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ROTARY HEARTH FURNACE TECHNOLOGIES FOR IRON ORE AND RECYCLING APPLICATIONS

TECHNOLOGIE W PIECU TRZONOWYM PRZESUWNYM STOSOWANE DLA RUD ŻELAZA I RECYKLINGU

Midrex Technologies and Kobe Steel offer the FASTMET[®], FASTMELT[®], and ITmk3[®] Technologies for processing iron ore and iron-containing by-products to produce DRI and pig iron products. These processes offer steelmakers methods for economically producing high quality iron products and recovering valuable mineral resources using fine ores, by-products, and coal. Several commercial FASTMET Plants have been operating successfully for a number of years, confirming the basic process concept. A number of new projects are under development worldwide for the three technologies. This paper provides technical details of the processes, reviews promising applications, and discusses current commercial developments.

Keywords: EAF dust recycling, Direct reduction, Iron ore, Rotary hearth furnace, Electric steelmaking

Midrex Technologies i Kobe Steel posiadają w swojej ofercie następujące technologie: FASTMET[®], FASTMELT[®] i ITmk3[®]. Znajdują one zastosowanie w procesach przeróbki rud żelaza oraz półproduktów zawierających żelazo, które następnie wykorzystywane jest w procesie DRI oraz wytwarzania surówki. Wykorzystanie tych technologii przez producentów stali stwarza możliwość bardziej ekonomicznej produkcji wytwarzania żelaza wysokiej jakości oraz odzysku wartościowych materiałów mineralnych takich jak drobna ruda, materiały odpadowe oraz węgiel. Różne komercyjne instalacje FASTMET pracują z powodzeniem od wielu lat, wykorzystując proste założenia technologii. Obecnie na świecie realizowanych jest wiele projektów związanych z wprowadzeniem tych trzech technologii. W artykule opisano techniczne detale procesów, omówiono najnowsze rozwiązania rynkowe oraz przedstawiono obiecujące perspektywy zastosowania nowych technologii.

1. Introduction

The coal-based direct reduction concept utilizing the rotary hearth furnace is a simple one. The RHF consists of a flat, refractory hearth rotating inside a stationary, circular tunnel kiln. Inside the RHF, direct reduction of iron ore or iron-bearing by-products occurs, using coal as the reductant. For decades, rotary hearth furnaces have been successfully used in a variety of industrial applications, including heat treating, calcining of petroleum coke and limestone, waste treatment and non-ferrous high-temperature metal recovery. Midrex Technologies, Inc. and Kobe Steel, Ltd. have evolved three primary technologies from the basic RHF concept to meet specific client needs: FASTMET[®], FASTMELT[®] and ITmk3[®].

2. The midrex/kobe steel RHF concept

To be successful, rotary hearth furnace direct reduction must be properly applied for each case, whether greenfield or at an existing facility. If so, the result is an energy-efficient, environmentally-friendly, economic system for producing quality alternative iron.

The Midrex/Kobe Steel RHF concept has been proven by continuous commercial-scale operation of three FASTMET Plants for direct reduction. The feed to the RHF consists of

composite agglomerates made from a mixture of iron oxides (virgin ore or by-products) and a carbon source such as coal, BF dust, charcoal or other carbon-bearing solid. The feed agglomerates (pellets or briquettes) are placed on the hearth evenly, one layer thick. Burners located above the hearth provide heat required to raise the agglomerates to reduction temperature and start the process. The burners are fired with natu-

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ral gas, fuel oil, waste oil or pulverized coal. Most of the heat required for maintaining the process is supplied by combustion of volatiles that are liberated from the carbon source and combustion of the carbon monoxide produced during reduction.

The agglomerates are fed and discharged continuously and stay on the hearth for only one revolution, typically six to 12 minutes, depending on the reactivity of the feed mixture and target product quality. Figure 1 shows details of a rotary hearth furnace. The product can be in the form of direct reduced iron (DRI) pellets or briquettes, hot metal, or nuggets. Hot metal and nuggets are superior EAF or BOF feed materials, comparable to blast furnace grade hot metal or high quality pig iron.

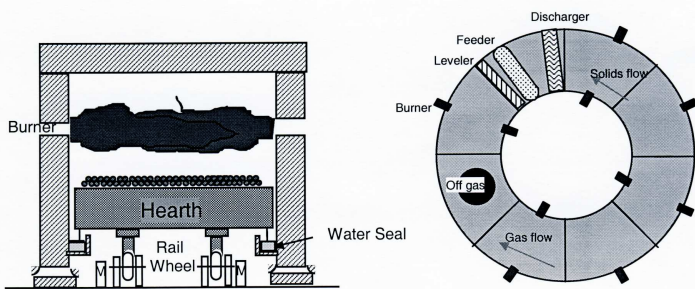


Fig. 1. Rotary Hearth Furnace Cross Section and Plan Views

3. FASTMET®

Process/Technology

The FASTMET flowsheet is shown in figure 2. It uses the Midrex/Kobe Steel rotary hearth furnace concept to convert iron-bearing by-products into highly metallized direct reduced iron (DRI). In addition, zinc contained in the feed materials can be recovered and recycled, which can provide for attractive economics. Carbon contained in the by-products or added as coal, charcoal or other carbon-bearing solid is used as the reductant. The FASTMET Process is extremely energy efficient, unlike other new coal-based ironmaking processes that require offgas energy credits, as all fuel energy is consumed within the FASTMET RHF (100 percent post combustion).

Products

FASTMET DRI can be discharged hot into transport vessels for melting in a BOF or EAF. Alternately, it can be discharged and cooled for later use. A third option is to make hot briquettes, which can be easily stored or transported.

Applications: By-product Recycling

Integrated and electric furnace steelmakers are finding that dealing with iron-bearing by-products is increasingly difficult. Stockpiling these materials on site, recycling them or sending them offsite for disposal all entail considerable difficulties and costs. FASTMET provides an excellent means to deal with materials including blast furnace dusts and sludges, BOF dust, EAF baghouse dust and iron ore fines. Recycling via FASTMET greatly reduces the volume to be disposed of and produces a cost-effective iron product. Another benefit is that any zinc contained in the waste is converted to a saleable zinc oxide dust, thus providing a valuable revenue stream.

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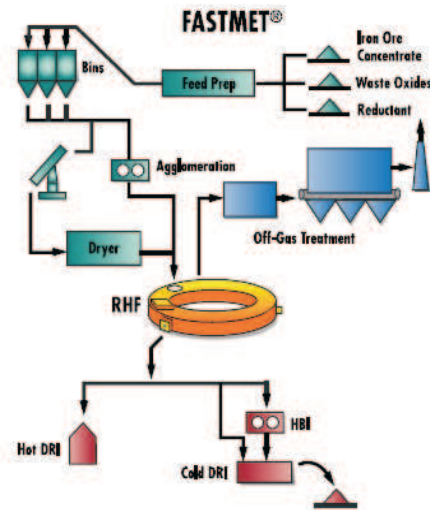


Fig. 2. FASTMET Flowsheet

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There are now several commercial-scale FASTMET Plants in Japan, as shown in table I.

TABLE I

Commercial FASTMET Plants

Owner	Location	Feed Cap. (t/y)	Start-up	Feed	Status
Nippon Steel	Hirohata, Japan	190,000	2000	BOF dust	operating
Kobe Steel	Kakogawa, Japan	16,000	2004	BF, BOF, EAF dust	operating
Nippon Steel	Hirohata, Japan	190,000	2005	BOF dust	operating
Nippon Steel	Hirohata, Japan	190,000	2008	BOF/BF dust	construction

Figure 3 shows one of the FASTMET Plants at Nippon Steel.



Fig. 3. FASTMET Plant at Nippon Steel Hirohata, Japan

4. FASTMELT®

Process/Technology

FASTMELT uses the same rotary hearth furnace as FASTMET, but adds a melting furnace to produce a high quality hot metal product. As with FASTMET, the feed materials are steel mill by-products, and carbon contained in the feed or added as coal, charcoal, or other carbon-bearing solid is used as the reductant. After reduction, the DRI pellets or briquettes are discharged hot into the melter. Figure 4 shows the FASTMELT flowsheet.

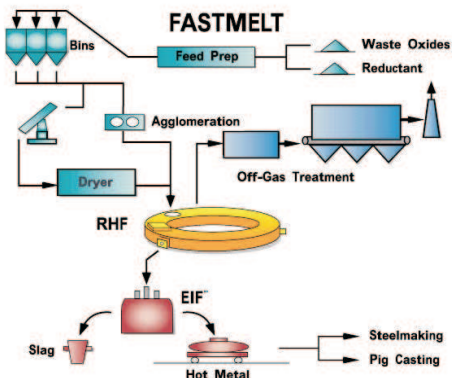


Fig. 4. FASTMELT Flowsheet

Product

The product from FASTMELT is blast furnace-grade hot metal. The product quality can be tailored to meet a desired specification by controlling the DRI chemistry. The most energy efficient use is to feed the molten hot metal directly into an EAF or Basic Oxygen Furnace (BOF) for producing steel. Alternately, it can be cast into pigs or granulated for sale or later use.

Following are typical specifications for the iron produced:

Carbon	3.0-4.5%
Silicon	0.3-0.5%
Manganese	0.2-1.0%
Sulfur	<0.05%
Phosphorus	<0.05%
Temperature	1550° C

Applications: By-product Recycling

FASTMELT can be used to economically convert steel mill by-products such as blast furnace dusts and sludges, BOF dust, EAF baghouse dust, and iron ore fines into high quality hot metal. As with FASTMET, it also recovers zinc.

5. ITmk3®

Process/Technology

ITmk3 (“IT mark 3”) uses the same type of rotary hearth furnace as the FASTMET and FASTMELT Processes. A flowsheet is shown in figure 5. The primary feed materials are iron ore and coal, but other feedstocks can be used as a supplement. The mixing, agglomeration and feeding steps are the same as with the other processes, but the RHF is operated differently. In the last zone of the RHF, the temperature is raised, thereby melting the reduced iron and enabling it to easily separate from the gangue. The result is an iron nugget containing iron and carbon, with almost no oxygen or slag. ITmk3 provides a flexible, economical and environmentally friendly technology for producing a high quality iron product.

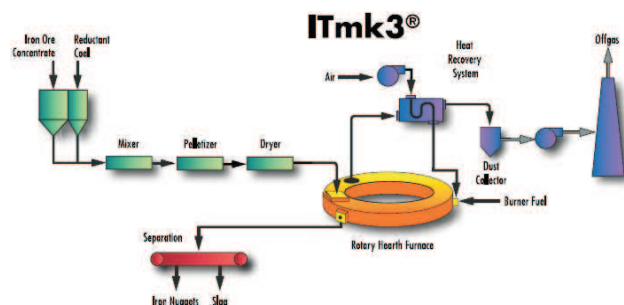


Fig. 5. ITmk3 Flowsheet

Product

ITmk3 produces a premium grade pig iron in the form of iron nuggets. In the process, all the iron oxide is reduced and no FeO remains in the nugget. The carbon level can be controlled by the input of carbon and the heating pattern, with the maximum carbon content around 3.0 percent. The contents of silicon, manganese and phosphorus in the product depend on raw material selection. The final nugget product does not re-oxidize, does not require special handling during shipment and it can be continuously fed to an EAF. Figure 6 shows ITmk3 nuggets.



Fig. 6. ITmk3[®] Nuggets

representative chemical and physical compositions are as follows:

Metallic iron	96-97%
Carbon	2.5-3.0%
Sulfur	0.05-0.07%
Size	5-25 mm
Density	7.0-7.6 g/cm ³

Applications: Ironmaking

ITmk3 is an ideal way for iron ore mining companies to process either magnetite or hematite and supply pig iron-grade nuggets to the EAF steelmaking industry. Plants can be located at mine sites, ports or in steelmaking facilities. ITmk3 enables mining companies to produce a value added product and steelmakers to obtain a premium quality feedstock for EAF use. The Mesabi Nugget 500,000 t/y plant is under construction for Steel Dynamics in Minnesota, USA, as seen in figure 7. Kobe Steel and Cleveland-Cliffs have signed partnership agreement providing the possibility for ITmk3 plants at Cliffs' mine sites worldwide. The first project will likely be at Cliffs' Empire Mine in Michigan, USA. Several other ITmk3 plants are under development worldwide.

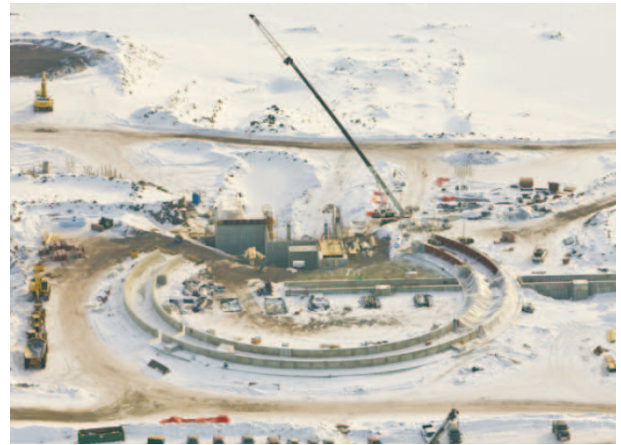


Fig. 7. Mesabi Nugget Plant Under Construction at Hoyt Lakes, Mn, USA

Since the ITmk3 process separates metal and slag in one step, it effectively concentrates the iron ore. Figure 8 shows the progress of reduction and melting. This opens the possibility of utilizing lower grade iron oxide such as very fine tailings from beneficiation plants. ITmk3 is very flexible regarding carbon sources. The process can use coal, petroleum coke or other forms of solid reductants.

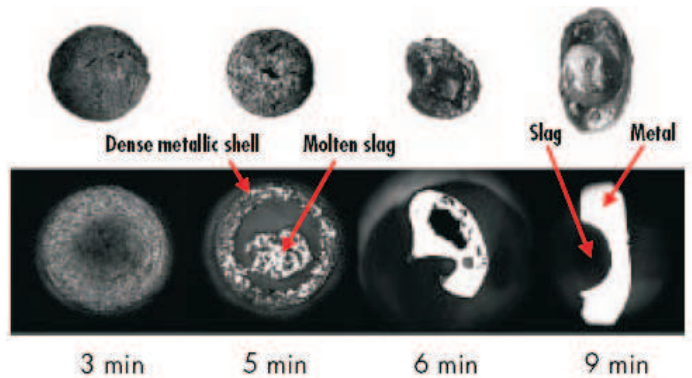


Fig. 8. Detail of Iron Nugget Reduction and Melting

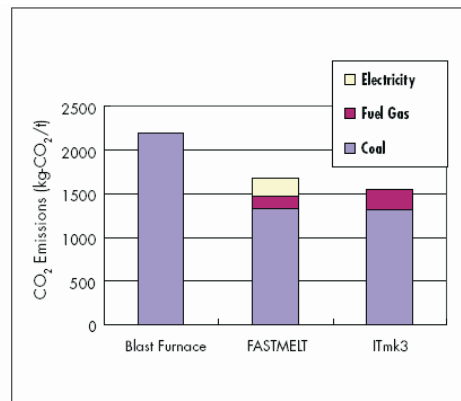
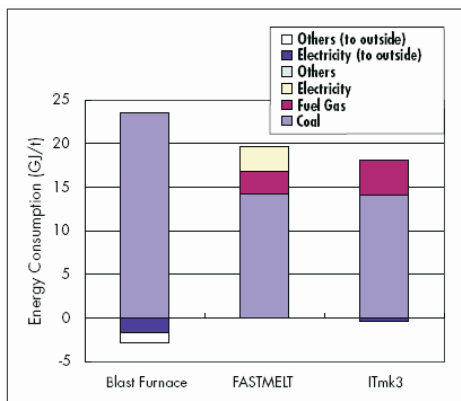


Fig. 9. Energy Consumptions and CO₂ Emissions for RHF processes vs. Blast Furnace

6. Environmental compatibility

Environmental issues are a major concern for today's steel industry. Gaseous emissions, including NO_x, SO₂, and CO₂ are being carefully scrutinized by government agencies and others. In addition, the disposal of metal-bearing by-products, both ferrous and non-ferrous, is a problem. The Midrex and Kobe Steel RHF processes are compatible with the environment and provide solutions for the world steel industry. Energy consumptions and emissions of CO₂ are lower than the blast furnace route, as shown in Figure 9. The FASTMET and FASTMELT processes provide an economical way to recycle iron-bearing by-products, by producing a valuable product and reducing disposal volumes.

7. A variety of possibilities

With the continued development of the Midrex and Kobe Steel RHF technologies, iron ore companies, steelmakers, metals recycling companies, and oth-

ers have several options for processing iron ore and other iron-bearing materials, including those containing non-ferrous materials. Table II shows the characteristics of the RHF processes compared with other ironmaking methods.

8. Conclusions

Midrex Technologies and Kobe Steel's FASTMET[®], FASTMELT[®], and ITmk3[®] Processes are outstanding solutions for treating iron ore and iron-containing by-products to produce DRI, hot metal, and pig iron products. The companies have dedicated their combined experiences and capabilities to ensure the success of the rotary hearth furnace business. This includes iron and steelmaking operating practice, the Midrex and KSL research facilities, databases from tests and operations, over 40 worldwide patents, and nearly 40 years of supplying the world's leading direct reduction technology. The RHF plants built to date and those under development confirm the promise of the technologies.

TABLE 2

IRONMAKING PROCESS COMPARISON

Process	Feedstock	Reductant	Product	Steelmaking vessel	Application/location
Blast furnace	Iron oxide sinter and pellets	Coke	Hot metal	BOF	Coastal works
MIDREX [®] Process	Iron oxide sinter and pellets	Natural gas	DRI/HBI	EAF	Gas-rich area
FASTMET [®]	BF dust, BOF dust, EAF dust, ore fines	Non-coking coal	DRI	EAF/BOF	Steel mill or central
FASTMELT [®]	BF dust, BOF dust, EAF dust, ore fines	Non-coking coal	Hot metal	EAF/BOF	Steel mill or central
ITmk3 [®]	Iron ore fines	Non-coking coal	Nuggets	EAF	Mine site