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(72) Inventors:
• **MORIOKA, Koichi**
Kakogawa-shi, Hyogo 675-0137 (JP)
• **TAKIGUCHI, Yuta**
Kakogawa-shi, Hyogo 675-0137 (JP)
• **KATO, Tsugunori**
Kakogawa-shi, Hyogo 675-0137 (JP)
• **KAJIYAMA, Yuki**
Kakogawa-shi, Hyogo 675-0137 (JP)

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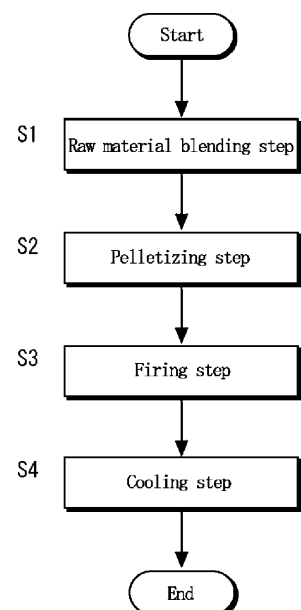
(71) Applicant: **Kabushiki Kaisha Kobe Seiko Sho**
(Kobe Steel, Ltd.)
Kobe-shi, Hyogo 651-8585 (JP)

(74) Representative: **Müller-Boré & Partner**
Patentanwälte PartG mbB
Friedenheimer Brücke 21
80639 München (DE)

(54) **METHOD FOR PRODUCING IRON ORE PELLETS, AND IRON ORE PELLETS**

(57) An aspect of the present invention is a method for producing iron ore pellets for use in blast furnace operation, wherein the iron ore pellets are self-fluxing, the method including: raw material blending, wherein an auxiliary material containing CaO and MgO is blended into an iron ore material such that a CaO/SiO₂ mass ratio is greater than or equal to 0.8 and a MgO/SiO₂ mass ratio is greater than or equal to 0.4; pelletizing, wherein green pellets having a porosity of greater than or equal to 15% and less than or equal to 22% are made from a raw material mixture obtained in the raw material blending; and firing the green pellets at a temperature of greater than or equal to 1,200 °C and less than or equal to 1,300 °C.

FIG. 1



EP 4 570 930 A1

Description

[TECHNICAL FIELD]

[0001] The present invention relates to a method for producing iron ore pellets and iron ore pellets.

[BACKGROUND ART]

[0002] As blast furnace operation, a method is known in which iron ore and/or fired iron ore agglomerates containing iron oxide as well as coke as a carbon source are charged from an upper part of the blast furnace, the air and/or oxygen are blown from (a) tuyere(s) in the lower part to promote generation of carbon monoxide and a reduction reaction for removing oxygen from the iron oxide in the furnace, and then molten iron is tapped from the lower part of the furnace.

[0003] To smoothly conduct the continuous operation, smooth blast is important. For this purpose, it is desired that the blast pressure is low and stable, i.e., that the gas permeability is favorable. The blast pressure depends on characteristics of burdens. Of the burdens, iron ore, sintered iron ore, and iron ore pellets are each turned to be a mixture of metallic iron and an oxide when exposed to high temperatures and a reducing atmosphere and subjected to a reduction reaction. At the same time, they are softened and transformed by a load in the blast furnace. The softening and transformation cause gaps between the burden particles to be filled, thereby impairing the gas permeability in the furnace. An event caused principally by this phenomenon is referred to as a furnace lower-part pressure loss, and a reduction thereof is intended.

[0004] As iron ore pellets which enable a reduction in the furnace lower-part pressure loss, self-fluxing pellets having a CaO/SiO₂ mass ratio of greater than or equal to 0.8, a MgO/SiO₂ mass ratio of greater than or equal to 0.4, and a predetermined grain diameter distribution are known (see Japanese Unexamined Patent Application, Publication No. 2008-280556).

[0005] With regard to the iron ore pellets, the reducibility at high temperatures is improved by setting the CaO/SiO₂ mass ratio to greater than or equal to 0.8 and setting the MgO/SiO₂ mass ratio to greater than or equal to 0.4, and the gas permeability is ensured by controlling the grain diameter distribution.

[PRIOR ART DOCUMENTS]

[PATENT DOCUMENTS]

[0006] Patent Document 1: Japanese Unexamined Patent Application, Publication No. 2008-280556

[SUMMARY OF THE INVENTION]

[PROBLEMS TO BE SOLVED BY THE INVENTION]

[0007] In the case of the conventional iron ore pellets, the gas permeability can be ensured, but this effect is relatively limited, and thus, the gas permeability resistance in a relatively low-temperature region in an upper part of a shaft furnace (upper pressure loss) is likely to degrade. Furthermore, in recent operation, it has become more popular to inject pulverized coal from a tuyere of a blast furnace to reduce the amount of expensive coke used. As a result, as the injection amount of the pulverized coal increases, the amount of the coke for supporting the gas permeability in the blast furnace decreases, leading to a tendency to entirely increase the gas permeability resistance. Therefore, it is required to particularly reduce an upper gas permeability resistance in the blast furnace.

[0008] The present invention has been made in view of the foregoing circumstances, and an object of the present invention is to provide: a method for producing iron ore pellets which are superior in reducibility at high temperatures and enable a reduction in the upper gas permeability resistance in the blast furnace; and the iron ore pellets.

[MEANS FOR SOLVING THE PROBLEMS]

[0009] An aspect of the present invention is a method for producing iron ore pellets for use in blast furnace operation, wherein the iron ore pellets are self-fluxing, the method including: raw material blending, wherein an auxiliary material containing CaO and MgO is blended into an iron ore material such that a CaO/SiO₂ mass ratio is greater than or equal to 0.8 and a MgO/SiO₂ mass ratio is greater than or equal to 0.4; pelletizing, wherein green pellets having a porosity of greater than or equal to 15% and less than or equal to 22% are made from a raw material mixture obtained in the raw material blending; and firing the green pellets at a temperature of greater than or equal to 1,200 °C and less than or equal to 1,300 °C.

[0010] Another aspect of the present invention is iron ore pellets for use in blast furnace operation, the iron ore pellets

being self-fluxing, wherein: a CaO/SiO_2 mass ratio is greater than or equal to 0.8, and a MgO/SiO_2 mass ratio is greater than or equal to 0.4; and an average crushing strength is greater than or equal to 270 kg/p.

[EFFECTS OF THE INVENTION]

[0011] According to the method for producing iron ore pellets of the present invention, iron ore pellets which are superior in reducibility at high temperatures and enable a reduction in the upper gas permeability resistance in the blast furnace can be produced. Furthermore, the iron ore pellets of the present invention are superior in reducibility at high temperatures and enable a reduction in the upper gas permeability resistance in the blast furnace.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0012]

FIG. 1 is a flowchart illustrating a method for producing iron ore pellets according to one embodiment of the present invention.

FIG. 2 is a schematic view illustrating a configuration of a production apparatus used in the method for producing iron ore pellets in FIG. 1.

FIG. 3 is a graph showing a relation between an average crushing strength and a ≤ 5 mm powder rate due to transportation of the iron ore pellets.

[DESCRIPTION OF EMBODIMENTS]

Description of Embodiments of Invention

[0013] As a result of intensive studies on the upper gas permeability resistance in the blast furnace, the present inventors have found that even when the proportion of iron ore pellets having small grain diameters, which leads to degradation of the pressure loss during the production of the pellets, is reduced, such pellets are broken during subsequent transportation and/or in a step of charging into the blast furnace to inevitably generate powder. Furthermore, they have found that a decrease in the powder generated from the iron ore pellets owing to transportation and/or an impact in the blast furnace leads to a reduction in the upper gas permeability resistance in the blast furnace. Moreover, the present inventors have found out that to decrease the powder, it is preferred to increase the average crushing strength to 270 kg/p.

[0014] However, with regard to iron ore pellets having a CaO/SiO_2 mass ratio of greater than or equal to 0.8 and a MgO/SiO_2 mass ratio of greater than or equal to 0.4 to have an increased reducibility required for iron ore pellets in the blast furnace operation, iron ore pellets having an average crushing strength of greater than or equal to 270 kg/p have not yet been obtained. It is considered that this is because coarse crystal grains of CaO , MgO , SiO_2 , and Fe_2O_3 compounds are generated during firing and cause a decrease in strength. In other words, when the crystal grains are large, it is likely that the orientations of sliding planes on which dislocations are likely to occur are aligned, and thus, dislocations are likely to occur with a low stress to cause breakage.

[0015] The present inventors have further studied and found that the firing temperature is high when the coarse crystal grains are generated. Crystals of a mineral texture are generated and expanded by diffusion. The diffusion coefficients of Fe , Ca , Si , Mg , Al , and the like in a solid phase and a liquid phase become larger as the temperature increases. That is to say, as the firing temperature increases, the crystal grains diffuse more and become larger, whereby coarse crystal grains are generated. Therefore, the present inventors have considered that a reduction in the firing temperature can inhibit the generation of the coarse crystal grains.

[0016] Meanwhile, when the firing temperature is low, there arises a problem in that the pellets fail to be sintered. That is to say, wider distances between ore particles, a decrease in the number of contacts between the particles, etc. weaken a force constituting the pellet strength; accordingly, the crushing strength tends to decrease. Therefore, even when the firing temperature is lowered to inhibit the generation of the coarse crystal grains, the crushing strength is not sufficiently improved.

[0017] At this point, the present inventors have focused on the fact that the porosity does not decrease when the pellets fail to be sintered owing to a low firing temperature. The decrease in porosity occurs when the ore particles come close to and are integrated with each other owing to a diffusion phenomenon such that the surface area of the iron ore particles is decreased to lower the surface energy thereof. Therefore, it is considered that in pellets having high porosity, the force constituting the pellet strength is weakened because, for example, the distance between the ore particles is still large and the number of contacts between the particles decreases. Thus, the present inventors have considered that if the porosity can be controlled independently from the firing temperature, the crushing strength can be sufficiently improved. Furthermore, they have found out that the crushing strength can be sufficiently improved by controlling the porosity at

a stage of green pellets, which has not been conventionally performed, and completed the present invention.

[0018] That is to say, an aspect of the present invention is a method for producing iron ore pellets for use in blast furnace operation, wherein the iron ore pellets are self-fluxing, the method including: raw material blending, wherein an auxiliary material containing CaO and MgO is blended into an iron ore material such that a CaO/SiO₂ mass ratio is greater than or equal to 0.8 and a MgO/SiO₂ mass ratio is greater than or equal to 0.4; pelletizing, wherein green pellets having a porosity of greater than or equal to 15% and less than or equal to 22% are made from a raw material mixture obtained in the raw material blending; and firing the green pellets at a temperature of greater than or equal to 1,200 °C and less than or equal to 1,300 °C.

[0019] Since being self-fluxing and having a CaO/SiO₂ mass ratio that is greater than or equal to the lower limit and a MgO/SiO₂ mass ratio that is greater than or equal to the lower limit, the iron ore pellets produced according to the method for producing iron ore pellets have high reducibility. Furthermore, since the green pellets are fired at a temperature within the above range in the firing after the porosity is set within the above range at the stage of green pellets, the crushing strength of the iron ore pellets produced can be sufficiently improved. Accordingly, by using the method for producing iron ore pellets, iron ore pellets which are superior in reducibility at high temperatures and enable a reduction in the upper gas permeability resistance in the blast furnace can be produced.

[0020] It is preferred that a rotary pelletizer is used in the pelletizing, and that the porosity is controlled by a raw material grain size in the raw material blending and balling time in the pelletizing. By thus controlling the porosity, the porosity can be easily controlled to be a desired value, and the crushing strength can be more surely improved.

[0021] A grain size range of the green pellets is preferably adjusted in the pelletizing such that a grain diameter after the firing is greater than or equal to 4 mm and less than or equal to 20 mm. By thus setting the grain diameter after the firing within the above range, a decrease in the upper gas permeability resistance in the blast furnace can be inhibited while maintaining the reducibility at high temperatures.

[0022] For the adjustment of the grain size range of the green pellets, classification by a sieve group including an oversize screen and a seed screen which are each adjusted to have a predetermined sieve mesh size is preferably used. By thus adjusting the grain size range of the green pellets by classification, the grain diameter after the firing can be easily and surely adjusted.

[0023] Another aspect of the present invention is iron ore pellets for use in blast furnace operation, the iron ore pellets being self-fluxing, wherein: a CaO/SiO₂ mass ratio is greater than or equal to 0.8, and a MgO/SiO₂ mass ratio is greater than or equal to 0.4; and an average crushing strength is greater than or equal to 270 kg/p.

[0024] Since being self-fluxing and having a CaO/SiO₂ mass ratio that is greater than or equal to the lower limit and a MgO/SiO₂ mass ratio that is greater than or equal to the lower limit, the iron ore pellets have high reducibility. Furthermore, since the iron ore pellets have an average crushing strength that is greater than or equal to the lower limit, powder generated from the iron ore pellets owing to transportation and/or an impact in the blast furnace can be decreased, and thus, the upper gas permeability resistance in the blast furnace can be reduced.

[0025] A proportion by mass of iron ore pellets having a crushing strength of less than or equal to 100 kg/p is preferably less than or equal to 10%. By thus setting the proportion by mass of the iron ore pellets having a crushing strength of less than or equal to 100 kg/p to be less than or equal to the upper limit, the powder generated from the iron ore pellets can be further decreased, and thus, the upper gas permeability resistance in the blast furnace can be further reduced.

[0026] As referred to herein, the "crushing strength" means a strength specified by JIS-M8718:2017, and the "average crushing strength" refers to an average value of crushing strengths of at least ten arbitrary iron ore pellets.

Details of Embodiments of Invention

[0027] Hereinafter, the method for producing iron ore pellets and the iron ore pellets according to the embodiments of the present invention will be described with reference to the drawings as appropriate.

Method for Producing Iron Ore Pellets

[0028] The method for producing iron ore pellets illustrated in FIG. 1 includes a raw material blending step S1, a pelletizing step S2, a firing step S3, and a cooling step S4. In the method for producing iron ore pellets, as illustrated in FIG. 2, self-fluxing iron ore pellets 1 for use in blast furnace operation can be produced using a production apparatus with a grate kiln system (hereinafter, may be simply referred to as "production apparatus 2"). The production apparatus 2 includes a pan pelletizer 3, a grate furnace 4, a kiln 5, and an annular cooler 6.

Raw Material Blending Step

[0029] In the raw material blending step S1, an auxiliary material containing CaO and MgO is blended into an iron ore material such that a CaO/SiO₂ mass ratio is greater than or equal to 0.8 and a MgO/SiO₂ mass ratio is greater than or equal

to 0.4.

[0030] Specifically, in the raw material blending step S1, limestone serving as a CaO source and dolomite serving as a MgO source are blended as the auxiliary material in accordance with the iron grade of iron ore (pellet feed) which is the iron ore material.

[0031] As needed, the iron ore material and the auxiliary material are preferably pulverized in a ball mill or the like in advance or after the blending to adjust the grain size of the raw material mixture in which the iron ore material and the auxiliary material are mixed. The present inventors have found that a porosity of green pellets P is proportional to a raw material grain size index. In other words, when the raw material grain size index is appropriately controlled, the porosity of the green pellets P is controlled, and the strength of the iron ore pellets 1 can be controlled by the porosity of the green pellets P.

[0032] As referred to herein, the "raw material grain size index" can be determined by the following method. First, a grain size distribution of the raw material mixture is measured. In the measurement, one of JIS-A-1204:2010, JIS-A-8815:1994, and JIS-Z-8825:2022 can be employed. Next, a sum $\sum 3/P_i \cdot m_i$ in a range from 3 μm to 1,000 μm is calculated using a proportion m_i by mass or volume in each grain size range P_i (representative value) and defined as the raw material grain size index.

[0033] The relation between the raw material grain size index and the porosity of the green pellets P holds in the case of a raw material mixture in which iron ore and an auxiliary material under the same brand are blended in the same proportion; however, for example, if the iron ore is under a different brand, the coefficient of proportionality may change owing to influences of the surface shape, wettability, and the like. Hence, a suitable value of the raw material grain size index can be determined by the following method. First, as raw material mixtures having a specific mixing ratio, raw material mixtures having at least two types of raw material grain size indices are prepared, green pellets P are produced, and the porosities thereof are measured. From the results, the relation between the raw material grain size index and the porosity can be calculated. As described later, a proportional relation also holds between the porosity and the strength of the iron ore pellets 1, and thus, a necessary porosity can be calculated from the strength required for the iron ore pellets 1. Consequently, a raw material grain size index at which the necessary porosity is obtained can be determined; therefore, the grain size of the raw material is adjusted such that this raw material grain size index can be obtained. It is to be noted that the adjustment of the grain size also includes purchasing a raw material having such a grain size.

[0034] Furthermore, a binder such as bentonite or the like may be appropriately blended into the raw material mixture to obtain the strength of the green pellets P required for transportation in the production process.

Pelletizing Step

[0035] In the pelletizing step S2, the green pellets P having a porosity of greater than or equal to 15% and less than or equal to 22% are made from the raw material mixture obtained in the raw material blending step S1. The green pellets P can be made using a rotary pelletizer. As the rotary pelletizer, the pan pelletizer 3 illustrated in FIG. 2, a drum pelletizer, or the like may be used.

[0036] Specifically, in the pelletizing step S2, moisture (water) is added to the raw material mixture, and then this water-containing mixture (the raw material mixture containing the water) is charged into the pan pelletizer 3 and rolled to produce the green pellets P having a ball shape.

[0037] In the method for producing iron ore pellets, the porosity of the green pellets P is controlled as described above. The lower limit of the porosity is 15% and more preferably 17%. On the other hand, the upper limit of the porosity is 22% and more preferably 20%. When the porosity is less than the lower limit, a phreatic explosion (bursting phenomenon) may occur in the firing step S3. Conversely, when the porosity is greater than the upper limit, the crushing strength of the iron ore pellets 1 may decrease.

[0038] The porosity is preferably controlled by the raw material grain size in the raw material blending step S1 and by the balling time in the pelletizing step S2. By thus controlling the porosity, the porosity can be easily controlled to be a desired value, and thus, the crushing strength can be more surely improved.

[0039] Furthermore, a grain size range of the green pellets P is preferably adjusted in the pelletizing step S2 such that a grain diameter after the firing step S3 is greater than or equal to 4 mm and less than or equal to 20 mm, more preferably greater than or equal to 6 mm and less than or equal to 15 mm. By thus setting the grain diameter after the firing step S3 within the above range, a decrease in the upper gas permeability resistance in the blast furnace can be inhibited while maintaining the reducibility at high temperatures.

[0040] For the adjustment of the grain size range of the green pellets P, classification by a sieve group including an oversize screen (upper limit sieve) and a seed screen (lower limit sieve) which are each adjusted to have a predetermined sieve mesh size. By thus adjusting the grain size range of the green pellets P by classification, the grain diameter after the firing step S3 can be easily and surely adjusted. It is to be noted that non-standard products removed by the classification are preferably disintegrated and reused as the raw material mixture.

Firing Step

[0041] In the firing step S3, the green pellets P are fired at a temperature of greater than or equal to 1,200 °C and less than or equal to 1,300 °C. In the production apparatus 2 illustrated in FIG. 2, the grate furnace 4 and the kiln 5 are used in the firing step S3.

Grate Furnace

[0042] As illustrated in FIG. 2, the grate furnace 4 includes a traveling grate 41, a drying chamber 42, a dehydrating chamber 43, and a preheating chamber 44.

[0043] The traveling grate 41 is configured to be endless and can transfer the green pellets P placed on the traveling grate 41 to the drying chamber 42, the dehydrating chamber 43, and the preheating chamber 44 in this order.

[0044] In the drying chamber 42, the dehydrating chamber 43, and the preheating chamber 44, the green pellets P are subjected to drying, dehydrating, and preheating by a heating gas G1, whereby strength sufficient to resist the rotation in the kiln 5 is imparted to the green pellets P to obtain preheated pellets H.

[0045] Specifically, the following procedure is followed. First, in the drying chamber 42, the green pellets P are dried at an ambient temperature of approximately 250 °C. Next, in the dehydrating chamber 43, the green pellets P after the drying are heated to approximately 450 °C to mainly decompose and remove water of crystallization in the iron ore. Furthermore, in the preheating chamber 44, the green pellets P are heated to approximately 1,100 °C, whereby carbonate contained in limestone, dolomite, and/or the like is decomposed to remove carbon dioxide, and magnetite in the iron ore is oxidized. Accordingly, the preheated pellets H are obtained.

[0046] As illustrated in FIG. 2, the heating gas G1 used in the dehydrating chamber 43 is reused as the heating gas G1 in the drying chamber 42. Similarly, the heating gas G1 in the preheating chamber 44 is reused as the heating gas G1 in the dehydrating chamber 43, and a combustion exhaust gas G2 used in the kiln 5 is reused as the heating gas G1 in the preheating chamber 44. By thus reusing the downstream heating gas G1 or combustion exhaust gas G2 which has a high temperature, heating cost of the heating gas G1 can be reduced. It is to be noted that a burner 45 may be provided in each chamber to control the temperature of the heating gas G1. In FIG. 2, the burners 45 are provided in the dehydrating chamber 43 and the preheating chamber 44. Furthermore, the heating gas G1 used in the drying chamber 42 is eventually discharged from a smokestack C.

Kiln

[0047] The kiln 5 is directly connected to the grate furnace 4 and is a rotary furnace having a sloped cylindrical shape. The kiln 5 fires the preheated pellets H discharged from the preheating chamber 44 of the grate furnace 4. Specifically, the preheated pellets H are fired by combustion with a kiln burner (not illustrated) provided on the outlet side. Accordingly, the iron ore pellets 1 having a high temperature are obtained.

[0048] The lower limit of a firing temperature at which the preheated pellets H are fired is 1,200 °C and more preferably 1,220 °C. On the other hand, the upper limit of the firing temperature is 1,300 °C and more preferably 1,280 °C. The present inventors have found that in the case in which the firing temperature falls within the above range, a proportional relation holds between the porosity of the green pellets P and the strength of the iron ore pellets 1. In other words, when the firing temperature is less than the lower limit, the pellets fail to be sintered, and furthermore, when the firing temperature is greater than the upper limit, coarse crystal grains are likely to be generated, resulting in a possibility that the crushing strength of the iron ore pellets 1 may decrease. Conversely, when a desired strength is determined, the porosity of the green pellets P can be determined from the proportional relation.

[0049] In the kiln 5, as air for combustion, an atmosphere serving as a cooling gas G3 used in the annular cooler 6 is used. Furthermore, the high-temperature combustion exhaust gas G2 used for firing the preheated pellets H is sent to the preheating chamber 44 as the heating gas G1.

Cooling Step

[0050] In the cooling step S4, the high-temperature iron ore pellets 1 obtained in the firing step S3 are cooled. In the cooling step S4, the annular cooler 6 is used. The iron ore pellets 1 cooled in the cooling step S4 are accumulated and used in the blast furnace operation.

[0051] In the annular cooler 6, the iron ore pellets 1 can be cooled by blowing the atmosphere serving as the cooling gas G3 by using a blowing apparatus 61, while transferring the high-temperature iron ore pellets 1 discharged from the kiln 5.

[0052] It is to be noted that the cooling gas G3 used in the annular cooler 6 and having an increased temperature is sent to the kiln 5 and used as the air for combustion.

Advantages

[0053] Since being self-fluxing and having a CaO/SiO_2 mass ratio of greater than or equal to 0.8 and a MgO/SiO_2 mass ratio of greater than or equal to 0.4, the iron ore pellets 1 produced according to the method for producing iron ore pellets have high reducibility. Furthermore, since the green pellets P are fired at a temperature of greater than or equal to 1,200 °C and less than or equal to 1,300 °C in the firing step S3 after the porosity at the stage of the green pellets P is set to greater than or equal to 15% and less than or equal to 22%, the crushing strength of the iron ore pellets 1 produced can be sufficiently improved. Accordingly, by using the method for producing iron ore pellets, the iron ore pellets 1 which are superior in reducibility at high temperatures and enable a reduction in the upper gas permeability resistance in the blast furnace can be produced.

Iron Ore Pellets

[0054] The iron ore pellets 1 according to another aspect of the present invention are self-fluxing iron ore pellets used in the blast furnace operation. The iron ore pellets 1 are obtained by pelletizing and firing finely pulverized ore to form agglomerated ore having high strength, and can be produced, for example, by the above-described method for producing iron ore pellets.

[0055] Regarding the production of the iron ore pellets 1, it is known that adding a CaO-containing compound such as limestone or the like to an iron ore material to increase the CaO/SiO_2 mass ratio in the iron ore pellets 1 improves the reducibility of the iron ore pellets 1. On the basis of this finding, the CaO/SiO_2 mass ratio in the iron ore pellets 1 is set to greater than or equal to 0.8.

[0056] In a case in which the raw materials are iron ore (iron oxide) and limestone (CaO-containing compound), calcium ferrite compounds are generated in the firing step by a solid phase reaction between the iron oxide and CaO generated by thermal decomposition, and are simultaneously bound at the interfaces thereof through solid phase diffusion bonding. Since this bonding is local, fine pores which were present prior to the firing are retained even after the firing, whereby the iron ore pellets 1 are porous bodies in which fine pores are present relatively uniformly.

[0057] During the blast furnace operation, a reducing gas diffusively enters the fine pores, whereby a reduction reaction proceeds from an outer surface to an inner portion of the iron ore pellets 1. Due to removal of oxygen from the iron oxide by the reduction reaction, the existing fine pores are enlarged and new fine pores are generated, while metallic iron is generated. In a process in which aggregation of the metallic iron causes shrinkage of an external shape of the iron ore pellets 1, the fine pores start to decrease. As a result, diffusion of the reducing gas into the iron ore pellets 1 is inhibited, whereby the reduction is likely to stagnate.

[0058] To inhibit this stagnation of the reduction, addition of a high-melting point component which inhibits a loss of the fine pores during the aggregation process of the metallic iron is effective. Particularly, it is known that adding dolomite as a source of MgO, which is a high-melting point component, to increase the MgO/SiO_2 mass ratio in the iron ore pellets 1 enables obtaining a powerful effect of inhibiting the stagnation of the reduction. On the basis of this finding, the MgO/SiO_2 mass ratio in the iron ore pellets 1 is set to greater than or equal to 0.4.

[0059] The iron ore pellets 1 are self-fluxing. Due to the iron ore pellets 1 being self-fluxing, melting down of reduced iron is easily accelerated. It is to be noted that the self-fluxing property of the iron ore pellets 1 is determined by an auxiliary material and/or the like.

[0060] The lower limit of an average crushing strength of the iron ore pellets 1 is 270 kg/p and more preferably 300 kg/p. As described above, as a result of intensive studies of the present inventors based on the finding that a decrease in the powder generated from the iron ore pellets 1 owing to transportation and/or an impact in the blast furnace leads to a reduction in the upper gas permeability resistance in the blast furnace, it has been concluded that the amount of the powder can be controlled by the average crushing strength. FIG. 3 shows a relation between the average crushing strength and a mass fraction of powder having a grain diameter of less than or equal to 5 mm (≤ 5 mm powder rate) generated owing to transportation of the iron ore pellets 1. These results are based on the results of an experiment conducted along a transportation path. FIG. 3 also includes a sample having a CaO/SiO_2 mass ratio of less than 0.8 and a sample having a MgO/SiO_2 mass ratio of less than 0.4; however, it can be seen that regardless of these characteristics, the ≤ 5 mm powder rate of the iron ore pellets 1 having an average crushing strength that is greater than or equal to the lower limit is stably low. It is to be noted that in the present invention, the upper limit of the average crushing strength of the iron ore pellets 1 is not particularly limited and is realistically, for example, 500 kg/p.

[0061] In the iron ore pellets 1, a proportion by mass of iron ore pellets having a crushing strength of less than or equal to 100 kg/p is preferably less than or equal to 10%, more preferably less than or equal to 5%, and still more preferably less than or equal to 1%. Even in a case in which the average crushing strength of the iron ore pellets 1 is high, it is considered that a large variation in strength between pellets leads to an increase in the absolute amount of the iron ore pellets 1 to be pulverized. In this regard, by setting the proportion by mass of the iron ore pellets having a crushing strength of less than or equal to 100 kg/p to be less than or equal to the upper limit, the powder generated from the iron ore pellets 1 can be further

decreased, and thus, the upper gas permeability resistance in the blast furnace can be further reduced.

Advantages

[0062] Since being self-fluxing and having a CaO/SiO₂ mass ratio of greater than or equal to 0.8 and a MgO/SiO₂ mass ratio of greater than or equal to 0.4, the iron ore pellets 1 have high reducibility. Furthermore, since the iron ore pellets 1 have an average crushing strength of greater than or equal to 270 kg/p, powder generated from the iron ore pellets 1 owing to transportation and/or an impact in the blast furnace can be decreased, and thus, the upper gas permeability resistance in the blast furnace can be reduced.

Other Embodiments

[0063] It is to be noted that the present invention is not limited to the above embodiments.

[0064] In the above embodiments, the method for producing iron ore pellets by using the production apparatus with the grate kiln system has been described; however, a production apparatus with a straight grate system may also be used in the production. In the production apparatus with the straight grate system, the grate furnace includes a traveling grate, a drying chamber, a dehydrating chamber, a preheating chamber, and a firing chamber, and the firing step is completed only in the grate furnace. Specifically, the green pellets are dried, dehydrated, and preheated by a heating gas in the drying chamber, the dehydrating chamber, and the preheating chamber, and finally fired in the firing chamber.

EXAMPLES

[0065] Hereinafter, the present invention will be described more in detail by way of Examples; however, the present invention is not limited to these Examples.

No. 1

[0066] Iron ore was prepared as an iron ore material, and limestone, dolomite, and bentonite were prepared as an auxiliary material. The auxiliary material was blended into the iron ore material such that the CaO/SiO₂ mass ratio was 1.2 and the MgO/SiO₂ mass ratio was 0.4 to obtain a raw material mixture.

[0067] Green pellets were made from the raw material mixture by using a disc pelletizer and fired at 1,260 °C by using a firing apparatus constituted by a stationary grate furnace and a kiln furnace to obtain iron ore pellets No. 1. With regard to the iron ore pellets No. 1, the raw material grain size index, the porosity of the green pellets, and the average crushing strength of the iron ore pellets are shown in Table 1.

No. 2

[0068] Iron ore pellets No. 2 were obtained in the same manner as No. 1, except that the raw material mixture was pulverized in a ball mill for 30 min. With regard to the iron ore pellets No. 2, the raw material grain size index, the porosity of the green pellets, and the average crushing strength of the iron ore pellets are shown in Table 1.

No. 3 to No. 5

[0069] Iron ore pellets No. 3 to No. 5 were obtained in the same manner as No. 1, except that their raw material grain size indices were set to 1.8 times, 2.0 times, and 2.2 times, respectively, of the raw material grain size index of No. 1 as a reference such that their average crushing strengths were greater than or equal to 270 kg/p relative to the raw material grain size indices of No. 1 and No. 2 and the iron ore pellets obtained. With regard to the iron ore pellets No. 3 to No. 5, the raw material grain size index, the porosity of the green pellets, and the average crushing strength of the iron ore pellets are shown in Table 1.

Table 1

	Raw material grain size index (relative value)	Porosity (%)	Average crushing strength (kg/p)
No. 1	1.0	27.5	210
No. 2	1.5	25.0	230
No. 3	1.8	24.0	270
No. 4	2.0	22.0	272

(continued)

	Raw material grain size index (relative value)	Porosity (%)	Average crushing strength (kg/p)
No. 5	2.2	21.0	272

[0070] The results in Table 1 indicate that even in the case of the iron ore pellets having a CaO/SiO₂ mass ratio of greater than or equal to 0.8 and a MgO/SiO₂ mass ratio of greater than or equal to 0.4, by setting the porosity of the green pellets to greater than or equal to 15% and less than or equal to 22% and firing them at a temperature of greater than or equal to 1,200 °C and less than or equal to 1,300 °C, iron ore pellets having an average crushing strength of greater than or equal to 270 kg/p can be obtained.

[INDUSTRIAL APPLICABILITY]

[0071] According to the method for producing iron ore pellets of the present invention, iron ore pellets which are superior in reducibility at high temperatures and enable a reduction in the upper gas permeability resistance in the blast furnace can be produced. Furthermore, the iron ore pellets of the present invention are superior in reducibility at high temperatures and enable a reduction in the upper gas permeability resistance in the blast furnace.

[EXPLANATION OF THE REFERENCE SYMBOLS]

[0072]

- 1 Iron ore pellets
- 2 Production apparatus
- 3 Pan pelletizer
- 4 Grate furnace
- 41 Traveling grate
- 42 Drying chamber
- 43 Dehydrating chamber
- 44 Preheating chamber
- 45 Burner
- 5 Kiln
- 6 Annular cooler
- 61 Blowing apparatus
- P Green pellets
- H Preheated pellets
- G1 Heating gas
- G2 Combustion exhaust gas
- G3 Cooling gas
- C Smokestack

Claims

1. A method for producing iron ore pellets for use in blast furnace operation, wherein the iron ore pellets are self-fluxing, the method comprising:

raw material blending, wherein an auxiliary material comprising CaO and MgO is blended into an iron ore material such that a CaO/SiO₂ mass ratio is greater than or equal to 0.8 and a MgO/SiO₂ mass ratio is greater than or equal to 0.4;

pelletizing, wherein green pellets having a porosity of greater than or equal to 15% and less than or equal to 22% are made from a raw material mixture obtained in the raw material blending; and
firing the green pellets at a temperature of greater than or equal to 1,200 °C and less than or equal to 1,300 °C.

2. The method for producing iron ore pellets according to claim 1, wherein:

a rotary pelletizer is used in the pelletizing, and

EP 4 570 930 A1

the porosity is controlled by a raw material grain size in the raw material blending and by balling time in the pelletizing.

5 3. The method for producing iron ore pellets according to claim 1 or 2, wherein a grain size range of the green pellets is adjusted in the pelletizing such that a grain diameter after the firing is greater than or equal to 4 mm and less than or equal to 20 mm.

10 4. The method for producing iron ore pellets according to claim 3, wherein for the adjustment of the grain size range of the green pellets, classification by a sieve group comprising an oversize screen and a seed screen which are each adjusted to have a predetermined sieve mesh size is used.

5. Iron ore pellets for use in blast furnace operation, the iron ore pellets being self-fluxing, wherein:

15 a CaO/SiO_2 mass ratio is greater than or equal to 0.8, and a MgO/SiO_2 mass ratio is greater than or equal to 0.4; and
an average crushing strength is greater than or equal to 270 kg/p.

20 6. The iron ore pellets according to claim 5, wherein a proportion by mass of iron ore pellets having a crushing strength of less than or equal to 100 kg/p is less than or equal to 10%.

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FIG. 1

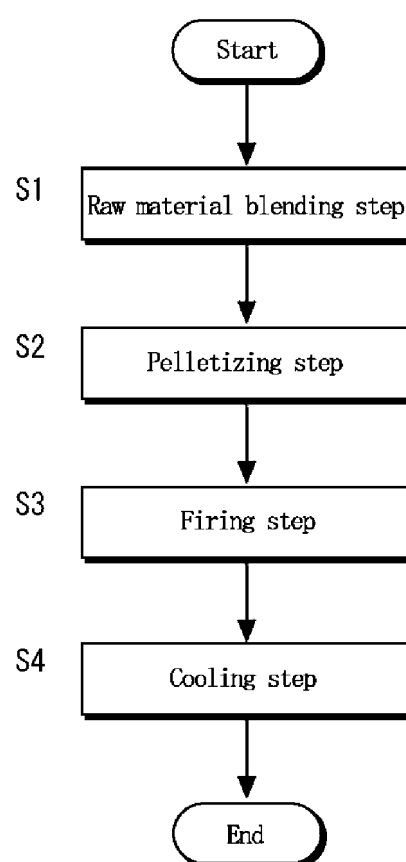


FIG. 2

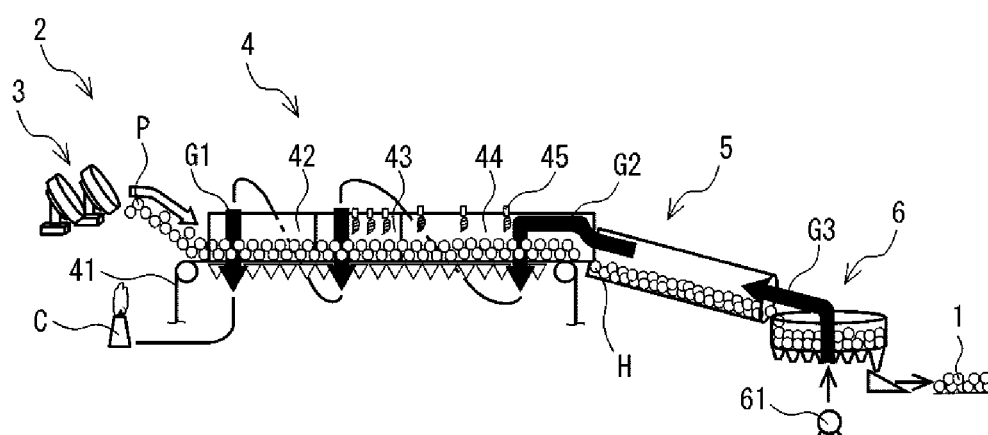
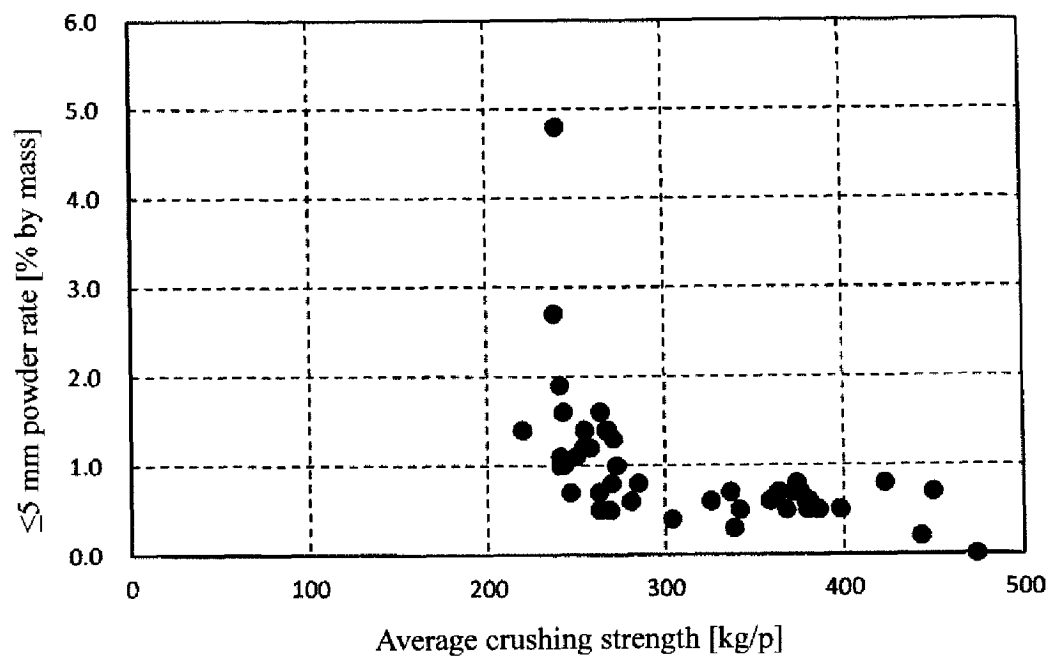


FIG. 3



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/038913

A. CLASSIFICATION OF SUBJECT MATTER

C22B 1/16(2006.01)i; **C21B 5/00**(2006.01)i; **C22B 1/14**(2006.01)i
FI: C22B1/16 K; C21B5/00 301; C22B1/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22B1/16; C21B5/00; C22B1/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 63-219534 A (KABUSHIKI KAISHA KOBE SEIKO SHO) 13 September 1988 (1988-09-13) claims, p. 2, lower right column, line 8 to p. 4, upper right column, line 18, fig. 1, 4	1-6
X	JP 2012-126947 A (NIPPON STEEL CORP.) 05 July 2012 (2012-07-05) paragraphs [0028]-[0088]	1-6

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

13 December 2022

Date of mailing of the international search report

27 December 2022

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)
3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915
Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/JP2022/038913

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP	63-219534	A	13 September 1988	(Family: none)	
JP	2012-126947	A	05 July 2012	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2008280556 A [0004] [0006]