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**Metallurgical and Materials Transactions B, April 2017**

**Transition of blast furnace slag from silicates-based to aluminates-based: viscosity.** Z. Yan, X. Lv, D. Liang, J. Zhang, C. Bai

The effect of Al2O3 and the Al2O3/SiO2(A/S) ratio on the viscosity of the CaOSiO2-Al2O3-MgO-TiO2 slag system was studied in the present work. At a fixed CaO/SiO2(C/S) ratio of 1.20, 9 mass pct MgO, and 1 mass pct TiO2, the viscosity increases with an increase in Al2O3 content at a range of 16 to 24 mass pct due to the polymerization of the aluminosilicate structures, while it decreases when the Al2O3 is higher than 24 mass pct, which means that Al2O3 acts as a network modifier at higher content. Increasing A/S from 0.47 to 0.92 causes a slight decrease in viscosity of the slags and has an opposite effect when A/S is more than 0.92. The free running temperature increases with the Al2O3 content and appears to show a peak at an A/S ratio of 0.92. The change of the apparent activation energy is in accordance with the change of viscosity. When Al2O3 content is more than 24 mass pct with low SiO2, CaO content ranges from 35 to 45 mass pct, and the slag transform from silicates-based to aluminates-based can still get a good operation region. Four different viscosity models were employed to predict the viscosity and RIBOUD’s model was found to be the best in predicting the viscosity by comparing the estimated viscosity with the measured viscosity.

**Activity of MnO in MnO-CaO-SiO2-Al2O3-MgO molten slags.** B. Yan, X. Chen, J. Tao

The activities of MnO in the MnO-CaO-SiO2-Al2O3-MgO (10, 20, and 30 mass pct)-MgO (5 mass pct) melts at 1873 K (1600 C) were measured by equilibrating the melts with liquid copper under an oxygen partial pressure controlled by CO/CO2 gas mixture with a volume ratio of 99/1. Over the investigated composition range, MnO shows a negative deviation from Raoultian behavior. On the basis of the experimental data, the activity
coefficient of MnO in this multicomponent melts was evaluated using the following quadratic formalism based on regular solution model:

\[ RT \ln \gamma_{\text{MnO}}(s) = \sum x_j^2 + \sum (x_{ij} + \alpha_{jk} - \alpha_{i} \alpha_{j}) x_j x_k + I' \]

The values of the conversion factor, I', for the melts containing 10, 20, and 30 mass pct Al2O3 were determined to be 6950, 2715, and 12092 J/mol, respectively. Iso-activity contours for MnO in the five component system were calculated using the quadratic formalism, and they showed a good agreement with the experimental data.

**Influences of Na2O and K2O additions on electrical conductivity of CaO-MgO-Al2O3-SiO2 melts. G. Zhang, W. Zheng, K. Chou**

The present study investigated the influences of Na2O and K2O additions on electrical conductivity of blast furnace type CaO-MgO-Al2O3-SiO2 melts by the four-electrode method. Both the single addition of Na2O or K2O and the double additions of Na2O and K2O were studied. It was found that electrical conductivity monotonously increased as the amount of Na2O addition was gradually increased, whereas, when K2O was added, there was a continuous decrease of electrical conductivity. With melts containing both Na2O and K2O, electrical conductivity first decreased but then increased when Na2O was gradually substituted for K2O while keeping the molar fractions of other components constant. In other words, the mixed-alkali effect took place in CaO-Mg-Al2O3-SiO2 melts.

**Steel Research International, March 2017**

**Catalytic Behavior of Potassium Vapor on Coke Gasification Reaction. Jian Bo Zhong, Jian Liang Zhang, Ke Jiang Li, Zheng Jian Liu, Guang Wei Wang, Run Sheng Xu, and Di Zhao**

Two types of coke are penetrated by different content of potassium (K) vapor using potassium-adsorption experiments. The K content of the alkalized coke is analyzed with inductively coupled plasma atomic emission spectrometry (ICP-OES). In order to explore the influence mechanism of K on the coke gasification, the industrial properties of alkalized coke samples are tested with standard method, while their gasification process is investigated by thermogravimetric analysis. It is found that the broken degree of coke structure after penetration by K vapor increases with the increase of K content, and a critical value near 5 wt% of K content may exist for the formation of coke fragment. The catalysis of K on coke gasification accelerates with the increase of K content, and reaches the limitation when the content of K exceeds 3.5 wt%. The catalysis of K vapor on coke gasification is mainly characterized by the reduced gasification temperature and the increased pre-exponential factor, which will increase the active carbon sites.

**ISIJ International, February 2017**

**Formation of [Mg1-x,Fex]O·Fe2O3 in solid-state reactions between MgO and Fe2O3 in the Fe2O3-rich system. Y. Guo, X. Guo**

Aiming to better understand the effect of MgO on sintering process of iron ores, the formation of [Mg1-x,Fex]O·Fe2O3 in solid-state reactions between MgO and Fe2O3 was studied. Experiment was carried out in air from 873 K to 1 573 K by MgO mixing with Fe2O3. X-ray diffraction, optical microscope, scanning electron microscopy and energy-dispersive spectroscopy were used to characterize the phase change of the sintered samples. The content of ferrous ion in the sintered samples was determined by potassium dichromate titration for distinguishing the MgO·Fe2O3 (x=0) and the Fe3O4 (x=1). Thermogravimetric and differential scanning calorimeter test was carried out in air by MgO mixing with Fe2O3 to investigate the thermal decomposition of Fe2O3. The results show that the reactions between the Fe2O3 and MgO in air formed first the magnesium ferrite at 1 073 K, subsequently magnetiferous magnetite appeared at 1 173
K, resulting that the thermal decomposition of Fe2O3 was carried out at a lower temperature than that of its own self.

Evaluating effect of coke layer thickness on permeability by pressure drop estimation model. K. Ichikawa, Y. Kashihara, N. Oyama, T. Hirosawa, J. Ishii, M. Sato, H. Matsuno
In this study, a new experimental device called the cohesive zone simulator was developed to clarify the minimum coke layer thickness. In the cohesive zone, gas flows horizontally along the coke layer. In order to quantify the effect of the coke layer thickness on permeability, this horizontal gas flow should be simulated. Therefore, this simulator simulates a horizontal gas flow. Next, the effect of the coke layer thickness was quantified by using the cohesive zone simulator. The results showed that melting iron ore penetrated into the coke layer and closed part of the layer. These phenomena caused a deterioration of permeability under thin coke layer thickness conditions. Finally, a pressure drop estimation model considering penetration of the coke layer by melting ore was developed with the aim of quantifying the minimum coke slit thickness.

High-speed video recording of particle trajectory via rotating chute of Nagoya No.3 Blast Furnace and its comparison with simulated behavior using DEM. H. Mio, T. Nakauchi, Y. Kawaguchi, T. Enaka, Y. Narita, A. Inayoshi, S. Matsuzaki, T. Orimoto, S. Nomura
The objective of this paper is to develop a prediction tool for burden distribution of a blast furnace (BF) by using Discrete Element Method (DEM). The high-speed video recording in an actual blast furnace process was tried to capture the particle behavior in Nagoya No.3 BF, and the particle trajectory discharged from a rotating chute was also measured by using a pressure sensitive sheet. The modeling of particle behavior was conducted by DEM, and the simulated behavior was compared with the measured results. The particle discharging behavior was recorded from a large manhole during a shutdown, and an individual particle was able to be seen in the images. It was observed that the particles were pressed up against the chute side wall due to the centrifugal force of chute rotation. The particle discharging velocity was analyzed by Particle Image Velocimetry (PIV). It is found that the velocity of coke particle is larger than that of sinter because of the particle size. This difference affects the particle discharging trajectory, and the one for coke particle is shifted toward the BF wall by comparing to that for sinter. The simulated particle behavior using DEM has a good agreement with the observations, both by the high-speed recording and the trajectory measurement. Therefore, it can be concluded that this particle simulation has high reliability for prediction of the particle trajectory in the actual blast furnace operation.

Effect of local oxygen-enrichment ways of oxygen-coal double lance on coal combustion. Z. Zhou, Y. Liu, G. Wang, X. She, Q. Xue, J. Wang
The extent of coal combustion within the tuyere and raceway region is one key factor affecting the maximum pulverized coal injection (PCI) rate. Oxygen enrichment, especially local oxygen enrichment, is the most effective way to increase the PCI rate. In this study, a three-dimensional numerical model was developed to simulate the lance-blowpipe-tuyere-raceway of a blast furnace. In the study, the characteristics of oxygen-coal combustion are investigated under the single oxygen-coal and oxygen-coal double lances. Under local oxygen enrichment ways, the oxygen content around the coal particles increases significantly, benefiting coal combustion. However, the cooling effect of room-temperature oxygen delays coal combustion. Therefore, the way by which the oxygen flows should not be neglected. The results indicate that the increase in the burnout is quite different under different lance patterns. The burnout had the maximum increase of 2.17% under the coaxial oxygen-coal lance. The burnout had the highest increase of 12.84% under the oxygen-coal double lance.
Dripping and evolution behavior of primary slag bearing TiO2 through the coke packed bed in a blast-furnace hearth. Yan-xiang Liu, Jian-liang Zhang, Zhi-yu Wang, Ke-xin Jiao, Guo-hua Zhang, and Kuо-chih Chou

To investigate the flow of primary slag bearing TiO2 in the cohesive zone of blast furnaces, experiments were carried out based on the laboratory-scale packed bed systems. It is concluded that the initial temperature of slag dripping increases with decreasing FeO content and increasing TiO2 content. The slag holdup decreases when the FeO content is in the range of 5wt%–10wt%, whereas it increases when the FeO content exceeds 10wt%. Meanwhile, the slag holdup decreases when the TiO2 content increases from 5wt% to 10wt% but increases when the TiO2 content exceeds 10wt%. Moreover, slag/coke interface analysis shows that the reaction between FeO and TiO2 occurs between the slag and the coke. The slag/coke interface is divided into three layers: slag layer, iron-rich layer, and coke layer. TiO2 in the slag is reduced by carbon, and the generated Ti diffuses into iron.

Steel Research International, January 2017
Distribution of Zn, Pb, K, and Cl in Blast Furnace Lining. Verena Trinkel, Philipp Aschenbrenner, Christoph Thaler, Helmut Rechberger, Ole Mallow, and Johann Fellner

The furnace campaign of a blast furnace represents an important factor for the iron-making industry due to the fact that maintenance such as relining is not only costly but also time consuming. The furnace campaign is largely determined by the functionality of the lining, which is influenced by wear mechanisms and the damaging behavior of certain elements. To these unwanted elements that may attack the lining belong, for example, Zinc (Zn), Lead (Pb), Potassium (K), and Chlorine (Cl). In this paper, the distribution of Zn, Pb, K, and Cl within the lining of a blast furnace at the end of its furnace campaign is investigated and discussed. The results demonstrate that the content of some elements (Zn, Cl, Pb) in the lining and also their penetration depth significantly varies over the blast furnace height. For Zn and Pb, the highest contents (43 g Zn kg\(^{-1}\) and 0.14 g Pb kg\(^{-1}\)) are observed in the inner lining stones (adjacent to the hot metal), whereas for Cl, a contrary distribution pattern is observed. The highest contents are detected in the outer stones of the lining at the top of the blast furnace.

Effect of Oxygen-Coal Lance Configurations on Coal Combustion Behavior. Zhenfeng Zhou, Hailong Huo, Guang Wang, Qingguo Xue, Xuefeng She, and Jingsong Wang

The extent of coal combustion within the tuyere and raceway region is one key factor affecting the maximum pulverized coal injection (PCI) rate. Coal burnout strongly depends on the availability of oxygen. In this paper, a three-dimensional model is developed to simulate the lance–blowpipe–tuyere–raceway of a blast furnace. This model aims to describe the coal flow and combustion behaviors along the coal plume under different local oxygen enrichment ways. Room-temperature oxygen has two effects on coal combustion. On one hand, the cooling effect of oxygen delays the coal combustion. On the other hand, the oxygen content around the coal particles significantly increases, benefiting coal combustion. Therefore, aiming at different local oxygen enrichment ways, three different lance configurations, including a single coaxial oxygen-coal lance, a double oxygen-coal lance, and an oxygen-coal double lance, are designed.

ISIJ International, January 2017
Effect of TiO2 on the liquid zone and apparent viscosity of SiO2- CaO-8wt%MgO-14wt%Al2O3 system. Z. Yan, X. Lv, W. He, J. Xu

The effect of TiO2 on the liquid zone and apparent viscosity of SiO2-CaO-8wt%MgO-14wt%Al2O3 system were studied in the present work. At fixed CaO/SiO2 between 0.5 and 1.3, higher TiO2 content decreases the slag viscosity indicating that TiO2 additions up to 50 wt.% behaved as a viscosity-decrease agent by loosening the silicate network
structure. The free running temperature increase at TiO2 content from 10 wt.% to 30 wt.%. At fixed TiO2 content of 20, 30 and 40 wt.%, increasing the CaO/SiO2 resulted in lower viscosity due to the depolymerization of the structure. Four different viscosity models were discussed and two of them were employed to predict the viscosity and found that the Urbain’s Model agrees well with experimental data at high viscosity (4–12 dPa·s) and the KCC’s Model agrees well with experimental data at a lower viscosity (0–4 dPa·s).

**Effects of gibbsite, kaolinite and Al-rich goethite as alumina sources on silico-ferrite of calcium and aluminium (SFCA) and SFCA-I iron ore sinter bonding phase formation.** N. Webster, D. O’dea, B. Ellis, M. Pownceby

The relative effects of gibbsite, kaolinite and aluminous goethite as alumina sources on the thermal stability, concentrations and formation mechanisms of silico-ferrite of calcium and aluminium (SFCA and SFCA-I) iron ore sinter bonding phases, was investigated using in situ X-ray diffraction. Iron ore containing gibbsite as the primary source of alumina is less likely to form high quality sinter due to the lower reactivity of the alumina leading to low amounts of SFCA-I and SFCA bonding phases being generated. Sintering of this ore is likely to require higher fuel as higher temperatures are required to generate the bonding phases. Alumina in the form of kaolinite or aluminous goethite, however, produced larger amounts of both SFCA-I and SFCA and at lower temperatures. Use of kaolinite resulted in the formation of a highly reactive gehlenite intermediate phase that maximised the formation of SFCA-I, the matrix phase that imparts high strength and good reducibility characteristics to sinter. Iron ore containing aluminous goethite also generated SFCA bonding phases however the difference in the reaction mechanism between kaolinite and aluminous goethite containing ore led to less SFCA-I being formed overall. These findings give some insight into why sintering investigations using Australian ores with kaolinite tend to show less impact on sinter quality than the more widely reported alumina studies involving gibbsite-rich ores.

**Dissection investigation of Ti(C,N) behavior in blast furnace hearth during vanadium titano-magnetite smelting.** K. Jiao, J. Zhang, Z. Liu, S. Kuang, Y. Liu

This paper presents a comprehensive study on the behaviors of titanium compounds generated in the blast furnace (BF) hearth during the vanadium titano-magnetite smelting by the dissection method combined with experimental and theoretical analysis. The results show that considerable titanium compounds are formed in the eroded furnace wall below the taphole level. The phases of titanium compounds consist of Ti(C,N) crystals, slag phase and liquid iron. The phase of Ti(C,N) crystals are mainly TiC0.3N0.7. The formation mechanism of titanium compounds is revealed. It is found that the Ti(C,N) phase is formed within hot metal, while the slag phase originates from the interaction between the mineral in coke and final slag in the BF hearth. Furthermore, the slag is confirmed present in the low part of the BF hearth. The thermal conductivity of the titanium compounds in the hearth is determined as 11.98 W/m/K by analyzing the thermodynamic and heat transfer characteristics of the compounds. This prediction is in satisfactory agreement with the measurement.

**Development of rapid curing process of reactive coke agglomerate.** K. Higuchi, H. Yokoyama, H. Sato, M. Chiba, S. Nomura

We commercialized Reactive Coke Agglomerate (RCA), a cement-bonded pellet to decrease the thermal reserve zone temperature for the reduction of the reducing agent rate of blast furnaces. To achieve a high productivity of supplying RCA to large blast furnaces, a rapid curing process of RCA using steam was investigated. We obtained rapid curing of RCA within 18 h by combining primary curing for 12 h and stream curing at 80°C for 5 h subsequently with drying for 1 h. This combination provided sufficient strength to an RCA product when compared with the strength obtained after conventional yard curing, which requires a long curing time of 14 days.
Plant trials revealed that a longer primary curing time was required because of the non-homogeneity of thermal conditions. Nevertheless, the curing period could be shortened by 12.5 days with drying and 9 days without drying. Mineralogy and morphology of hardened cement in RCA after rapid curing were investigated. XRD and thermal analysis revealed that the basic mineral composition of cement after rapid curing was comparable with that after conventional yard curing. In plant tests, during rapid curing, hydration and microstructural evolution of cement in RCA were accelerated by steam curing. RCA involving the steam curing process has been implemented in Oita works and it has been helping in a stable operation of two large blast furnaces under a low RAR.

**Reaction between CaO and Fe3O4 under CO–CO2 atmosphere at 800°C–1 100°C.** Z. Su, Y. Zhang, Y. Chen, G. Li, T. Jiang

A considerable amount of works were focused on the formation mechanism of calcium ferrite phases during the iron ore sintering process, especially under various O2 content atmospheres at temperatures higher than 1 100°C. But little attention has been paid on reactions between CaO and iron oxides in CO– CO2 atmospheres at lower temperatures. In this study, the solid state reaction mechanisms between CaO and Fe3O4 under CO–CO2 atmospheres at 800°C–1 100°C were revealed by using XRD, VSM, etc. The results indicated that Ca2Fe2O5 was easily formed under 5–50 vol% CO/(CO+CO2) atmosphere above 850°C via the reaction of 6CaO + 2Fe3O4 +CO2 = 3Ca2Fe2O5 + CO and the reaction would be promoted with increasing the roasting temperature. In the CO–CO2 atmosphere, Fe3O4 is easily oxidized to Fe2O3 in the presence of CaO because CO2 components act as oxidative medium for the oxidation of Fe2+ to Fe3+.

**Adaptive weighting just-in-time-learning quality prediction model for an industrial blast furnace.** K. Chen, Y. Liu

Development of accurate soft sensors for online quality prediction (e.g., silicon content) in an industrial blast furnace is a difficult task. A novel just-in-time-learning (JITL) prediction approach using adaptive feature-weighting for similar samples is developed. First, a dual-objective joint-optimization framework is proposed to introduce both input and output information into the model. Then, a suitable similarity criterion with feature weighting strategy is formulated, which is not considered in conventional JITL methods. Moreover, the trade-off parameter in the joint-optimization problem can be chosen automatically, without the time-consuming cross-validation procedure. The proposed method is applied to online predict the silicon content in an industrial blast furnace in China. Compared with other JITL-based soft sensors, better prediction performance has been obtained.

**Online heat pattern control of a shaft furnace based on a realtime visualization by particle filter.** Y. Hashimoto, K. Tsuda, T. Anyashiki, H. Fujimoto

In the steel works, direct observation of the internal states of many processes, such as the blast furnace, is difficult. Automation of such processes based on process visualization is an urgent issue. Because the number of sensors is limited, the state estimation utilizing partial sensor information is necessary. We developed a technique which visualizes the entire temperature distribution of a shaft furnace by means of the particle filter, which combines the sensor information and a nonlinear model calculation. This state estimation was incorporated in the heat pattern control logic based on future prediction, in which the estimated heat pattern is set as the initial condition. The control logic was implemented in a ferro-coke pilot plant. As a result, the control accuracy of 10°C was achieved. Furthermore, the operational condition was adjusted based on the correlation between the estimated heat pattern and the product strength. In consequence, the product strength improved by 0.5 points (Drum Index 150/15 mm, DI15015).
**Industrial Heating, January 2017**

**Blast furnaces: optimizing 1750 technology to the energy standards of tomorrow. C. Pistorius** (2 pages)

The blast furnaces used today in the U.S. are similar in form and function to those built about 260 years ago, but the energy efficiency is incomparably better. Through steady engineering improvements, the smelting process has become nearly 20 times more energy-efficient since the mid-18th century.[1] The challenge now is to better understand how to use alternative fuel sources in order to continue to decrease the carbon intensity of blast-furnace ironmaking.

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**71st ABM Annual Congress – ABM Week 2016**

**Monitoring and control of refractory wear for intensive operation of blast furnace. Afshin Sadri, S. Filatov, I. Kurunov, Y. Gordon, W. L. Ying, J. Erskine**

One of the main reasons for blast furnace reline is the loss of refractory lining, particularly in the hearth and taphole regions. Intense operation of the blast furnace can result in extensive refractory wear and deterioration. This can then affect the continuity of the operation and the furnace campaign life. Novo-Lipetsks (NLMK) and Hatch developed a systematic approach to monitor the condition of blast furnace hearth linings using Acousto Ultrasonic-Echo (AU-E), a non-destructive testing system developed by Hatch. Continuous and periodic inspections of blast furnaces revealed areas with accelerated refractory deterioration, formation of elephant foot, extent and speed of refractory wear, as well as cracks and other anomalies. Improvement in coke quality, stave washing, the addition of titania, and other changes were recommended and implemented to prolong furnace life while maintaining the intensity of furnace operation. This paper demonstrates how the coordinated efforts between NLMK and Hatch resulted in prolonging the blast furnace campaign life.

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**46th Ironmaking Seminar – ABM Week 2016, October 2016**

**Advanced Technology Developments in Remedial Stave Cooling. Dustin Vickress, Darryl Metcalfe, David Rudge, Ian Cameron, Maciej Jastrzebsk, Barry Hyde, Andrew Shaw, Andriy Ponomar**

The premature failure of copper staves in the lower stack and bosh is frequently the cause for an interim blast furnace repair at great cost to the blast furnace owner. Protective accretions may form on the stave hot face, but when these accretions are lost the staves can begin to deteriorate both due to abrasive wear from exposure to the descending burden materials and due to thermal cracking from exposure to high-temperature process excursions. These mechanisms can lead to failure of cooling passages, which forces blast furnace operators to shut off these channels, accelerating the rate of copper stave wear. Finger cooler technology was developed to extend blast furnace life by restoring cooling to damaged staves. Evidence for their effectiveness is presented herein in the form of experimental test work and conjugate heat transfer (CHT) analysis carried out using computational fluid dynamics (CFD) simulations. These tests demonstrate that under typical blast furnace excursion conditions, a stave fitted with finger coolers will undergo half the temperature rise of a stave fitted with conventional cigar coolers.

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**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.

**Metallurgical and Environmental Assessment of Injection of Pulverized Coal and Elephant Grass (Pennisetum Purpureum) in Blast Furnace.** Ricardo dos Santos Oliveira, Carlos Frederico Campos de Assis, Paulo Santos Assis
Due to the large increase in the concentration of greenhouse gases, creating a clean energy it has been a challenge for science and industry. After identifying possible solutions to this problem an alternative would be the use of biomass with thermal capacity as a reduction energy source in the process of reduction of iron ore in blast furnaces. This work aimed to use elephant grass (Pennisetum purpureum) and coal in the pulverized fines injection on tuyeres of blast furnace of steel mills in order to reduce costs of production of pig iron and reduce dependence on fossil fuels in the process. Elephant grass is a renewable source and rapid growth that through photosynthesis captures CO2 from the atmosphere, reducing the pollution caused by blast furnaces. To simulate the injection of the materials studied was built at the School of Mines - UFOP a model of combustion particles to analyze the samples. Other techniques are used for characterization as combustion calorimetry, gas analysis, and elemental chemical analysis. Thus, in theory, this research shows that elephant grass mixed with coal through its injection in blast furnaces proved viable in metallurgical and environmental terms.

**Integrated Mass Balance Between the Blast Furnace and the Pre-Treatment of Hot Metal.** Péricles Guimarães Oliveira Aguiar, Luis Fernando Andrade de Castro
This work aims to develop a steel production planning tool in Steelmaking focusing on reducing the solidified pig iron, through the integrated mass balance between the blast furnace and the pre-treatment of hot Metal Aperam South America. Studies have shown that the developed mass balance showed a satisfactory degree of confidence when correlated to industrial data. The integrated mass balance is able to predict the best production mix in Steelmaking depending on the quality and type of pig iron refining route.

**Continuous Carbonization: Blast Furnace Performance.** Rosiane Mary Rezende Faleiro, Cláudio Musso Velloso, Ronaldo Santos Sampaio, Flávio Roberto Silva de Azevedo, Fernando Lopes Latorre
Charcoal is the individual component that has the most impact on the final cost of an integrated plant. Given this reality, it was developed a continuous carbonization process, a modern technology that differs from traditional carbonization, allowed that the charcoal produced has better physicochemical characteristics. So the challenge now is to find appropriate operating conditions to produce in large-scale at a competitive cost. Based on this, it was developed this work in order to evaluate the performance of a blast furnace in actual operating conditions and on an industrial scale, using two types of charcoal: Reference charcoal and charcoal produced by continuous carbonization (Carboval). The main operating parameters were monitored. Carboval charcoal showed better results for chemical and grain size analysis, better permeability.

**Continuous Carbonization: Charcoal Consumption Simulation of Vallourec Tubos do Brasil Blast Furnace 1.** Rosiane Mary Rezende Faleiro, Ronaldo Santos Sampaio, Cláudio Musso Velloso, Flávio Roberto Silva de Azevedo, Fernando Lopes Latorre
Vallourec has invested in continuous carbonization technology in order to produce charcoal with good quality and higher conversion wood to charcoal, making the process feasible in technical and economic terms for the Brazilian scenario. The goal of this study was to compare, by thermochemical simulation, the impact on the specific consumption of the granular charcoal fed to the top of the blast furnace, using the charcoal from the traditional masonry kilns and the charcoal produced by the continuous carbonization reactor of Vallourec, the Carboval. The top steel quality of Carboval charcoal allowed to reduce the specific consumption of granular charcoal fed to the top in 18.2kg/t that, adding to higher gravimetric yield and less generation of the fine fractions, makes it attractive and feasible this technology. These advantages drive the industry out of the artisanal to the industrial production of charcoal.

**Efficiency Improvement of Reducing Agents in the Blast Furnace to Reduce CO₂ Emissions and Costs.** Robin Schott, Franz Reufer
The blast furnace process is the most important process to produce pig iron. The necessary process energy is mainly covered by coke. But the production of coke is connected with CO₂-emissions and high costs. A significant measure to reduce the coke rate and with it the CO₂-emissions plus costs is pulverized coal injection (PCI) through the tuyeres into the blast furnace. A further increase to substitute coke by coal can be achieved by using the Oxycoal+ technology. This article compares and shows the cost effectiveness and the decrease of CO₂-emissions with the help of simplified energy balances for the only coke operation of the blast furnace, the operation using pulverized coal injection and the operation using the Oxycoal+ technology.

**Study About Influence of the Sinter’s Basicity and FeO Content in Softening and Melting Area of the Blast Furnace.** Aline Aguiar Lopes, Arnaldo Ledig Aguiar Silva, Fernando Tadeu Pereira de Medeiros, José Adilson de Castro, Marcelo Alves de Carvalho, Sebastião Jorge Xavier Noblat
The worsening of the iron ore has driven many companies to adapt their process to new raw material quality parameters, hence the need to develop new studies that helps in the process of decision making. This article’s aim was to evaluate the influence of the sinter quality at the cohesive zone of the blast furnace through the ferrous burden softening e melting parameters. The importance of obtaining such informations about the cohesive zone is due, mainly, to the fact that most of the pressure drop occurs inside this region of the blast furnace. Five samples of sinter with different quimical analyses, produced at C.S.N’s (Companhia Siderúrgica Nacional) sinter plant, where selected and characterized for this study. The softening and melting analysis where conducted at the C.T.F. (Centro de Tecnologia de Ferrosos) due to a technical cooperation agreement between C.S.N. and Vale. The achieved results proves that the technics used on this research are suitable to evaluate the properties under high temperatures, providing important data to interpret how the metal burden behaves inside the blast furnace, such as thickness and the positioning, the burden’s permeability and reducibility, indicating the metal burden composition that optimizes the blast furnace’s performance.

**Hot Blast Air Distribution Main Design Modifications for Improved Performance.** Kyle T. Chomyn, Salustiano M. Pinto, Matthew E. DeGorter, Adam D. Blackmore, John W. Busser, Hamid R. Ghorbani
Multi-disciplinary engineering analysis and advanced modeling techniques were used to identify and develop low cost design modifications to improve a blast furnace hot blast air distribution main that experienced frequent refractory failures. Piping flexibility analysis helped identify the root causes of refractory damage and determine the need for new expansion joints. Finite element analysis was used to optimize a custom-designed elbow-to-elbow tie-rod system, which ensures thermal expansión loads are not placed on connecting piping. Heat transfer coefficients through the elbows were
estimated using computational fluid dynamics (CFD) flow modeling. The cast refractory design was changed to a more reliable brick refractory design. Excessive draft was occurring during furnace back-drafting, so the system was assessed using CFD, and a passive flow-reduction spool was designed. This first principles engineering design approach allowed for optimization and verification, ensuring that the new design addressed the root cause of the previous deficiencies.

**Influence of the Loss of Suction Pressure of the Exhaustion Gas into Sintering Process.**
Lindaura de Souza Cândido d’Avila, Railson Nogueira de Azevedo, Robert Nogueira de Azevedo, Mauricio Covcevich Bagatini
This study aimed to evaluate, in pilot plant, the influence of the loss of suction pressure of the exhaustion gases in sintering productivity parameters, fuel specific consumption, total mixture yield and quality of the sinter. Tests were performed with different values of suction pressure of the exhaustion gases which were controlled in 1,200, 1,000 and 800mmH2O. From of the results of these tests it was possible to verify the influence of the loss of suction pressure of the exhaustion gases in the performance of the sintering process and its impact on the quality of the sinter produced. The results demonstrated that, with the increasing loss of suction pressure of the exhaustion gases, there was significant sintering productivity drop, drop of the reduction disintegration index (RDI), drop of the fuel consumption, and rise of the reducibility index (IR), total mixture yield and tumbler test (TI).