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Iron as a Raw Material in Forging and Industry

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Abstract

Iron is a chemical element; it has the symbol Fe (from Latin ferrum 'iron') and atomic number 26. It is a metal that belongs to the first transition series and group 8 of the periodic table. It is, by mass, the most common element on Earth, just ahead of oxygen (32.1% and 30.1%, respectively), forming much of Earth's outer and inner core. It is the fourth most common element in the Earth's crust, being mainly deposited by meteorites in its metallic state, with its ores also being found there. The melting and boiling points of iron, along with its enthalpy of atomization, are lower than those of the earlier 3d elements from scandium to chromium, showing the lessened contribution of the 3d electrons to metallic bonding as they are attracted more and more into the inert core by the nucleus; however, they are higher than the values for the previous element manganese because that element has a half-filled 3d sub-shell and consequently its d-electrons are not easily delocalized. This same trend appears for ruthenium but not osmium.

Keywords: Iron; metal application; forging and industry.

Introduction

Iron ore is what iron is made from. It is extracted from rocks and placed in a very high-temperature furnace to be melted, purifying the metal from the dirt. It also filters every metal from its soil except aluminum. Iron ores are rocks, minerals, and iron ores that can be economically extracted. They are usually rich in iron oxides and vary in color from dark grey, bright yellow, or deep purple to rusty red. Iron is usually found in the form of magnetite. [1, 2]

Iron ore

kIron ores are rocks and minerals from which metallic iron can be economically extracted. The ores are usually rich in iron oxides and vary in color from dark grey, bright yellow, or deep purple to rusty red. The iron is usually found in the form of magnetite (Fe_3O_4, 72.4% Fe), hematite (Fe_2O_3, 69.9% Fe), goethite (FeO(OH), 62.9% Fe), limonite (FeO(OH)n (H_2O), 55% Fe) or siderite ($FeCO_3$, 48.2% Fe). [3]

Ores containing very high quantities of hematite or magnetite, typically greater than about 60% iron, are known as natural ore or direct shipping ore and can be fed directly into iron-making blast furnaces. Iron ore is the raw material used to make pig iron, which is one of the main raw materials to make steel-98% of the mined iron ore is used to make steel. [4] In 2011 the Financial Times quoted Christopher LaFemina, mining analyst at Barclays Capital, saying that iron ore is "more integral to the global economy than any other commodity, except perhaps oil".

Iron ore and its final product, steel, are arguably the most historically social and economically significant commodities of the last three millennia. Matched with the increased demand for higher grade material, changes in the economic viability of iron ore deposits have seen iron ore production shift from early, low-grade bog iron ore and marine ironstones to the gigantic BIF-hosted deposits and locally the terrestrial Phanerozoic ironstones. [5, 6]

Despite their significance and the abundant literature devoted to these deposits, questions remain

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regarding their genesis and their relationship with past global and/or local events. For instance, BIF geochemistry has been reasonably well studied, whereas only very few studies are concerned with the geochemistry of high-grade BIF-hosted deposits. [7-9]

Sources

Metallic iron is virtually unknown on the surface of the Earth except as iron-nickel alloys from meteorites and very rare forms of deep mantle xenoliths. Some iron meteorites are thought to have originated from accreted bodies 1,000 km (620 mi) in diameter or larger. [10]

The origin of iron can be ultimately traced to the formation through nuclear fusion in stars, and most of the iron is thought to have originated in dying stars that are large enough to collapse or explode as supernovae. [11]

Although iron is the fourth-most abundant element in the Earth's crust, composing about 5%, the vast majority is bound in silicate or, more rarely, carbonate minerals.

The thermodynamic barriers to separating pure iron from these minerals are formidable and energy-intensive; therefore, all sources of iron used by human industry exploit comparatively rarer iron oxide minerals, primarily hematite.

Before the industrial revolution, most iron was obtained from widely available goethite or bog ore, for example, during the American Revolution and the Napoleonic Wars Prehistoric societies used laterite as a source of iron ore. Historically, much of the iron ore utilized by industrialized societies has been mined from predominantly hematite deposits with grades of around 70% Fe. [9, 12]

These deposits are commonly referred to as "direct shipping ores" or "natural ores". Increasing iron ore demand, coupled with the depletion of high-grade hematite ores in the United States, led after World War II to the development of lower-grade iron ore sources, principally the utilization of magnetite and taconite.

Iron ore mining methods vary by the type of ore being mined. There are four main types of iron ore deposits worked currently, depending on the mineralogy and geology of the ore deposits. These are magnetite, titanomagnetite, massive hematite, and pisolitic ironstone deposits. [13]

■*Hématite*

It is the mineral iron(III) oxide (Fe_2O_3). It is the primary material for producing iron. Hematite crystallizes in the triclinic crystal system and has the same crystal form as the minerals ilmenite and corundum. Hematite and ilmenite are solid liquids (glassy in composition) above 950°C. [14]

The color of raw hematite is between gray and red, and it is extracted as the main ore for the iron industry in various forms. Its hardness is higher than that of pure iron, but it is more brittle.

Iron is found in the layers of the Earth's crust, and gray iron is found in areas that are full of water, such as in the Yellowstone region of the United States of America. The metal can precipitate from the water and concentrate at the bottom of lakes. Iron can also be found away from water as a result of volcanic activity.

Figure 1

■*Magénite*

It is one of the mineral ores found in iron. It is present in approximately 72% as one of the basic components of iron metal. It is considered a pure iron ore. It is distinguished by its bright, shiny black color and is chemically referred to as (Fe_3O_4). [15]

Figure 2

■*Limonite*

It is one of the iron ores and is found at a rate ranging between 40% - 50% as one of the components of iron metal. Water forms part of this ore, the percentage of which reaches approximately 10%. It is characterized by its yellow color close to brown, or red, and is chemically referred to as with the symbol ($2Fe_2O_3H_2O$). [16, 17]

Figure 3

Banded iron formations

(BIFs) are sedimentary rocks containing more than 15% iron composed predominantly of thinly bedded iron minerals and silica (as quartz). Banded iron formations occur exclusively in Precambrian rocks, and are commonly weakly to intensely metamorphosed. Banded iron formations may contain iron in carbonates (siderite or ankerite) or silicates (minnesotaite, greenalite, or grunerite), but in those mined as iron ores, oxides (magnetite or hematite) are the principal iron mineral. [17] Banded iron formations are known as taconite within North America.

The mining involves moving tremendous amounts of ore and waste. The waste comes in two forms: non-ore bedrock in the mine (overburden or interburden locally known as mullock), and unwanted minerals, which are an intrinsic part of the ore rock itself (gangue). The mullock is mined and piled in waste dumps, and the gangue is separated during the beneficiation process and is removed as tailings. Taconite tailings are mostly the mineral quartz, which is chemically inert. This material is stored in large, regulated water-settling ponds. [17]

Magnetite ores

The key parameters for magnetite ore being economic are the crystallinity of the magnetite, the grade of the iron within the banded iron formation host rock, and the contaminant elements that exist within the magnetite concentrate.

The size and strip ratio of most magnetite resources is irrelevant as a banded iron formation can be hundreds of meters thick, extend hundreds of kilometers along strike, and can easily come to more than three billion or more tonnes of contained ore.

Currently, magnetite iron ore is mined in Minnesota and Michigan in the United States, Eastern Canada, and Northern Sweden.

Magnetite-bearing banded iron formation is currently mined extensively in Brazil, which exports significant quantities to Asia, and there is a nascent and large magnetite iron ore industry in Australia. [18]

Direct-shipping (hematite) ores

DSO deposits are typically rarer than the magnetite-bearing BIF or other rocks which form its main source or protolith rock, but are considerably cheaper to mine and process as they require less beneficiation due to the higher iron content. However, DSO ores can contain significantly higher concentrations of penalty elements, typically being higher in phosphorus, water content (especially pisolite sedimentary accumulations), and aluminum (clays within pisolites). Export-grade DSO ores are generally in the 62–64% Fe range.

Direct-shipping iron ore (DSO) deposits (typically composed of hematite) are currently exploited on all continents except Antarctica, with the largest intensity in South America, Australia, and Asia. Most large hematite iron ore deposits are sourced from altered banded iron formations and rarely igneous accumulations. [19]

Magmatic magnetite ore deposits

Some magnetite skarn and hydrothermal deposits have been worked in the past as high-grade iron ore deposits requiring little beneficiation. There are several granite-associated deposits of this nature in Malaysia and Indonesia.

Other sources of magnetite iron ore include metamorphic accumulations of massive magnetite ore such as at Savage River, Tasmania, formed by shearing of ophiolite ultramafics. [20]

Another, minor, source of iron ores is magmatic accumulations in layered intrusions which contain a typically titanium-bearing magnetite often with vanadium. These ores form a niche market, with specialty smelters used to recover the iron, titanium, and vanadium. These ores are beneficiated essentially similar to banded iron formation ores but usually are more easily upgraded via crushing and screening. The typical titanomagnetite concentrate grades 57% Fe, 12% Ti, and 0.5% V_2O_5. [21]

Cast iron

It is an alloy composed of iron with other elements such as Magnesium and phosphorus, and the carbon content ranges from 1.1% to 4%, and the types of this limit vary according to the distribution of carbon molecules in the alloy, so its types result: [22]

a) Gray cast iron.
b) White cast iron.
c) Wrought iron.
d) Flexible cast iron.

<u>How to produce iron</u>

Iron is obtained from its ores through heat treatment technology. The first involves heating iron ore in a furnace, reducing the metal oxides to metals. The registration process, called cycles, removes impurities and allows iron to be released. Once the iron is made, it is purified through a smelting process, where it is dispersed with carbon and subjected to high temperatures, resulting in the desired iron and monoxide.

Iron is extracted from ores containing iron compounds by a process called flotation. This process takes place in flotation cells containing an aqueous solution enriched with chemicals such as oil, air popcorn, soap, and caustic soda. [23]

The flotation process is carried out by dissolving the ores in the enriched aqueous solution, and then adding other materials to it to separate the precious metals from other impurities. The desired mineral is then dried and removed from the cells. [24]

After that, the extracted metal undergoes further purification processes, which is done by heating at high temperatures and applying electrical energy to move the atoms to separate them from other impurities, paving the way for its conversion into various iron products such as steel and others. [25]

Iron production by smelting

Alternative methods of producing iron have emerged, and some of these processes produce steel directly in a single step rather than producing cast iron and then refining it to produce steel.

The most important of these methods is what is known as smelting, and the basic difference between direct reduction and smelting is that the product in the second case is liquid, while in the first the iron is produced in a solid form. This process is carried out in a melting furnace, or it may be smelting and reduction using plasma.

Reduction and plasma fusion

It is clear from the name that this process uses plasma resulting from the ionization of gases at a temperature of about 3000°C. Melting and plasma reduction occur in two stages:

- **In the first step**, the iron ore is partially reduced by between 50% and 60% in two chambers forming a fluidized bed, before it is mixed with coal and limestone. This is achieved through a plasma generator in the form of a cylindrical kiln filled with coke.
- **In the second step**, final reduction and melting are carried out. It is a cylindrical furnace unit, which is very similar to the reduction in a blast furnace. The main difference is the presence of a plasma generator that ionizes gases near the bronchi.

Irned method

It is considered the second modern method to produce iron and then steel in the reactor itself without the need to transfer the produced iron to another reactor. The primary fuel is coal and the production of steel from iron ore takes place in two different sequential processes.

The work is carried out by injecting fine iron ore granules from the top of the furnace, in addition to coal shavings, limestone, and oxygen. This leads to flash smelting with partial reduction of the iron ore, which is in suspended form with the rest of the charge. This is then followed by smelting and complete reduction of the ore in the lower part of the reactor. The new additions to this method of producing steel are:

- Using one furnace instead of two furnaces and completing the work without having to transfer the products of the first stage to the following stage reactors.
- Ideal use of energy, as the excess heat released from the combustion of coal in the upper sector is used to generate electrical energy and is used to produce steel in the lower sector.

Blast oven method

- A stream of hot air enters through the blower pipes located below, where oxygen reacts with coke, forming carbon monoxide (CO).
- Hot gas rises through the coke cracks and the iron oxides are reduced, and carbon monoxide is converted during the reduction of iron oxides into carbon dioxide.
- The gas leaves the top of the furnace through the outlets above.
- Molten iron and slag flow through the coke bed towards the burner.

Blast furnace products

- **Slag**: Slag contains small amounts of iron oxides and coal ash, which is used in paving roads and the cement industry.
- **Gases**: These gases are produced at a rate of 4000 m/ton. Crocodile
- **Iron**: It contains 5% carbon and 93% iron, which is why it is fragile and cannot withstand hammering. But by remelting it, cast iron is made.

Production of iron by direct reduction

The term “direct reduction” has been defined at present as a method of reducing iron oxides to produce iron from them using various gases as a reducing medium. This process takes place at a temperature lower than the melting temperature, where the temperature is between 800 and 900°C.

The iron resulting from this process was known as sponge iron, and by the end of the eighties of the twentieth century, direct reduction iron production reached about 50 million tons/year. It can be said that the factors that help increase the production of reductive iron are due to the advantages of this method. [26-30]

Advantages of direct reduction

This method of producing iron has many advantages, and among these advantages that have helped this method to flourish and grow, especially in developing countries, are the following:

- This method does not require coke, which in turn leads to many advantages:
    - Reducing the risks of the industry relying on an expensive and unavailable raw material.
    - The coke industry is associated with many problems, especially those related to environmental pollution.
    - Lack of suitable coal for the coke industry in Arab countries.
- The possibility of creating units with small production capacity, the cost of establishing which is much lower than blast furnaces.
- This technology is simple and modern in developing countries and is easy to absorb and use.
- The required energy sources are available in many countries, specifically natural gas.
- It does not take a long time to create a blast furnace.
- The iron produced from this process is carbon-free, while the alligator iron produced from the blast furnace contains approximately 4% carbon.

Production and consumption

Iron is the most widely used metal in the world - steel, of which iron ore is the main component, accounts for approximately 95% of all metals used annually. It is mainly used in structures, ships, cars, and machinery.

Iron-rich rocks are common throughout the world, but ore-grade commercial mining operations are dominated by the countries listed in the table. The main constraint on the economics of iron ore deposits is not necessarily the grade or size of the deposit, because it is not particularly difficult to prove the presence of a sufficient amount of rock geologically. The main constraint is the position of iron ore relative to the market, the cost of rail infrastructure to get it to market, and the cost of the energy required to do so.

Iron ore mining is a high-volume, low-margin business, as the value of iron is much lower than the base metals. It is capital intensive and requires large investments in infrastructure such as railways to transport the ore from the mine to the cargo ship. For these reasons, iron ore production is concentrated in the hands of a few major players.

The average global production is two billion metric tons of crude oil annually. The world's largest producer of iron ore is Brazilian mining company Vale followed by Anglo-Australian companies Rio Tinto Group and BHP. Another Australian supplier, metals group Fortescu Ltd, has helped achieve Australia's first-world production.

Seaborne trade in iron ore - that is, iron ore that would be shipped to other countries - reached 849 million tons in 2004. Australia and Brazil dominate seaborne trade, with 72% of the market. BHP, Rio, and Vale control 66% of this market between them.

In Australia iron ore is obtained from three main sources: piezolithic ore derived from mechanical erosion of primary banded iron formations and accumulated in alluvial channels such as Panawonica, Western Australia; Related metasomatically modified ores are prevalent in iron-forming ranges such as in the Newman, Chichester Range, Hammersley Range and Cullianoping, Western Australia. Other types of ore have come to the fore recently, such as hard oxidized iron beds, for example, laterite iron ore deposits near Lake Argyle in Western Australia.

The total recoverable reserves of iron ore in India are about 9,602 million tons of hematite and 3,408 million tons of magnetite. Chhattisgarh, Madhya Pradesh, Karnataka, Jharkhand, Odisha, Goa, Maharashtra, Andhra Pradesh, Kerala, Rajasthan and Tamil Nadu are the major Indian producers of iron ore. Global consumption of iron ore is growing by 10% per year on average with the main consumers being China, Japan, Korea, the United States, and the European Union.

China is currently the largest consumer of iron ore, which translates to being the largest steel-producing country in the world. It is also the largest importer, buying 52% of the sea trade in iron ore in 2004. It is followed by Japan and Korea, which consume a large amount of raw iron ore and metallurgical coal. In 2006, China produced 588 million tons of iron ore, an annual growth rate of 38%.

Abundance by country

Iron ore resources available in the world

Iron is the most abundant element on Earth but not in the crust. The extent of accessible iron ore reserves is unknown, although Lester Brown of the World watch Institute suggested in 2006 that iron ore could be exhausted within 64 years (i.e. by 2070), based on demand growth of 2% per year. [30, 31]

Australia

Geoscience Australia estimates that the country's "proven economic resources" of iron currently stand at 24 gigatonnes or 24 billion tons.

Current production from the Pilbara region of Western Australia is approximately 430 million tons per year and growing. Gavin Maude (RMIT University) and Jonathan Law (CSIRO) expect it to disappear in 30-50 years and 56 years respectively.

The 2010 estimates require continued review to take into account the shifting demand for low-grade iron ore and improved mining and recovery techniques (allowing mining deeper below the groundwater level). [31]

Pilbara

In 2011, the Pilbara's leading iron ore mining companies – Rio Tinto, BHP, and Fortescue Metals Group (FMG) – announced significant capital investments in the development of existing and new mines and associated infrastructure (railways and ports). Collectively, this would reach a production of 1,000 million tons per year (Mt/y) by 2020. In practice, this would require doubling production capacity from the current production level of 470 Mt/y to 1,000 Mt/y (an increase of 530 Mt/y). / year).

These figures are based on production rates of Rio 300 million tons per year, 240 million tons per year, FMG 55 million tons per year, and 15 million tons per year, increasing to Rio 360 million tons per year, BHP 356 million tons per year, FMG. 155 million tons per year and others 140 million tons per year (the latter 140 million tons per year is based on planned production from new entrants in the industry to Hankook, Atlas and Brockman via Port Hedland and API and others through the proposed Antilles Port). In March 2014, Fortescue officially opened its 40 million tonnes per annum (MTPA) project at Kings Valley, marking the completion of a $9.2 billion expansion that increased its production capacity to 155 MTPA.

The expansion included the construction of the greenfield Solomon Hub in the Hamersley Ranges, one of the world's largest iron ore projects comprising Kings Valley and the nearby 20 mtpa Firetail mine; Expansion of the Christmas Creek mine to 50 million tons per year; and major expansions of Fortescue's global ports and rail facilities.

A production rate of 1,000 million tons per year would require a significant increase in production from existing mines and the opening of a large number of new mines. Furthermore, a significant increase in railway and port infrastructure capacity will also be needed.

For example, Rio will be required to expand its operations at the ports at Dampier and Cape Lambert by 140 million tons per year (from 220 million tons per year to 360 million tons per year). BHP will be required to expand Port Hedland port operations by 180 million tons per year (from 180 million tons per year to 360 million tons per year). FMG will be required to expand its port operations in Port Hedland by 100 million tons per year (from 55 million tons per year to 155 million tons per year).

United States of America

In 2014, mines in the United States produced 57.5 million metric tons of iron ore with an estimated value of $5.1 billion. Iron mining in the United States accounts for 2% of the world's iron ore output.

In the United States, there are 12 iron ore mines with nine open pit mines and three reclamation operations.

There were also ten pelletizing plants, nine concentration plants, two direct iron ore plants and one iron tone plant operating in 2014.

In the United States, most iron ore mining is located in the iron ranges around Lake Superior. These iron ranges occur in Michigan which together accounted for 93% of the usable iron ore produced in the United States in 2014.

Seven of the nine open pit mines operating in the United States are located in Minnesota as well as two of the three tailings reclamation operations. The other two active open-pit mines are located in Michigan, and in 2016 one of the mines was closed.

There were also iron ore mines in Utah and Alabama. However, the last iron ore mine in Utah closed in 2014 and the last iron ore mine in Alabama closed in 1975.

Canada

In 2017, Canadian iron ore mines produced 49 million tons of iron ore in pellets and 13.6 million tons of raw steel. Of the 13.6 million tons, 7 million tons were exported, and 43.1 million tons of iron ore were exported, worth $4.6 billion.

Of the exported iron ore, 38.5% of the volume is iron ore pellets, worth $2.3 billion, and 61.5% is iron ore concentrate, worth $2.3 billion.

The majority of Canadian iron ore comes from Mary River Mine, Nunavut and from Schefferville, Quebec.

Brazil

Brazil is the second largest producer of iron ore and Australia is the largest. In 2015, Brazil exported 397 million tons of usable iron ore.

In December 2017, Brazil exported 346,497 metric tons of iron ore and from December 2007 to May 2018 they exported a monthly average of 139,299 metric tons. [26-30]

Effect of elements

The inclusion of small amounts of some elements can have profound effects on the behavioral characteristics of a batch of iron or the operation of a smelter.

These effects can be both good and bad, and some are catastrophically bad. Some chemicals are intentionally added such as flux which makes the blast furnace more efficient. Others are added because they make the iron more flexible, stiffer, or give it some other desirable quality.

The choice of ore, fuel, and flow determines how the slag behaves and the operational characteristics of the iron produced. Ideally, iron ore contains only iron and oxygen. This rarely happens.

Typically, iron ore contains a combination of elements that are often undesirable in modern steel.

During the smelting process

Iron ores consist of oxygen and iron atoms bound together into molecules. To convert it into metallic iron, it must be melted or sent through a direct reduction process to remove oxygen.

The bonds of oxygen and iron are strong, and to remove iron from oxygen, a stronger elemental bond must be introduced to attach to the oxygen. Carbon is used because the bond strength of carbon and oxygen is greater than the bond strength between iron and oxygen, at high temperatures.

Thus, the iron ore must be crushed and mixed with coke, to be burned in the smelting process.

Carbon monoxide is the primary component of chemically deoxygenating iron. Thus, the smelting of iron and carbon must be maintained in a (reducing) anoxic state to promote the combustion of carbon to produce CO but not CO_2.

-Air and coal explosion (coke): $2C + O_2 \rightarrow 2CO$

-Carbon monoxide (CO) is the main reducing agent.

-The first stage: $3\ Fe_2O_3 + CO \rightarrow 2\ Fe_3O_4 + CO_2$

-The second stage: $Fe_2O_3 + CO \rightarrow 3\ FeO + CO_2$

-The third stage: $FeO + CO \rightarrow Fe + CO_2$

-Limestone calcination: $CaCO_3 \rightarrow CaO + CO_2$

-Lime acts as a flux: $CaO + SiO_2 \rightarrow CaSiO_3$

Silicone

Silica (SiO_2) is almost always present in iron ore. Most of them are eliminated during the smelting process. At temperatures above 1300°C (2370°F), some of it will be reduced and form an alloy with iron. The hotter the oven, the more silicon is present in the iron. It is not uncommon to find up to 1.5% Si in European cast iron from the 16th to 18th centuries.

The main effect of silicon is to promote the formation of gray iron. Gray iron is less brittle and easier to finish than white iron. It is preferred for casting purposes for this reason. Turner reported that silicone also reduces shrinkage and the formation of holes, reducing the number of bad castings.

Phosphorus

Phosphorus (P) has four main effects on iron: increasing hardness and strength, lowering the temperature of solids, increasing fluidity, and shortening the cold.

Depending on the intended use of iron, these effects are either good or bad. Swamp ore often has a high phosphorus content.

The strength and hardness of iron increases with increasing phosphorus concentration. 0.05% phosphorus in wrought iron makes it as hard as medium carbon steel.

High phosphorus iron can also be hardened by cold forging. The hardening effect is true for any concentration of phosphorus. The more phosphorus, the harder the iron becomes and the stronger it is with the hammer.

Modern steelmakers can increase hardness by up to 30%, without sacrificing impact resistance by keeping phosphorus levels between 0.07 and 0.12%. It also increases the depth of solidification due to quenching, but at the same time, it also reduces the solubility of carbon in iron at high temperatures.

This would reduce its usefulness in making blister steel, where the speed and quantity of carbon absorption are the primary consideration.

There are two treatments for high phosphorus iron. The older and easier is avoidance. If the iron ore produced was short, one would look for a new source of iron ore.

The second method involves oxidizing phosphorus during the fining process by adding iron oxide. This technique is usually associated with staining in the 19th century, and may not have been understood before.

For example, Isaac Zane, owner of the Marlboro Iron Works, apparently knew nothing about it in 1772. Given Zane's reputation for keeping up with the latest developments, this technology was probably unknown to the ironworks of Virginia and Pennsylvania.

Aluminum

Aluminum is difficult to reduce. As a result, contamination of iron with aluminum is not a problem. However, it increases the viscosity of the slag.

This will have several negative effects on the operation of the furnace. Thick slag will slow the descent of the charge, prolonging the process.

High aluminum will also make it difficult to utilize liquid slag. At extremes, this can result in a frozen oven.

There are several solutions for high aluminum slag. The first is avoidance. Do not use an ore or lime source with a high aluminum content. Increasing the lime flow rate reduces the viscosity. [20-23]

Sulfur

A hot short iron is brittle when hot. This was a serious problem because most of the iron used during the 17th and 18th centuries was iron or wrought iron. Wrought iron is shaped by repeated blows with a hammer while hot.

A piece of hot short iron will break if you work it with a hammer. When a piece of hot iron or steel cracks, the exposed surface is instantly oxidized. This layer of oxide prevents the crack from being repaired by welding.

Large cracks cause iron or steel to crack. Smaller cracks can cause the object to fail during use. The higher temperature is directly proportional to the amount of sulfur present. Today, iron-containing more than 0.03% sulfur is avoided.

In cast iron sulfur promotes the formation of white iron. Up to 0.5% can resist the effects of slow cooling and high silicon content.

White cast iron is more brittle, but also harder. It is generally avoided, as it is difficult to work, except in China where highly sulfurous cast iron, some as low as 0.57%, made from coal and coke, was used in making bells and bells.

Good cast iron should contain less than 0.15% sulfur. In the rest of the world, high-sulfur cast iron can be used to make castings, but it makes poor wrought iron

Conflict of Interest

There is no conflict of interest in the publication of this article

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