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Preparation of iron ore for metallurgical processing

Iron ore is one of the main types of minerals which is used by people. Iron is one of the most wide-spread elements on Earth. Almost all iron ores are processed in cast iron, steel, and iron-base alloys. Cast irons and steels are the basis of the modern industry. The material, which is called iron, almost always is an alloy of iron and carbon. The carbon content in the alloy determines the properties of the alloys. When the content of carbon is less than 0.3 %, alloy is refractory, tough and ductile metal that can be called simply iron. Alloys containing 0.3–2.0 % of carbon, called steel. Steel is easy processed, many types of steel are subjected to hardening (in contrast to iron and cast iron), which greatly increases its hardness. Alloys with carbon content more than 2.0 % are called cast iron, which is fragile, fusible, castable, but almost not forgeable.

Deposits of rich iron ores contain more than 55 % of iron and do not need beneficiation; there are only few such deposits in our country. Almost all Russian deposits contain 20-40 % of iron in ore and therefore need beneficiation. Usually beneficiation includes two, three and sometimes more stages of grinding and magnetic separation. That's why concentrate is fine and not suitable for metallurgical processing. Modern production of iron consists of two main stages - reduction of iron ore by carbon coke in the blast furnace to produce cast iron and refining of pig iron in steelmaking furnaces of various types for steel production. Blast furnace process needs sufficiently high gas permeability of the charge material, which is loaded into the blast furnace (it is not possible to use fine concentrate), so concentrate is always subjected to clotting. Three basic types of clotting - agglomeration, pelletizing, briquetting – are known.

Agglomeration is the process of getting pieces (agglomerate) by sintering fine ore or concentrate by high temperature of combustion, which is added to the agglomerate batch of fuel. Due to the high temperature sintering process removes harmful impurities (for example sulfur).

Pelletizing (granulation) is the process of obtaining pellets, based on the property of moist fine particles of ore or concentrate to create granules (pellets) during rolling. After this, pellets are usually roasted for hardening.

Briquetting is mechanical or thermomechanical process of different raw materials to get briquettes, which are pieces with the same size and shape.

Briquetting in ferrous industry is the earliest method of clotting, which was widely used for this purpose in the second half of the XIX century. In the beginning of XX century it was replaced by agglomeration of briquettes mainly due to significantly higher capacity of agglomeration device than briquette press. As alternative to agglomeration, pelletizing became popular in XX century, that is quite explainable by essential increase of production of small concentrates.

By the way, from the technological and economical point of view, production of briquettes has a number of advantages:

– briquettes have the same shape and weight, with big iron content in the metal, have higher strength and are more suitable for transportation;

– briquettes have higher density, the quantity of a turnaround product on agglomeration factory is about 20–25 % (and sometimes more) from the general stream mixture, while on briquetting factory this parameter is no more than 2 %;

– all oxygen of ore remains active in a briquette, in agglomerate it is connected with other elements (in the form of silicates), the first is especially important for iron production;

– ecological safety of briquettes (waste-free operation, absence of high temperatures at manufacturing);

– possibility to include in briquette any quantities (such as, coal, coke, flux, etc.);

– possibility of using all kinds of fine metallurgical waste [1] in briquettes.

For some types of iron ore briquetting the process of clotting may be preferable. These ores are rich iron ores with Fe content equals to 60 % and more. These ores don't need processing and fine grinding and it is obvious that their pelletizing, requiring pre-pulverizing irrationally. In comparison with agglomeration, briquetting is cheaper and more environmentally friendly process.

Rich ores of the Yakovlevskoe deposit can be considered as an example of such ores. Ore has martite, martite-hydrohematite, hydrohematite varieties and consequently the iron content, in different particle size classes, and also distribution of particle size has great variety (the less is particle size, the more iron content is in ore).

The flow sheet of briquetting consists of crushing to 10 mm size (maximum size of feeding is 350 mm). Then, depending on the properties of the ore is processed by following ways.

If ore has comparatively the same distribution of iron content in different particle sizes, there is one variant of classes for such ore processing (Fig. 1), which provides preliminary crushing of feeding ore to size 10 mm. Further crushed ore is gone to screening and the fraction which is larger than 5 mm is gone directly to metallurgical processing department (for example, raw materials for blast furnace). The class with particle size less than 5 mm is briquetted.

Sulfuric acid, forming with the carbonates which are contained in the ore, or gypsum, can be used as a self-stiffen binder, allowing to obtain sufficiently durable briquettes. Quantity of sulfuric acid depends mainly on the carbonate content. If carbonate content in the ore is more than 0.5 – 1.0 %, it is optimal addition of acid in stoichiometric relative to the carbonates contained in the ore. If carbonate content is less, durability of bricks is falling and then it is necessary to add more acid, while oxides and hydroxides of iron will be joining to forming sulfates, acting as a binder. Acid consumption is chosen experimentally, and ranged from 1 to 5 %.

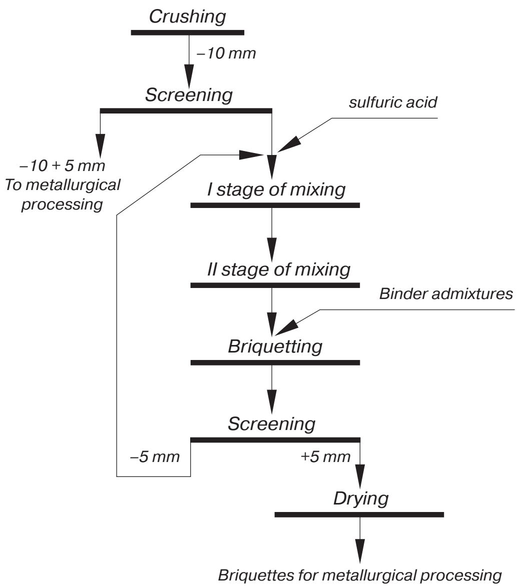

Fig. 1. Flow sheet of rich iron ore briquetting

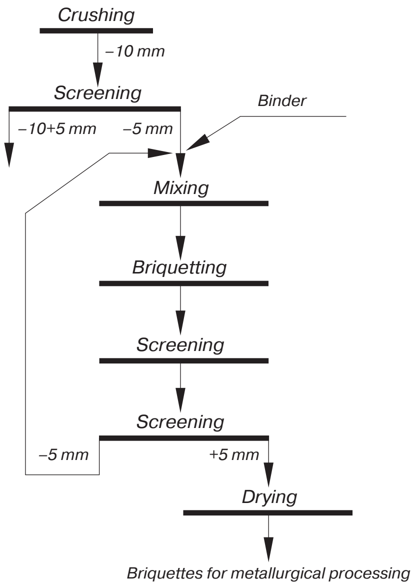

Fig. 2. Flow sheet of briquetting with preliminary screening

Concentration of sulfuric acid was chosen to the humidity of the charge was within the range 8–12 mass. %. Sulfuric acid promotes evenly mixing of all components, forming a strong structural links for better molded briquettes, which increases strength of the briquettes. Humidity of a charge less than 8 % provides difficult mixing of the components, while humidity over 12 % is excessive and reduces strength of the briquettes [2].

Drying of crude briquettes allows to raise durability of briquettes, especially in the case when content of carbonates in ore is less than 0.5–1.0 % and acts as additional iron sulfate binder.

According to the developed technology of briquetting, it is possible to receive durable iron ore briquettes (durability on uniaxial compression is more than 4–5 MPa) with raised iron content (using particle size class from –5 to +0 mm).

Also carboxymethyl cellulose can be used as the binder or a combined binder [3]. Combined binder is a suspension consisting of fine ore grades, carboxymethyl cellulose and oleic acid. In another way, carboxymethyl cellulose can be used as combined binder with the addition of bentonite.

If iron is unevenly distributed over the particle size classes (in large classes iron content is less), then screening is used after crushing operation (Fig. 2).

Particles with size less then 5 mm are separated from ore and then used for briquetting, particles with size more then 5 mm are separated and (depending on the iron content) can be sent to metallurgical processing (such as blast-furnace process), or for agglomeration. The flow sheet in this case is more difficult than showed on Fig. 1, but it allows to receive briquettes with higher iron content. Screening here is a beneficiation operation. It should be noted that the process of screening is rather cheap and easy, and for most of ore types located at Yakovlevskoe deposit have uneven distribution of iron content in different particle size classes – the smaller the particle size class, the higher is iron content in it.

It is also possible to use size class –10 +0 mm for briquetting. Received durability of briquettes with particle size class -5 +0 mm is almost the same comparing with the class –10 +0 mm.

With usage of sulfuric acid, average durability on uniaxial compression of briquettes is about 4.5 MPa (particle size class –10 +0 mm).

With usage of carboxymethyl cellulose, average durability is about 7.6 MPa (particle size class –5 +0 mm), and 7.4 MPa (particle size class –10 +0 mm).

With usage of combined binder (suspension of fine grinned particles and carboxymethyl cellulose), average durability is about 7.9 MPa (particle size –5 +0 mm), and 7.7 MPa (particle size –10 +0 mm).

With combination binder (suspension of carboxymethyl cellulose and bentonite) average durability is about 12,3 MPa using particle size class –5+0 mm, and 11,4 MPa (–10 +0 mm).

According to the developed technology of briquetting, it is possible to receive durable iron-ore briquettes without iron content reduction or a small decrease of iron content in briquettes. And the raw material (without wastes) is used for metallurgical processing.

Metallurgical properties of the briquettes are examining.

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