FEATURING 12

IRONMAKING

papers from Primetals Technologies at the ESTAD Conference 2017 in Vienna covering the topics of ore preparation, sintering, direct reduction, blast furnace ironmaking, process control, and cold-briquetting of coal and ferrous by-products.

The direct-reduction plant of voestalpine, Corpus Christi, Texas, U.S.A.

Customers benefit by achieving maximum production efficiency at lowest processing costs.

COMPREHENSIVE COMPETENCE IN BENEFICIATION TECHNOLOGIES – FROM THE RAW MATERIALS TO STEEL

Paper number: 43
Principal author: Reinhard Redl

Efficient iron and steel production is of vital importance for any producer in the world. The source and quality of the iron ores has a major impact on the overall costs in the downstream steelmaking area. Impurities originating from the ore account for a large portion of the processing costs in the blast furnace and meltshop because undesirable elements have to be removed in the form of slag, which requires additional thermal or electrical energy.

In order to optimize the selection and use of iron ores, Primetals Technologies has intensified its efforts in the field of beneficiation. A single-calculation model was developed that takes into account the complete production chain in a steelworks – from the incoming raw materials to the liquid steel. The model is capable of assessing the suitability of iron ores for steelmaking, calculates the mass and energy balances of each individual plant, and also the overall mass and energy balance of the complete production route. Furthermore, the required beneficiation measures and the most feasible production route is identified by the model in accordance with customer requirements. Upgrading processes for dumped tailings were also developed in order to recover the otherwise lost iron minerals and generate a valuable additional iron ore concentrate.

Through a holistic evaluation of the entire value-added production chain, Primetals Technologies is now in a position to offer a complete range of proven industrial-scale plant solutions that extends from the beneficiation of run-of-mine ores, including the recovery of tailings, up to steel production. Customers benefit by achieving maximum production efficiency at lowest processing costs.

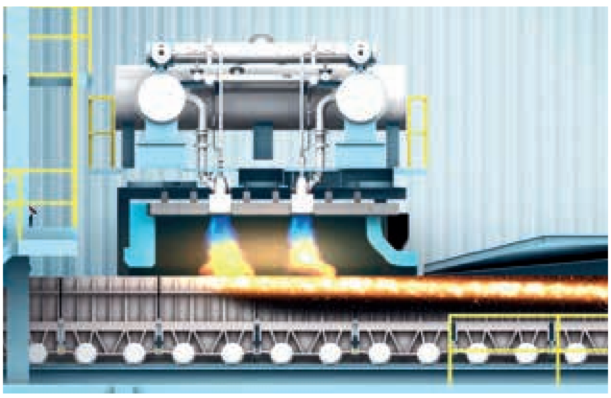
NUMERICAL SIMULATION OF THE SINTER PROCESS AND OPTIMIZATION OF THE TOP-BURNER SYSTEM BY CFD SIMULATIONS

Paper number: 46
Principal author: Edmund Fehringer

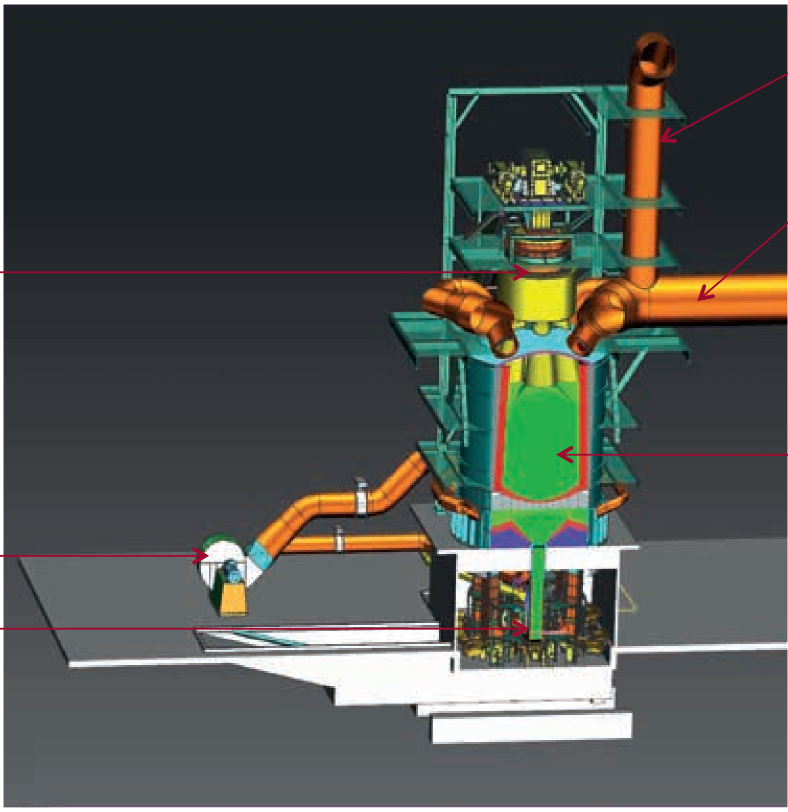
There are a number of factors that constantly challenge iron and steel producers: decreasing iron ore quality, the need to use lower-quality iron ores due to economic pressure, and ever-stricter environmental standards. The use of different raw materials, however, can have a significant impact on the sintering process. Adjusting all process parameters to regain stable and productive operation can take a lot of time and usually results in production loss. Raw material changes also lead to variations in the process-gas flows and emission concentrations.

Primetals Technologies has therefore developed an advanced model for the numerical simulation of the sintering process. Solid and gaseous flows that take place during sintering can be simulated, and all influencing factors are entered into the model either as input values (such as the chemical composition of the raw materials), boundary conditions (for example, suction pressure), or are calculation results. The simulation tool, which utilizes integrated calculation models, is highly flexible to evaluate different processing scenarios. It provides an accurate prediction of operational parameters and sinter offgas emissions.

Primetals Technologies has also improved the design of the top-burner system with the use of computational fluid dynamics (CFD). The CFD software simulates not only the burner flame itself but also the complete combustion process within the ignition furnace and annealing hood. The results can be used to support the engineering of the ignition hood and, if necessary, to efficiently implement design changes at an early stage of a project. Use of the numerical simulation tool is a well-proven and cost-efficient alternative to conducting serial tests on a laboratory scale.



Newly designed top-burner ignition furnace for the sinter plant



Schematic drawing of a shaft-type sinter cooler

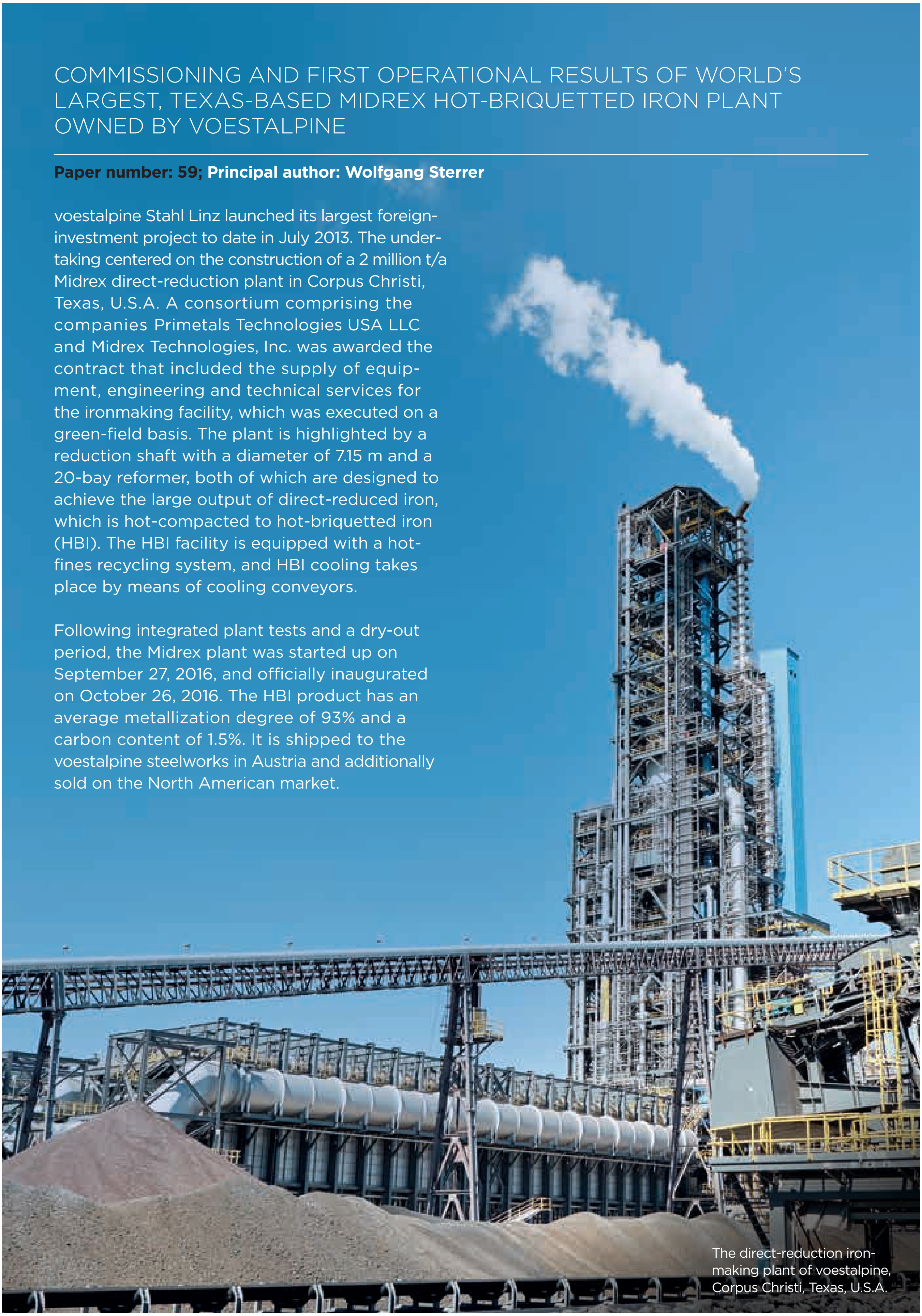
EFFICIENT AND ENVIRONMENTALLY FRIENDLY SINTER COOLING BASED ON THE COUNTER-FLOW PRINCIPLE

Paper number: 45; Principal author: Dr. Michaela Böberl

Most state-of-the-art sinter coolers apply a cross-flow cooling principle. With plant setups based on this concept, only a portion of the thermal energy contained in the hot off-air can be used for heat-recovery applications and the remaining energy is lost to the environment. Considerable improvement potential for recovering and utilizing the heat from sinter coolers therefore exists. At the same time, environmental regulations are becoming increasingly stringent, and further reductions in dust emissions and a more intelligent use of energy are required.

For these reasons, Primetals Technologies has developed two types of sinter coolers based on the counter-flow principle. The first type consists of a stationary shaft into which the hot sinter is charged. Hot sinter descends through the shaft from the top to the bottom in the opposite direction of the ascending cooling air. The second cooler type is a circular hopper cooler. Hot sinter is charged onto the top of a moving sinter bed that moves in a circular path. The cooled lower portion of the sinter bed is scraped from the hopper with the use of a so-called scrapper prior to the sinter-charging station. Cooling air flows through the sinter bed from the bottom to the top in the opposite direction of the gradually descending sinter (counter-flow principle). This type of sinter cooler was first built at the Wakayama Works of Nippon Steel & Sumitomo Metal Corporation (NSSMC) by the Metals Division of Mitsubishi Heavy Industries, which is now part of Primetals Technologies.

In both types of sinter coolers based on the counter-flow principle, a direct heat transfer from the hot sinter to the cooling air takes place. Because the total heat energy of the hot sinter is transferred to the cooling air, the temperature of the exhausted off-air is maximized. This allows it to be ideally used for subsequent applications such as for the generation of steam and even electrical energy. Since sinter cooling takes place in a closed system, diffusive dust emissions are reduced to zero. Depending on available space and the quantity of sinter to be cooled, both counter-flow sinter cooler types is available to customers for the efficient cooling of hot sinter and a maximum recovery of the inherent heat energy.



COMMISSIONING AND FIRST OPERATIONAL RESULTS OF WORLD'S LARGEST, TEXAS-BASED MIDREX HOT-BRIQUETTED IRON PLANT OWNED BY VOESTALPINE

Paper number: 59; Principal author: Wolfgang Sterrer

voestalpine Stahl Linz launched its largest foreign-investment project to date in July 2013. The undertaking centered on the construction of a 2 million t/a Midrex direct-reduction plant in Corpus Christi, Texas, U.S.A. A consortium comprising the companies Primetals Technologies USA LLC and Midrex Technologies, Inc. was awarded the contract that included the supply of equipment, engineering and technical services for the ironmaking facility, which was executed on a green-field basis. The plant is highlighted by a reduction shaft with a diameter of 7.15 m and a 20-bay reformer, both of which are designed to achieve the large output of direct-reduced iron, which is hot-compacted to hot-briquetted iron (HBI). The HBI facility is equipped with a hot-fines recycling system, and HBI cooling takes place by means of cooling conveyors.

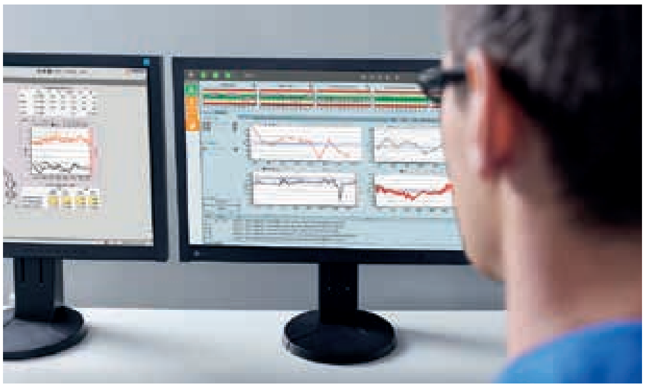
Following integrated plant tests and a dry-out period, the Midrex plant was started up on September 27, 2016, and officially inaugurated on October 26, 2016. The HBI product has an average metallization degree of 93% and a carbon content of 1.5%. It is shipped to the voestalpine steelworks in Austria and additionally sold on the North American market.

The direct-reduction iron-making plant of voestalpine, Corpus Christi, Texas, U.S.A.

DIRECT-REDUCTION PLANT PROCESS OPTIMIZATION WITH THE DRIPAX™ EXPERT SYSTEM

Paper number: 93; Principal author: Dieter Bettinger

An integrated process-optimization system for Midrex direct-reduction (DR) plants was jointly developed by Primetals Technologies and Midrex Technologies. The new product-quality prediction models achieve a high degree of prediction accuracy – already hours before measured data is available. This supports a quick decision-making process toward maintaining the quality targets and consistency of the direct-reduced iron (DRI) product. Due to improved quality control, significant operational savings can be expected at the downstream production facilities.



Monitor display of the DRIpax process-optimization system for direct-reduction plants

The DRIpax expert system, a rule-based advisory system that assists panel operators, is the next step for improved process control in direct-reduction plants. The expert system was first launched as part of the process-optimization system of the new Midrex direct-reduction plant of voestalpine Texas LLC in the U.S.A.

> **"The DRIpax system has already shown its value in contributing to the production of high-quality HBI at the new voestalpine direct-reduction plant in Texas."**
>
> Christopher Harris, voestalpine Texas LLC

THE FUTURE OF DIRECT REDUCTION IN EUROPE – MEDIUM- AND LONG-TERM PERSPECTIVES

Paper number: 60; Principal author: Robert Millner

Driven by global demands to reduce CO_2 emissions and improve energy efficiency, a changing trend in the use of energy systems can be noted. The E.U. roadmap, for example, suggests CO_2 emission reductions by 80% between 2005 and 2050. This is already having an impact on the way steel is produced in Europe.

Ironmaking technologies such as natural-gas-based direct-reduction processes are characterized by smaller CO_2 footprints compared to integrated iron and steel mills. Direct-reduction plants are therefore seen as a medium-term bridge solution on the path toward industrial decarburization and to reduce process-related CO_2 emissions by more than 60%. Certain European iron and steel producers are already producing or plan to produce hot-briquetted iron (HBI) at locations with low-cost natural gas and electricity. The simultaneous use of HBI at their own steelworks will further contribute to lower CO_2 emissions.

In order to eventually reach the targeted CO_2 reduction figure set by the E.U., the additional or sole use of "green" hydrogen from renewable natural resources in iron and steel production will be required over the long-term. The direct reduction of iron ores or iron ore pellets is a highly efficient and well-proven technology that potentially allows natural gas to be supplemented or replaced by hydrogen for DRI or HBI production. Hydrogen would then serve as the basis for ironmaking. Additional synergy benefits could then be achieved in steelmaking by combining direct-reduction plants and electric arc furnaces (EAF). An example for this is the linking of the direct-reduction facility and the EAF at Saudi Iron & Steel Company (Hadeed) by a hot-transport system, which further decreases energy requirements and related emissions.

Direct linking of the direct-reduction plant (right) and EAF steel mill (left) at Saudi Iron & Steel Company (Hadeed) by means of an insulated DRI hot-transport system. This allows DRI to be charged to the EAF at temperatures in excess of 600°C, leading to major electrical energy savings for melting work.

TATA STEEL LIMITED KPO BLAST FURNACE 1 – DESIGN, COMMISSIONING AND START-UP

Paper number: 49
Principal author: Mark Geach

In 2012, Tata Steel Ltd. commenced construction of an integrated iron and steel plant in Kalinganagar, Orissa, India. The first phase of the project included steelmaking facilities, a coking plant, a sintering plant and Blast Furnace No. 1. A contract had been previously awarded to Primetals Technologies in January 2007 to design and supply the new 14-m-hearth-diameter blast furnace and additional facilities as part of the overall site arrangement.

The project comprised the supply of equipment required for a modern free-standing blast furnace, including a copper-stave cooling system, a flat-floor casthouse arrangement, bell-less top-charging facilities and a full suite of blast furnace unit equipment. Also supplied were wet-slag granulation facilities, three external-combustion-chamber hot-blast stoves, and a gas-cleaning plant with a top-gas recovery turbine arrangement. The furnace is designed with a capability to produce 9,150 tons of hot metal per day. Blow-in took place on February 29, 2016.

This paper discusses the project scope and highlights some of the design features such as pneumatic dust conveying, the cyclone and dust-catcher combination, trough-forced cooling, and the latest stove-crossover design. Some of the challenges faced during the various phases of the project (design, supply, construction, commissioning and operation) are also reviewed.

View of the new Blast Furnace No. 1 at the Kalinganagar steelworks of Tata Steel Ltd. – the largest blast furnace in India

New dry-slag granulation technologies are in development to cool the molten slag with air and recover the thermal energy.

INSTALLATION OF A DRY-SLAG-GRANULATION PILOT PLANT AT BLAST FURNACE A OF VOESTALPINE

Paper number: 71
Principal author: Thomas Fenzl

With a tapping temperature of around 1,500°C and an annual worldwide output of approximately 400 million tons, blast furnace slag represents a huge – and largely unused – source of energy that potentially can be recovered. Current state-of-the-art practice is to granulate blast furnace slag in wet-granulation plants without utilizing the thermal energy. However, new dry-slag granulation technologies are in development to cool the molten slag with air and recover the thermal energy for applications such as steam production or the generation of electrical energy.

On the basis of their acquired experience with dry-slag-granulation testing facilities and from various research programs, Primetals Technologies and its partners are now taking the next step. A large-size pilot plant has been installed on the casthouse floor of Blast Furnace A of voestalpine in Linz, Austria, for the treatment of blast furnace slag. The slag is granulated applying so-called rotating-cup technology to produce a saleable product. Cooling of the slag then takes place under dry conditions with the use of air. Through a gradual step-by-step increase of the off-air temperature, significant potential exists to utilize the inherent energy of the heated air for various applications such as steam generation. Extensive tests at the pilot plant are expected to provide the technical expertise required for the commercialization of the process. Valuable insight will be acquired related to factors such as the layout and arrangement of a slag-granulation plant, operational factors and the feasibility of the dry-slag-granulation process.

Aerial view of the Finex 2.0M plant with a nominal capacity of 2 million ton of hot metal per year

ENHANCING PERFORMANCE OF INTEGRATED STEEL PLANTS BY COMBINING EXISTING BLAST FURNACES WITH FINEX TECHNOLOGY

Paper number: 280; Principal author: Norbert Rein

Growing energy demands and steadily deteriorating raw material quality are major challenges for steel producers today. The Finex process, jointly developed by Korea's Pohang Iron and Steel Company (Posco) and Primetals Technologies, offers the ironmaking sector the capability to lower hot-metal production costs and environmental emissions while simultaneously increasing operational flexibility and the choice of suitable raw materials. The process combines gas-based iron ore reduction in a series of fluidized-bed reactors with smelting in a melter-gasifier. The innovative Finex solution produces hot metal that is identical in quality to blast furnace hot metal, however, without the need for coke oven or sintering plants.

The first commercial Finex plant with an annual production capacity of 1.5 million tons of hot metal was started up at Posco's Pohang steelworks in Korea in April 2007. This was followed by the installation of a 2.0 million t/a third-generation (3G) Finex 2.0M facility at the same site, which has been reliably operating since its initial blow-in in January 2014.

Based on the well-proven plant concept, new process features, highly competitive production costs and environmental benefits, the Finex process represents an ideal alternative or supplement to blast furnace-based ironmaking. Integration of Finex plants within the existing infrastructure of an integrated steelworks allows producers to benefit from the available synergies between the blast furnace and Finex plant for an enhanced overall performance of the steelworks. This is because all generated coke and sinter fines can be ideally used at each ironmaking facility. Producers can therefore increase their total iron output in a highly cost-efficient and environmentally compatible manner.

Example of a ferrous by-production recycling plant supplied by Primetals Technologies

BRIQUETTING OF FERROUS AND COAL FINES – SAVING RESOURCES, CREATING VALUE

Paper number: 55
Principal author: Stefan Hötzinger

One of the global trends that constantly challenges the iron and steel industry is related to the generation of fines, slurry, sludge and scale – summed up as "ferrous by-products." The recycling of these by-products is regularly done in many steel plants. Normally, such materials cannot be directly used in primary production processes. With consideration to their chemical composition and grain-size distribution, ferrous by-products are usually added to the sinter raw mix. However, other solution possibilities exist. In this paper, the latest developments by Primetals Technologies dealing with the cold briquetting of ferrous by-products are presented. Examples of executed projects for the direct charging of cold briquettes to the direct-reduction shaft are described, and other solutions for integrated steel mills reviewed.

Furthermore, briquettes made from coal fines that arise during coal transport and handling can be used in smelting-reduction processes such as Corex or Finex, or for enhanced coke-oven operations in the traditional blast furnace ironmaking route. The target of Primetals Technologies is to enable the production of coal briquettes that are superior to normal coal with respect to their mechanical properties and hot strength. The use of such briquettes leads to higher productivity and reduced costs. Different technological applications and solutions from Primetals Technologies in the area of coal briquetting are highlighted in this paper.

TOWARD A CLEANER FUTURE – TRENDS IN GAS-CLEANING TECHNOLOGY FOR IRONMAKING

Paper number: 66
Principal author: Andreas Steinwandter

Traditional approaches to blast furnace gas cleaning using wet scrubbers are being challenged by the reemergence of dry-gas cleaning technologies because of their successful application in other parts of the iron and steel production chain. Wet-gas cleaning of blast furnace top gas is a proven solution that removes dust and certain trace substances contained in the gas in a single step. However, wet-gas cleaning requires cleansing the water of dissolved solids and then treatment of these solids. Blast furnace upgrades offer an opportunity to consider improving existing wet-gas cleaning systems. This paper reviews how such upgrading measures can be implemented in a cost-effective manner.

Technologies to remove nitrous oxides ($DeNO_x$) are now widely used in many high-temperature processes. With consideration to ever-stricter regulations governing emission limits that need to be met, Selective Catalytic Reduction (SCR) technology will therefore find an increased application in the future. The paper also presents an overview of the implementation of SCR technology in sinter plants, and the special considerations that need to be made.

The target is to enable the production of coal briquettes that are superior to normal coal with respect to their mechanical properties and hot strength.

HOLISTIC OPTIMIZATION MODELS – RECENT DEVELOPMENTS IN IRONMAKING-RELATED PROCESS CONTROL

Paper number: 87; Principal author: Dieter Bettinger

State-of-the-art process-control systems are currently used with the intention to optimize production processes at each step along the iron and steel production route. This is achieved on the basis of local, only temporarily available information. In accordance with the ideas behind "Industry 4.0," holistic optimization models go much further by enhancing the performance of a plant through a detailed analysis of historical data and by connecting information from different plant facilities. Primetals Technologies considers its holistic optimization models for ironmaking an important step toward the implementation of the vision of a Smart Factory. In this paper, the most recent developments from Primetals Technologies related to Level 2 process-optimization systems for blast furnaces and sinter plants are presented. Improved decision support and detailed process analyses are two areas among many that benefit from this holistic approach. Several case studies from recent plant installations demonstrate how operators and process engineers can derive maximum value from the seamless integration of holistic optimization models into a proven process-optimization solution.

IRONMAKING HIGHLIGHTS OF PRIMETALS TECHNOLOGIES

Agglomeration

- Use of up to 80% pellet feed in the sintering process with the Intensive Mixing and Granulation System
- 25% reduced fuel consumption with vertical-type roof burners in the ignition furnace of sintering plants
- Up to 50% reduction of the waste-gas volume of sintering plants with the Selective Waste-Gas Recirculation System
- 99% reduction of sinter-plant emissions with the Meros waste-gas treatment process
- Generation of 15 kg to 25 kg of steam in a heat-boiler system per ton of sinter at the sinter cooler
- 50% reduced space requirements for the induration furnace with Circular Pelletizing Technology (CPT)

Blast furnace ironmaking

- Injection of >200 kg of pulverized coal per ton of hot metal into the blast furnace for major coke savings
- Generation of 30 kWh to 40 kWh of electricity per ton of hot metal through the recovery of the hot-blast pressure energy with a top-gas recovery turbine
- >25% increased generation of electricity in a blast-furnace top-gas recovery turbine with the application of the Merim dry-type blast-furnace dedusting system

Direct reduction (Midrex process)

- 500,000 t/a to 2,500,000 t/a production capacity range of Midrex direct-reduction modules
- >60% reduction of process-related CO_2 emissions compared to coal-based ironmaking plants
- Direct charging of hot DRI from the direct-reduction plant to the EAF with a temperature of 600°C leads to the following benefits compared to cold DRI charging: 15% to 20% productivity increase, 120 kWh/t to 140 kWh/t reduced electricity consumption, 0.5 kg/t to 0.6 kg/t lower electrode consumption, and 1.8 kg/t to 2.0 kg/t lower refractory consumption

Smelting reduction

- 8% to 14% OPEX (operational expenditures) advantage of coal-based Corex ironmaking plant compared to the blast furnace route
- 15% to 33% reduced CO_2 emissions in a plant configuration comprising Corex, a direct-reduction plant (based on the use of Corex export gas) and an electric arc furnace, compared to the integrated blast furnace – LD (BOF) production route
- Use of iron ores with up to 4% Al_2O_3 content in coal-based Corex and coal- and fine-ore-based Finex plants