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(54) RAW MATERIAL PARTICLES FOR PRODUCTION OF AGGLOMERATE, METHOD FOR PRODUCING RAW MATERIAL PARTICLES FOR PRODUCTION OF AGGLOMERATE, AGGLOMERATE, METHOD FOR PRODUCING AGGLOMERATE, AND METHOD FOR PRODUCING REDUCED IRON

(57) Provided is a raw material particle for production of agglomerate that can be used to produce an agglomerate with better reducing performance than conventional agglomerates. The raw material particle 1(2) of the present disclosure is a raw material particle for producing an agglomerate as a raw material for producing reduced iron, including a central part 11(21), and a peripheral part 12(22) that covers the periphery of the central part 11(21). The central part 11 has a metal iron-containing substance, the central part 12 has a volatile substance, and the peripheral part 12(22) has iron oxide.

FIG. 2A

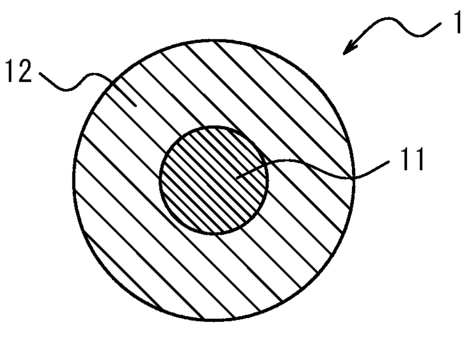
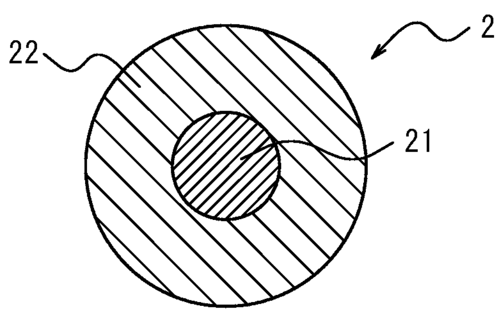


FIG. 2B



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Description

TECHNICAL FIELD

[0001] This disclosure relates to a raw material particle for production of agglomerate, a method for producing a raw material particle for production of agglomerate, an agglomerate, a method for producing an agglomerate, and a method for producing reduced iron.

BACKGROUND

[0002] In iron and steel industry, a blast furnace method has been the mainstream of pig iron production processes for many years. In the blast furnace method, coke and a raw material containing iron oxide such as sintered ore are charged into a blast furnace from the top of the furnace, and hot blast is blown into the blast furnace from a tuyere at the bottom of the blast furnace. This causes the hot blast blown in to react with the coke in the blast furnace to form high-temperature reducing gases (mainly carbon monoxide (CO) gas), which heats and reduces the raw material. The raw material then melts, and it is further reduced by the coke as it drips inside the blast furnace and is finally stored in the furnace hearth as hot metal (pig iron). The stored hot metal is taken out from a taphole and used in subsequent steelmaking processes. As described above, the blast furnace method uses a carbon material such as coke as a reducing agent to indirectly reduce the iron oxide contained in a raw material.

[0003] In recent years, however, there have been calls for prevention of global warming, and there is a strong need to reduce emissions of carbon dioxide (CO_2), which is one of the greenhouse gases. As described above, the blast furnace method uses a carbon material as a reducing agent, which causes the formation of a large amount of CO_2. Therefore, various blast furnace operation methods have been proposed to reduce the reducing agent rate (the amount of reducing agent used per ton of hot metal) (see, for example, JP 2020-45508 A (PTL 1)).

[0004] On the other hand, there are known methods of directly reducing the iron oxide contained in a raw material, such as a method of producing reduced iron by charging agglomerates such as baked pellets and sintered bodies of iron ore powder, which are raw materials for reduced iron, from the top of a reducing furnace such as a shaft furnace while introducing gases (CO gas or H_2 gas) as reducing agents from the bottom of the reducing furnace (for example, JP H02-46644 B (PTL 2)), and MIDREX® (MIDREX is a registered trademark in Japan, other countries, or both) (ATSUSHI, UEMURA, SAKAGUCHI: "MIDREX® Process" KOBE STEEL ENGINEERING REPORTS/Vol. 60 No. 1 (2010) (NPL 1)). In this method, if only H_2 gas is used as a reducing gas, it is theoretically possible to produce reduced iron without CO_2 emissions.

CITATION LIST

Patent Literature

[0005]

PTL 1: JP 2020-45508 A
PTL 2: JP H02-46644 B

Non-patent Literature

[0006] NPL 1: ATSUSHI, UEMURA, SAKAGUCHI: "MIDREX® Process" KOBE STEEL ENGINEERING REPORTS/Vol. 60 No. 1 (2010)

SUMMARY

(Technical Problem)

[0007] In the method described in PTL 2 or NPL 1, it is sufficient to suppress the reduction reaction by CO gas and accelerate the reduction reaction by H_2 gas to suppress CO_2 emissions, and the concentration of Hz in the reducing gas used should be increased for this purpose.

[0008] However, the reduction reaction by CO gas is an exothermic reaction (+6710 kcal/kmol (Fe_2O_3)), whereas the reduction reaction by H_2 gas is an endothermic reaction (-22800 kcal/kmol (Fe_2O_3)). Therefore, increasing the concentration of Hz in the reducing gas causes an endothermic reaction, which lowers the temperature inside the furnace, stagnates the reduction reaction, and deteriorates the reducing performance.

[0009] To solve the aforementioned problem of deteriorated reducing performance, there is a need for an agglomerate with good reducing performance, as well as raw material particles that can be used to produce such an agglomerate.
[0010] It could thus be helpful to provide a raw material particle for production of agglomerate that can be used to produce an agglomerate with better reducing performance than conventional agglomerates.

(Solution to Problem)

[0011] We thus provide the following.

[1] A raw material particle for production of agglomerate, which is a raw material particle for producing an agglomerate as a raw material for producing reduced iron, comprising

a central part, and a peripheral part that covers a periphery of the central part, wherein
the central part has a metal iron-containing substance or a volatile substance, and the peripheral part has iron oxide.

[2] The raw material particle for production of agglomerate according to aspect [1], wherein the iron oxide contains at least either or both of more than 4 mass% of combined water and more than 1.5 mass% of alumina.
[3] The raw material particle for production of agglomerate according to aspect [1] or [2], wherein the central part has a particle size of 2 mm or more and 6 mm or less.
[4] The raw material particle for production of agglomerate according to any one of aspects [1] to [3], wherein the peripheral part has a thickness of 2 mm or more and 5 mm or less.
[5] A method for producing a raw material particle for production of agglomerate, which is a method for producing the raw material particle as recited in any one of aspects [1] to [4], comprising

a pretreatment process of grinding a raw material containing the iron oxide into raw material powder, and then classifying the raw material powder to adjust a particle size of the raw material powder, and
a process of mixing and granulating the raw material powder whose particle size has been adjusted, the metal iron-containing substance or the volatile substance, and a binder to obtain the raw material particle.

[6] The method for producing a raw material particle for production of agglomerate according to aspect [5], wherein the metal iron-containing substance or the volatile substance with a particle size of 2 mm or more and 6 mm or less is used in the granulation process.
[7] The method for producing a raw material particle for production of agglomerate according to aspect [5] or [6], wherein a thickness of the peripheral part is adjusted to 2 mm or more and 5 mm or less in the granulation process.
[8] An agglomerate obtained by baking or sintering and agglomerating the raw material particle as recited in any one of aspects [1] to [4], wherein

for the agglomerated raw material particle,
when the central part before baking or sintering has the metal iron-containing substance, the agglomerated raw material particle has a three-layer structure, where the central part has a first portion having the metal iron-containing substance and a second portion that covers a periphery of the first portion, and metal iron contained in the metal iron-containing substance is oxidized in the second portion, and
when the central part before baking or sintering has the volatile substance, the agglomerated raw material particle has a hollow structure where the central part is a void.

[9] A method for producing an agglomerate, comprising baking or sintering and agglomerating the raw material particle as recited in any one of aspects [1] to [4] or a raw material particle obtainable by the production method as recited in any one of aspects [5] to [7] in an oxidizing atmosphere of 1200 °C or higher and 1350 °C or lower to obtain an agglomerate.
[10] A method for producing reduced iron, comprising charging the agglomerate as recited in aspect [8] or an agglomerate obtainable by the production method as recited in aspect [9] into a reducing furnace while introducing a reducing gas into the reducing furnace, and reducing iron oxide contained in the agglomerate by the reducing gas to obtain reduced iron.
[11] The method for producing reduced iron according to aspect [10], wherein a gas containing hydrogen as a main component is used as the reducing gas.

(Advantageous Effect)

[0012] According to the present disclosure, it is possible to provide a raw material particle for production of agglomerate that can be used to produce an agglomerate with better reducing performance than conventional agglomerates.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] In the accompanying drawings:

FIG. 1 illustrates an example of a particle of a conventional agglomerate;
FIGS. 2A and 2B illustrate raw material particles for production of agglomerate of the present disclosure, where FIG. 2A is a particle having a metal iron-containing substance in the central part, and FIG. 2B is a particle having a volatile substance in the central part; and
FIGS. 3A and 3B illustrate particles of an agglomerate of the present disclosure, where FIG. 3A is a particle having a three-layer structure, and FIG. 3B is a particle having a hollow structure.

DETAILED DESCRIPTION

(Raw material particle for production of agglomerate)

[0014] The following describes embodiments of the present disclosure with reference to the drawings. The raw material particle for production of agglomerate of the present disclosure is a raw material particle for producing an agglomerate that is a raw material for producing reduced iron, including a central part and a peripheral part that covers the periphery of the central part, where the central part has a metal iron-containing substance or a volatile substance, and the peripheral part has iron oxide.
[0015] We have diligently studied raw material particles for production of agglomerate that can be used to produce an agglomerate as a raw material for producing reduced iron with better reducing performance than conventional agglomerates. FIG. 1 illustrates an example of a particle of a conventional agglomerate. The particle 100 illustrated in FIG. 1 has a central part 110 and a peripheral part 120 that covers the periphery of the central part 110. In the particle 100, the central part 110 is composed of coarse-grained iron oxide, and the peripheral part 120 is composed of fine iron ore powder (that is, iron oxide).
[0016] We have studied methods to improve the reducing performance of an agglomerate. As a result, we have come up with the idea of having the central part of a particle of the agglomerate be composed of a substance that requires little or no reduction.
[0017] That is, the whole particle 100 is composed of iron oxide, and a reducing gas needs to pass through the peripheral part 120 to reach the central part 110 to reduce the iron oxide in the central part 110, and a gas formed by the reaction needs to be exhausted from the surface of the particle 100. Therefore, it takes more time to reduce the iron oxide in the central part 110 of the particle 100 than it does to reduce the iron oxide in the peripheral part 120. This leads to the deterioration of the reducing performance of the whole particle.
[0018] Therefore, we thought that when the central part 110, which requires much time for reduction, in the conventional particle 100 is composed of a metal iron-containing substance with a high content of metal iron, or a substance that requires little or no reduction such as a void, it is possible to reduce the time required for the reduction of the whole particle and improve the reducing performance.
[0019] We found that when an agglomerate as described above is produced using raw material particles in which the central part is composed of the aforementioned metal iron-containing substance or a volatile substance that loses a large proportion at high temperatures and the peripheral part is composed of iron ore powder, the particles of the agglomerate obtained after an agglomeration process (baking process or sintering process) can be made into a state in which the central part requires little or no reduction as described above, thereby completing the present disclosure. The following describes each part of the present disclosure.
[0020] The raw material particle for production of agglomerate in the present embodiment is a raw material particle for producing an agglomerate that is a raw material for producing reduced iron with a reducing gas, and the raw material particle is generally called a green pellet. FIGS. 2A and 2B illustrate the raw material particles for production of agglomerate of the present disclosure. The raw material particle 1 illustrated in FIG. 2A includes a central part 11 having a metal iron-containing substance and a peripheral part 12 having iron oxide. The raw material particle 2 illustrated in FIG. 2B includes a central part 21 having a volatile substance and a peripheral part 22 having iron oxide.

<Central part>

[0021] The central part 11(21) is a part that constitutes the nucleus of the raw material particle 1(2), and in the present disclosure, it contains a substance that requires no reduction or a substance that requires little reduction with a reducing gas. Specifically, the central part 11(21) contains a metal iron-containing substance (volatile substance).

-Metal iron-containing substance-

[0022] In the present disclosure, the metal iron-containing substance is a substance with a high content of metal iron, and specifically, it is a substance with a metal iron concentration of 70 mass% or more. Examples of such a metal iron-containing substance include defective reduction products produced during the production of reduced iron, sieved products of reduced pellets (pellet chips), and various scraps of cast iron and the like, and it may be a substance with a metal iron concentration of 70 mass% or more. The metal iron-containing substance is more preferably a substance with a metal iron concentration of 90 mass% or more.

-Volatile substance-

[0023] On the other hand, the volatile substance is a substance that volatilizes in an agglomeration process (baking process or sintering process), and specifically, it is a substance with a mass reduction rate of 90 % or more at 1000 °C. Used paper or an organic material may be used as the volatile substance, for example. Specific examples thereof include polypropylene-based pellets, woody biomass-based pellets, used paper, and pellets made from paper pulp waste.

[0024] The following describes a preferred raw material particle configuration in a case where the size of a whole particle of an agglomerate, which is a raw material for production of reduced iron, is 6 mm to 16 mm when it is used as a green pellet. The particle size of the central part 11 is preferably 2 mm or more and 6 mm or less. When the particle size of the central part 11 is 2 mm or more, not all of the central part 11 is oxidized and the metal iron-containing substance remains even when the raw material particle 1 is baked or sintered in an agglomeration process, which can improve the reducing performance of the agglomerate. When the particle size of the central part 11 is 6 mm or less, the thickness of a coating layer can be sufficiently secured in a case where the particle size of the raw material particle 1(2) is 6 mm to 16 mm, so that the amount of new raw material for reduced iron can be increased.

<Peripheral part>

[0025] The peripheral part 12(22) constitutes a coating layer that covers the periphery of the central part 11(21), which is the nucleus, of the raw material particle 1(2). In the present disclosure, the peripheral part 12(22) may contain iron oxide.

[0026] The source of iron of the peripheral part 12(22) preferably includes an iron oxide powder, which is powdery iron oxide. This allows a reducing gas to circulate through the gaps between the iron oxide powders during the reduction of an agglomerate, thereby reducing the iron oxide efficiently. The composition of the peripheral part 12(22) may also contain secondary materials such as CaO and MgO.

[0027] When the peripheral part 12(22) contains iron oxide powder, the particle size is preferably 125 μm or less. When the particle size of the iron oxide powder is 125 μm or less, it is possible to granulate and produce a dense raw material particle 1(2) with a low void ratio between powders without deteriorating the strength of the raw material particle 1(2), where a high void ratio may cause collapse during transport. The particle size of the iron oxide powder is more preferably 63 μm or less and still more preferably 45 μm or less.

[0028] The thickness of the peripheral part 12 is preferably 2 mm or more and 5 mm or less. When the thickness of the peripheral part 12 is 2 mm or more, it is possible to prevent the layers forming the peripheral part 12 from breaking or collapsing during a baking process. When the thickness of the peripheral part 12 is 5 mm or less, it is possible to control the particle size of the raw material particle 1(2) in a range of 6 mm to 16 mm, thereby ensuring the reaction time in a reducing furnace.

[0029] The iron oxide in the peripheral part 12(22) may contain a relatively low-quality raw material. Specifically, the iron oxide may contain at least more than 4 mass% of combined water and/or more than 1.5 mass% of alumina. A high-quality material with a high content of iron oxide has been conventionally used as a raw material in a process of producing reduced iron using a reducing furnace. In recent years, however, the quality of iron ore powder for producing an agglomerate that is a raw material for reduced iron is decreasing due to the depletion of high-quality iron ore. Low-grade iron ore contains a large amount of combined water and gangue (alumina (Al_2O_3) and silica (SiO_2)), where the combined water deteriorates the strength of an agglomerate and causes explosions during a baking process, and the gangue melts during a baking process and deteriorates the strength of an agglomerate.

[0030] To compensate the deterioration of strength, it is effective to reduce the content of combined water contained in the iron ore in a drying process and to increase the amount of heat for baking. However, an agglomerate thus obtained has a dense structure, which deteriorates the reducing performance of the agglomerate. If the reducing performance of the agglomerate is deteriorated, it will take more time to reduce the agglomerate in a reduced iron production process than otherwise, which decreases the efficiency of reduced iron production. Therefore, there is a trade-off relationship between the strength and the reducing performance of an agglomerate.

[0031] One way to achieve both good strength and good reducing performance in an agglomerate is, for example, to make the size of a raw material particle smaller than a conventional one. In this case, however, it is necessary to strictly control the granulation size when granulating a raw material particle prior to baking or sintering in a granulation process, which is difficult to operate in a conventional granulator. Further, fine pellets may inhibit the gas permeability when they are charged into a reducing furnace, which is not desirable in terms of operation.

[0032] In the raw material particle 1(2) of the present disclosure, the central part 11(21) contains a metal iron-containing substance (volatile substance), which is a substance that requires little or no reduction. Therefore, even when the low-grade iron ore, specifically the iron oxide of the peripheral part, contains at least more than 4 mass% of combined water and/or more than 1.5 mass% of alumina, it can compensate for the deterioration of reducing performance caused by the production of a dense agglomerate. Thus, with the raw material particle 1(2) of the present disclosure, it is possible to produce an agglomerate that has both good strength and good reducing performance. For example, iron ore from Australia or iron ore from India with a relatively high content of impurities may be used as the iron oxide.

[0033] The particle size of the raw material particle 1(2) is preferably 6 mm or more and 16 mm or less. When the particle size of the raw material particle 1(2) is 6 mm or more, the furnace can be operated while ensuring the gas permeability inside the furnace when reducing the iron oxide contained in an agglomerate obtained by agglomerating the raw material particles 1(2). When the particle size of the raw material particle 1(2) is 16 mm or less, the delay of reduction inside the raw material particle 1(2) can be minimized to produce an agglomerate with a high degree of reduction. The particle size of the raw material particle 1(2) is preferably 9 mm or more and 16 mm or less.

[0034] The proportion of the central part 11 in the whole raw material particle 1 is preferably 5 mass% or more and 50 mass% or less. When the proportion of the central part 11 is 5 mass% or more, it is possible to obtain an agglomerate with good reducing performance. When the proportion of the central part 11 is 50 mass% or less, the amount of new raw material for reduced iron can be increased while securing the thickness of the peripheral part 12 which is a coating layer. The proportion of the central part 11 is more preferably 10 mass% or more and 20 mass% or less.

(Method for producing raw material particle for production of agglomerate)

[0035] The method for producing a raw material particle for production of agglomerate of the present disclosure is a method for producing the raw material particle of the present disclosure described above, including a pretreatment process of grinding a raw material containing iron oxide into raw material powder, and then classifying the raw material powder to adjust the particle size of the raw material powder, and a process of mixing and granulating the raw material powder whose particle size has been adjusted, a metal iron-containing substance or a volatile substance, and a binder to obtain the raw material particle of the present disclosure.

[0036] As described above, the raw material particle for production of agglomerate of the present disclosure can be used to produce an agglomerate with better reducing performance than conventional agglomerates because the central part contains a substance that requires no reduction or a substance that requires little reduction. The raw material particle of the present disclosure can be produced with a known green pellet production method. The following describes each process.

[0037] First, in the pretreatment process, a pretreatment necessary for the subsequent granulation process is performed. Specifically, a raw material is ground, and the obtained raw material powder is classified to adjust the particle size, where the raw material is a material having iron oxide containing 4 mass% or less of combined water and/or 1.5 mass% or less of alumina such as high-quality iron ore, or a material having iron oxide containing more than 4 mass% of combined water or more than 1.5 mass% of alumina such as low-quality iron ore. The grinding of the iron ore raw material may be performed using a ball mill or other means. The classifying may be performed using a rotating rotor or a sieve or other means.

[0038] Next, in the granulation process, the raw material powder whose particle size has been adjusted in the pretreatment process, a metal iron-containing substance or a volatile substance, and a binder such as quicklime or bentonite are mixed and granulated. They are also component regulators of CaO and MgO. The process can be performed using a pelletizer, such as a disk pelletizer, or a drum mixer, or other means. In this way, the raw material particle for production of agglomerate can be produced.

[0039] As described above, it is preferable to use a metal iron-containing substance or a volatile substance with a particle size of 2 mm or more and 6 mm or less in the granulation process. As described above, it is preferable to adjust the thickness of the peripheral part to 2 mm or more and 5 mm or less in the granulation process.

(Agglomerate)

[0040] The agglomerate of the present disclosure is an agglomerate obtained by baking or sintering and agglomerating the raw material particle for production of agglomerate of the present disclosure described above, where when the central part of the agglomerated raw material particle has a metal iron-containing substance before baking or sintering, the agglomerated raw material particle has a three-layer structure, where the central part has a first portion having a metal iron-containing substance and a second portion that covers the periphery of the first portion, and the metal iron contained in the metal iron-containing substance is oxidized in the second portion, and when the central part of the agglomerated raw material particle has a volatile substance before baking or sintering, the agglomerated raw material particle has a hollow structure where the central part is a void.

[0041] As described above, in the raw material particle for production of agglomerate of the present disclosure, the central part has a metal iron-containing substance or a volatile substance. When the central part 11 of the raw material particle 1 has a metal iron-containing substance, if the raw material particle 1 is baked or sintered, the heat during the baking or sintering process oxidizes the metal iron in a portion of the central part 11 adjacent to the peripheral part 12, and the interior of the central part 11 remains unoxidized and remains as a metal iron-containing substance. As a result, as illustrated in FIG. 3A, the particle 3 of the agglomerate has a three-layer structure, including a first portion 31a having a metal iron-containing substance, a second portion 31b with oxidized metal iron that covers the periphery of the first portion 31a, and a peripheral part 32 having iron oxide.

[0042] On the other hand, when the central part 21 of the raw material particle 2 has a volatile substance, if the raw material particle 2 is baked or sintered, the heat during the baking or sintering process causes the volatile substance in the central part 21 to volatilize. As a result, as illustrated in FIG. 3B, the particle 4 of the agglomerate has a hollow structure where the central part 41 is a void and the peripheral part 42 has iron oxide.

[0043] In the particles 3 and 4 illustrated in FIGS. 3A and 3B, the central parts 31a and 41 are in a state that requires no reduction. Therefore, the agglomerate of the present disclosure, which contains the particles 3 or 4, has better reducing performance than conventional agglomerates.

[0044] For the particle 3, the layer (second portion) 31b formed by oxidation of the metal iron-containing substance of the central part 11 of the raw material particle 1 forms a shell, and therefore the particle has a stabler structure than otherwise. For the particle 4, although a shell like the layer (second portion) 31b of the particle 3 is not formed, it has a dense baking layer formed in the inner wall structure of the hollow portion 41 because of the heat formed by the combustion of the volatile substance of the central part 21 of the raw material particle 2. As a result, the particle 4 has a higher strength than one with a hollow structure from the start, taking advantage of the heat from the inside.

(Method for producing agglomerate)

[0045] The method for producing an agglomerate of the present disclosure includes baking or sintering and agglomerating the raw material particle of the present disclosure or a raw material particle obtainable by the method for producing a raw material particle of the present disclosure described above in an oxidizing atmosphere of 1200 °C or higher and 1350 °C or lower to obtain an agglomerate.

[0046] In the raw material particle for production of agglomerate of the present disclosure or the raw material particle obtainable by the method for producing a raw material particle of the present disclosure described above, the central part has a metal iron-containing substance or a volatile substance, and the peripheral part has iron oxide. By baking or sintering the raw iron powder in an oxidizing atmosphere of 1200 °C or higher and 1350 °C or lower to form an agglomerate, the metal iron in a portion adjacent to the peripheral part is oxidized when the central part of the raw material particle has a metal iron-containing substance, and a volatile substance volatilizes when the central part of the raw material particle has a volatile substance. As a result, the particle of the agglomerate has either a three-layer structure as illustrated in FIG. 3A or a hollow structure as illustrated in FIG. 3B, thereby obtaining an agglomerate with better reducing performance than conventional agglomerates.

[0047] The baking of the raw material particle can be performed using a rotary kiln or the like. Specifically, the raw material particles for production of agglomerate of the present disclosure or the raw material particles obtainable by the method for producing a raw material particle of the present disclosure described above are charged into a rotary kiln and placed in an oxidizing atmosphere such as air at 1200 °C or higher and 1350 °C or lower. Baked pellets can be obtained in this way.

[0048] The sintering of the raw material particle can be performed using a sintering machine. Specifically, the raw material particles for production of agglomerate of the present disclosure or the raw material particles obtainable by the method for producing a raw material particle of the present disclosure described above and granulated particles obtained by granulating conventional raw material particles are mixed, and the mixture is placed in an oxidizing atmosphere at 1200 °C or higher and 1350 °C or lower. Sintered ore can be obtained in this way.

(Method for producing reduced iron)

[0049] The method for producing reduced iron of the present disclosure includes charging the agglomerate of the present disclosure or an agglomerate obtainable by the method for producing an agglomerate of the present disclosure described above into a reducing furnace while introducing a reducing gas into the reducing furnace to reduce the iron oxide contained in the agglomerate to obtain reduced iron.

[0050] As described above, the agglomerate of the present disclosure or an agglomerate obtainable by the method for producing an agglomerate of the present disclosure has better reducing performance than conventional agglomerates. By charging such an agglomerate into a reducing furnace such as a shaft furnace while introducing a reducing gas, reduced iron can be produced efficiently.

[0051] In the present disclosure, coke oven gas, gas reformed from natural gas (containing hydrocarbon as a component), mixed gas of CO gas and H_2 gas, H_2 gas (gas with a H_2 concentration of 100 %), and the like can be used as the reducing gas. However, it is preferable to use a gas containing H_2 as a main component as the reducing gas. As used herein, "a gas containing H_2 as a main component" means a gas having a H_2 concentration of 50 vol.% or more. This can reduce CO_2 emissions.

[0052] The Hz concentration of the reducing gas is preferably 65 vol.% or more. This can further enhance the effect of reducing CO_2 emissions. The H_2 concentration of the reducing gas is more preferably 70 vol.% or more, still more preferably 80 vol.% or more, even more preferably 90 vol.% or more, and most preferably 100 vol.%, that is, it is most preferable to use H_2 gas as the reducing gas. By using H_2 gas as the reducing gas, reduced iron can be produced without CO_2 emissions.

EXAMPLES

[0053] The following describes examples of the present disclosure, but the present disclosure is not limited to the following examples.

(Conventional Example 1)

[0054] A baked pellet was prepared using Brazilian iron ore whose chemical composition is listed in Table 1. Specifically, the iron ore was first ground, and the resulting iron ore powder was classified to obtain iron ore powder with a particle size of -63 μm. Next, the iron ore powder was mixed with quicklime as a binder, and a green pellet with a diameter of 12 mm was prepared while adjusting the humidity with a pelletizer. The prepared green pellet was then baked at 1350 °C in air for 60 minutes. A baked pellet as an agglomerate of Conventional Example 1 was prepared in this way. The reducibility value of the obtained baked pellet was determined according to JIS-M8713, and the result was 60 %.

[Table 1]

[0055]

Table 1

	T.Fe	SiO_2	Al_2O_3	MgO	Combined water
Brazilian iron ore	66.3	1.24	1.0	0.05	2.3
Australian iron ore	60.1	4.85	3.1	0.07	4.7

(Conventional Example 2)

[0056] Sintered ore was prepared using a raw material powder obtained by mixing Brazilian iron ore and Australian iron ore whose composition is listed in Table 1 at a ratio of 50:50. Specifically, granulated particles were first prepared by granulating the iron ore as it is together with limestone, returned ore, and coke breeze as secondary materials. The average diameter of the prepared granulated particles was about 3 mm to 4 mm, and the interior of the particle contained a nuclear particle (iron concentration: 57 mass%) with a maximum size of about 1 mm. The granulated particles thus obtained were charged into a small sintering tester and sintered. A steel vessel with a filling layer height of 600 mm and a diameter of 300 mm was used for sintering, and the sintering was performed under a constant differential pressure with a suction negative pressure of 6.9 kPa. The obtained sintered ore was dropped four times from a height of 2 m to select sintered ore particles with a particle size of 19 mm to 22 mm from the obtained sintered ore. Sintered ore as an agglomerate of Conventional Example 2 was prepared in this way. The reducibility value of the obtained sintered ore was determined according to JIS-M8713, and the result was 65 % to 70 %.

(Example 1)

[0057] A baked pellet as an agglomerate of Example 1 was prepared in the same manner as in Conventional Example 1. However, when producing a green pellet (raw material particle) for production of agglomerate, a DRI powder (iron concentration: 80.4 mass%, particle size: 3 mm to 5 mm (under a 5-mm sieve and above a 3-mm sieve), metallization ratio (= reduced iron proportion/total iron content): 80 %) obtained in a reduced iron production process was added to prepare a green pellet (raw material particle) having the DRI powder as the central part. All other conditions were the same as in Conventional Example 1. The reducibility value of the obtained baked pellet was determined, and the result was 80 %.

(Example 2)

[0058] A baked pellet as an agglomerate of Example 2 was prepared in the same manner as in Conventional Example 1. However, when preparing a green pellet (raw material particle) for production of agglomerate, a DRI powder (iron concentration: 75.2 mass%, particle size: 3 mm to 5 mm (under a 5-mm sieve and above a 3-mm sieve), metallization ratio (= reduced iron proportion/total iron content): 65 %) obtained in a reduced iron production process was added to prepare a green pellet (raw material particle) having the DRI powder as the central part. All other conditions were the same as in Conventional Example 1. The reducibility value of the obtained baked pellet was determined, and the result was 78 %.

(Example 3)

[0059] Sintered ore as an agglomerate of Example 3 was prepared in the same manner as in Conventional Example 2. However, the granulated particles were prepared using only Australian iron ore, the obtained granulated particles were mixed with green pellets prepared by the same method as in Example 1 to prepare a mixed granulation raw material, and the obtained mixed granulation raw material was charged into a small sintering tester and sintered. All other conditions were the same as in Conventional Example 2. The reducibility value of the obtained sintered ore was determined, and the result was 90 %.

(Example 4)

[0060] Sintered ore as an agglomerate of Example 4 was prepared in the same manner as in Example 3. However, the green pellet was prepared by the same method as in Example 2. All other conditions were the same as in Example 3. The reducibility value of the obtained sintered ore was determined, and the result was 84 %.

(Example 5)

[0061] Sintered ore as an agglomerate of Example 4 was prepared in the same manner as in Example 1. However, polypropylene particles (diameter: 3 mm to 5 mm) were added instead of the DRI powder when producing green pellets. All other conditions were the same as in Example 1. The reducibility value of the obtained baked pellet was determined, and the result was 79 %.

<Evaluation of reducing performance of agglomerate>

[0062] As described above, the reducibility of the sintered ore in Conventional Examples 1 and 2 was about 60 % to 70 %, and the reducibility of the sintered ore in Examples 1 to 5 was 79 % or more, indicating the sintered ore in Examples 1 to 5 had better reducing performance than those in Conventional Examples 1 and 2. Comparison of Example 1 with Example 2 and comparison of Example 3 with Example 4 indicate that when the metallization ratio of the central part of the green pellet (raw material particle) increases, the reducibility value also increases.

<Evaluation of strength of agglomerate>

[0063] The agglomerates of Examples 1 to 5 had the same level of strength as the agglomerates of Conventional Examples 1 and 2, and they could be used for the production of reduced iron without any problems. Therefore, the agglomerates of Examples 1 to 5 had both good strength and good reducing performance.

INDUSTRIAL APPLICABILITY

[0064] According to the present disclosure, it is possible to provide a raw material particle for production of agglomerate that can be used to produce an agglomerate with better reducing performance than conventional agglomerates, which is useful in the steel industry.

REFERENCE SIGNS LIST

[0065]

1, 2	raw material particle
3, 4	particle of sintered ore
11, 21, 31, 41	central part
12, 22, 32, 42	peripheral part
31a	first portion
31b	second portion

Claims

1. A raw material particle for production of agglomerate, which is a raw material particle for producing an agglomerate as a raw material for producing reduced iron, comprising

a central part, and a peripheral part that covers a periphery of the central part, wherein
the central part has a metal iron-containing substance or a volatile substance, and the peripheral part has iron oxide.

2. The raw material particle for production of agglomerate according to claim 1, wherein the iron oxide contains at least either or both of more than 4 mass% of combined water and more than 1.5 mass% of alumina.

3. The raw material particle for production of agglomerate according to claim 1 or 2, wherein the central part has a particle size of 2 mm or more and 6 mm or less.

4. The raw material particle for production of agglomerate according to any one of claims 1 to 3, wherein the peripheral part has a thickness of 2 mm or more and 5 mm or less.

5. A method for producing a raw material particle for production of agglomerate, which is a method for producing the raw material particle according to any one of claims 1 to 4, comprising

a pretreatment process of grinding a raw material containing the iron oxide into raw material powder, and then classifying the raw material powder to adjust a particle size of the raw material powder, and
a process of mixing and granulating the raw material powder whose particle size has been adjusted, the metal iron-containing substance or the volatile substance, and a binder to obtain the raw material particle.

6. The method for producing a raw material particle for production of agglomerate according to claim 5, wherein the metal iron-containing substance or the volatile substance with a particle size of 2 mm or more and 6 mm or less is used in the granulation process.

7. The method for producing a raw material particle for production of agglomerate according to claim 5 or 6, wherein a thickness of the peripheral part is adjusted to 2 mm or more and 5 mm or less in the granulation process.

8. An agglomerate obtained by baking or sintering and agglomerating the raw material particle according to any one of claims 1 to 4, wherein

for the agglomerated raw material particle,
when the central part before baking or sintering has the metal iron-containing substance, the agglomerated raw material particle has a three-layer structure, where the central part has a first portion having the metal iron-containing substance and a second portion that covers a periphery of the first portion, and metal iron contained

in the metal iron-containing substance is oxidized in the second portion, and
when the central part before baking or sintering has the volatile substance, the agglomerated raw material particle has a hollow structure where the central part is a void.

9. A method for producing an agglomerate, comprising baking or sintering and agglomerating the raw material particle according to any one of claims 1 to 4 or a raw material particle obtainable by the method for producing a raw material particle for production of agglomerate according to any one of claims 5 to 7 in an oxidizing atmosphere of 1200 °C or higher and 1350 °C or lower to obtain an agglomerate.

10. A method for producing reduced iron, comprising charging the agglomerate according to claim 8 or an agglomerate obtainable by the method for producing an agglomerate according to claim 9 into a reducing furnace while introducing a reducing gas into the reducing furnace, and reducing iron oxide contained in the agglomerate by the reducing gas to obtain reduced iron.

11. The method for producing reduced iron according to claim 10, wherein a gas containing hydrogen as a main component is used as the reducing gas.

FIG. 1

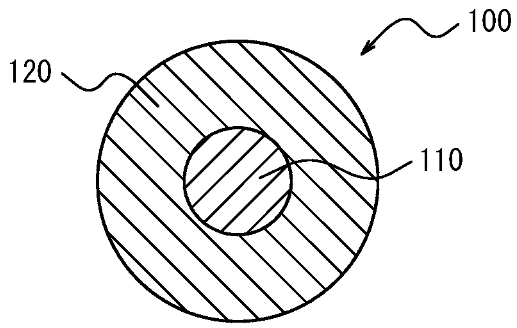


FIG. 2A

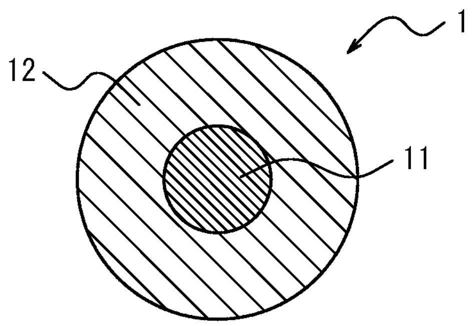


FIG. 2B

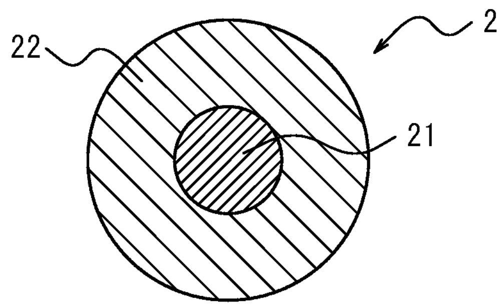


FIG. 3A

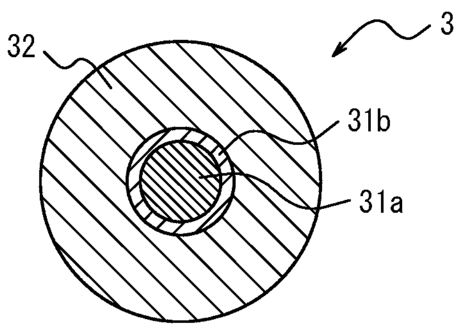
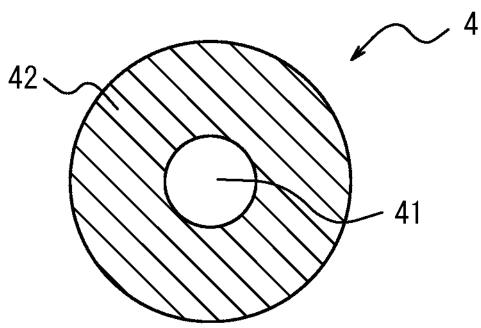


FIG. 3B



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/044584

A. CLASSIFICATION OF SUBJECT MATTER

C21B 13/00(2006.01)i; ***C22B 1/14***(2006.01)i; ***C22B 5/12***(2006.01)i
FI: C22B1/14; C21B13/00; C22B5/12

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)

C21B13/00; C22B1/14; C22B5/12

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 1971-2021
Registered utility model specifications of Japan 1996-2021
Published registered utility model applications of Japan 1994-2021

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 2014-080649 A (NIPPON STEEL & SUMITOMO METAL CORP.) 08 May 2014 (2014-05-08) paragraphs [0032]-[0041]	1-4, 8-11
A	entire text, all drawings	5-7
X	JP 2012-126963 A (KOBE STEEL, LTD.) 05 July 2012 (2012-07-05) claims, paragraphs [0056]-[0059]	1-4
A	entire text, all drawings	5-11
A	JP 2015-209570 A (KOBE STEEL LTD.) 24 November 2015 (2015-11-24) entire text, all drawings	1-11
A	JP 2015-101740 A (KOBE STEEL LTD.) 04 June 2015 (2015-06-04) entire text, all drawings	1-11

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 December 2021	**28 December 2021**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/044584

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2014-080649 A	08 May 2014	(Family: none)	
JP 2012-126963 A	05 July 2012	(Family: none)	
JP 2015-209570 A	24 November 2015	(Family: none)	
JP 2015-101740 A	04 June 2015	(Family: none)	

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2020045508 A **[0003] [0005]**
- JP H0246644 B **[0004] [0005]**

Non-patent literature cited in the description

- **ATSUSHI ; UEMURA ; SAKAGUCHI.** MIDREX® Process. *KOBE STEEL ENGINEERING REPORTS,* 2010, vol. 60 (1 **[0004] [0006]**