Объединение независимых экспертов в области минеральных ресурсов, металлургии и химической промышленности

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Direct Reduced Iron (DRI/HBI)

Production, Market and Forecast in Russia and the World

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Annotation

The present report is **the second edition** of a study of the market of direct reduced iron (DRI).

Research objective is the analysis of the market of direct reduced iron/HBI, covering the period of 2007-2017.

A feature of the report is the analysis of production of DRI in Russia, with information about the main processes of receiving DRI.

Object of research is direct reduced iron.

This work represents **a desk research**. As **sources of information** we used data of Federal State Statistics Service of the Russian Federation (Rosstat), statistics of rail transportation of the Russian Federation, the Federal Customs Service of the Russian Federation; the databases of the UN, the Infomine databases, and data of Midrex. Also, we employed data of the industry and regional press, annual and quarterly reports of issuers of securities, and the websites of the companies making and consuming DRI.

Chronological framework of a research: 2007-2017.

Research geography: World in general, Russia, India, Mexico.

Scope of investigation: the report consists of **9** chapters, contains **94** pages, including **33** Tables, **24** Figures and **2** Appendices.

Chapter 1 is devoted to the analysis of the current state of production of direct reduced iron with allocation of the main processes of its release and a product form. The chapter also briefly presents the main directions of development of the DRI production technology.

Chapter 2 presents characteristics of the main processes of production of DRI, in particular, Midrex (Midrex®, MXCOL®, HOTLINK®) and HYL/Energiron (HYL ZR). Besides, it gives characteristics of the technology of production of reduced iron by the process of the liquid-phase reduction and by the "hybrid" process (ITmk3, COREX, HIsmelt).

Chapter 3 outlines requirements to quality of DRI of some producers.

Chapter 4 is devoted to the analysis of production of DRI in the world by the main technological processes and by countries in 2007-2017. The main regions and the countries of release of DRI and also large manufacturing companies are specified. Production of DRI in India, Mexico, Russia and Iran is analyzed.

Chapter 5 presents new projects on production of DRI, provides data on the economy of projects, including investments, etc.

Chapter 6 analyzes foreign trade in DRI in the world during 2007-2017. It is noted that Russia came out on the top on deliveries of DRI to the world market.

Chapter 7 analyzes the prices of DRI in the world, and presents the forecast of prices for HBI until 2025.

Chapter 8 provides data on volumes of consumption of DRI in the world and in the certain countries, and determines the main drivers having an impact on demand for this type of products, and points out some largest consumers of DRI.

Chapter 9 shows the role and the place of DRI in the structure of consumption of ferriferous raw materials at the steel smelting.

Appendices to the report provide contact information of some participants of the market of DRI and the metallurgical enterprises of the CIS having experience with the use of the pre-reduced raw materials in production of steel.

Target audience of a research:

- Participants of the market of DRI – vendors and consumers;
- Potential investors.

The offered research applies for **a handbook** role for the services of marketing and for specialists making management decisions, working at this market.

Introduction

The market of DRI/HBI is very important for many metallurgical enterprises, which carry out production of steel, first of all electrical steel. The issues of providing the production of electrical steel with necessary metal-containing raw materials become more relevant due to the limited supply of metal scrap in the market and the general reduction of volumes of the world trade in scrap of ferrous metals.

If the metallurgical enterprises of a full cycle with the blast-furnace ironmaking are able to resolve an issue of providing the steel-smelting complex with raw materials, then the enterprises, which produce steel in electric furnaces, are forced to use scrap of ferrous metals.

One of the possible solutions of the full ensuring of production of quality steels without considerable impurities is the use of DRI.

The world production of DRI currently increases owing to the implementation of new projects in the different countries, including Iran, India, Russia, the USA and others.

The release of DRI in 2017 significantly grew in comparison with previous years owing to the increase in production of steel, in particular the smelting of electrical steel. Nevertheless, the share of DRI remains insignificant in the structure of consumption of metal-containing raw materials when smelting steel. There are considerable perspectives for the increase of the role of DRI in production of steel.

This market has considerable perspectives of development. A significant increase in production and consumption of DRI in the world is expected, first of all in India and Iran, which plan a significant growth in production of steel.

Production and consumption of DRI will increase in Russia as well, where recently a new unit was put into operation on Lebedinsky GOK. Gradually the Russian metallurgical enterprises come to understand the need to increase the consumption of DRI in production of steel in connection with the increase in requirements to the steel's parameters (by availability of impurities) at the release of rolling products and steel pipes.

Difficulties can arise only in case of negative changes in the world economy in general or in the economy of certain regions and countries.

1. Current state of processes of production of direct reduced iron (pre-reduced pellets and hot briquetted iron, i.e. sponge iron) – DRI

For smelting of steel in both converters and electric furnaces cast iron and scrap of ferrous metals are generally applied. The use of direct reduced raw materials (DRI) significantly concedes to the consumption of cast iron and scrap. Nevertheless, a number of factors determines a gradual expansion of both the production and consumption of DRI at the steel smelting.

First of all, it is connected with considerable reserves of natural gas at limited reserves of coals; the development of the inexpensive electrical power in a number of regions; the increasing deficit of the coke-coal and coke; the need for iron, which is not contaminated by impurities of non-ferrous metals, due to stricter requirements to the steel quality; limited resources of scrap of ferrous metals of the guaranteed purity and a stable composition; a need of reducing the environmental footprint, etc.

Depending on the temperature of the metallization process, the final product turns out in the form of sponge iron (pre-reduced raw materials or DRI), an iron ball or liquid iron and nuggets.

Sponge iron or direct reduced iron is the porous lumpy or powdered product received directly from the iron ore, its concentrates or pellets by the reduction of the oxides by a solid carbon at a temperature of 1200-1250 °C or by gaseous reducers H_2 and CO (at a temperature of 850-900 °C). In any method, DRI contains inclusions, which are removed only in steel-smelting furnaces.

At this, it is necessary to outline several features of processes of the DRI production.

Proceeding from conditions of profitability of the steel-smelting process (the minimum quantity of slag), strict requirements are imposed to the content of dead rock in the initial iron ore raw materials (no more than 3-3.5%). For this purpose, the iron content in initial raw materials should be not less than 69-70%.

Many harmful impurities (sulfur, phosphorus, etc.) due to the low temperature of process almost completely go into a pre-reduced product. In order to obtain quality steel without considerable over-expenditures of energy, it is necessary to have a low content of harmful impurities in DRI. It means, that their content in initial raw materials also should be low (<0.01 - 0.02%).

The content of such impurities as nickel, chromium, cobalt, etc. also should be limited because for smelting of some steel grades they are unwanted. Generally, the optimum iron ore raw materials for production of DRI is the one that is rich in iron and devoid of any impurity elements.

Temperatures are lower compared with temperatures for production of cast iron, this leads to a lower specific productivity of units. A high annual production rate is reached by the increase in the size of units.

DRI processes may use different types of fuel: only a solid fuel, only a gaseous fuel, a combination of solid and gaseous fuels.

The share of direct reduced iron in a charge of the electric furnace can reach 100%, that allows avoiding completely additional purchases of scrap.

DRI is delivered to consumers in different forms (pieces, pellets, hot briquetted raw materials), but generally in the form of pre-reduced pellets and hot briquetted iron, i.e. direct reduced iron (DRI).

Currently three forms of pre-reduced products with the general name DRI (direct reduction iron) are made – direct reduced iron or pre-reduced raw materials.

Depending on the production technology and the scope of use they have the following names:

- a cold pre-reduced product (CDRI - cool direct reduction iron),
- hot briquetted iron (HBI - hot briquetted iron),
- a hot pre-reduced product (HDRI - hot direct reduction iron).

CDRI is the most widely released product of the direct reduction of iron. It is the reduced pellets and the lumpy material cooled to 50 °C. It is usually stored for the subsequent use in the arc furnaces, which are located near units of direct reduction. The sizes of pellets or lumpy material are generally within 4-20 mm.

HBI is the briquetted product most adapted for the storage and distant transportation. For production of HBI the hot pre-reduced product is unloaded from furnaces at a temperature of 700 °C and pressed into briquettes in the form of pillows, which normal size is 30x50x110 mm. The density of HBI is by 50% higher than that of pre-reduced pellets and lumpy material, which decreases a possibility of oxidation.

HDRI is the product unloaded from the furnace in a hot form (at a temperature about 650° C). It is directly supplied into the arc furnace for smelting.

Iron ball is the firm spongy mass of iron with the slag inclusions, filling pores and cavities. It is received directly from ore by its reduction at a temperature of 1250-1350° C by coal in the rotating pipe furnaces. Unlike processes of receiving DRI, the iron ball process is carried out at a higher temperature, at which dead rock partially melts, forming viscous pasty slag. Slag included the metal particles, which are enlarged at rotation of the furnace in the course of the process. The use of iron ores with the iron content of more than 35-40% is excluded, because the process of formation of an iron ball requires a large amount of slag. Due to the economic inefficiency and the unsatisfactory quality of products this process lost its industrial value.

Processes of the liquid-phase reduction are carried out in metallization furnaces at the ore reduction by coal at a temperature of about 1500 °C. At high temperatures a very high speed of reduction of iron is achieved, and a product of a higher quality by impurities in comparison with DRI and an iron ball process is obtained.

These technological processes have the distinctive features (in comparison with receiving DRI), including:

- a possibility of the use of iron ore raw materials with a low content of iron because all dead rock is removed from an initial product into slag. The decrease in the content of iron in raw materials increases the fuel consumption and the cost of the product, however it does not affect a further technology of its processing in the steel-smelting unit;
- harmful impurities of initial raw materials (sulfur, zinc, in some units phosphorus, etc.) are partially removed from a product and pass into slag or, owing to high temperature, into the gas phase;
- the temperature of the process provides high speeds of all metallurgical reactions and, as a result, the larger specific efficiency of units;
- the maintenance of high temperature in the unit demands either the application of the oxygen blasting and the construction of the powerful oxygen station (processes of Corex, Romelt) or the heating of the blasting air and the construction of air heaters (the Hismelt process).

Besides, there are so-called "hybrid processes". In spite of the fact that many processes of the liquid-phase reduction of iron use separate stages of the preliminary reduction of ore, processes also were developed with a direct reduction of oxides of iron by the carbon dissolved in metal, and not connected, thus, with dead rock of coal, on which use the process is based.

To such processes belongs, in particular, the ITkm3 technology. The reduction is carried out on the rotating hearth of the furnace at high temperatures with receiving the melted pig-iron granules (nuggets).

Processes of receiving iron from ore materials without the use of the blast furnace technology exist, by some estimates, hundreds of years. Processes of receiving the solid DRI and the liquid metal (the liquid-phase reduction) may be distinguished.

Processes of production of DRI and the metal of the liquid-phase reduction exist many years, but still they cannot fully compete with the blast-furnace process.

Nevertheless, periodically the interest in processes of the direct reduction of iron arose that led to the emergence of dozens of technologies.

In the first half of the last century, the development of processes of receiving sponge iron in crucibles (Hoganas), in shaft furnaces (Wiberg) and in rotary furnaces (Krupp) with the use of coal as a reducer was observed. Since the end of the 50th years of the last century there were developments of processes of receiving DRI in stationary retorts (HYL I) and in suspension bed reactors (FIOR) with the use of a gas as the reducer.

In the 70th years of the XX century, there were more than ten processes of receiving DRI in shaft furnaces with the use of a reduction gas. Among which broad industrial use found only two (processes of Midrex and HYL).

Then there were developments of processes of receiving DRI with the use of coal as a reducer in the rotating hearth furnaces (processes FASTMET, INMETCO), more efficient processes with the suspension bed (FINMET) and processes in shaft furnaces with a self-reforming of natural gas (HYL III).

There are significantly fewer processes of the liquid-phase reduction of iron. At first there were technologies of the iron reduction in rotary furnaces (Basset, Struzerlberg, SL/RN), and then in stationary reactors with the use of coal or natural gas (Cyclosteel, Jet Smelting). Besides, processes were developed with the use of coal and electricity (Elred, Inred, Plasmasmelt) and also the two-stages processes using coal, the most known of which is the Corex process.

In the 80th years of last century several processes were developed for production of the liquid-phase metal without the use of coke with a small productivity (0.5-1.0 million tons per year), generally two-stages processes - DIOS, by Hismelt, CCF, AISI.

Now there are more than 100 different processes of the receiving of direct reduction cast iron (processes of the liquid-phase reduction) and DRI, generally pre-reduced pellets (DRI - direct reduced iron) and hot briquetted iron (HBI – hot briquetted iron), i.e. the pre-reduced pellets subjected to briquetting for their shipment in the form of products. These processes differ by types of the used units, by the form of the employed fuel and iron ore raw materials.

Despite a big variety of processes of direct reduction of iron, the processes **Midrex and HYL**, using pellets and/or lumpy ore as raw materials, became the main processes in the world for receiving sponge iron.

2. Characteristic of the main technological processes of receiving DRI and its quality

In the previous section, it was noted that in the world there is a large number of processes of receiving DRI. However, the main are **Midrex and HYL** processes**.** Besides, it is necessary to consider also processes of receiving nuggets, which by their parameters are close to cast iron. A distinctive feature of DRI and nuggets is their quality indicators (on the purity of the chemical composition and the lack of considerable impurities). This allows to use DRI and nuggets in electrical furnaces and also converters, when receiving quality steels. They also can partially be used in a charge of blast furnaces. DRI can be used in blast furnaces to increase their productivity and reduce the consumption of coke. It is especially favorable for the enterprises during the periods when they have limited capacities on cast iron and are required to make a large amount of steel. The use in a charge of blast furnaces of some amount of DRI leads to an increase in performance of the blast furnace and a decrease in consumption of coke.

So, the iron content in nuggets is about 94-97% (depending on a process) at the low content of S, P, Si. At this, manganese in nuggets was noted only when receiving by the process of ITmk3, but no more than 0.1%. The impurities of non-ferrous metals are extremely undesirable.

In general, the chemical composition of nuggets approaches the chemical composition of cast iron though the content of manganese is either absent, or is minimal.

The extent of metallization of DRI is also very high and makes 92-94%, and impurities are also extremely insignificant, especially it concerns impurities of non-ferrous metals and manganese.