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The production process of sponge iron in rotary kilns from the perspective of mechanics and chemistry

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Abstract

The importance of iron and steel in global development is so great that it can be said that iron is the foundation of today's civilization. Abundance, low price, recyclability, high strength as well as alloying capability have created various features in its application. Globally, iron ore is the most important feedstock for blast furnaces and oxygen furnaces (BF-BOFs), which accounted for 65.4% of global crude steel production in 2005. But to use this method, various processes must be done on raw materials that require a high amount of investment in infrastructure. In addition, it has created many environmental problems and the period of its operation is long. Sponge iron is a better alternative to scrap in EAF / IF steelmaking units because of its homogeneity, good productivity and lower coke consumption. Sponge iron can be used as a substitute for steel scrap in the LD converter as a coolant. Not a firefighter. It does not contain harmful or waste elements such as copper, zinc, tin, chromium, tungsten, molybdenum, etc., which are usually found in steel scrap. Sponge iron has less sulfur and sulfur. Sponge iron is produced using non-crushing coal through the iron ore reduction process in a rotary kiln. In this paper, the production process of sponge iron in rotary kilns from the perspective of mechanics and chemistry is investigated.

Keywords: Sponge iron, rotary kilns, alloying, iron ore reduction.

1. Introduction

Globally, iron ore is the most important feedstock for blast furnaces and oxygen furnaces (BF-BOFs), which accounted for 65.4% of global crude steel production in 2005. But to use this method, various processes must be done on raw materials that require a high amount of investment in infrastructure. In addition, it has created many environmental problems and the period of its operation is long. To get rid of the shortcomings of the BF-BOF process, the EAF steelmaking method was developed, which also has a long life. The share of arc steel production in world crude steel production has increased from 26.6% in 1988 to 33.1% in 2005. Rising scrap prices and shortages have led to the development of new technologies and the production of a suitable charge combination in the form of sponge iron (DRI direct iron reduction) [1].

Sponge iron is obtained by direct reduction of iron ore with a grade of 84 to 95%. Regeneration removes or eliminates oxygen in the iron ore and turns the stone into a honeycomb or a porous spongy structure, which is why it is called sponge iron. Sponge iron as an intermediate product is mainly used in steel production. Sponge iron is in fact one of the most important links in the steel production chain from mining to the production of final steel products. The main reason for producing this product is to create a suitable raw material for charging in electric arc furnaces for refining and producing steel. Almost all sponge iron produced in the world is used in electric arc furnaces for steel production. Numerous methods have been introduced for the production of sponge iron in small capacities (less than 150,000 tons per year), which are generally based on the direct reduction of iron by thermal coal. The most popular of these methods is the rotary kiln or SL / RN method. Another popular method is the tunnel kiln method. On the other hand, the high flexibility of this method to the input feed, no need for pelletizing process and also the inactivation of iron produced by this method and the possibility of selling the product as an intermediate product are other factors that lead to the choice of reduction method in the furnace [2].

According to the above and with the aim of increasing the added value of resources in the country, one of the most appropriate and popular methods for the production of sponge iron in low capacities (below 150 thousand tons per year) is the tunnel kiln method. This method, despite more than a century since its introduction, has recently received a lot of attention, especially in China. Today, the tunnel kiln method is recognized as a successful method of producing sponge iron on a small scale [3].

2. Growing demand for sponge iron

In a world where blast furnaces are charged or fed with iron ore and arc furnaces and alkaline oxygen furnaces with scrap iron, these raw materials are the main raw materials of steelmakers. But markets for alternative "metallic" ferrous raw materials, such as sponge iron and hot-briquette iron, appear to be relatively small. However, global direct recovery figures for 2013, published by Midrex Technologies magazine, show that 75.2 million tonnes of substituted ferrous raw materials were produced that year. Future opportunities to increase production for sponge iron and, to some extent, cast iron depend on the growth of arc steelmaking. Arched steelmaking capacity outside China has grown at a rate of 5 to 6 percent over the past 30 to 40 years. The World Iron and Steel Association believe that this growth is likely to continue, and we will see a commensurate growth in demand for sponge iron and other ferrous raw materials [2].

Historically, sponge iron accounts for 12 to 15 percent of the total charge or power supply of all arc steels used worldwide. It is predicted that in the future, the current production of sponge iron in the world will increase from 75 million tons last year to 140 million tons in 2025, in order to meet the growth of projected demand outside China by then. According to global statistics, Iran is the second largest producer of sponge iron in the world after India. This trend has been going on since 2017. Sponge iron is currently traded at a world price of around $ 310 and a domestic price of $ 300 FOB Bandar Abbas. What is ahead this year is an increase in demand for sponge iron from steel ingot producers in the country. This increase is not only in the field of demand, but this year we are witnessing an increase in the supply of sponge iron due to the joining of several development projects to sponge iron producers. The ingot producers had production below the nominal capacity in the previous year; but for the new year, they have a production plan for full capacity [3].

Therefore, the demand for ingots to buy sponge iron is also increasing. Last year, sponge iron was exported by the producers of this product; But the plan of Sirjan Steel World is to meet the domestic need first and make this a priority. Although the export price of sponge iron is higher than the domestic price; But our preference is to give priority to meeting the needs of steel ingot producers in the country. With the arrival of two projects, Neyriz Steel and Sabzevar Steel, the equivalent of 1.6 million tons was added to the country's sponge iron production capacity and the gap with India will be reduced to 2.29 million tons. The production volume of this product in India and Iran was 24 million and 390 thousand tons and

20 million and 500 thousand tons at the end of 2017, respectively, but it should be borne in mind that India for 2018, plans to increase production by 7% and achieve production. It has 26 million tons of sponge iron, which will affect the production rank gap between the two countries. This is while previously Iran was a leader in the production of this product. He continued: "Considering the price of the dollar and the difference between the price of sponge iron in the country and its world price, the export of surplus production of sponge iron is valuable for its producers." [4].

3. Reasons for using sponge iron

The use of sponge iron in areas with limited scrap supply but sufficient access to natural gas for regeneration has always been a rational reason for its use; however, the supply or allocation of natural gas has become increasingly competitive in areas such as the Middle East. Low scrap of ferrous raw materials obtained from iron ore and production of higher quality steels (such as hot dipped steels or SBQ) which are not easy or impossible to produce from 100% scrap charge, or in other words, especially in the production of steels Advanced with high strength, it can be mentioned as an element that always plays a role in the competition between aluminum and steel. If price is a priority, the use of a percentage of ferrous raw materials in the charge can reduce the waste elements in the scrap. Therefore, to compensate for the consumption of cheaper grades of scrap, a balance must be established by adding better quality raw materials [5].

Experts say that the price difference between scrap and ferrous raw materials is less important. Research shows that by doing the above, $ 2 to $ 3 per ton of costs is reduced, given that because of the type of steelmaking Contrary to the higher purity of the cast, it is sold lower than premium scrap, which correlates with changes in the price of scrap iron. The price of hot briquette iron is equivalent to a certain grade of scrap iron. Greater efficiency can also be achieved by adding ferrous raw materials, and many steelmakers prefer to minimize the amount of cleaning required to achieve the correct final grade to produce clean primary molten steel. Other technical advantages include homogeneity of charge to the furnace and formation of slag.

4. Description of the process of producing sponge iron

The most important raw materials required for the production of sponge iron are oxides in the form of iron ore / pellets, coking coal (with high reactive properties) and melting materials such as lime and dolomite. Exercise caution and care. By using high purity pellets and low phosphorus at an economical price, the economical production of sponge iron can also be achieved. Sponge iron is produced using non-crushing coal through the iron ore reduction process in a rotary kiln.

Regeneration takes place at a predetermined temperature and controlled atmospheric pressure. Input raw materials such as iron ore, coking coal (with high reactivity) and smelting materials such as limestone and dolomite in calibrated sizes are fed into the rotary kiln by means of weight and volume feeders.

Due to the inclination and rotational motion of the rotary kiln, the raw materials move slowly from the end of the feeder to the end of the discharge or charge. During the movement, the iron ore is converted to DRI along with the previously heated coal. The material is then discharged directly to the rotary cooler, where it is cooled.

The temperature of the cooled product is about 80 ° C, which is drained from the coolant and then taken to the separation and transfer system. This product, which contains sponge iron with magnetic materials such as coal, etc., is separated by a sieve of different sizes and then magnetically separated by a magnetic separator, then the sponge iron is poured into a tank and sent out.

5. Advantages of using sponge iron in rotary kilns

By adding sponge iron to the scrap in the feed tank, an arc furnace process reduces impurities such as sulfur and phosphorus significantly. By diluting the charge composition, the need for refining is reduced, and as a result, metallurgical operations inside the furnace are facilitated and the efficiency of the furnace is increased. It is often stated that if the charge is thin enough, it can be completely refined in the smelting operation in the furnace itself, thus increasing productivity.

According to the statistics of sponge iron production with natural coal in the world, 22.6% of the total iron production, of which 12% of coal iron production is done by SL / RN method. The number of large coal-fired iron ore mills in India is about 55, and the number of small mills, each producing between 11,000 and 31,000 tonnes a year, is estimated at more than

311, with a total of 71% supporting Indian sponge iron and 31% the rest of the sponge iron production is produced by gas method in 7 factories. Continuous feeding: Continuous feeding of DRI to an EAF increases the power or power capacity of the furnace under 100% scrap charge under the same conditions. Due to the heterogeneous nature of the scrap and the constant change in the arc length between the electrode and the scrap cause severe fluctuations in the melting of the scrap. It has been shown that such sharp fluctuations reduce the input power. On the other hand, continuously fed DRI melting has reduced the power consumption of 15 kWh per ton of DRI generated using UHP transformers. Hot charging of sponge iron: Hot charging of sponge iron is one of the effective ways to reduce the production cost per ton of molten steel because it reduces power consumption and electrodes.

In addition, DRI hot charging increases the efficiency of the melting unit designed to charge the DRI gain. In India, hot DRI charging technology is an innovation of Essar Company and reduces energy consumption by about 120 kWh per ton by consuming hot DRI by EAF at 650 ° C in iron.

6. Methods of producing sponge iron

The methods of producing sponge iron (direct reduction of iron ore) that are discussed here are selected from methods that are known, their references are available and can be cited. Therefore, we examine 3 different methods of producing sponge iron.

1. Midrex process

Midrex's involvement in the direct recovery process can be traced to the work done by Surface Combustion in the 1930s. In 1959, the company joined Midland Ross, where the Heat fast process company was being developed and developed as the forerunner of the Fastmet process. Surface Combustion was later renamed Midrex.

The first Medrex direct reduction unit, installed in 1969 in Portland, Oregon, USA, had two vertical furnaces with an inside diameter of 3.7 meters, each designed to produce 150,000 tons of sponge iron per year. Over time and due to the need of steelmakers for high quality metal loads and reasonable prices, Midrex Company during the last forty years has the design and construction of larger units in its agenda and gradually Midrex vertical furnaces from the inner diameter of 7 / 3 meters to 25.2 and finally to 7.5 meters and introduced to the steel industry. Of course, it should be noted that the smaller furnaces of the Midrex process are still in production and operate economically (Hamburg HSW unit and Canadian unit SIDBEC). This shows the ability of this process to supply different capacities.

The main characteristics of the Midrex method are as follows (Fatemi Ardakani and Kalantar, 2016):

A) Input iron ore: Input iron ore in this process is cooked in the form of pellets and hematite iron ore lumps with high grade and suitable conditions can be used to a certain extent according to its conditions.

B) Reducing agent: It is broken natural gas after the reforming process. In the Midrex process, carbon monoxide has a larger share of the reducing gas mixture than hydrogen gas.

C) Type of regeneration furnace and its conditions: Midrex furnace is a vertical shaft furnace that operates under pressure slightly above the atmosphere and its inlet and outlet are dynamic sealing and is regulated by the flow of material inlet and outlet.

D) Reduction temperature: about 850 to 920 degrees Celsius

E) History of the process: since about 1969

F) Process position: Fully established and commercial

G) Process capacity: Midrex furnace initially had smaller dimensions (diameter) and with the improvement of technology to furnaces with higher diameter and more capacity has been developed. The emergence of a generation of mega-module furnaces with an annual capacity of 1.5 million tons and more shows this. Of course, it should be noted that the smaller furnaces of the Midrex process are still in production and operate economically. This indicates the ability of this process to supply different capacities.

H) Market share: about 60% of total sponge iron production

2. SL / RN process and similar

This process is one of the oldest methods of direct reduction and the idea of its structure is based on a horizontal cement kiln. In this method, thermal coal is mixed with iron ore as a reducing agent and sponge iron is produced in a horizontal furnace.

A) Input iron ore: In the process of Midrex or HIV, the use of high quality cooked pellets and a maximum of about 30% of iron ore lumps is generally recommended. In this process, it is possible to use lumps up to 100% and also some types of raw pellets can be used. The use of magnetite ores in this process is also not recommended and this process requires high grade hematite ores.

B) Reducing agent: The advantage of this method is the possibility of using relatively low quality thermal coal as a reducing agent. Coal in the furnace produces carbon monoxide, which regenerates iron oxide. Despite the relatively high temperature in the furnace, the reaction speed is relatively low and the furnace will have a low capacity by nature. There is no hydrogen gas in this process.

C) Type of reduction furnace: Rotary kiln horizontal furnace that operates at a pressure slightly above the atmosphere. The main rotary furnace consists of a preheating section and a reduction zone, and the reaction gases are removed at a temperature of about 1000 ° C, and recycling systems are not provided, so this energy is generally used to generate electricity. The cooling section of the furnace is a completely separate chamber that is cooled by water from outside.

D) Reduction temperature: about 1000 to 1100 degrees Celsius

E) History of the process: since about 1980

F) Process position: stabilized and commercial

G) Optimal capacity: about 100 to 150 thousand tons per module

H) Market share: a total of about 23% of total sponge iron production

3. Tunnel kiln process

This process is the oldest method of direct resuscitation. In this method, thermal coal is mixed with iron ore as a reducing agent. Natural gas generates the required temperature for regeneration, and regeneration takes place in silicon carbide plants in a tunnel furnace.

A) Input iron ore: Hematite or magnetite iron ore in soft form with preferably high grades such as 65%.

B) Reducing agent: The advantage of this method is the possibility of using relatively low quality thermal coal as a reducing agent. Coal in the furnace produces carbon monoxide, which regenerates iron oxide. Unlike SL / RN, the temperature required for reduction is not obtained from coal, but from natural gas using burners. Therefore, pollution in this method is very low.

C) Type of regeneration furnace: tunnel furnace. The tunnel kiln consists of three sections: preheating, regeneration and cooling

D) Reduction temperature: about 1200 to 1250 degrees Celsius

E) Process history: since about 1908 (more than 100 years)

F) Process position: stabilized and commercial

G) Optimal capacity: about 50,000 tons per module

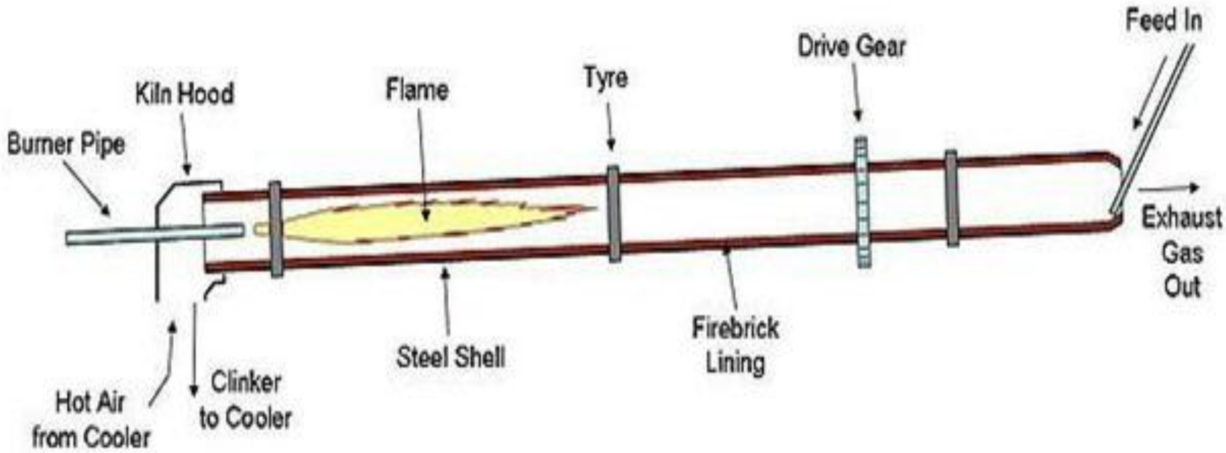
H) Market share: A total of about 5% of total sponge iron production

7. Schematic drawing of a sponge iron production plant with coal by rotary kiln method

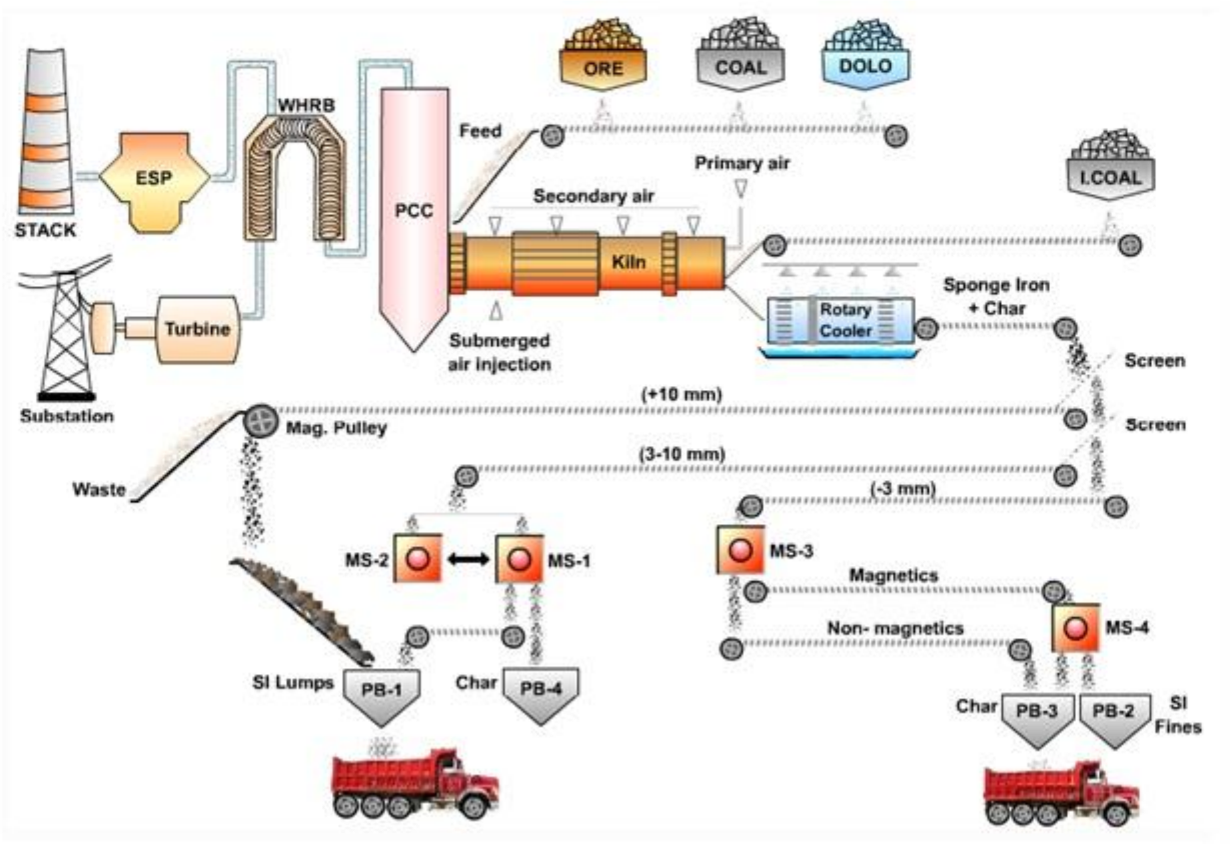
Sponge iron is produced using non-crushing coal through the iron ore reduction process in a rotary kiln. Regeneration takes place at a predetermined temperature and controlled atmospheric pressure. Input raw materials such as iron ore, coking coal (with high reactivity) and smelting materials such as limestone and dolomite in calibrated sizes are fed into the rotary kiln by means of weight and volume feeders. Due to the inclination and rotational motion of the rotary kiln, the raw materials move slowly from the end of the feeder to the end of the discharge or charge. During the movement, the iron ore is converted to DRI along with the previously heated coal. The material is then discharged directly to the rotary cooler, where it is cooled. The temperature of the cooled product is about 80 ° C, which is drained from the coolant and then taken to the separation and transfer system.

This product, which contains sponge iron with magnetic materials such as coal, etc., is separated by a sieve of different sizes and then magnetically separated by a magnetic separator, then the sponge iron is poured into a tank and sent out.

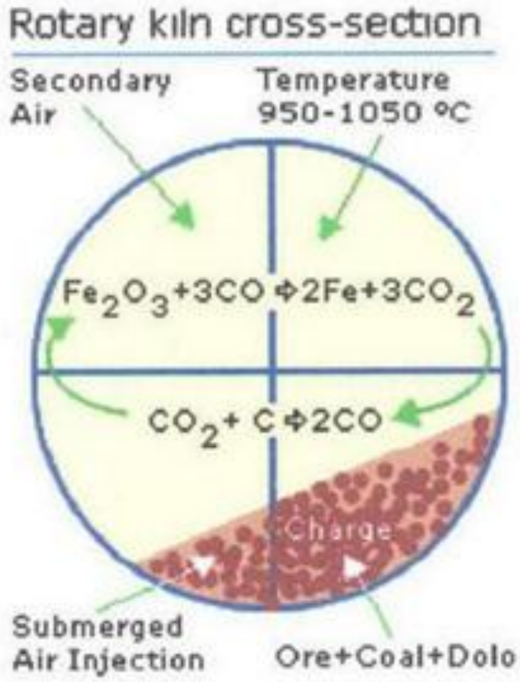
The schematic diagram of the sponge iron factory is shown in the figure below, as it is clear that the main unit in the factory is a unit in which the three raw materials of iron ore, coal and dolomite are combined and reactions take place between them.



As shown in the figure below, all reactions take place in a rotating cylindrical furnace around its axis and with a gentle slope (below 5 degrees) to the ground, hematite or magnetite rocks or pellets containing coal and limestone or Dolomite enters the rotary kiln and, while moving in the opposite direction of the gas flow, heats up and regenerates at a temperature of about 1100 ° C to about 92%, and turns into sponge iron.



Features of this method are the installation of pipes along the body of the rotary kiln and the installation of a burner at the outlet of the sponge iron. With this equipment, it is possible to precisely adjust the temperature along the furnace.



8. Conclusions

The HYL process has undergone relatively many changes in terms of the basic design of the process over the past years. have been. In recent years, the fourth generation of HIV furnaces has entered the market with the aim of eliminating the reformer box. This report is based on the fourth generation of this process.

A) Input iron ore: Input iron ore in this process is cooked in the form of pellets and the use of hematite iron ore lumps in an acceptable level is possible according to the characteristics of the rock.

B) Reducing agent: In this process, like the Midrex method, broken natural gas (but with the removal of the reformer) is used as the reducing agent. Is. In this process, the amount of hydrogen in the reduction gas mixture is much higher than carbon monoxide, and hydrogen acts as the main reducing agent.

C) Type of reduction furnace and its conditions: The furnace of this method is similar to the vertical shaft furnace of Midrex method. The furnace is sealed by mechanical (hydraulic) mechanisms and the reaction medium pressure is much higher and up to 7 atmospheres to achieve the desired reduction reaction speed.

D) Reduction temperature: about 850 to 870 degrees Celsius

E) Process history: since about 2003

F) Process position: not established but commercial

G) Capacity: The capacity of fourth generation furnaces is adjustable and highly variable based on the needs of the market according to the claims of its technical knowledge. Currently, units of 200 to 800 thousand tons per year are offered.

H) Market share: Currently, 4 modules have been launched or are under construction.

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