voestalpine Texas — A New Market for Hot Briquetted Iron

Hot briquetted iron (HBI) is the compacted, denser form of direct reduced iron (DRI). Manufactured for easier handling and trans-ocean shipping, the majority of this product has been melted in electric arc furnaces (EAFs). This paper discusses voestalpine Texas, which is the first HBI plant designed specifically to supply blast furnaces.

Exploration of shale gas in North America has drastically reduced the price of natural gas (NG) and opened up economic possibilities of using NG for iron- and steelmaking. One such project to capitalize on this new North American NG market is the voestalpine Texas LLC hot briquetted iron (HBI) plant, which recently began operation. This plant is North America's first-ever HBI facility and is the largest of its kind. The plant is also unique in that it is the first HBI plant built based on blast furnace demand rather than the electric arc furnace (EAF) market. About half of its product will be shipped to voestalpine's blast furnaces in Austria to increase hot metal production. This practice constitutes a revolutionary step forward in carbon abatement since the carbon footprint of the blast furnace hot metal made via this route will be decreased by half.

Discussion

The voestalpine Decision — Steel is essential to our modern world. It is used in a broad range of applications, from construction of bridges and buildings to automotive and machine parts, as well as food packaging, power generation and aerospace engineering. Steel is strong yet formable, making it one of the most versatile and adaptable engineering materials available. However, the production of steel is one of the most energy-intensive industries, and the steel production route most widely used today — basic oxygen furnace (BOF) coupled with coke oven-blast furnace (CO-BF) ironmaking — is heavily dependent on carbon-intensive fuels, which are sources of significant CO_2 emissions.

In future decades, the traditional model of the integrated steel works (i.e., taking in iron ore and using coke to reduce it to metallic iron) will come under great challenges. Starting from scrap and using the EAF rather than the blast furnace to make steel could result in a significant change in the carbon footprint of the steel production cycle. However, as long as scrap remains fairly scarce, production economics will tend to favor the BF-BOF route. But what happens when new steel enters the scrap cycle and a transfer from carbon to renewable energy takes place? There could be a shift toward EAF metallurgy for new units and a more or less constant level of BF-BOF units, as projected in Fig. 1.

However, there are two primary limitations related to replacing carbon-intensive steel production: plant lifetime and the availability of carbon-lean energy. Iron and steel production units have lifetimes measured in decades, and almost all existing blast furnace plants of the world's leading steelmakers have the latest technology and will remain in production until the middle of the century. The availability of carbon-lean energy, such as natural gas, on a continuous basis for more than 8,500 hours per year and at a competitive price is not the case for most integrated steel producers, especially in Europe and Asia.

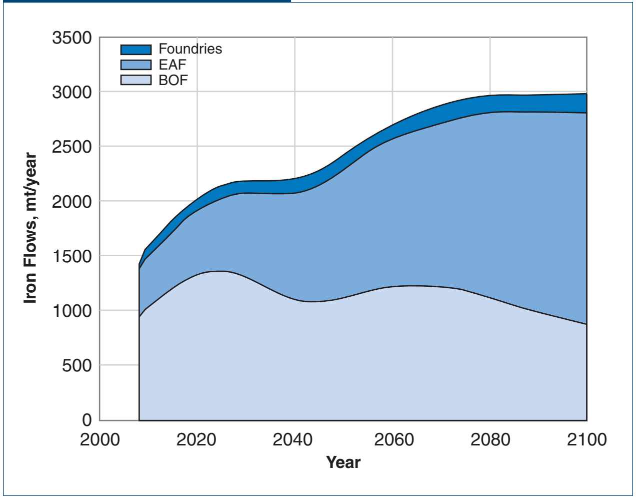
Perhaps the DR/EAF route could be a future option for an integrated

Authors

Robert L. Hunter
market research manager,
Midrex Technologies Inc.,
Charlotte, N.C., USA
rhunter@midrex.com

Christopher M. Ravenscroft
manager — global marketing and communications,
Midrex Technologies Inc.,
Charlotte, N.C., USA
cravenscroft@midrex.com

Figure 1



Projected developments in world steel production (Source: Allwood, J., New Mindset for Material Efficiency and Reduced Energy Demand, *ECSC, 2014).*

steelmaker, but such a significant technology change could be considered only when significant new investment is planned.

So the question becomes, "What is now the best available technology for a new production unit?" A possible answer is the decision by the voestalpine AG to build an HBI plant in Corpus Christi, Texas, USA, to produce iron metallics for its BF-BOF steel works in Austria, as well as to be a source of merchant product to sell to other steelmakers.

voestalpine AG is a steel-based technology and capital goods group and a world leader in the manufacture, processing, and development of sophisticated steel products. With its cutting-edge technology, voestalpine is regarded as the European benchmark for low-emissions steel production and processing.

On 3 July 2013, voestalpine signed a contract with Siemens Industry Inc. and its consortium partner, Midrex Technologies Inc., to build a MIDREX® direct reduction plant designed to produce 2 million tons per year of HBI (Fig. 2). The HBI project is voestalpine's largest foreign direct investment and a major step in its commitment to support the European Union's low-carbon economy goals.

When Wolfgang Eder, chief executive officer and chairman of the management board of the voestalpine Group, announced the decision to invest in the HBI plant in Texas, he pointed out that the use of a natural gas-based reduction process will significantly improve the overall carbon footprint of voestalpine and will serve as an important step in achieving the Group's ambitious internal energy efficiency and climate protection objectives.

Role of Ironmaking in Global CO_2 Emissions — A major challenge for all industry worldwide is how to comply with more stringent environmental emissions standards. This will be essential for sustainability. The general consensus is that emissions restrictions will get tighter for all industries globally and this will severely affect the ability of many integrated steelmakers going forward. Carbon dioxide (CO_2) has become the symbol for the plight of society against industry over the greenhouse gas (GHG) effect. Although not the most powerful GHG, CO_2 is the most abundant and captures the most attention.

In December 2015, China had its first-ever red alert for air pollution in Beijing. A red alert is issued when the air quality index is above 300 ("Heavily Polluted") on a scale that tops out at 500 ("Severely Polluted") for three consecutive days. During the red alert, $PM_{2.5}$ (fine particulate measured in micrometers) was 10 times the recommended level. In addition, in 2015 the World Health Organization named India as having the worst air pollution on the planet. As a result, Delhi restricted the use of cars to alternating days and is closing a coal-fired power plant. Although these examples of air quality are not the same exact issue as GHGs, they are causing media and government focus on industry emissions as a whole.

Total production of CO_2 by human activities is currently around 35 billion tons per year.

Figure 2

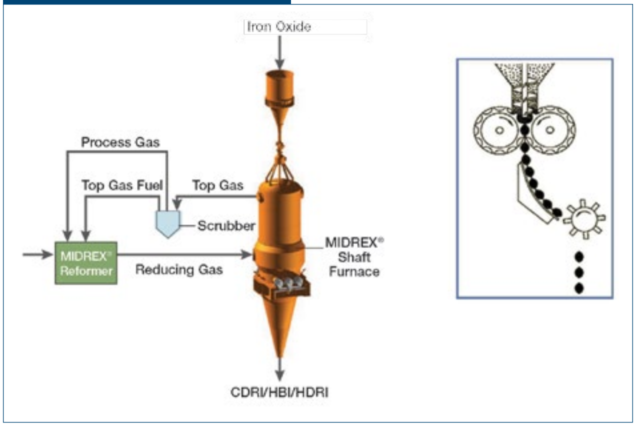
Rendering of voestalpine Texas LLC hot briquetted iron (HBI) plant.

Ironmaking and steelmaking account for almost 7% of mankind's entire carbon footprint. Ironmaking alone constitutes 80–85% of iron and steel's total CO_2 output. Integrated mills are the largest contributor of CO_2 by both volume and percentage, with coke-fueled blast furnaces currently producing well over 90% of the world's iron.

Based on the world steel industry's coal consumption, it is estimated that blast furnace ironmaking (including the processing step to make the coke from metallurgical coal) generates approximately 1.8 tons of CO_2 for every ton of iron produced. As no proven carbon capture system exists for blast furnaces, the best way for integrated steelmakers to reduce CO_2 emissions is simply to not create the emissions in the first place.

A practical way to keep BFs operational and comply with tighter environmental standards is needed.

Figure 3



MIDREX® shaft furnace designed and equipped for HBI production.

Direct Reduction Ironmaking — The Cleanest and Safest Way of Making Iron — While there is no currently known and proven path to totally eliminate carbon from the iron and steel production cycle, the most effective way to reduce CO_2 emissions is to replace ironmaking capacity that relies on burning coals and charcoal with natural gas–based direct reduction ironmaking (DRI) plants. This type of technology is the most environmentally friendly technology to produce ore-based metallics (OBMs).

Most naturally occurring iron oxide has the composition of hematite (Fe_2O_3) and contains about 30% oxygen. The direct reduction process removes most of this oxygen by exposing the iron oxide pellets to a reducing gas comprised of hydrogen and carbon monoxide produced from natural gas.

Direct reduction of iron using MIDREX technology occurs in a low-pressure, shaft-type reactor (Fig. 3). Iron oxide pellets enter the top of the reactor through multiple feed pipes. The pellets are reduced to metallic iron by intimate contact with counter-flowing reducing gas while descending by gravity through the reactor. The reducing gas is comprised primarily of hydrogen (H_2) and carbon monoxide (CO). The reduced pellets are either cooled in the reactor's lower cone and discharged at close to ambient temperature (in the case of cold DRI (CDRI)) or discharged while hot but not molten (approximately 700°C or 1,300°F) as hot DRI (HDRI). HDRI can be transferred by insulated conveyor or container, charged directly into an adjacent melting furnace, or discharged into a roller press-type briquetting machine, where the HDRI is compacted and formed into palm-sized, pillow-shaped briquettes (HBI) without the use of a binder material. After being cooled, the HBI can be handled and stored similar to other bulk materials.

The hot briquetting system is specially configured to provide voestalpine Texas the capability to produce 2 million tons per year of HBI, making it the largest plant of its kind in the world. Midrex has worked for three decades with Maschinenfabrik Köppern GmbH & Co. KG (Köppern) to develop the most reliable and productive system for producing HBI.

The system installed at voestalpine Texas includes seven roller-type briquetting machines, each equipped with a briquette separator and a hot screen, which removes undersized material for recycling back to the briquetting machines. The briquetting machines are arranged in two rows, with each row serviced by a product cooling system that cools the HBI and transports it to the plant's product handling system.

Benefits of HBI Use in BF — Conventional wisdom has held that DRI is not suitable as a significant feed material for a blast furnace. However, the advent of HBI has more and more integrated steel producers considering its use in their blast furnaces on a regular basis in order to increase hot metal output when needed and to help limit CO_2 emissions.

Some of the benefits of using HBI in the blast furnace are:

- Higher productivity: When using HBI, the primary reduction work has already taken place outside of the BF in a direct reduction plant. Therefore, more reduction gas is available in the blast furnace to reduce the remaining burden, which results in increased blast furnace productivity. A rule of thumb is that for each 10% increase in burden metallization, production output rises by 8%.
- Lower coke consumption: A direct reduction plant uses only natural gas, which is much more environmentally friendly than using coke as the main reducing agent, as in traditional blast

Figure 4

View of voestalpine Texas LLC HBI plant site.

furnaces. Less reduction gas is required to reduce the burden in the blast furnace at the same productivity level when HBI is used. Therefore, coke consumption is reduced. Again, a rule of thumb is that each 10% increase in burden metallization decreases the coke rate by 7%.

- Reduced CO_2 emissions: Iron oxides are reduced in a MIDREX plant by the use of natural gas, which is processed by a reformer to generate a reduction gas consisting of approximately two-thirds H_2 and one-third CO. During the reduction process, CO is converted to CO_2 and H_2 to H_2O (water). The reduction of iron oxides by means of hydrogen gas creates no CO_2 at all. In a blast furnace, the major source of the reduction gas is coal, which produces mostly CO and CO_2 and very little H_2. Therefore, the carbon footprint of voestalpine's steelmaking operations is reduced, as is the carbon footprint of other HBI users.
- Safer handling, transport and storage of HBI: Despite its high temperature when exiting the reduction furnace (approximately 700°C or 1,300°F), DRI is not in a molten state and is not subject to manual handling until after being compacted into HBI and the briquettes are cooled to close to ambient temperature. This reduces the danger of product handling compared to traditional blast furnaces where hot metal is tapped at temperatures of approximately 1,500°C (2,700°F).

Due to its outstanding physical characteristics, HBI can be shipped more easily and safely than CDRI. In fact, the International Maritime Organization (IMO) recognizes HBI as the only form of DRI that is to safe to transport by sea without additional precautions. Ships carrying non-briquetted DRI cargoes must have their holds inerted with a non-reactive gas, such as nitrogen, and maintained at safe levels throughout the voyage, which can be costly over long voyages. As a result, the insurance cost for HBI cargoes is considerably less than for non-briquetted DRI shipments and there is no additional cost for inerting the cargo holds.

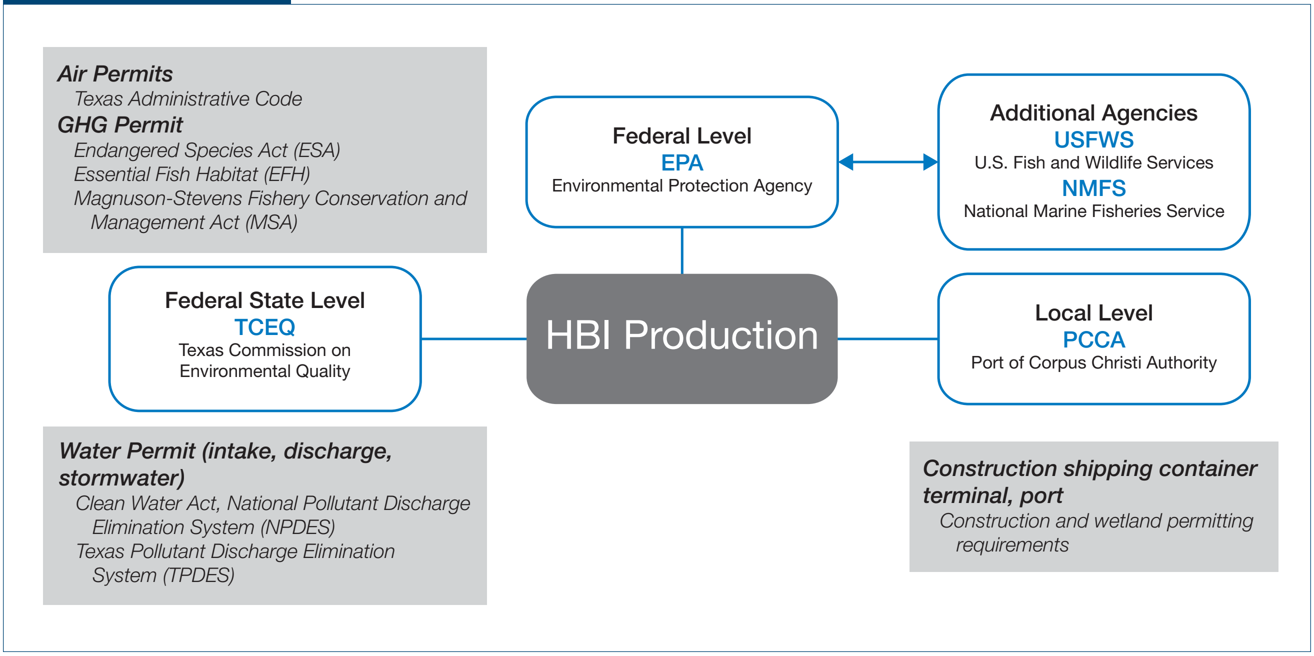
HBI can be stored outdoors much like scrap steel. In contrast, non-briquetted DRI must be kept out of the rain in order to prevent contact with moisture, which could lead to oxidation and combustion.

The voestalpine Texas Project — The voestalpine Texas LLC HBI plant is the first investment in the U.S. for its steel division and is simultaneously the largest foreign investment in the history of the voestalpine Group. voestalpine examined a total of 17 sites for the project before choosing the La Quinta Trade Gateway in San Patricio County just outside the city of Corpus Christi, Texas. The La Quinta Trade Gateway proved to be the best fit in terms of logistics, energy supply, a well-educated workforce and the political environment. The site, strategically located on Corpus Christi Bay, covers an area of almost 500 acres (approximately 2 km^2) and has direct access to the shipping channel to the Gulf of Mexico (Fig. 4).

The plant is equipped to accommodate deep sea freighters dimensioned to support the innovative logistics plan of the voestalpine Texas plant. Based on the concept of circular hauls, the same ships that deliver iron oxide pellets from raw materials sources will transport HBI to customers, thus reducing freight costs. Here's how it works:

- Approximately 3 million tons of iron oxide pellets will be received by the plant each year from suppliers in the Americas.
- The same ships that deliver the pellets will transport up to 110,000 tons of HBI each voyage to ports in northern Europe (Rotterdam, the Netherlands) and southern Europe (Koper, southwestern Slovenia). The annual volume of HBI received at the ports is expected to be approximately 800,000 tons.
- Barges or trains will move the HBI to voestalpine's steel mills in Linz and Donawitz, Austria, where the blast furnaces will use about 40%. The remaining 60% will be sold to external customers worldwide.

Figure 5



Applicable environmental regulations and authorities.

- When possible, HBI will be loaded and transported to users in North and South America in the same ships that deliver it to the European posts. Already Altos Hornos de México (AHMSA), Mexico's largest steel manufacturer, has signed a five-year agreement with voestalpine for the supply of 400,000–650,000 tons per year of HBI.

The logistics plan will keep empty trips to a minimum, which will lower freight costs by conserving fuel while reducing the environmental impact of the shipping operations.

The layout of the plant is designed with the neighboring communities and the environment in mind. Best available emissions control technologies will be applied in strict compliance with all applicable environmental regulations and standards (Fig. 5). Natural gas and pre-treated iron oxide pellets are the only raw materials needed for producing HBI, ensuring that no hazardous and/or toxic byproducts will be produced. All conveyors and transfer towers are enclosed and equipped with baghouse filters, and iron oxide pellets will be stored in a fully enclosed building, which will keep dust emissions well below the significant impact level. The collected iron oxide dust is a valuable raw material and can be recycled in the process.

The plant's core technology, process engineering, mechanical equipment and electrical systems for the direct reduction plant have been supplied by Midrex Technologies Inc. and consortium partner, Primetals Technologies Ltd.

The voestalpine Texas plant is able to meet its cooling and process water needs without impacting the local freshwater resources by drawing in seawater from Corpus Christi Bay. Approximately 80% of the seawater is used for non-contact cooling in a heat exchanger loop with closed-circuit cooling towers and a filter backwash system. The process water is treated in an on-site process water treatment facility, which allows approximately 97% of the water to be recycled in the plant. More than 80% of the water withdrawn from Corpus Christi Bay is returned, meeting or exceeding all regulatory requirements.

Conclusion

The decision by the voestalpine Group to invest in an HBI plant in the U.S. ushers in a new way of addressing the challenge of lowering emissions while simultaneously maintaining production at an integrated works. The new voestalpine Texas plant is an example of a cleaner and safer form of ironmaking that takes advantage of lower-cost U.S. natural gas.

Sustainability is ultimately the key issue for every steelmaker going into the future. DRI products, which have been viewed by integrated steelmakers as an EAF-specific charge material, may actually present a long-term scalable solution going forward. The use of HBI as a charge material in the blast furnace is now being seen as a powerful way to help displace CO_2

emissions while increasing hot metal production of the BF.

Investing in natural gas–based direct reduction plants, either directly or through long-term supply contracts, in strategically located sites around the globe is no longer a hypothetical scenario, as the first direct reduction plant built specifically to supply HBI to blast furnaces in Austria is in operation on the Gulf Coast of Texas in the U.S. The first shipment of about 100,000 tons was dispatched from Corpus Christi on 22 November 2016, making voestalpine Texas a pioneer in opening a promising new market for HBI.

References

1. R.L. Hunter, "Massive Savings in CO_2 Generation by Use of HBI," *Direct From Midrex,* Midrex Technologies Inc., 3–4Q 2009, pp. 9–11.
2. H.P. Gaines and C.M. Ravenscroft, "A Scenario for Integrated Sustainability: Application of the TRS® for the Integrated Blast Furnace Steel Industry," 2014.
3. T. Buergler, J. Prammer, R. Hackl and B. Kohl, "Raw Materials and Technologies for Iron- and Steelmaking Under the Aspects of the EU Low-Carbon Roadmap," 2015.
4. V. Steininger, voestalpine Corporate Blog, www.voestalpine.com/blog/en/innovation-en/facts-figures-on-the-new-hbi-plant-in-texas, 2016. ✦

AISTech — This paper was presented at AISTech 2016 — The Iron & Steel Technology Conference and Exposition, Pittsburgh, Pa., USA, and published in the Conference Proceedings.