Alert Recycling of Byproducts (February 2017)

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Bayer red mud is characterized by its highly oxidizing nature (high Fe₂O₃ content) and high alkalinity (high Na₂O content). It can work as an ideal flux and dephosphorizer in the steelmaking process. In this study, laboratory experiments on the use of Bayer red mud-based flux in hot metal dephosphorization and simulated steelmaking processes have been carried out. In hot metal dephosphorization, good slag fluidity and a much better separation between the slag and the melt phases are obtained while using Bayer red mud. This result is attributed to the fact that Al₂O₃ and Na₂O present in Bayer red mud act as a flux and serve to decrease the melting point of the CaO–FeO–SiO₂-based slag. For a mass ratio of Bayer red mud:CaO between 1:1 and 2:1, high hot metal dephosphorization ratios (more than 80%) and low final [P] (lower than 0.018%) are obtained. The experimental results obtained while using Bayer red mud-based flux in simulated steelmaking processes show that good slag fluidity is observed during the entire process. The dephosphorization ratio can be more than 85%, and the final [P] can be lowered to less than 0.005%. No rephosphorization phenomenon is observed in the whole experiment.

Metallurgical and Materials Transactions A, February 2017

Selective separation of Fe-concentrates in EAF slags using mechanical dissimilarity of solid phases. S. Jung, K. Jung, I. Sohn

We sought to develop an optimized particle size-dependent separation method to lower the Fe content of pulverized glass-ceramic electric arc furnace (EAF) slag for its improved reclamation as construction materials by considering the structures and the mechanical behavior of the discrete solid phases. After an isothermal crystallization process to enhance the spinel growth, the Vickers hardness and fracture toughness were measured on the spinel and amorphous phases separately from the solidified slag using indentation methods. The characteristic differences in the hardness of the phases were magnified when this glass-ceramic composite was isothermally crystallized. The hardness of the spinel was observed to be lower in slags with higher Fe₇O₃/Al₂O₃ mass ratios due to the triclinic unit cell expansion of the spinel, whereas the hardness of the amorphous phase decreased with increasing isothermal period because of the structural transformation into a silicate-dominant network. Fracture toughness could be calculated based on the hardness and crack length, where the Young’s modulus was determined using nanoindentation. The amorphous phase with a lower Fe content and lower fracture toughness resulted in finer powder distribution after pulverization, allowing better separation of the primary crystalline spinel containing higher Fe content from the Fe-deficient amorphous phase according to the particle size.

Ironmaking & Steelmaking, February 2017

Development and use of mill scale briquettes in BOF. D. Kumar, R. Sah, V. Sekhar, S. Vishwanath

Generation of high iron containing wastes such as mill scale, dust and sludge are inevitable in steelmaking process. It is important to develop and implement processes to recycle and re-use these wastes. An attractive option is to recycle these wastes through BOF steelmaking process, but is not suitable for handling and efficient operation in available forms. Present work shows the briquetting of steel making wastes using various binders in a pilot scale briquetting machine. In briquetting tests, the effecting parameters have been studied for determining the best combination of binders and operating parameters. A process for briquetting mill scale in optimum combination with CRM dust and BOF dusts using an organic binder has been established. Separate indices were formulated as acceptance criterion for use of mill scale briquettes in BOF service conditions involving dynamic, crushing, abrasive and thermal loads. Subsequently, series of trials were conducted with use of mill scale briquettes as secondary coolant replacing iron ore in 130T LD converter. The present paper compares the effect of mill scale briquettes vis-à-vis iron
Mineral Processing and Extractive Metallurgy, January 2017


New methods to further utilize steelmaking slag must be developed from the viewpoint of not only the stable consumption of steelmaking slag but also the establishment of sustainable and environmental friendly steelmaking process. It is well known that the lack of iron in sea water, which is an essential minor nutrient for seaweeds, is a major reason for the severe deterioration of coastal environment all over the world. The trial application of steelmaking slag as a material to supply such mineral nutrients has revealed the positive effects on the improvement of coastal ecological system. Dissolution mechanisms of various elements from steelmaking slag into sea water must be clarified in order to apply the rehabilitation technology to seriously damaged coasts. In the present paper, the dissolution behaviours of nutrient elements from steelmaking slag and steelmaking slag blended with dredged soil into sea water, or sea water containing gluconic acid which have been previously studied through laboratory-scale experiments by authors were summarized, and the dissolution mechanisms were reviewed.

Bottlenecks in rare metal supply and the importance of recycling – a Japanese perspective. T. Okabe

Rare metals are less common metals that are generally perceived to be scarce. The media often presents one-track thinking on the depletion of mineral resources. Despite this common notion, the supply of most rare metals – including rare earth metals (REMs) – in terms of the amount of minerals available in known deposits is not a serious problem. Key factors that determine the supply of rare metals are the costs of mining and smelting, and related environmental destruction. These are the major practical constraints, rather than the amount of mineral deposits in the earth. When extracting rare metals from recycled feed material, harmful wastes generated from natural ore processing can be avoided. This is the primary advantage of the cyclical use of rare metal resources. In this article, bottlenecks of rare metal supply, and the importance of recycling, are discussed, using REMs as an example.

Solid wastes utilization in the iron and steel industry in China: towards sustainability. Y. Suna, H. Wanga, L. Liua, X. Wanga

With the continuous industrialization and urbanization in China, the energy saving, emission reduction and environmental protection have become increasingly significant issues to be addressed in modern society. As a carbon-intensive and energy-intensive industry, the iron and steel industry faces great pressure especially in the context that China has pledged to peak its carbon emission by 2030. Nowadays the output of pig iron and crude steel in China has accounted for half of global capacity and during the production of these products, substantial solid wastes including iron tailings, blast furnace slags and steel slags have been discharged. The timely and efficient disposal of these three kinds of solid wastes has been severe problems and consequently, numerous strategies and technologies have been developed. These routes could be generally divided into the large-scale extensive utilization style and the small-scale high-value utilization style. In this study, these routes were first systemically reviewed and the fundamental principles were analysed and then the promising strategies were summarized and predicted. Upon reasonable treatment, these solid wastes could not only reduce the environmental impact but also contribute to valuable resources for modern industry.

A review on the generation of solid wastes and their utilization in Indian steel industries. N. Sharma, V. Nurni, V. Tathavadkar, S. Basu
More and more primary metal production and processing units are being shifted away from the developed countries to the developing countries. India is poised to become one of the largest producers of metals after China. This poses its own challenges in terms of solid waste management. As far as the production of primary metals are concerned, steel industries produce the largest amount of solid wastes. India has rich deposits of haematite. Because of high alumina content and inferior coke quality, approximately 1.6 tons of solid wastes are generated per ton of the steel produced. Most of the Blast Furnace slag is granulated and is used for manufacturing cement. However, steel making slag that contains high amounts of Fe poses challenges. This paper discusses the issues pertaining to solid waste generation from iron and steel making processes in terms of volumes, challenges and efforts towards recycling and utilization.

**Development of a novel process for energy and materials recovery in steelmaking slags.** J. Li, D. Bhattacharjee, X. Hu, D. Zhang, S. Sridhar, Z. Li

This work aims at gathering fundamental knowledge for the development of a novel process for energy (H2 gas) and materials (magnetite Fe3O4) recovery in hot steelmaking slags by reacting molten steelmaking slag with steam. Thermodynamic simulation was carried out to calculate the accumulated amount of produced H2 gas as a function of the volume of H2O–Ar gas introduced and the precipitated phases of the molten slags during controlled cooling. Laboratory experiments of crystallization behaviours of molten slags during cooling were visualized in situ through a confocal laser scanning microscope, and the cooled slags obtained were characterized by using SEM-EDS and XRD. CCT diagrams for different slags were created showing the slag crystallization/phase transformation at different cooling rates. The recovery ratio of H2 gas and the maximum potential recovery ratio of iron oxide in the oxidized slags were calculated, which concludes that with increasing the slag basicity from 1.0 to 1.5 and 2.0, the recovery ratio of H2 was found to increase from 12.6 to 23.7% and 22.6%, and the maximum potential recovery ratio of iron oxide was found to increase from 18.3 to 34.4% and 32.8% under the investigated conditions.

**Refining fluxes for metallurgical melts based on waste materials of the aluminium industry.** A. McLean, Y. Yang, M. Barati

Waste slag is a major source of environmental pollution within the metallurgical industry. In the steel industry, about 100–150 kg of waste slag is produced in making one tonne of liquid steel in addition to that produced during ironmaking. In the aluminium industry, about 2–4 tonnes of waste materials are generated during the production of one tonne of aluminium. The waste products from these two industrial sectors are of particular concern because of the sheer volume and causticity of the materials. Extensive studies have been carried out at the University of Toronto to investigate potential applications for these metallurgical waste products. Studies have included: (1) desulphurization of hot metal and liquid steel using calcium aluminate fluxes made from the dross of aluminium electrolysis and remelting; (2) ferronickel desulphurization as well as simultaneous desulphurization and dephosphorization using red mud and white mud generated during alumina extraction from bauxite; and (3) recovery of nickel from spent catalysts generated by the petroleum industry. The results confirm that the application of waste byproducts from the aluminium industry, as a basis for refining fluxes in the steel industry, could be beneficial from technical, economical and environmental perspectives, thus generating social benefits for both industrial sectors.

**ISIJ International, January 2017**

**Effects of CaO and Fe2O3 on the microstructure and mechanical properties of SiO2–CaO–MgO–Fe2O3 ceramics from steel slag.** L. Zhao, Y. Li, L. Zhang, D. Cang

A new SiO2–CaO–MgO–Fe2O3 system ceramics, namely pyroxene ceramics in this paper, was put forward for efficiently utilizing the steel slag. The prepared ceramic with
30 wt% of steel slag has excellent properties with flexural strength of 107 MPa and water absorption rate of 0.045%. Microstructure evolution in the new system ceramics was studied by X-ray diffractometry and scanning electron microscopy. High content CaO in this system contributes to crystallization in low temperature. Diopside (CaMgSi2O6) formed at temperature below 800°C, and was predominant at approximately 1 000°C before densification. The main phases of pyroxene have not changed except the solution of ions of Fe2+/Fe3+, Al3+, Mn2+, Ti4+ and so on. Melting of iron-rich andradite, Fe2O3 and RO (solution of FeO, MgO, MnO etc.) phases at temperature between 1 100°C to 1 180°C promoted liquid sintering and densification process. The crystallization process at temperature between 700°C to 1 100°C is prior to the densification process at temperature between 1 150°C to 1 220°C, and the formed crystals played an important role of framework during the densification process. Sole interlocking pyroxene phases and less glass phase in the final ceramic are contributed to its excellent mechanical performances.

Estimation of the environmental impact for recycling blast furnace slag with a hydrothermal reaction based on life cycle inventory data. S. Tae, T. Adachi, K. Morita

Blast furnace (BF) slag has been recycled in the construction industry mainly as cement and concrete. However, in the past few years, recycling conditions have changed and other recycled materials have become dominant; thus, new applications for BF slag need to be considered. In this study, we first reviewed applications in which BF slag was treated by hydrothermal reactions. Under hydrothermal conditions, tobermorite (Ca5Si6O16(OH)2·4H2O) was formed from BF slag. This tobermorite, which was produced in a CaO–SiO2–H2O system, was used as the main binding mineral in autoclaved lightweight concrete (ALC), and the corresponding ALC exhibited excellent properties in terms of heat insulation and lightness. Next, in the present study, the utilization of BF slag in the ALC manufacturing process as an alternative raw material was evaluated based on the environmental impacts associated with its use. Specifically, the environmental impact was evaluated with life cycle inventory (LCI) data for the resulting CO2 emissions. The LCI data for ALC prepared with BF slag were compared with LCA data for other conventional production processes, and the results showed that the ALC prepared with recycled BF slag had lower levels of CO2 emissions than the other processes that were evaluated.

Mineral Processing and Extractive Metallurgy, December 2016

Complex evaluation and development of electrolytic tin refining in acidic chloride media for processing tin-based scrap from lead-free soldering. T. Kulcsar, G. Toth, T. Kekesi

Different ways of investigation were applied to address the main difficulties of electrolytically refining the tin-based lead-free soldering waste materials in chloride solutions. The characteristics of electrorefining and the phenomena of electrocrystallisation have been targeted by examining the electrode processes with different copper and silver concentrations in the anodes. Galvanostatic experiments were carried out using a specially developed system detecting the changes in the electrode masses continually, complemented by the recording of the electrode potentials. In order to clarify the main cathode and anode processes, further investigations were carried out by the potentiodynamic technique. Galvanostatic results pointed out the causes of current losses and rough deposit structure. Potentiodynamic examinations have demonstrated the strong influence of material transport on the electrode processes. Nevertheless, with a quasi-optimised procedure, cathode tin of higher purity than technical standards could be achieved from the soldering waste material in a conventional cell.

The modified central paradigm of materials science and engineering in the extraction and development of new and recycled materials. M. Pech-Canul, F. Kongoli
In order to meet the ever-growing human needs, the development of new materials implies generation of byproducts or residues that might pollute the environment. This has been a fact not only in massive commercial production but also at pilot-plant and laboratory scale. In today’s world the issue of residues not only cannot be neglected anymore but should also constitute a key requirement for any new research or technology proposal. Consequently, sustainability, reutilisation and recycling aspects should be considered from the outset as equal factors. This can be achieved systematically and methodologically through ‘the modified central paradigm of materials science and engineering’, described previously by the authors as ‘processing → structure → property → performance → reutilisation/recyclability’ and presented here through a new graphical model. This modified central paradigm is equally valid during the extraction and production of a given material for the first time as well as during its reutilisation/recycling.

In production of stainless steel 10–70 kg of dusts per tonne of steel is produced. The final rolling and pickling stages produce significant amounts of metal-rich wastes and acid sludge. The dusts are usually treated by pyrometallurgical methods such as plasma processing or Waelz kiln. Hydrometallurgical methods have been developed especially for the recovery of zinc from electric arc furnace (EAF) dusts, focusing on unalloyed steel EAF dust. A new concept has been developed to selectively leach out zinc from stainless steel production dusts enabling recycling the remaining iron, nickel and chromium compounds back to melting. Zinc can be dissolved using either a strong alkaline solution or strong acid solution. Factors affecting the leaching efficiency have been determined. Mineralogical factors limiting the zinc dissolution have been determined and pre-treatment methods have been developed. Using the optimal conditions the zinc level in the treated dust has been low enough allowing recycling of the dust to melting.

Analysis of Carbon Content in the Dust And Blast Furnace Mud. Walisson Silva Gomes, Aline Aguiar Lopes, Sidiney Nascimento Silva
The injection of pulverized coal through tuyeres of blast furnaces is a key of reducing production costs of the pig iron. The injection should be effective, to prevent possible fuel waste. This study aimed to develop a methodology to quantify the carbon content in the sludge and dust, generated in the gas cleaning blast furnace to assist the evaluation of coal burning efficiency injected through tuyeres and its correlation with the variables process. No standard specifies the quantification of carbon in the mud and dust collector. We used two techniques to quantify carbon in coal and coke used in Companhia Siderurgica Nacional, Immediate analysis, based on ASTM D 5142-09 standard, and Elemental Analysis. A more detailed study to investigate the possible interference in these analysis methods, because the difference in results between them was used Diffraction X-ray associated with the Rietveld method, and Analysis Thermo-Gravimetric from Differential Scanning Calorimetry (TG-DSC). From these analyzes it was possible to determine the best method for quantification of carbon in the dust collector and blast furnace sludge.

The Waelz process, that recovers part of these residues through metallurgical reactions of oxidation and reduction in a rotary kiln, is a leading technology used for the recovery of volatile metals, and has been widely used over the past 40 years. In this work, an
initial thermodynamic and kinetic study of the Waelz reduction process was conducted, aiming to optimize the metallurgical conditions needed to ensure the recovery of volatile metals (especially zinc) and therefore assure the minimization of environmental impacts and maximization of more sustainable processing options and with higher added value due to the increase of zinc recovery from the dust and metallurgical residues. Kinetic variables were studied by running a series of six experiments, covering the main processing variables such as content and type of the binder, content and type of the reducer and processing time/temperature. The behavior and thermomechanical properties will also be assessed. There were used characterizations by electron microscopy, X-ray diffraction, X-ray fluorescence, particle size analysis with laser, compressive strength, percentage of volatile matter, fixed carbon and ash were employed.

**Comparative Study of Formation and Reduction of Zinc Ferrite Contained Electric Arc Furnace Dusts by CO - CO₂ Gas Mixtures.** Mery Cecilia Gómez Marroquín, Jose Carlos D’abreu, Helio Marques Kohler, Raimundo Nonato Rodrigues Filho

The present work deals about the zinc ferrite synthesis, occurred through a solid-solid reaction in a selected range of temperatures, using as reactant an equimolar mixture of pure iron oxide- Fe₂O₃ and pure zinc oxide - ZnO. The range temperature of formation was of 1073 to 1373K. After that, took place the reduction of equimolar synthetic zinc ferrite-ZF and Electric Arc Furnace Dusts-EAFD by gas mixtures CO - CO₂, from 50% and 100% of CO. Both testes (formation and reduction) were supported by physical, chemical, structural and microscopic characterizations of both, initial zinc ferrite generated in laboratory and the remained after reaction. It was observed that the temperature and CO content were the main factors affecting the zinc ferrite reduction. The maximum reductions of ZF indexes obtained in these experiments were 85%, for 100%CO at 1373K, in 105 min, and 52%, for 50%CO at 1373K, elapsed 105 min. Other hand for 100%, has got with 100%CO at 1273K, in 80.75 min, and 60%, for 50%CO at 1373K during 105 min in the case of EAFD reduction.

**37th Energy Balances – ABM Week 2016, October 2016**

**Utilization of Coffee Husk and Charcoal as Reducing and Energetic Material in Injection of Pulverized Material in Tuyeres for Blast Furnace.** Ricardo dos Santos Oliveira, Carlos Frederico Campos de Assis, Paulo Santos Assis, Bruno Sardenberg de Castro Lima, Marina do Carmo Carias (in Portuguese)

This present paper was accomplished from the identification of the problem of high generation of coffee waste and greenhouse gas emissions by the steel industry. By analyzing the national energy system emissions, it was observed that the steel industry segment has an important role due to the high consumption of charcoal and coke in the energy balance. The project aimed to use two biomasses, coffee husk and charcoal as a source of energy in the iron ore reduction process through fine injection sprayed by tuyeres of blast furnaces. The coffee and eucalyptus plant are renewable, unlike coal, and through photosynthesis capture the CO₂ gas from the atmosphere, reducing of the pollution caused by the blast furnace to coke. To simulate the possibility of injecting the biomasses studied, an injection simulator pulverized material was used. We used also techniques to characterize the materials as size, combustion calorimetry gas analysis, specific surface, microscopic and chemical classification. Through the study, this research shows that coffee husk can be injected into blast furnaces partially replacing charcoal.