water resource demand, and capital cost.

Study of the Distribution of Impurities in Flash Smelting and Mitsubishi Smelting Technologies

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Abstract

Birla Copper being a custom smelter, procures copper concentrates from various mines across the globe. Besides copper, concentrates contain various hazardous impurities such as As, Bi, Sb, Pb, Zn, Se, Te, etc. However, these impurities affect smelting operations, product quality, and imposing challenges in managing solid wastes. Intermediate process streams such as dust, reverts, slags are recycled at different stages, resulting in an increased accumulation of impurities within the process. To identify the distribution and mass balance, mapping of elements was carried out from concentrate to all process streams in the entire copper value chain.

In flash smelting, the distribution of As to slag, effluent and liberators is 32%, 23%, and 11% respectively, with the remaining circulated to dust. Whereas in Mitsubishi smelting, it is 39%, 33%, and 3% respectively. Bulk of Sb and Zn in both the smelting processes is distributed to slag 58% to 68% and 60% to 80%. Differences have been observed in distribution of Pb and Bi due to the reason that, pierce-smith converting in flash process uses silica as flux dissolving and disposing off both the elements with fayalitic slag. In contrary, Mitsubishi converting with lime-ferritic slag system doesn't eliminate Pb and Bi due to the low solubility of respective oxides in basic slag. Ultimately, Pb and Bi gets collected in anode slimes and eliminated through dore slag. Distribution models and recycling strategies have been developed for controlling the impurities in smelters.

Study on Carbon Emissions of "FSF+FCF" and "SBF+MTC" Copper Smelting Processes

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Abstract
The "FSF+FCF" (flash smelting and flash converting) copper smelting process, which has been widely used in China in recent years. Up to now, besides projects under construction, five chinese copper smelters have adopted this process, and the capacity of this process is generally 400kt/a of cathode copper. With the maturity of the "SBF+MTC" (oxygen-enriched side blown smelting + multi-lances top blown continuous converting) copper smelting process, its capacity is gradually enlarged, and the technology has been widely used. Besides the projects under construction, there are four copper smelters in China, with a total of six systems adopting the process, and the capacity of cathode copper varies from 100kt/a to 400kt/a. In this paper, the carbon emissions of the two copper smelting processes are studied. The results show that the carbon emissions of the smelting system, acid making system and slag flotation system of the " FSF+FCF" process are higher than those of the " SBF+MTC " process. The carbon emissions of the electrolysis workshop under the same capacity are the same. The carbon emissions of the whole plant of the "FSF+FCF" process are 8.18% higher than that of the "SBF+MTC" process. Therefore, the "SBF+MTC" copper smelting process has lower carbon emissions and is a green and low-carbon copper smelting technology, which should be vigorously promoted in the future.

Keywords: Copper Smelting, Carbon Emissions, Flash Smelting, Flash Converting, Oxygen-enriched Side Blown Smelting, Multi-lances Top Blowing Continuous Converting

The Double-ISASMELT™ Process for New and Existing Smelters

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Abstract

The ISASMELT™ top submerged lance (TSL) furnace is set apart from other smelting technologies due to the flexibility and efficiency of the reactor for treating feed materials; from clean concentrates to complex feeds and recyclables. With the recent adaption of the technology to continuous converting, via the ISACONVERT™ Furnace at Kansanshi Copper Smelter, both stages of the process have now been successfully proven on an industrial scale. In the "Double-ISA" process, an ISASMELT™ Furnace is used to smelt copper bearing feeds to produce a copper matte, which is subsequently converted in an ISACONVERT™ Furnace to produce a low-sulphur blister copper. By incorporating other technologies and know-how from Glencore Technology the by-products from a copper smelting and refining plant that utilises the Double-ISA process are optimised in volume, valuable metal content, and disposal cost.

This paper outlines the basic process conditions and parameters used in the design of the Double-ISA process.

The installation of the Double-ISA process results in a significantly lower CAPEX and OPEX when compared to other smelting flowsheets. The ability to de-couple the two furnaces whilst sharing infrastructure, utilities, and spares also results in a smelter that is quicker and cheaper to construct. Additionally, due to the similarities in the furnaces, and the unique Glencore Technology technology-transfer model, a faster plant ramp-up than other modern copper smelting processes has been demonstrated

Thermodynamic Analysis and Optimization of Window of Operation of Flash Furnace Slag for Glencore's Pasar Smelter

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Abstract

Glencore's PASAR Cu smelter in the Philippines operates an Outokumpu Flash Smelting Furnace to process several types of Cu concentrate. The ability to process different concentrates depends on the capability to accept certain levels of oxides that ultimately deport to the furnace slag phase. In an effort to increase the smelter's flexibility and potential to negotiate and possibly accept concentrate from different sources, a thermodynamic analysis of the furnace, focusing on slag properties and composition was carried out.
The purpose of the study was to optimize the window of operation for the furnace based on slag liquidus temperature as a function of Fe/SiO_2 ratio and various levels of CaO, Al_2O_3 and MgO. The model was carried out for the specific thermodynamic conditions at Pasar's Flash Furnace and considered reviewing and analyzing a large set of plant samples, performing several thermodynamic equilibrium calculations and determining the limits of operation for Pasar. Therefore, providing better guidelines to improve operating conditions and open the possibility to process concentrates that otherwise would not have been processed.

This article highlights the data analysis and results from the thermodynamic model as well as the implications in the operation.

Optimization of complex matte converting

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Abstract

Within the complex smelter network of Aurubis treatment of lead rich materials plays an important role. The converting process of complex matte enables the separation of copper and lead from each other.
Whereas the technology for converting copper matte is a well-known process which is state of the art in industries and has been intensively investigated during the last decades, the treatment of lead rich mattes mainly depends on the initial composition. This causes a limited quality of shared information along the society.

This paper will provide an overview where complex matte is originated from and will introduce into the principles of an adapted converting process. The motivation for this research work is to optimize the top blown converting process in order to investigate the influence of lance technology on converting time and oxidation performance. Therefore results from pilot test work of top blown- and submerged lance are compared.

Keywords: *copper lead matte, top blown, submerged, lance*

Theoretical framework and practical recommendations for proper thermal lance use and selection

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Abstract

Drill bits and thermal lances are both perforation tools used in a variety of situations. For drill bit solution there exists a lot of theory regarding the proper drill bit selection for each application. However, for thermal lances, despite being a century-old tool, there is no technical information neither a theoretical framework that allows to understand its underlying science, required to properly select a thermal lance for a specific application.

This article presents a theoretical framework, developing the concepts and variables that rules the thermal lances behaviour and performance. The proposed framework fits well with experimental results, therefore could be used as a guide to select the proper thermal lance for each tapping process, potentially allowing time savings leading to an increase of the profitability of furnaces operation.

Keywords: Tap-hole, Thermal lance, Thermal resistance, Furnace stopped.