Hot charging of DRI for lower cost and higher productivitysteelmaking

The well known cost benefits of charging hot DRI to the EAF are enhanced by directly linking the DR plant with the EAF via gravity feeding. The first such facility is due for commissioning in early 2006 to produce 300kt/yr of billets.

Robert Klawonn and Stephen C. Montague
Midrex Technologies, Inc.

At the end of 2003, Midrex Technologies, Inc. (USA) and Al-Ghaith Holdings (UAE) signed a pre-engineering contract to start work on a new integrated mini-mill: Hamil Steel. A Midrex direct reduction plant using the industry's first HOTLINK system will be integrated with a new melt shop to feed hot direct reduced iron (HDRI) to the electric-arc furnace (EAF) using gravity.

HOTLINK provides a simple, reliable and economic means for charging HDRI at temperatures at or above 700°C from a Midrex shaft furnace to an adjacent EAF using gravity. This optimisation of EAF productivity and energy efficiency is an evolutionary step that will achieve increased productivity and energy savings in the production of high-quality steel. By combining the well-proven Midrex hot discharge furnace with conventional EAF gravity-feed know-how, Midrex, VAI/Fuchs and Hamil Steel will demonstrate cost savings, greatly increased throughput and high availability.

Hot charging direct reduced iron

The idea of hot charging DRI for improved process efficiency is not new. Hot charging can reduce operating costs and increase EAF productivity. Typically, power consumption can be reduced by about 20kWh/t of liquid steel for each 100°C increase in the composite metallic charge temperature, and electrode consumption is reduced given its linear relationship with power consumption (about 0.004kg/kWh). Hot charging will increase EAF productivity for a melt shop sized to charge cold DRI because of the shorter melting cycle. The composite charge may consist of a mixture of HDRI with traditional metallics (cold DRI, HBI, pig iron or scrap whether cold or preheated).

For a greenfield site, capital cost savings can also be realised by downsizing the EAF electrical system in order to take advantage of this increase in productivity, or, conversely, specific capital costs can be reduced significantly by increasing the throughput of a DR/EAF combination using HOTLINK.

The concept

Preheating of DRI cannot be accomplished by applying conventional off-gas preheating systems, however, a variety of systems could be selected for the purposes of conveying HDRI from a DR plant to an EAF. These include mechanical conveyors (apron type or drag chain), transport vessels (by rail or truck) and pneumatics.

These systems, although functional, have inherent maintenance and reliability problems and typically require significant capital investment. Some systems, although proven to work, degrade the quality of the DRI in chemistry, physical size and temperature very significantly. Brownfield or existing sites are forced to choose such systems as a close arrangement is not physically possible. Midrex designed HOTLINK as a system to transport HDRI to an EAF (or similar melter) using gravity as the principal method of transport, and is primarily intended for greenfield sites.

Gravity transport is the simplest, most reliable and least maintenance-intensive, allowing delivery of HDRI to the EAF between 700°C and 750°C. The HDRI arrives with no metallisation loss, at maximum temperature, and in better physical condition than cold DRI stored in conventional cold DR/EAF combination facilities, as it has not cooled down or been handled excessively.

Midrex pioneered the continuous gravity-flow direct reduction plant design, as well as the hot discharge furnace feature. This configuration of gravity-fed hot DRI has been used on all MIDREX HBI plants to produce more than 56Mt since 1984 (see *Figures 1* and 2 showing the Amsteel and Comsigua plants). HOTLINK places a Midrex hot discharge furnace just outside and above the exterior wall of the melt shop and provides the opportunity to discharge directly from the shaft furnace to a hot DRI surge bin and then from the surge bin directly to the EAF by gravity. *Figure 3* is a 3D model of the arrangement.

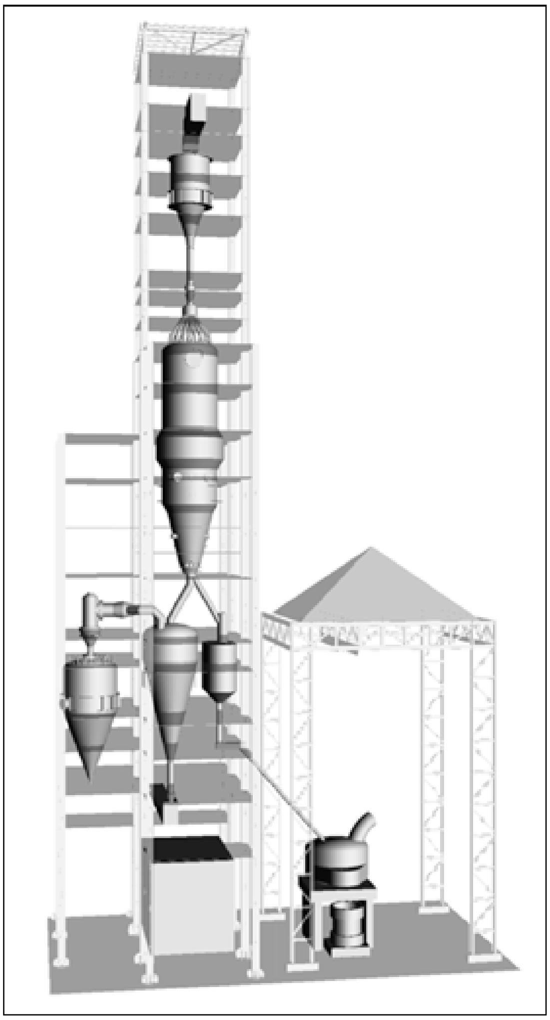
● Figure 1 ***AMSTEEL – the oldest operating HBI plant in the world (since 1984)***

● Figure 2 ***COMSIGUA HBI Plant***

Hot transport and charging of HDRI to the nearby melt shop has been successfully performed by Essar Steel for many years by container, in batches of up to 90t. These containers operate on the same principal as the HOTLINK system – once charged to the sealed movable bin by gravity, the HDRI is then released into the EAF by gravity. The only difference is that instead of being fixed above the melt shop, the bin is transported by truck and lifted into place by a crane. Thus, the containers can mimic the same results as HOTLINK, giving the brownfield DR/EAF combination the best return on investment.

Details of the system

HOTLINK modules are equipped to handle any EAF delay conditions via the hot DRI surge bin. The primary goal of the arrangement (see *Figure 4*) is to



● Figure 3 ***3D model of HOTLINK***

supply hot DRI to the EAF as demanded. However, the DR plant must also be capable of continuing production in a steady-state mode, even if EAF operations are interrupted. Thus, transitioning quickly and by-passing to the production of cold metallics (cold DRI or HBI) for storage is critical to maintaining annual DRI production targets.

It is critical that the transport method from the DR furnace to the EAF be capable of delivering HDRI without adversely affecting product quality while providing maximum operational flexibility. Additionally, the transport system must be reliable, well-sealed from oxygen, maintenance friendly and easy to operate. The HOTLINK system meets these criteria very well.

Maintaining product quality

Midrex can design a direct reduction facility to produce up to 1.6Mt/yr of hot and/or cold DRI with at least 94% metallisation and with carbon contents from 0.5 to

3.0% (although such a high carbon content may not be desirable in short tap-to-tap time cases). With DR furnace bed temperatures approaching 900°C in many plants, HDRI temperatures to the EAF are maximised and can exceed 700°C.

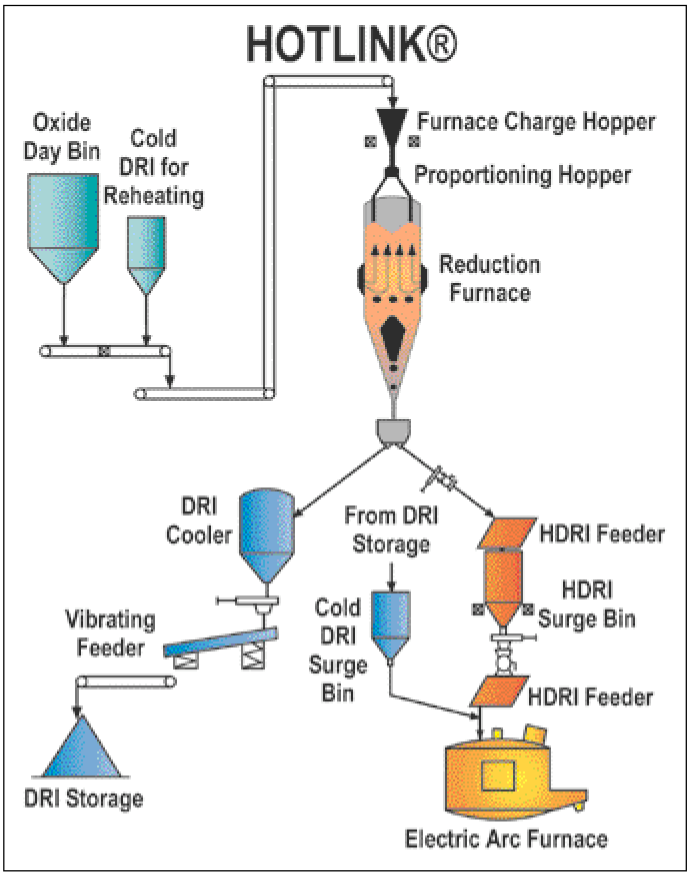
Product degradation
Gravity transport equipment can be properly designed and arranged to limit material velocities. Unlike pneumatic transport, the minimum HDRI velocity is not restricted for purposes of conveyance. This is important because material velocity directly affects product degradation and the wear rate of the equipment. Low material velocities will prevent unnecessary fines generation and promote longer equipment life. There will be minimal degradation of HDRI during transport from the DR furnace to the EAF.

Re-oxidation
As the HDRI is kept oxygen-free from the discharge of the DR furnace to the inlet of the EAF, there will be no re-oxidation or loss in metallisation. The design philosophy is similar to the design of the briquetter feed legs of an HBI plant where inert gas from the products of combustion in the reformer provide the seal. Minimised gas flows will also result in the highest possible DRI temperature.

Operational flexibility
Midrex recognises the difficulty of matching a continuous process (the DR plant) with a batch process (the EAF). A HDRI surge bin, located between the DR furnace and the EAF, acts as a buffer to account for the difference in instantaneous throughputs of the two plants. Typically, there is also a significant difference in the availability of the DR plant (8,000 hr/yr) and the EAF (7,200 hr/yr) due to operational and maintenance schedules. The lower annual EAF operating hours are compensated by higher instantaneous consumption rates, making the annual material balance easier.

A gravity-fed DRI cooler or briquetting machine can be incorporated into the design to provide maximum availability of both the DR furnace and the EAF depending on the commercial requirements. This allows the DR plant to produce cold DRI or HBI when the EAF is unable to receive the HDRI. Conversely, the EAF can also maintain production using cold DRI or HBI from storage when the DR plant is down. In the case of HBI the excess can be sold to market.

Simultaneous production of DRI and HDRI
Both DRI (or HBI) and HDRI can be produced simultaneously and in any combination on demand (see *Figure 5*; ie, from virtually 100% cold metallics to 100% HDRI) and the plant can quickly switch from producing DRI to HDRI, or vice versa, without stopping production.



● Figure 4 ***HOTLINK flowsheet***

Product size variation
HOTLINK can operate with large variations in product size and is designed to convey all product less than 200mm diameter to the EAF. This results in higher yield when compared to stockpiling cold DRI and reclaiming it for melt shop consumption.

● Figure 5 ***Direct Reduced Iron (DRI) and Hot Briquetted Iron (HBI)***

Provisions for cold DRI usage

The material handling system has several provisions for cold DRI usage. These options are very important to ensure that EAF availability and productivity are maximised. The integrated plant has the ability to do any one or all of the following:

- Charge cold DRI (or HBI) directly to the EAF
- Mix cold DRI (or HBI) with HDRI during charging the EAF
- Send cold DRI back to the DR furnace to be reheated
- Sell cold DRI (or HBI)

If the DR plant is shut down while the melt shop is in operation, then cold DRI (or HBI) can be charged directly to the EAF through the surge bin. If the plant would like to consume cold DRI (or HBI) from storage while the DR plant is online, then cold material from the surge bin can be blended with HDRI and charged to the EAF. This option will of course lower the composite charge temperature, thus reducing the savings in power and electrode consumption. Alternatively, a significant amount of cold DRI (up to 10% of furnace discharge) can be added back into the DR furnace for re-heating to avoid lowering the charge temperature and without affecting DR furnace productivity significantly.

Since the cold DRI is already reduced, it will not consume much reductant. This effectively means the discharge rate of the DR furnace can be increased by almost the same amount of cold DRI that is being reheated. Certainly more energy is required to heat the additional throughput, but nearly the same quantity of oxide can be reduced.

The capital cost of an integrated HOTLINK facility making slabs is about 3% higher than that of an equivalent facility equipped to charge cold DRI. However, the increased throughput has the effect of significantly reducing the specific capital costs and thus greatly improving return-on-investment.

Charging 90% HDRI at 700°C with its associated throughput benefit, results in approximately $10/t liquid steel cost savings in most cases. Combining this saving with lower specific investment costs make HOTLINK a natural evolutionary preference for green field projects.

HOTLINK in United Arab Emirates (UAE)

Midrex Technologies, Inc. and Al-Ghaith Holdings (UAE) signed a pre-engineering contract in December 2003 to start work on a new integrated mini-mill with the industry's first HOTLINK DR-EAF combination. The new facility, Hamil Steel, will be the Middle East's newest EAF-based mini-mill and will produce approximately 300,000t/yr of steel billets. HDRI will be delivered to a newly designed VAI/FUCHS EAF. About half of the 500,000t/yr of HDRI will be fed directly to the EAF, and about half will be delivered to a hot briquetting system for the production of approximately 250,000t/yr of HBI.

Start-up is expected in the first half of 2006.

Summary of HOTLINK

- Reduces specific EAF electrical power requirement by 120–140kWh/t
- Reduces EAF electrode consumption by 0.5–0.6kg/t
- Reduces refractory consumption
- Increases EAF productivity or allows EAF electrical system to be downsized
- Promotes low-nitrogen steel for flat products like all DRI-based melt shops
- Improves DRI-to-liquid-steel yield compared to conventional cold DRI storage/reclaim facilities
- Lower specific investment costs for the integrated mini-mill
- Higher yield of DRI-to-liquid-steel
- Simultaneously discharge any combination of DRI or HBI and HDRI as operations dictate
- Midrex plant can continue operation when the EAF is off-line and EAF can continue operation using stored DRI/HBI when the MIDREX Plant is off-line
- Implementation of the proprietary SIMPAX Process Automation and HDRI quality prediction software will enable the plant operators to optimise plant availability, efficiency and productivity, thus paving the way in future for Level II control and optimisation of EAF and the HOTLINK module
- Excess DRI or HBI can be sold

Conclusions

Hot charging is a viable means of reducing the operating cost of producing liquid steel or hot metal, while increasing yield and throughput. Intended primarily for greenfield facilities, HOTLINK is the most efficient way to charge HDRI to an EAF or similar melter because gravity is used for transport.

The plant at Hamil Steel in the UAE will be Midrex's 9th HDRI plant, and the first to utilise the HOTLINK system. The concept is based on simple design philosophy and proven equipment, which provides low risk and high reliability. More than 56Mt of hot DRI experience will be applied in application of this evolutionary technology.

HOTLINK® and MIDREX® are registered trademarks of Midrex Technologies, Inc.

Robert Klawonn is Vice President-Commercial and Stephen C. Montague is Director-Engineer at Midrex Technologies, Inc., Charlotte, North Carolina, USA.