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(71) Applicant: **JFE Steel Corporation**
Tokyo 100-0011 (JP)

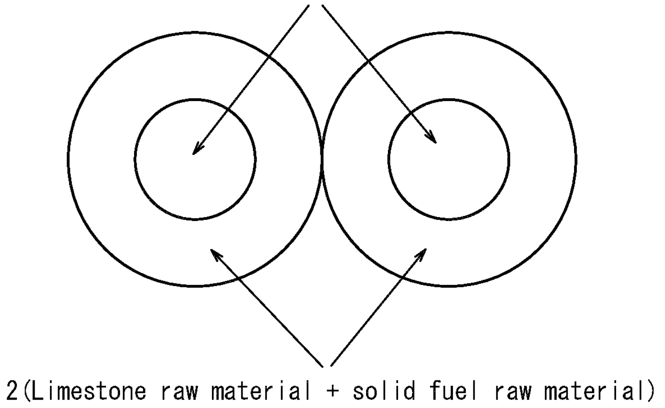
(72) Inventors:
- **HIROSAWA, Toshiyuki**
  Tokyo 100-0011 (JP)
- **HIGUCHI, Takahide**
  Tokyo 100-0011 (JP)
- **YAMAMOTO, Tetsuya**
  Tokyo 100-0011 (JP)
- **OYAMA, Nobuyuki**
  Tokyo 100-0011 (JP)

(74) Representative: **Grünecker Patent- und Rechtsanwälte**
PartG mbB
Leopoldstraße 4
80802 München (DE)

(54) QUASIPARTICLES FOR SINTERING AND METHOD OF PRODUCING SAME

(57) To improve reducibility of sintered ore, disclosed is a quasiparticle for sintering including, at least, iron ore raw material, limestone-based raw material, and solid fuel-based raw material, each being used to produce sintered ore for blast furnaces, in which the iron ore raw material forms a core of the quasiparticle, and the limestone-based raw material and the solid fuel-based raw material are coated on the circumference of the core, and in which the core formed of the iron ore raw material contains general iron ore having an alkali metal content of less than 0.05 mass% and high-alkaline iron ore having an alkali metal content of 0.05 mass% or more.

FIG. 7



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Description

TECHNICAL FIELD

[0001] This disclosure relates to quasiparticles for sintering that are used as raw material for sintering to be placed on a palette of, e.g. a downward suction-type Dwight Lloyd sintering machine, for the purpose of producing sintered ore for blast furnaces, and to a method of producing the same.

BACKGROUND

[0002] In general, sintered ore that is used as raw material for blast furnaces is produced by a sintering raw material processing method as follows. Firstly, for example, as illustrated in FIG. 1, iron ore with a particle size of 10 mm or less, SiO_2-containing raw material with a particle size of 10 mm or less that is formed of silica stone, serpentinite, nickel slag, or the like, limestone-based raw material that contains powder CaO, and powder coke or solid fuel-based raw material such as anthracite as heat source, are placed in a drum mixer with addition of a suitable amount of water, then mixed and granulated to form granulated products called quasiparticles. Such mixed raw materials formed of the granulated products are charged on a palette of a Dwight Lloyd sintering machine to a suitable thickness, e.g. 500 mm to 700 mm, solid fuel in the surface layer is ignited, and after the ignition solid fuel is combusted while air is drawn downwardly. Consequently the mixed sintering raw materials are sintered by the heat of combustion, and sinter cake is formed. The sinter cake is crushed into uniformly-sized particles to obtain sintered ore with a particle size equal to or larger than a predetermined size. Other sintered ore with a smaller particle size is return ore, which is reusable as sintering raw material.

[0003] It is important for such sintered ore thus produced to exhibit, among other things, good reducibility, which greatly affects blast furnace operations. Reducibility of sintered ore is normally defined by JIS M8713 ("JIS" stands for Japanese Industrial Standard), and is denoted herein as JIS-RI. As illustrated in FIG. 2, there is a positive correlation between reducibility of sintered ore (JIS-RI) and gas utilization rate in a blast furnace (ηco) and, as illustrated in FIG. 3, there is a negative correlation between gas utilization rate and fuel ratio in a blast furnace. From this follows that reducibility of sintered ore (JIS-RI) has a good negative correlation with fuel ratio via gas utilization rate (ηco) in a blast furnace, and accordingly fuel ratio will decrease as reducibility of sintered ore improves in the blast furnace.

It this regard, gas utilization rate (ηco) and fuel ratio are defined as:

$$\eta co = CO_2\ (\%)/(CO\ (\%) + CO_2\ (\%))$$

, where CO_2 (%) and CO (%) are both concentrations expressed in volume percent in the gas at the furnace top of the blast furnace.

$$\text{fuel ratio} = (\text{coal} + \text{coke consumption (kg/day)})/\text{pig iron production (t/day)}$$

[0004] Cold strength of sintered ore is also an important factor in guaranteeing permeability in a blast furnace. Individual blast furnaces have lower limits on cold strength for proper operation.

Therefore, sintered ore that has excellent reducibility and high cold strength is desirable as blast furnace raw material. In this respect, Table 1 lists the reducibility and tensile strength (cold strength) of primary mineral structures forming sintered ore, calcium ferrite (CF): $nCaO \cdot Fe_2O_3$, hematite (He): Fe_2O_3, FeO-containing calcium silicate (CS): $CaO \cdot xFeO \cdot y SiO_2$, and magnetite (Mg): Fe_3O_4. Note that tensile strength was measured by subjecting disk-shaped ore test pieces to splitting tensile test (radial compression test or Brazilian test). As can be seen from Table 1, hematite (He) shows high reducibility and calcium ferrite (CF) has high tensile strength.

[Table 1]

[0005]

Table 1

	Calcium Ferrite (CF)	Hematite (He)	Calcium Silicate (CS)	Magnetite (Mg)
Reducibility (%)	34	50	3	27
Tensile Strength (MPa)	102	49	19	58

[0006] Therefore, a sintering structure that is suitable for sintered ore is obtained by, as schematically illustrated in FIG. 4, forming calcium ferrite (CF), which is high in strength, on the surface of a lump and forming hematite (He), which is high in reducibility, inside the lump. It is preferable for such sintering structure to minimize the formation of FeO-containing calcium silicate (CS) low in reducibility and strength. In most conventional sintering machines, however, iron ore, SiO_2-containing raw material, limestone-based raw material, and solid fuel-based raw material are mixed at the same time as mentioned above and, as a consequence, in a quasiparticle structure obtained by mixing and granulating raw materials as illustrated in FIG. 5, powder ore, lime, and coke are present, in a mixed manner, on the circumference of coarse core ore. A sintered ore structure obtained by sintering such quasiparticles will include a mixture of four types of mineral structures: hematite (He), calcium ferrite (CF), calcium silicate (CS) containing FeO, and magnetite (Mg).

[0007] In such a situation, many attempts have been made to form more calcium ferrite (CF) and hematite (He). For example, considering the fact that FeO-containing calcium silicate (CS) forms more when sintered at high temperature, one technique is described in JPS63149331A (PTL 1) that involves granulating powder iron ore with addition of a binder or limestone, coating the surfaces of the granules with coke breeze as heat source to increase combustibility of coke, and performing sintering at low temperature to improve reducibility.

[0008] According to the conventional method proposed, however, CaO reside in close proximity to SiO_2 or SiO_2-based raw material in the iron-based raw material, which fact inevitably generates a large amount of FeO-containing calcium silicate (CS). Consequently, a structure that is formed mainly of calcium ferrite (CF) and hematite (He) may not always be provided.

[0009] To address the above problem, WO2001092588A (PTL 2) describes that by using as raw material such quasi-particles that does not require any large-scale apparatus as pretreatment for producing sintered ore and that have a layered structure in which iron ore raw material is separated from limestone-based raw material and solid fuel-based raw material, it becomes possible to produce sintered ore having the structure such that calcium ferrite (CF) with high strength is selectively formed on the surface of the sintered ore and hematite (He) with high reducibility is selectively formed on the inside of the sintered ore, and the sintered ore thus obtained exhibits improved cold strength and improved reducibility.

CITATION LIST

Patent Literature

[0010]

PTL 1: JPS63149331A
PTL 2: WO2001092588A

SUMMARY

(Technical Problem)

[0011] With the technique described in PTL 2, as illustrated in FIG. 6, if iron ore and SiO_2-containing raw material, each containing SiO_2 in large quantities, are used with quasiparticles that are separated from limestone-based raw material and from solid fuel-based raw material, in production of sintered ore, it becomes possible to delay reaction between CaO and SiO_2 during a sintering process, thereby reducing formation of calcium silicate (CS) containing FeO, which is poor in reducibility and low in cold strength. The resulting sintered ore has the structure such that calcium ferrite (CF) with high strength is selectively formed on the surface of the sintered ore and hematite (He) with high reducibility is selectively formed on the inside of the sintered ore.

[0012] By applying the quasiparticles for sintering as described in PTL 2, sintered ore with excellent reducibility and high cold strength can be obtained. To achieve, however, low-reduction-agent-ratio operations of blast furnaces (low RAR (Reduction Agent Ratio) operations are operations with a reduction in the total amount of reducing agents blown in from tuyeres and coke charged in from the furnace top per 1 t of produced pig iron) by further improving reducibility of sintered ore in blast furnaces, there is a need for further improvement of reducibility (JIS-RI) of sintered ore.

(Solution to Problem)

[0013] Upon carefully examining, in particular, the way of improving reducibility of sintered ore that is produced with quasiparticles for sintering having a layered structure that are obtained by separating iron ore raw material from limestone-based raw material and from solid fuel-based raw material, we newly discovered that to include an alkali metal in iron ore raw material within a particular range is effective for increasing the advantages of quasiparticles for sintering having a layered structure.

[0014] We thus provide:

1. A quasiparticle for sintering comprising, at least, iron ore raw material, limestone-based raw material, and solid fuel-based raw material, each being used to produce sintered ore for blast furnaces,
wherein the iron ore raw material forms a core of the quasiparticle, and the limestone-based raw material and the solid fuel-based raw material are coated on the circumference of the core, and
wherein the core formed of the iron ore raw material contains high-alkaline iron ore having an alkali metal content of 0.05 mass% or more.
In this case, examples of the alkali metal include lithium, sodium, potassium, rubidium, and cesium; among these, sodium and potassium are suitably used as the iron ore raw material for sintered ore.
2. The quasiparticle for sintering according to aspect 1, wherein the core formed of the iron ore raw material comprises:

    a first layer that is formed of general iron ore having an alkali metal content of less than 0.05 mass%; and
    a second layer that is formed of the high-alkaline iron ore having an alkali metal content of 0.05 mass% or more and that covers the surface of the first layer.

3. The quasiparticle for sintering according to aspect 1, wherein the core formed of the iron ore raw material comprises:

    a first layer that is formed of the high-alkaline iron ore having an alkali metal content of 0.05 mass% or more; and
    a second layer that is formed of the general iron ore having an alkali metal content of less than 0.05 mass% and that covers the surface of the first layer.

4. The quasiparticle for sintering according to any one of aspects 1 to 3, wherein the iron ore raw material contains the high-alkaline iron ore having an alkali metal content of 0.05 mass% or more in an amount of 20 mass% or more.
5. The quasiparticle for sintering according to any one of aspects 1 to 4, wherein the high-alkaline iron ore having an alkali metal content of 0.05 mass% or more has a mean particle size of 2 mm or more, and the general iron ore having an alkali metal content of less than 0.05 mass% has a mean particle size of less than 2 mm.
6. The quasiparticle for sintering according to any one of aspects 1 to 5, wherein the alkali metal content of the high-alkaline iron ore having an alkali metal content of 0.05 mass% or more is 0.30 mass% or less.
7. The quasiparticle for sintering according to any one of aspects 1 to 6, wherein the limestone-based raw material and the solid fuel-based raw material are coated layer-by-layer on the circumference of the core.
8. The quasiparticle for sintering according to any one of aspects 1 to 7, wherein a mixed layer of the limestone-based raw material and the solid fuel-based raw material is coated on the circumference of the core.
9. A method of producing a quasiparticle for sintering, the method comprising:

    when mixing and granulating, at least, iron ore raw material, limestone-based raw material, and solid fuel-based raw material, each being used to produce sintered ore for blast furnaces,

        mixing and granulating the iron ore raw material containing high-alkaline iron ore having an alkali metal content of 0.05 mass% or more to obtain a granulated particle; and
        causing the limestone-based raw material and the solid fuel-based raw material to be adhered to the granulated particle and, subsequently, performing granulation.

10. A method of producing a quasiparticle for sintering, the method comprising:

    when mixing and granulating, at least, iron ore raw material, limestone-based raw material, and solid fuel-based raw material, each being used to produce sintered ore for blast furnaces,

        mixing and granulating general iron ore having an alkali metal content of less than 0.05 mass% and SiO_2-containing raw material to form a first layer;
        causing high-alkaline iron ore having an alkali metal content of 0.05 mass% or more to be adhered to the surface of the first layer, and subsequently performing granulation to form a second layer; and
        causing the limestone-based raw material and the solid fuel-based raw material to be adhered to the surface of the second layer and, subsequently, performing granulation.

11. A method of producing a quasiparticle for sintering, the method comprising:

when mixing and granulating, at least, iron ore raw material, limestone-based raw material, and solid fuel-based raw material, each being used to produce sintered ore for blast furnaces,

mixing and granulating high-alkaline iron ore having an alkali metal content of 0.05 mass% or more to form a first layer;
causing general iron ore having an alkali metal content of less than 0.05 mass% to be adhered to the surface of the first layer, and subsequently performing granulation to form a second layer; and
causing the limestone-based raw material and the solid fuel-based raw material to be adhered to the surface of the second layer and, subsequently, performing granulation.

12. The method of producing a quasiparticle for sintering according to any one of aspects 7 to 11, wherein the high-alkaline iron ore having an alkali metal content of 0.05 mass% or more has a mean particle size of 2 mm or more, and the general iron ore having an alkali metal content of less than 0.05 mass% has a mean particle size of less than 2 mm.
13. The method of producing a quasiparticle for sintering according to any one of aspects 7 to 12, wherein mixed powder of the limestone-based raw material and the solid fuel-based raw material is adhered and, subsequently, granulation is performed.
14. The method of producing a quasiparticle for sintering according to any one of aspects 7 to 12, wherein after the adhering of the limestone-based raw material, the solid fuel-based raw material is adhered to an outer surface of a layer of the limestone-based raw material and, subsequently, granulation is performed.

(Advantageous Effect)

[0015] According to the present disclosure, it is possible to provide quasiparticles that are optimal raw material for achieving further improvement of reducibility of sintered ore.

BRIEF DESCRIPTION OF THE DRAWING

[0016] In the accompanying drawings:

FIG. 1 is a diagram illustrating the flow of mixture and granulation of sintering raw material in a conventional example;
FIG. 2 is a graph illustrating the relation between reducibility JIS-RI (%) of sintered ore and gas utilization rate ηco (%) in a blast furnace;
FIG. 3 is a graph illustrating the relation between gas utilization rate ηco (%) and fuel ratio (kg/t-pig) in a blast furnace;
FIG. 4 illustrates a desirable sintered ore structure;
FIG. 5 illustrates a conventional quasiparticle structure and a conventional sintered ore structure;
FIG. 6 illustrates a conventionally desirable quasiparticle structure;
FIG. 7 illustrates a basic quasiparticle structure according to the disclosure;
FIG. 8 illustrates a flow (process A) of mixture and granulation of sintering raw material according to the disclosure;
FIG. 9 illustrates a flow (process B) of mixture and granulation of sintering raw material according to the disclosure; and
FIG. 10 illustrates a flow (process C) of mixture and granulation of sintering raw material according to the disclosure.

DETAILED DESCRIPTION

[0017] In the following, quasiparticles for sintering according to the disclosure are described in detail with reference to the accompanying drawings.

[0018] As quasiparticles for sintering used to produce sintered ore with excellent reducibility and high cold strength, quasiparticles for sintering contain at least iron ore raw material, limestone-based raw material, and solid fuel-based raw material, and have a basic structure, as illustrated in FIG. 7, such that the iron ore raw material is contained as core 1, and layer 2 formed of the limestone-based raw material and solid fuel-based raw material is coated on the circumference of core 1.

[0019] In other words, such quasiparticles can be produced by containing iron ore raw material as core 1 in a state in which core 1 is separated from limestone-based raw material and does not contain limestone. Layer 2, which is formed of limestone-based raw material and solid fuel-based raw material and which covers the surface of core 1, enables a calcium ferrite (CF)-based melt to be formed during a sintering process at the interface between limestone-based raw material and iron ore so that the CF covers the circumference of the iron ore, thereby providing sufficient cold strength. The sintered ore that is obtained by using the above quasiparticles for sintering as sintering raw material has calcium ferrite (CF) with high strength on the surface and hematite (He) with high reducibility on the inside.

[0020] Note that layer 2 may be a mixed layer of limestone-based raw material and solid fuel-based raw material, or a lamination of a limestone-based raw material layer (inside) and a solid fuel-based raw material layer (outside). In either case, limestone contents in layer 2 allow calcium ferrite (CF) with high strength to be formed on the surface of the sintered ore.

[0021] In this respect, it is important for the iron ore raw material of core 1 to contain iron ore having an alkali metal content of 0.05 mass% or more (also referred to hereinafter as "high-alkaline iron ore"). In other words, by containing high-alkaline iron ore in the iron ore raw material of core 1, a catalytic effect can be obtained via an alkali metal, and close arrangement of calcium ferrite can be achieved, thereby further improving reducibility of sintered ore. It is difficult to obtain the above effect if the alkali metal content of the high-alkaline iron ore is less than 0.05 mass%.

[0022] It is preferred, however, that the alkali metal content of the high-alkaline iron ore having an alkali metal content of 0.05 mass% or more is 0.30 mass% or less. The reason is that if the alkali metal content is excessively high, the proportion of the alkali metal obtained in the sintering machine increases even when the mix proportion is small, and the amount of the alkali metal in the blast furnace increases accordingly. This may cause accumulation of the alkali metal in the furnace, and formation of layers of alkali metals and adhesion to the furnace wall, thereby disturbing proper blast furnace operations. The dispersibility of the alkali metal in the sintered ore may also decrease, thereby reducing the above effect.

[0023] In the iron ore raw material, the mix proportion of the high-alkaline iron ore is preferably 20 mass% to 60 mass%. The reason is that a mix proportion of less than 20 mass% is less effective for improving reducibility, while a mix proportion of more than 60 mass% increases the proportion of the alkali metal in the sintered ore obtained in the sintering machine, which may result in an increase in alkali contents in the blast furnace, accumulation of the alkali metal in the furnace, and formation of alkali metal layers and adhesion to the furnace wall, which may adversely affect blast furnace operations. There is another concern that the reduction-disintegration index of the sintered ore may excessively increase, thereby deteriorating permeability in the blast furnace and resulting in an increased coke ratio. The remaining part of the iron ore raw material other than the high-alkaline iron ore is iron ore having an alkali metal content of less than 0.05 mass% (also referred to hereinafter as "general iron ore"). Moreover, SiO_2 raw material may optionally be added to the iron ore raw material.

[0024] The iron ore raw material preferably forms core 1 such that the core takes any of Forms I to III below. In each case, the above action can be provided by the alkali metal. Each form has the following characteristics.

Form I: Mixed layer of general iron ore and high-alkaline iron ore

[0025] In this Form A, a mixed layer of general iron ore and high-alkaline iron ore enables an alkali metal to be uniformly dispersed within the sintered ore. As a consequence, it becomes possible to increase reducibility by increasing the surface area of the alkali metal which exhibits catalytic action, and by enhancing the catalytic effect. Additionally, the strength of the sintered ore may also mitigate formation of a brittle zone, thereby ensuring cold strength.

Form II: Lamination of a first layer formed of general iron ore and a second layer formed of high-alkaline iron ore covering the surface of the first layer

[0026] In this Form B, an alkali metal which exhibits catalytic action is present on the surface side of the core. As a consequence, it becomes possible to fully make use of the catalytic effect of the alkali metal, thereby increasing reducibility.

Form III: Lamination of a first layer formed of high-alkaline iron ore and a second layer formed of general iron ore covering the surface of the first layer

[0027] In this Form C, high-alkaline iron ore is present inside the core of each quasiparticle before subjection to sintering, and the proportion of an alkali metal present in the calcium ferrite phase formed in the surface of the sintered ore is reduced. As a consequence, reduction disintegration properties can be improved without interfering with the catalytic action of the alkali metal.

[0028] It is also preferred that the high-alkaline iron ore has a mean particle size of 2 mm or more, and the general iron ore has a mean particle size of less than 2 mm. As used herein with respect to each iron ore, a mean particle size refers to an arithmetic mean of the weight ratio and the representative particle size of the iron ore when classified by particle size using a sieve.

[0029] Specifically, the high-alkaline iron ore preferably has a mean particle size of 2 mm or more for the following reason. During the process of granulating the raw material to be fed to the sintering machine into quasiparticles, ore having a relatively large particle size will be unevenly distributed in the center of each quasiparticle, which fact is advantageous for reducing the proportion of an alkali metal present in the calcium ferrite phase that is formed in the surface of iron ore after sintering the quasiparticles. If an alkali metal is contained in large quantities in the calcium ferrite phase, reduction disintegration properties deteriorate. Thus, setting the mean particle size of the high-alkaline iron ore to 2 mm or more is advantageous for producing sintered ore that has a low reduction-disintegration index.

[0030] On the other hand, the general iron ore preferably has a mean particle size of less than 2 mm for the following reason.

[0031] Specifically, during the process of granulating into quasiparticles, ore having a small mean particle size will be unevenly distributed on the outside of quasiparticles, which fact may mitigate incorporation of large amounts of high-alkaline ore and calcium ferrite phase.

[0032] A method of producing quasiparticles for sintering according to the disclosure will now be described below.

[0033] Firstly, FIG. 8 illustrates an exemplary granulation flow (process A) for producing a desirable quasiparticle structure according to the disclosure. In this process A, the aforementioned high-alkaline iron ore 1a and general iron ore 1b, and optionally SiO_2-containing raw material 1c are charged from the mixer inlet of a drum mixer 4. Then, limestone-based raw material 2a and solid fuel-based raw material 2b are added to the drum mixer 4 from the mixer outlet of the drum mixer 4 and granulated therein, and quasiparticles for sintering, in the form of Form I above, can be obtained with limestone-based raw material 2a and solid fuel-based raw material 2b adhered to the circumference of a core with mixture of the high-alkaline iron ore 1a and the general iron ore 1b.

[0034] In addition, FIG. 9 illustrates an exemplary granulation flow (process B) for producing quasiparticles according to the disclosure. In this process B, the following materials are subjected to pre-granulation using a granulator 3: high-alkaline iron ore and general iron ore, e.g. high-alkaline iron ore 1a that has an alkali metal content of approximately 0.05 mass% to 1.0 mass% and a mean particle size of 2 mm or more, and general iron ore 1b that has an alkali metal content of less than 0.05 mass% and a mean particle size of less than 2 mm; and, optionally, fine SiO_2-containing raw material 1c (such as iron ore, silica stone, serpentinite, and Ni slag) that has a SiO_2 content of approximately 0.5 % to 5.0 % and a mean particle size of less than 2 mm, e.g. approximately 0.1 mm to 1.0 mm. In this pre-granulation, a first layer is formed by the general iron ore 1b and optionally added SiO_2, and the high-alkaline iron ore 1a is caused to be adhered, as a second layer, to the circumference of the first layer.

[0035] By changing the order of granulation in the pre-granulation process, the layering order of the high-alkaline iron ore 1a and the general iron ore 1b can be altered. That is, opposite to the above, the high-alkaline iron ore 1a and optionally added SiO_2 may be formed as a first layer, and a second layer may be formed by adhering the general iron ore 1b to the circumference of the first layer.

[0036] Subsequently, limestone-based raw material 2a alone, or limestone-based raw material 2a and solid fuel-based raw material 2b as heat source (such as coke and anthracite) are further added to, and mixed and granulated in the drum mixer 4 to thereby obtain quasiparticles for sintering in Form II or III, as described above, such that limestone-based raw material 2a and solid fuel-based raw material 2b are adhered to the circumference of each core of the iron ore raw material that comprises a first layer formed of high-alkaline iron ore 1a and a second layer formed of general iron ore 1b adhered to the circumference of the first layer.

[0037] Further, FIG. 10 illustrates an exemplary granulation flow (process C) for producing another desirable quasiparticle structure according to the disclosure. In this process C, a plurality of (in this example, two) drum mixers are provided, and the aforementioned high-alkaline iron ore 1a and general iron ore 1b, and optionally SiO_2-containing raw material 1c are charged from the inlet of the drum mixer 4 and granulated therein, limestone-based raw material 2a alone, or limestone-based raw material 2a and solid fuel-based raw material 2b are added from the inlet of the final stage drum mixer 4' located at the position pointed to by broken arrow, or from the outlet located at the position pointed to by solid arrow, and granulated. If only limestone-based raw material 2a is added, solid fuel-based raw material 2b may be added subsequently, and the limestone-based raw material 2a and the solid fuel-based raw material 2b may be granulated layer-by-layer. Note that if the limestone-based raw material 2a and the solid fuel-based raw material 2b have a mean particle size of 0.5 mm or less, preferably 0.25 mm or less, they can adhere to each other more easily, enabling the solid fuel-based raw material 2b to cover the surface of the limestone-based raw material 2a.

[0038] According to Process A, B, or C, iron ore raw material including high-alkaline iron ore may be formed as a core, and limestone-based raw material and solid fuel-based raw material as heat source may be adhered to the circumference of the core, so that the resulting quasiparticle can be coated and granulated with more than one layer. This configuration enables delaying the reaction between CaO and SiO_2 during a sintering process of sintering raw material formed of quasiparticles, mitigating the formation of calcium silicate (CS) with low cold strength, and causing calcium ferrite (CF) with high strength to be selectively formed on the surface of the lump and hematite (He) with high reducibility to be selectively formed on the inside of the lump. As a result, sintered ore that is rich in fine pores, excellent in reducibility, and high in cold strength may be stably produced.

EXAMPLES

[0039] Sintering raw materials were formulated as illustrated in Table 2, and quasiparticles for sintering were granulated by Process A or B in FIG. 8 or 9 according to the disclosure. The quasiparticles were transported to a Dwight Lloyd sintering machine and charged on a palette. For comparison, an operation was also conducted in which quasiparticles were granulated by the process of simultaneously mixing iron ore raw material, SiO_2-containing raw material, limestone-based raw material, and coke powder, and the quasiparticles were transported to the Dwight Lloyd sintering machine and charged on the palette. Then sintering was performed on the palette, and measurement was made of the reducibility (JIS-RI), reduction-disintegration index (RDI), and sintering strength (TI) of the resulting sintered ore. The measurement results are shown in Table 3.

[0040] The reducibility (JIS-RI) was measured in conformance with JIS M8713. The reduction-disintegration index (RDI) was measured in accordance with JIS M8720. The sintering strength was determined by measuring the tumble strength (tumbler strength TI) of sintered ore products in accordance with JIS M8712.

[Taable 2]

[0041]

Table 2

Formulation	Unit	a	b	c	d	e
High-alkaline Iron Ore	mass%	0	20	40	60	80
General Iron Ore	mass%	85	65	45	25	5
SiO_2-containing Raw Material	kg/t-sintered ore	15	15	15	15	15
Limestone-based Powder Raw Material	kg/t-sintered ore	13	13	13	13	13
Solid Fuel-based Powder Raw Material	kg/t-sintered ore	5	5	5	5	5

Notes:
(1) In the formulation, the total amount of high-alkaline iron ore, genral iron ore, and SiO_2-containing raw material is taken as 100 %, excluding limestone-based raw material and solid fuel-based raw material.
(2) As the SiO_2-containing raw material, limestone-based powder raw material, and solid fuel-based powder raw material, the following used:
SiO_2-containing raw material: silica sand
Limestone-based poweder raw material: limestone, quick lime
Solid fuel-based powder raw material: coke, anthracite

[Table 3-1]

[0042]

Table 3-1

No	Formulation	FormofQuasiparticle	Alkali Metal Content (mass%)		Mean Particle Size (mm)		Carbonaceous Material (kg/t-sintered ore)		JIS-RI (%)	RDI (%)	TI (%)	Remarks
			High-alkaline Ore	General Ore	High-alkaline Ore	General Ore	Lime	Solid Fuel				
1	a	Simultaneous Mixing	-	0.02	-	1.4	(13)	(5)	56.5	35.2	90.2	Comparative Example 1
2	a	Form I	-	0.02	-	1.4	13	5	60.5	30.0	90.1	Comparative Example 2
3	a	Simultaneous Mixing	-	0.045	-	1.4	(13)	(5)	58.2	38.3	90.0	Comparative Example 3
4	a	Form I	-	0.045	-	1.4	13	5	61.1	31.4	90.1	Comparative Example 4
5	b	Simultaneous Mixing	0.1	0.02	1.4	1.4	(13)	(5)	58.9	39.2	90.2	Comparative Example 5
6	b	Form I	0.1	0.02	1.4	1.4	13	5	65.8	33.2	90.4	Example 1

Note: In "Carbonaceous Material Coating," parentheses indicate simultaneous mixing of lime, solid fuel, and ore (Form of Quasiparticle corresponds to "Simultaneous Mixing").

[Table 3-2]

[0043]

Table 3-2

No	Formulation	Form of Quasiparticle	Alkali Metal Content (mass%)		Mean Particle Size (mm)		Carbonaceous Material Coating (kg/t-sintered ore)		JIS-RI (%)	RDI (%)	TI (%)	Remarks
			High-alkaline Ore	General Ore	High-alkaline Ore	General Ore	Lime	Solid Fuel				
7	b	Form I	0.12	0.02	2.5	1.4	13	5	65.3	32.2	89.8	Example 2
8	b	Form II	0.12	0.02	2.5	1.4	13	5	63.3	33.4	89.9	Example 3
9	b	Form III	0.12	0.02	2.5	1.4	13	5	66.5	32.6	90.1	Example 4
10	c	Form I	0.12	0.02	2.5	1.4	13	5	66.2	30.7	90.1	Example 5
11	c	Form II	0.12	0.02	2.5	1.4	13	5	64.3	31.8	90.0	Example 6
12	c	Form III	0.12	0.02	2.5	1.4	13	5	67.4	31.4	90.0	Example 7
13	d	Form I	0.12	0.02	2.5	1.4	13	5	65.8	31.4	90.1	Example 8
14	d	Form II	0.12	0.02	2.5	1.4	13	5	63.7	32.7	89.8	Example 9
15	d	Form III	0.12	0.02	2.5	1.4	13	5	66.8	32.1	89.9	Example 10
16	e	Form I	0.3	0.02	2.5	1.4	13	5	65.3	40.2	90.1	Example II
17	e	Form II	0.3	0.02	2.5	1.4	13	5	63.3	41.7	90.1	Example 12
18	e	Form III	0.3	0.02	2.5	1.4	13	5	66.2	41.4	90.1	Example 13

[Table 3-3]

[0044]

Table 3-3

No	Formulation	Form of Quasiparticle	Alkali Metal Content (mass%)		Mean Particle Size (mm)		Carbonaceous Material Coating (kg/t-sintered ore)		JIS-RI (%)	RDI (%)	TI (%)	Remarks
			High-alkaline Ore	General Ore	High-alkaline Ore	General Ore	Lime	Solid Fuel				
19	c	Form III	0.05	0.02	2.5	1.4	13	5	66.3	29.4	89.8	Example 14
20	c	Form III	0.10	0.02	2.5	1.4	13	5	67.1	31.1	90.0	Example 15
21	c	Form III	0.15	0.02	2.5	1.4	13	5	67.7	32.0	89.8	Example 16
22	c	Form III	0.30	0.02	2.5	1.4	13	5	69.6	33.4	90.1	Example 17
23	c	Form III	0.35	0.02	2.5	1.4	13	5	69.2	38.4	89.8	Example 18
24	c	Form III	0.12	0.02	0.5	1.0	13	5	62.3	34.9	89.8	Example 19
25	c	Form III	0.12	0.02	1.0	1.0	13	5	62.6	34.8	89.9	Example 20
26	c	Form III	0.12	0.02	1.5	1.0	13	5	62.7	34.7	89.8	Example 21
27	c	Form III	0.12	0.02	2.0	1.0	13	5	63.5	33.3	89.9	Example 22
28	c	Form III	0.12	0.02	2.5	1.0	13	5	64.5	31.6	90.0	Example 23

[0045] It can be seen from Table 3 that Nos. 6 to 28, in which limestone-based raw material and coke powder were coated on the circumference of each core formed of iron ore raw material according to the present disclosure, were all improved in reducibility (JIS-RI) over Nos. 1, 3, and 5, in which iron ore raw material, SiO_2-containing raw material, limestone-based raw material, and coke powder were mixed simultaneously. Moreover, Nos. 6 to 28 differ from Nos. 2 and 4, in which limestone-based raw material and coke powder were also coated on the circumference of each core formed of iron ore raw material, in that Nos. 6 to 28 contained high-alkaline iron ore in each core formed of the iron ore raw material. This difference contributes to improved reducibility.

Claims

1. A quasiparticle for sintering comprising, at least, iron ore raw material, limestone-based raw material, and solid fuel-based raw material, each being used to produce sintered ore for blast furnaces,
   wherein the iron ore raw material forms a core of the quasiparticle, and the limestone-based raw material and the solid fuel-based raw material are coated on the circumference of the core, and
   wherein the core formed of the iron ore raw material contains high-alkaline iron ore having an alkali metal content of 0.05 mass% or more.

2. The quasiparticle for sintering according to claim 1, wherein the core formed of the iron ore raw material comprises:

   a first layer that is formed of general iron ore having an alkali metal content of less than 0.05 mass%; and
   a second layer that is formed of the high-alkaline iron ore having an alkali metal content of 0.05 mass% or more and that covers the surface of the first layer.

3. The quasiparticle for sintering according to claim 1, wherein the core formed of the iron ore raw material comprises:

   a first layer that is formed of the high-alkaline iron ore having an alkali metal content of 0.05 mass% or more; and
   a second layer that is formed of the general iron ore having an alkali metal content of less than 0.05 mass% and that covers the surface of the first layer.

4. The quasiparticle for sintering according to any one of claims 1 to 3, wherein the iron ore raw material contains the high-alkaline iron ore having an alkali metal content of 0.05 mass% or more in an amount of 20 mass% or more.

5. The quasiparticle for sintering according to any one of claims 1 to 4, wherein the high-alkaline iron ore having an alkali metal content of 0.05 mass% or more has a mean particle size of 2 mm or more, and the general iron ore having an alkali metal content of less than 0.05 mass% has a mean particle size of less than 2 mm.

6. The quasiparticle for sintering according to any one of claims 1 to 5, wherein the alkali metal content of the high-alkaline iron ore having an alkali metal content of 0.05 mass% or more is 0.30 mass% or less.

7. The quasiparticle for sintering according to any one of claims 1 to 6, wherein the limestone-based raw material and the solid fuel-based raw material are coated layer-by-layer on the circumference of the core.

8. The quasiparticle for sintering according to any one of claims 1 to 7, wherein a mixed layer of the limestone-based raw material and the solid fuel-based raw material is coated on the circumference of the core.

9. A method of producing a quasiparticle for sintering, the method comprising:

   when mixing and granulating, at least, iron ore raw material, limestone-based raw material, and solid fuel-based raw material, each being used to produce sintered ore for blast furnaces,

      mixing and granulating the iron ore raw material containing high-alkaline iron ore having an alkali metal content of 0.05 mass% or more to obtain a granulated particle; and
      causing the limestone-based raw material and the solid fuel-based raw material to be adhered to the granulated particle and, subsequently, performing granulation.

10. A method of producing a quasiparticle for sintering, the method comprising:

when mixing and granulating, at least, iron ore raw material, limestone-based raw material, and solid fuel-based raw material, each being used to produce sintered ore for blast furnaces,

mixing and granulating general iron ore having an alkali metal content of less than 0.05 mass% and SiO_2-containing raw material to form a first layer;
causing high-alkaline iron ore having an alkali metal content of 0.05 mass% or more to be adhered to the surface of the first layer, and subsequently performing granulation to form a second layer; and
causing the limestone-based raw material and the solid fuel-based raw material to be adhered to the surface of the second layer and, subsequently, performing granulation.

11. A method of producing a quasiparticle for sintering, the method comprising:

when mixing and granulating, at least, iron ore raw material, limestone-based raw material, and solid fuel-based raw material, each being used to produce sintered ore for blast furnaces,

mixing and granulating high-alkaline iron ore having an alkali metal content of 0.05 mass% or more to form a first layer;
causing general iron ore having an alkali metal content of less than 0.05 mass% to be adhered to the surface of the first layer, and subsequently performing granulation to form a second layer; and
causing the limestone-based raw material and the solid fuel-based raw material to be adhered to the surface of the second layer and, subsequently, performing granulation.

12. The method of producing a quasiparticle for sintering according to any one of claims 7 to 11, wherein the high-alkaline iron ore having an alkali metal content of 0.05 mass% or more has a mean particle size of 2 mm or more, and the general iron ore having an alkali metal content of less than 0.05 mass% has a mean particle size of less than 2 mm.

13. The method of producing a quasiparticle for sintering according to any one of claims 7 to 12, wherein mixed powder of the limestone-based raw material and the solid fuel-based raw material is adhered and, subsequently, granulation is performed.

14. The method of producing a quasiparticle for sintering according to any one of claims 7 to 12, wherein after the adhering of the limestone-based raw material, the solid fuel-based raw material is adhered to an outer surface of a layer of the limestone-based raw material and, subsequently, granulation is performed.

FIG. 1

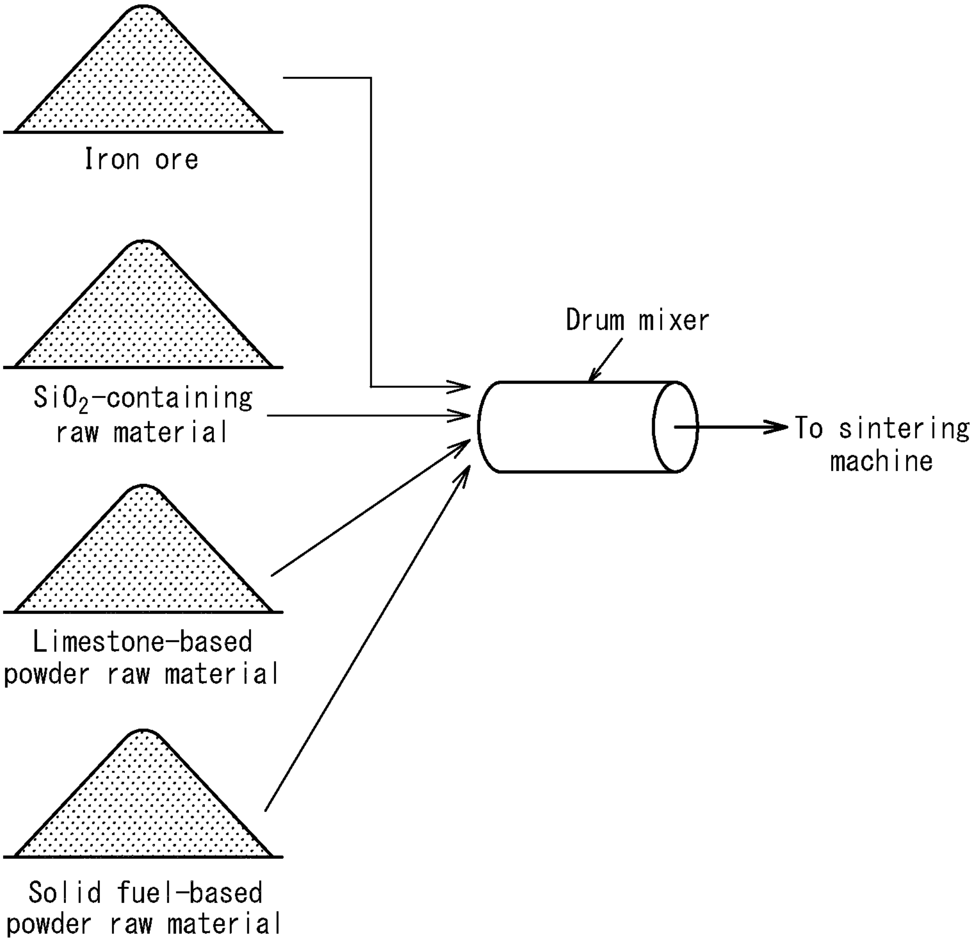

Iron ore
SiO_2-containing raw material
Limestone-based powder raw material
Solid fuel-based powder raw material
Drum mixer
To sintering machine

FIG. 2

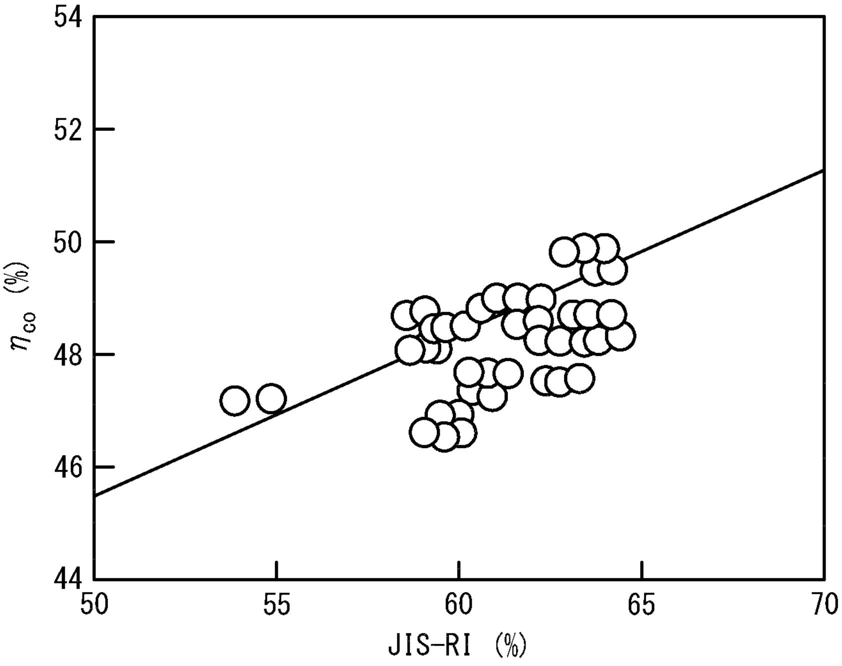

54
52
50
48
46
44
η_{co} (%)
50
55
60
65
70
JIS-RI (%)

FIG. 3

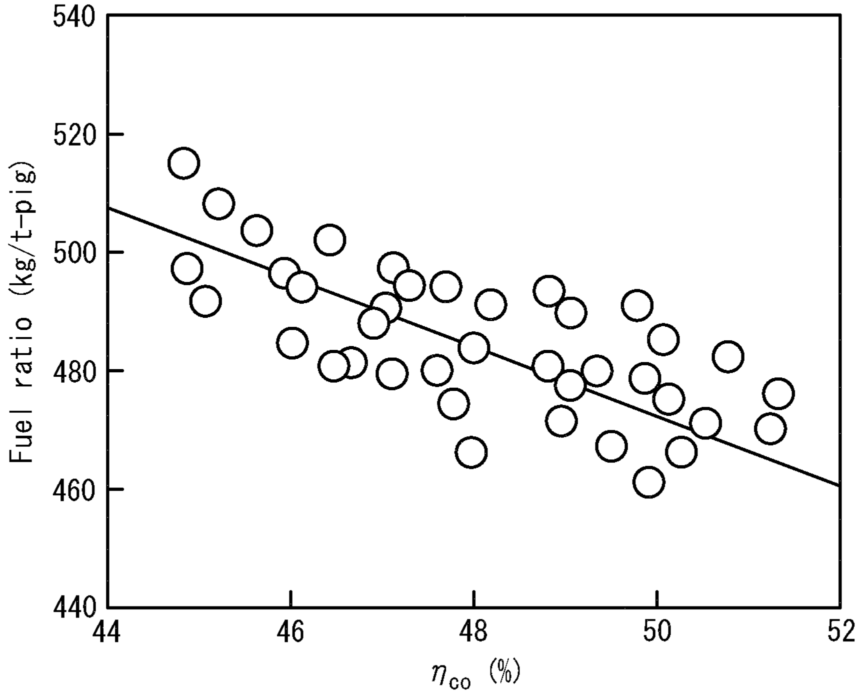

540
520
500
480
460
440
Fuel ratio (kg/t-pig)
44
46
48
50
52
η_{co} (%)

FIG. 4

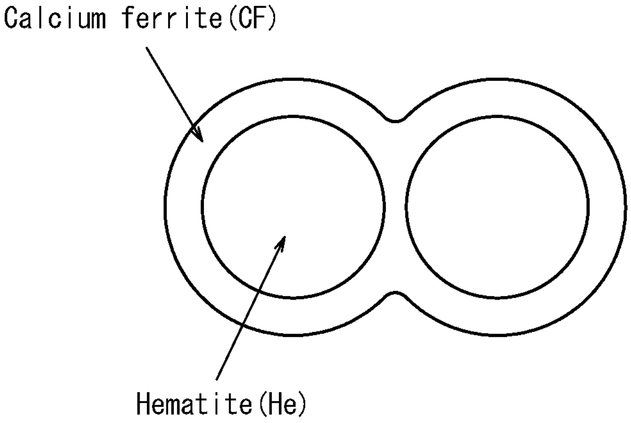

Calcium ferrite(CF)
Hematite(He)

FIG. 5

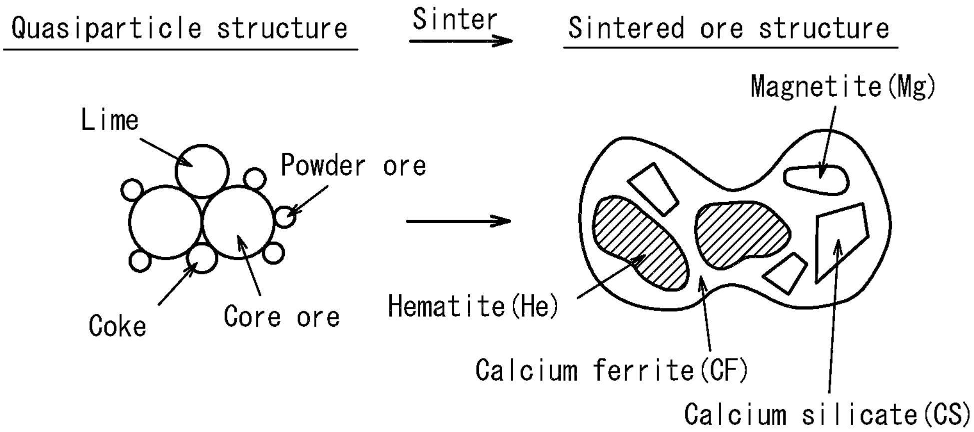

Quasiparticle structure
Sinter
Sintered ore structure
Lime
Powder ore
Coke
Core ore
Magnetite(Mg)
Hematite(He)
Calcium ferrite(CF)
Calcium silicate(CS)

FIG. 6

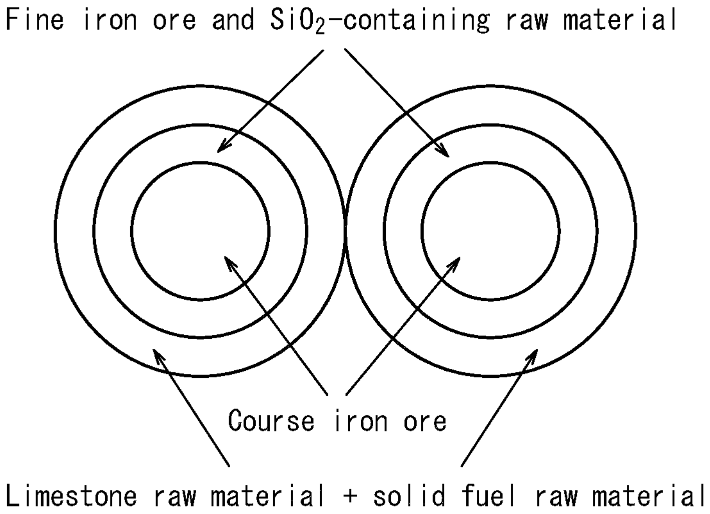

Fine iron ore and SiO_2-containing raw material
Course iron ore
Limestone raw material + solid fuel raw material

FIG. 7

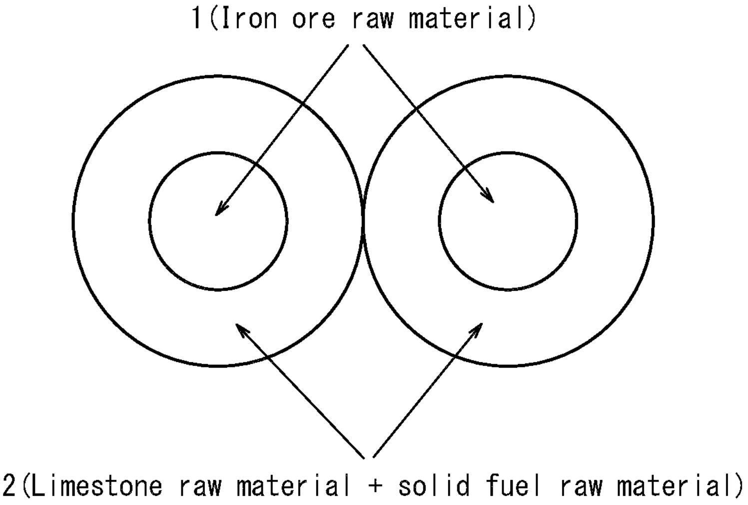

1(Iron ore raw material)
2(Limestone raw material + solid fuel raw material)

FIG. 8

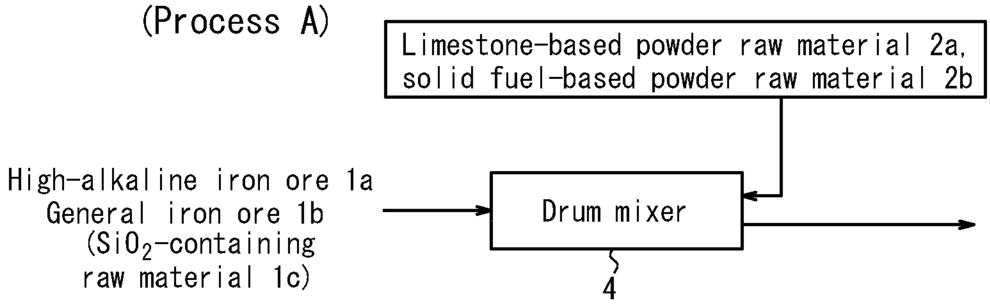


FIG. 9

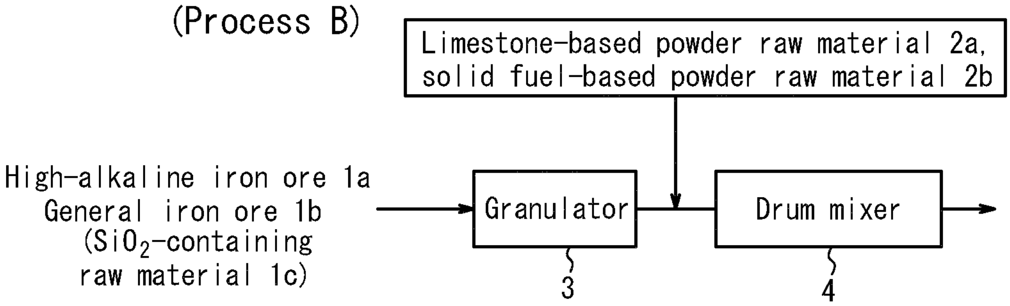
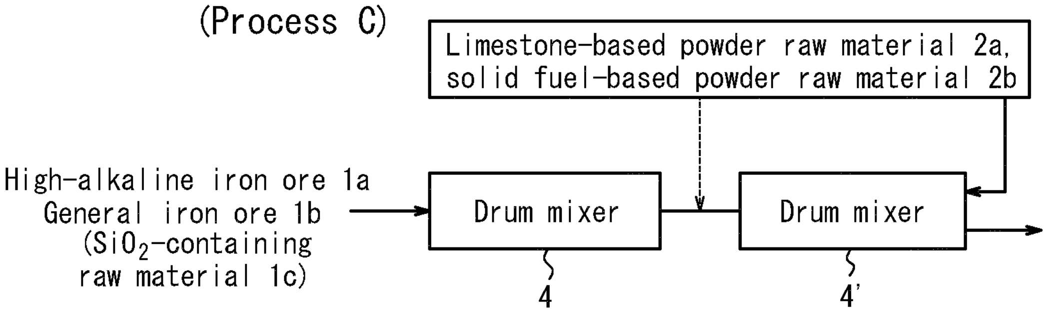


FIG. 10



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/001243

A. CLASSIFICATION OF SUBJECT MATTER
C22B1/16(2006.01)i, *C22B1/243*(2006.01)i

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, C22B1/243

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

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.
A	JP 2002-322514 A (Nippon Steel Corp.), 08 November 2002 (08.11.2002), all pages; all drawings & WO 2002/066688 A1 & EP 1367141 A1	1-14
A	JP 2003-147370 A (NKK Corp.), 21 May 2003 (21.05.2003), all pages; all drawings (Family: none)	1-14

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Date of the actual completion of the international search 29 May 2015 (29.05.15)	Date of mailing of the international search report 09 June 2015 (09.06.15)
Name and mailing address of the ISA/ Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- WO 2001092588 A **[0009] [0010]**