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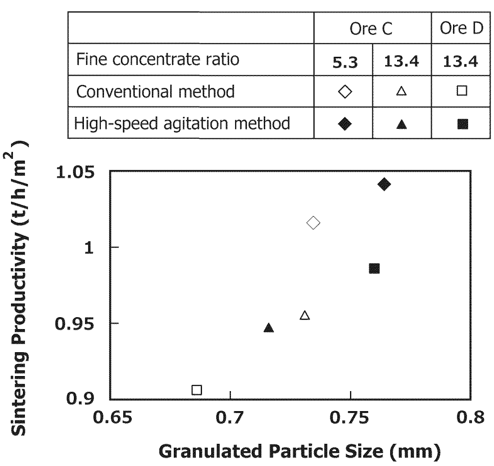
(54) METHOD FOR PRODUCING GRANULATED STARTING MATERIAL FOR SINTERING, AND METHOD FOR PRODUCING SINTERED ORE

(57) There is established a more advanced technology for producing a granulated raw material for sintering by exploring optimization of agitation conditions (energy of agitation) taking into account the varying properties of iron ore (due to pulverization etc.), and proposed a method for improving the manufacturability of sintered ore by using a granulated raw material obtained by adopting that method. There are provided a method for producing a granulated raw material for sintering characterized in that, in producing a granulated raw material for sintering by performing high-speed agitation and then granulation of a blended raw material for sintering, an agitation power for the high-speed agitation is adjusted according to a particle size distribution of an iron-containing raw material in the blended raw material for sintering, and a method for producing sintered ore using that method.

[Fig. 2]



EP 4 506 475 A1

Description

Technical Field

[0001] The present invention relates to a method for producing a granulated raw material for sintering that is used in a DL-type sintering machine etc., and to a method for producing sintered ore that uses that production method.

Background Art

[0002] Sintered ore is produced as follows: a blended raw material for sintering in which powdery iron ores (typically what are called sinter feeds of about 125 to 1000 μm) of some brands are mixed with appropriate amounts of auxiliary raw material powders such as limestone, silica, and serpentinite, miscellaneous raw material powders such as dust, scale, and returned ore, and solid fuels such as coke breeze is mixed with water added and then granulated, and the obtained granulated raw material is charged into a sintering machine and fired.

[0003] Generally, when water is included into a blended raw material for sintering, the material agglomerates and forms quasi-particles during granulation. It is known that when charged onto a pallet of a DL sintering machine, this granulated raw material for sintering turned into quasi-particles serves to secure favorable permeability in a layer of the charged sintering raw material and allows smooth progress of a sintering reaction. During the sintering reaction, water in the heated granulated raw material particles evaporates and the granulated raw material particles on a downwind side come to have a high water content, which leads to the formation of a region with reduced strength (wet zone). In this wet zone, the particles of the granulated raw material tend to break apart, thereby hindering the flow and deteriorating the gas permeability in the layer of the charged raw material.

[0004] Meanwhile, in recent years, iron ore has been made increasingly finer, and granulated particles produced using fine iron ore are known to have low strength. In particular, when water is added to fine iron ore, the strength decreases significantly, resulting in a reduced gas permeability. Moreover, fine iron ore sometimes makes granulation difficult in production of a granulated raw material for sintering. Under these circumstances surrounding sintering iron ore powder, technologies for producing high-quality sintered ore using iron ore that contains a large amount of fine powder and is difficult to granulate have recently been proposed.

[0005] For example, one of such conventional technologies is a hybrid pelletized sinter method (HPS method) as described in Patent Literature 1. This technology aims to produce fired agglomerated ore having a low slag ratio and high reducibility by granulating fine iron ore with a high iron content using a drum mixer and a pelletizer. However, this technology faces a problem that granulating a large amount of fine iron ore requires installing a large number of pelletizers, which adds to the production cost.

[0006] Next, methods have been proposed in which, before a granulation step of blended raw material for sintering powder, a raw material including fine iron ore is pre-processed or granulated using a high-speed-rotation mixer. Specifically, as such methods, a method in which fine iron ore and iron-making dust are pre-mixed by an agitating mixer before the granulation step and subsequently granulated by that agitating mixer, and a method in which a sintering raw material composed mainly of fine powder is agitated by an agitation machine and then granulated using a granulator have been proposed (Patent Literatures 2 and 3). However, these methods face a problem that, as the granulated particles are composed mainly of fine raw material, the strength of the granulated particles is reduced compared with when nuclear particles (iron ore) having higher strength than granulated particles are used.

[0007] Next, methods have been proposed in which a sintering raw material in which fine powder and sinter feed are blended is subjected to a premixing process using an Eirich mixer and then granulated by a drum mixer (Patent Literatures 4 to 6). In these methods, however, there is a concern that when the ratio of fine powder increases, the layer of adherent powder becomes excessive, which may degrade the combustibility of granulated particles. Another problem is that due to a lack of nuclear particles, the granulation property degrades and firing is performed while granulation is incomplete.

[0008] Next, technologies for processing hard-to-granulate ore containing fine powder as well as a large amount of crystallization water (Patent Literatures 7 to 9) have been proposed. However, these prior technologies have a problem that a large amount of water evaporates from highly crystalline ore during sintering, which makes it difficult to prevent an increase in pressure loss in the wet zone. Moreover, these methods have another problem that the pressure loss in the wet zone is likely to increase even more when fine iron ore prone to a decrease in the strength of granulated particles is used in a large amount.

[0009] Further, as to a method of using high-speed agitation when using fine powder, granulation methods taking into account agitation conditions and a device size as well as the properties of ore, such as core ore, have been proposed (Patent Literatures 10 and 11). In actuality, however, the proposals disclosed in these literatures have not gone so far as to study the agitation conditions according to the properties of ore.

Citation List

Patent Literature

[0010]

Patent Literature 1: JP-A-S62-37325
Patent Literature 2: JP-A-H01-312036
Patent Literature 3: JP-A-2007-247020
Patent Literature 4: JP-A-H11-061282
Patent Literature 5: JP-A-H07-331342
Patent Literature 6: JP-A-H07-48634
Patent Literature 7: JP-A-2005-194616
Patent Literature 8: JP-A-2006-63350
Patent Literature 9: JP-A-2003-129139
Patent Literature 10: International Publication No. WO 2017/094255
Patent Literature 11: International Publication No. WO 2017/150428

Summary of Invention

Technical Problem

[0011] Therefore, the present invention aims to establish a technology that can overcome the problems faced by the above-described conventional technologies. In particular, the present invention establishes a more advanced technology for producing a granulated raw material for sintering by exploring optimization of agitation conditions (energy of agitation) taking into account the properties of iron ore that vary on a daily basis (due to pulverization etc.), and proposes a method for improving the manufacturability of sintered ore by using a granulated raw material obtained by adopting that method.

Solution to Problem

[0012] While vigorously examining the problems faced by the above-described conventional technologies, the present inventors continued research with a focus on the properties of iron ore, particularly the adhesiveness of a pulverized part. It turned out that in the case of iron ore of which fine powder had poor adhesiveness, performing agitation to a greater degree or not performing the agitation process could maximally exploit the operational effect of high-speed agitation. On the other hand, it was noted that in the case of iron ore with low adhesiveness, applying low agitation energy could exploit the effect of high-speed agitation. Here, the agitation energy cannot be estimated from the circumferential velocity of a blade or the length of the blade, but varies depending on mechanical conditions including a water content relevant to the stickiness of a raw material, the type of mineral, and at which height and position the raw material hits the blade, which makes the estimation anything but easy.

[0013] In particular, it was found that the problems faced by the conventional technologies could be controlled by focusing attention on an index that takes into account the particle size distribution of iron ore itself, i.e., a size distribution index (SDI). It was therefore decided to determine the energy to be applied during agitation of a blended raw material for sintering based on this index (SDI) so as to maximize the productivity of a granulated raw material for sintering and sintered ore.

[0014] Thus, the present invention proposes a method for producing a granulated raw material for sintering characterized in that, in producing a granulated raw material for sintering by performing high-speed agitation and then granulation of a blended raw material for sintering, an agitation power for the high-speed agitation is adjusted according to a particle size distribution of an iron-containing raw material in the blended raw material for sintering.

[0015] In addition, the present invention proposes a method for producing sintered ore characterized in that a granulated raw material for sintering produced based on this method for producing a granulated raw material for sintering is charged into a sintering machine and sintered.

[0016] In the present invention, embodiments adopting the following would be more preferable:

(1) In the high-speed agitation of the blended raw material for sintering, the agitation power is adjusted based on a size distribution index (SDI) of the following Formula (1):

$$SDI = \left(\frac{W_{fS}}{100d_S} - \frac{W_{fL}}{100d_L}\right) \times W_{io500}/100 \quad \cdot\cdot\cdot \quad (1)$$

where

a ratio of particles up to 500 μm in the iron-containing raw material: W_{io500} (mass%),
a ratio of particles with a particle size of 15 to 500 μm in the iron-containing raw material: W_{fL} (mass%),
a ratio of particles with a particle size smaller than 15 μm in the iron-containing raw material: W_{fS} (mass%),
a mean particle size of the particles with a particle size of 15 to 500 μm in the iron-containing raw material: d_L (mm), and
a mean particle size of the particles with a particle size smaller than 15 μm in the iron-containing raw material: ds (mm).

(2) In the high-speed agitation of the blended raw material for sintering, a blended raw material for sintering of which the size distribution index (SDI) expressed by Formula (1) satisfies a relation SDI > 7 is used.
(3) In the high-speed agitation of the blended raw material for sintering, the high-speed agitation is performed with an agitation power that meets the following Formula (2):

$$0.172 \times \{1 + (1.12SDI - 8.95)\} \times Q > 0 \quad \cdot\cdot\cdot \quad (2)$$

where Q (kWh/t) is obtained by dividing a difference in electricity consumption (kWh) of a rotor of an agitation blade between when under load and when under no load by a weight (t) of the blended raw material for sintering to be subjected to the high-speed agitation (when under load: the blended raw material for sintering is present; when under no load: when operating in an empty state without the blended raw material for sintering).

Advantageous Effects of Invention

[0017] In the present invention, high-speed agitation as a process preceding granulation can be appropriately performed, which makes it possible to get closer to a more completely mixed state and thereby improve the so-called granulation property after high-speed agitation. This in turn makes it possible to increase the production of sintered ore.

Brief Description of Drawings

[0018]

[Fig. 1] Fig. 1 is a view showing a relationship between agitation energy and a granulated particle size.
[Fig. 2] Fig. 2 is a view showing a relationship between the granulated particle size and sintering productivity.
[Fig. 3] Fig. 3 is a view showing a relationship between a size distribution index and an influence coefficient.
[Fig. 4] Fig. 4 is a view showing a relationship between the agitation energy and an increase value of the granulated particle size.

Description of Embodiments

[0019] First, the present inventors studied the physical properties of an adherent powder layer to enhance the operational effect of high-speed agitation as a process preceding granulation. As a result, when the adhesiveness of adherent powder was poor, particles that had already adhered to one another ended up separating from one another due to high-speed agitation, which necessitated an additional time for the subsequent granulation process. On the other hand, in the case of adherent powder with high adhesiveness, when in a completely mixed state, the particles had high adhesiveness and promoted granulation; however, when not mixed, the particles are not optimized in terms of the particle size distribution and are less likely to grow in particle size during granulation. This finding led us to develop the present invention.
[0020] In the following, an example of implementation that was conducted to confirm the effects of the present invention will be described. In a study according to this example of implementation, first, a blended raw material for sintering including an iron-containing raw material was subjected to high-speed agitation and subsequently granulated by a drum mixer to produce a granulated raw material for sintering. Thereafter, this granulated raw material was sintered by a DL sintering machine, and an improving effect on the production rate of the resulting sintered ore was examined.
[0021] Table 1 shows the compositions of raw materials in this case. In this test, as the iron-containing raw materials,

three brands, namely, a sinter feed, an ore C that is ore concentrate, and an ore D that is a pellet feed, were used at varied blending ratios. A test using a base composition with increased ratios of the ores C and D that are fine concentrates was conducted, and a test in which each fine concentrate was blended up to a 15 mass% level was performed. Being a pellet feed, the ore D is extremely fine compared with the ore C and enables evaluation on the influence of fine powder. While a pellet feed (ore D) is used as the pulverized iron-containing raw material here, dust may instead be used that is generated in an iron-making process and includes particles with a particle size smaller than 15 μm like a pellet feed (ore D).

[Table 1]

Sample No.	Case 1	Case 2	Case 3	Case 4
Sinter feed	78.0	73.4	65.0	65.0
Fine concentrate: ore C	0.0	5.3	13.4	0.0
Pellet feed: ore D	0.0	0.0	0.0	13.4
Dolomite	7.6	6.8	7.1	6.9
Mill scale	1.9	2.2	2.2	2.2
Limestone	11.5	11.1	10.6	10.9
Quicklime	1.0	1.1	1.1	1.1
Total	100	100	100	100
Coke breeze	4.5	4.4	4.4	4.4

[0022] To evaluate the performance of a high-speed agitator, this test looked at changes in the granulated particle size relative to a retention time (agitation time) inside the high-speed agitator. This agitation machine is used for continuous operation; therefore, the retention time: T (sec) is determined by a ratio between an amount of raw material fed: M_f (t/sec) and a load capacity: M_{in} (t) as shown in Formula (3) below.

$$T = \frac{M_{in}}{M_f} \quad \cdot \cdot \cdot \quad (3)$$

[0023] To evaluate the agitation energy applied to the raw material to be agitated, the electricity consumption of a rotor of an agitation blade attached to the high-speed agitator was measured. The electricity taken for the raw material was obtained by subtracting the value of electricity when no raw material was charged (when operating in an empty state) from the electricity when the raw material was charged under each condition, and the amount of electricity consumption was calculated from that electricity and the retention time in Formula (3) above. A value obtained by dividing this amount of electricity consumption by the load capacity is the amount of electricity consumption added per unit raw material, and this amount was defined as agitation energy per unit raw material.

[0024] Fig. 1 shows a relationship of the ores C and D with the granulated particle size relative to the agitation energy per unit raw material in an actual agitation machine. As shown in this view, when there was no fine concentrate, the granulated particle size increased as the agitation energy increased. When the ore C that is concentrate was 5.3 mass%, the granulated particle size increased somewhat by the high-speed agitation method, but when the ore C was added in as large an amount as 13.4 mass%, the granulated particle size decreased conversely. On the other hand, when the ore D that is a pellet feed was added in as large an amount as 13.4 mass%, the granulated particle size increased significantly by the high-speed agitation method.

[0025] Fig. 2 shows a relationship between the granulated particle size and sintering productivity when a fine concentrate was mixed in a test using an actual machine. As shown in this view, it was found that regardless of which of the ores C and D was increased, compared with a case in which granulation was performed with the ore C blended at a ratio of 5.3 mass% and which constitutes a base condition (conventional method), the granulated particle size became smaller and the sintering production rate decreased in both of the conventional method and the high-speed agitation method. On the other hand, when attention is focused on the effect of pre-processing by high-speed agitation, a comparison between the case where the ore C was blended at a ratio of 5.3 mass% by high-speed agitation and by the conventional method shows that the sintering production rate increased by 0.03 t/h/m^2 from 1.01 to 1.04 t/h/m^2 by high-speed agitation. When the ore C was 13.4 mass%, the influence of the high-speed agitation method was smaller. On the other hand, when the ore D that is a pellet feed was added, compared with when agitation was not performed, the production rate was increased by 0.07 t/h/m^2 from 0.92 to 0.99 t/h/m^2 by the high-speed agitation method.

[0026] From these results of implementation, while it has been believed that when a fine concentrate of fine powders is used in a sintering process in an actual machine, a decrease in the sintering productivity due to a decrease in the granulated particle size is unavoidable, but the above-described results demonstrate that introducing the high-speed agitation method according to the present invention can prevent a decrease in the granulated particle size and improve the sintering productivity.

[0027] Next, to quantitatively clarify the effect of high-speed agitation that is characteristic of the method for producing a granulated raw material for sintering according to the present invention, a study was conducted on the influence of the agitation energy on an increase value of the granulated particle size. As a result, it can be said that under the same conditions of the type of fine concentrate and the ratio of addition, the increase value of the granulated particle size is a value obtained by subtracting the granulated particle size in the conventional method from the granulated particle size in the high-speed agitation method. Therefore, first, the increase value of the granulated particle size in the high-speed agitation method using a raw material containing 0 mass% fine concentrate was evaluated. Specifically, the increase value of the granulated particle size in the high-speed agitation method under a condition of 0 mass% fine concentrate was denoted by $\Delta D(Q)$ (mm), and the agitation energy was expressed as a function of Q (kWh/t). When a relationship between Q and $\Delta D(Q)$·is obtained as a function based on Fig. 1, the following Formula (4) is obtained:

$$\Delta D(Q) = 0.172\,Q \quad \cdot\cdot\cdot \quad (4)$$

[0028] Further, to evaluate the influence of the type of fine concentrate on the increase value ΔD_p (mm) of the granulated particle size under any conditions of the type of fine concentrate and the amount of addition shown in Fig. 2, an influence coefficient α was defined from Formula (4) for each type of fine concentrate. Thus, the following Formula (5) was obtained:

$$\alpha = \left(\Delta D\mathrm{p} - \Delta D(Q)\right)/\Delta D(Q) \quad \cdot\cdot\cdot \quad (5)$$

[0029] It is presumed that, with 15 μm as a borderline, ultra-fine particles smaller than that particle size increase the adhesiveness between ores while particles larger than that particle size reduce the adhesiveness (S. Kawachi, S. Kasama: Tetsu-to-Hagane, 94 (2008), 475). Based on this idea, a size distribution index (SDI) is newly defined using a ratio of particles up to 500 μm in iron ore that is considered to be adherent powder: W_{io500} (mass%), a ratio of particles with a particle size of 15 to 500 μm in an iron-containing raw material: W_{fL} (mass%), a ratio of particles up to 15 μm: W_{fS} (mass%), a mean particle size of the particles with a particle size of 15 to 500 μm: d_L (mm), and a mean particle size of the particles with a particle size up to 15 μm: ds (mm).

[0030] Here, as the mean diameter of particle sizes 15 to 500 μm, 87 μm that is a geometric mean of 15 μm and 500 μm was used, and as that of particle sizes up to 15 μm, 4 μm that is a geometric mean of 1 μm and 15 μm was used. In the following Formula (6), the reason why the weight ratios of the particles are divided by their respective mean particle sizes d_L and ds is to reflect the influence of the specific surface areas of the particles that are considered to have an influence on the adhesiveness.

$$SDI = \left(\frac{W_{\mathrm{fS}}}{100d_{\mathrm{S}}} - \frac{W_{\mathrm{fL}}}{100d_{\mathrm{L}}}\right) \times W_{io500}/100 \quad \cdot\cdot\cdot \quad (6)$$

[0031] In the present invention, the particle size is the size of particles as sifted using a sieve with a nominal opening size complying with Japanese Industrial Standards (JIS) Z 8801-1. For example, a particle size of 1 mm or less means such a particle size that all the particles pass through a sieve with a nominal opening size of 1 mm complying with JIS Z 8801-1, and is also written as - 1 mm. The smallest value of the nominal opening size specified by Japanese Industrial Standards (JIS) Z 8801-1 is 20 μm. A particle size smaller than that, for example, 15 μm or less means such a particle size that a cumulative fraction of particles with a size of 15 μm or less that is obtained by a laser diffraction and scattering method complying with JIS Z 8825 or a gravitational liquid sedimentation method complying with JIS Z8820-2 is substantially 100%.

[0032] Next, using the data shown in Fig. 2, the following Formula (7) is obtained from an analysis result obtained from a relationship between the influence coefficient α in Formula (5) and the size distribution index SDI in Formula (6). This relationship is shown in Fig. 3.

$$\alpha = 1.12SDI - 8.95 \quad \cdot\cdot\cdot \quad (7)$$

[0033] As shown in Fig. 3, it can be seen that there is a clear positive correlation between the size distribution index SDI and the influence coefficient α. This means that the larger the size distribution index SDI is, the larger the increase value ΔD_p of the granulated particle size by the high-speed agitation method. These results demonstrate that, to increase the granulated particle size by high-speed agitation, it is effective to increase the ratio of particles up to 15 μm in fine concentrates while reducing the ratio of particles of 15 to 500 μm. As to the effect of adding particles up to 15 μm, it is presumed that these particles are evenly dispersed among raw material particles during high-speed agitation and consequently exert an adhesiveness improving effect.

[0034] On the other hand, it is conjectured that particles of 15 to 500 μm have low adhesiveness and cannot keep particles connected to one another, and rather act to hinder the particles from adhering to one another during granulation.

[0035] Next, when ΔD_p (the increase value of the granulated particle size) is solved from Formula (5) and Formula (7) above, the following Formula (8) is obtained.

$$\Delta D_P = (1+\alpha)\cdot \Delta D(Q) = \left(1+(1.12SDI-8.95)\right)\cdot \Delta D(Q) \quad \cdot\cdot\cdot \quad (8)$$

[0036] Next, Fig. 4 shows a result of calculating an influence on the increase value: ΔD_p of the granulated particle size using the size distribution index SDI and the agitation energy Q as parameters. From Fig. 4, it can be seen that when the SDI is the same, the increase value ΔD_p of the granulated particle size becomes larger as the agitation energy (kWh/t) applied to the raw material becomes higher, and that when the agitation energy is the same, the increase value ΔD_p of the granulated particle size becomes larger as the SDI becomes larger. Therefore, in the case where the ratio of particles of 15 to 500 μm that reduce adhesiveness is increased and the SDI is reduced as in the case where concentrate is blended, producing the same particle size increasing effect requires higher agitation energy. Conversely, in the case where the ratio of particles up to 15 μm is increased and the SDI is increased as in the case where a pellet feed is blended, applying relatively low agitation energy can produce the granulation property improving effect by the high-speed agitation method.

[0037] These results demonstrate that, to maintain the granulation property when using a large amount of pulverized ore in producing a granulated raw material for sintering, it is important to perform high-speed agitation with a pellet feed preferentially blended in a large amount. It is presumed that this has an effect of improving the filling property and improving the adhesiveness of granulated particles as the pellet feed in the adherent powder layer is mixed to a greater degree.

Industrial Applicability

[0038] The present invention is applicable as a technology for granulating and agglomerating not only granulated raw materials for sintering but also other iron-making raw materials.

Claims

1. A method for producing a granulated raw material for sintering,
characterized in that,
in producing a granulated raw material for sintering by performing high-speed agitation and then granulation of a blended raw material for sintering, a power for the high-speed agitation is adjusted according to a particle size distribution of an iron-containing raw material in the blended raw material for sintering.

2. The method for producing a granulated raw material for sintering according to claim 1, wherein,
in the high-speed agitation of the blended raw material for sintering, the agitation power is adjusted based on a size distribution index (SDI) of the following Formula (1):

$$SDI = \left(\frac{W_{\mathrm{fS}}}{100d_{\mathrm{S}}} - \frac{W_{\mathrm{fL}}}{100d_{\mathrm{L}}}\right) \times W_{io500}/100 \quad \cdot\cdot\cdot \quad (1)$$

where

a ratio of particles up to 500 μm in the iron-containing raw material: W_{io500} (mass%),
a ratio of particles with a particle size of 15 to 500 μm in the iron-containing raw material: W_{fL} (mass%),
a ratio of particles with a particle size smaller than 15 μm in the iron-containing raw material: W_{fS} (mass%),
a mean particle size of the particles with a particle size of 15 to 500 μm in the iron-containing raw material: d_L (mm), and
a mean particle size of the particles with a particle size smaller than 15 μm in the iron-containing raw material: ds (mm).

3. The method for producing a granulated raw material for sintering according to claim 2, wherein, in the high-speed agitation of the blended raw material for sintering, a blended raw material for sintering of which the size distribution index (SDI) expressed by Formula (1) satisfies a relation SDI > 7 is used.

4. The method for producing a granulated raw material for sintering according to any one of claims 1 to 3, wherein,

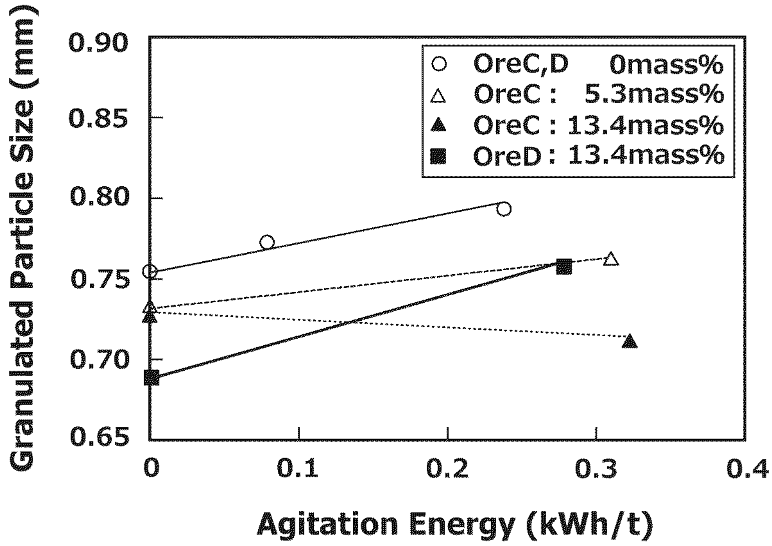
in the high-speed agitation of the blended raw material for sintering, the high-speed agitation is performed with an agitation power that meets the following Formula (2):

$$0.172 \times \{1 + (1.12SDI - 8.95)\} \times Q > 0 \quad \cdot\cdot\cdot \quad (2)$$

where Q (kWh/t) is obtained by dividing a difference in electricity consumption (kWh) of a rotor of an agitation blade between when under load and when under no load by a weight (t) of the blended raw material for sintering to be subjected to the high-speed agitation (when under load: the blended raw material for sintering is present; when under no load: when operating in an empty state without the blended raw material for sintering).

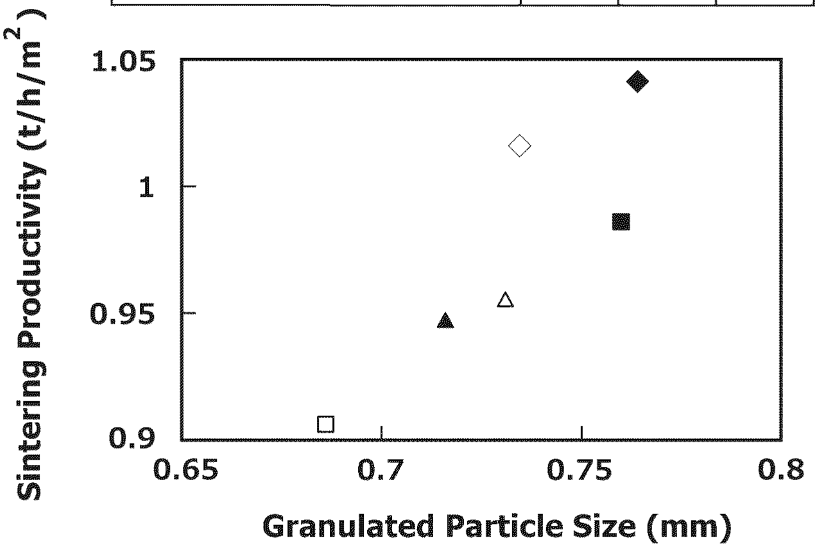
5. A method for producing sintered ore,
characterized in that
a granulated raw material for sintering produced based on the method for producing a granulated raw material for sintering according to claim 4 is charged into a sintering machine and sintered.

[Fig. 1]

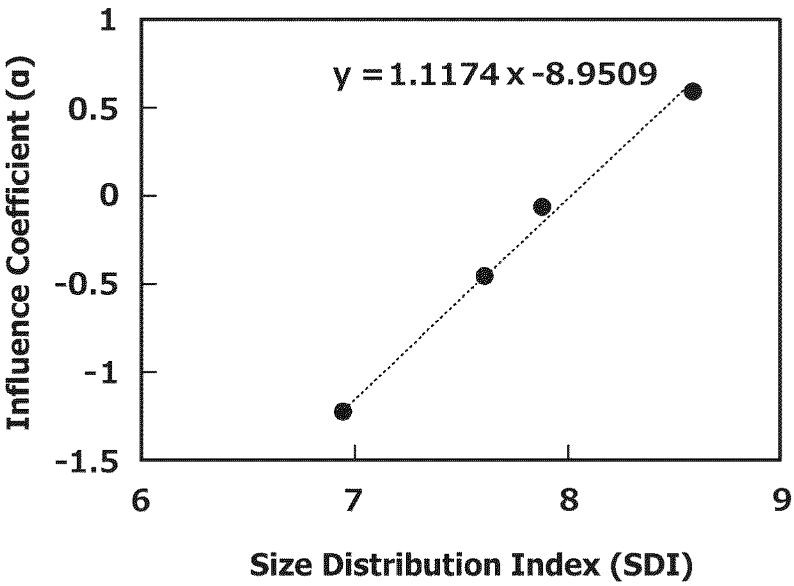


[Fig. 2]

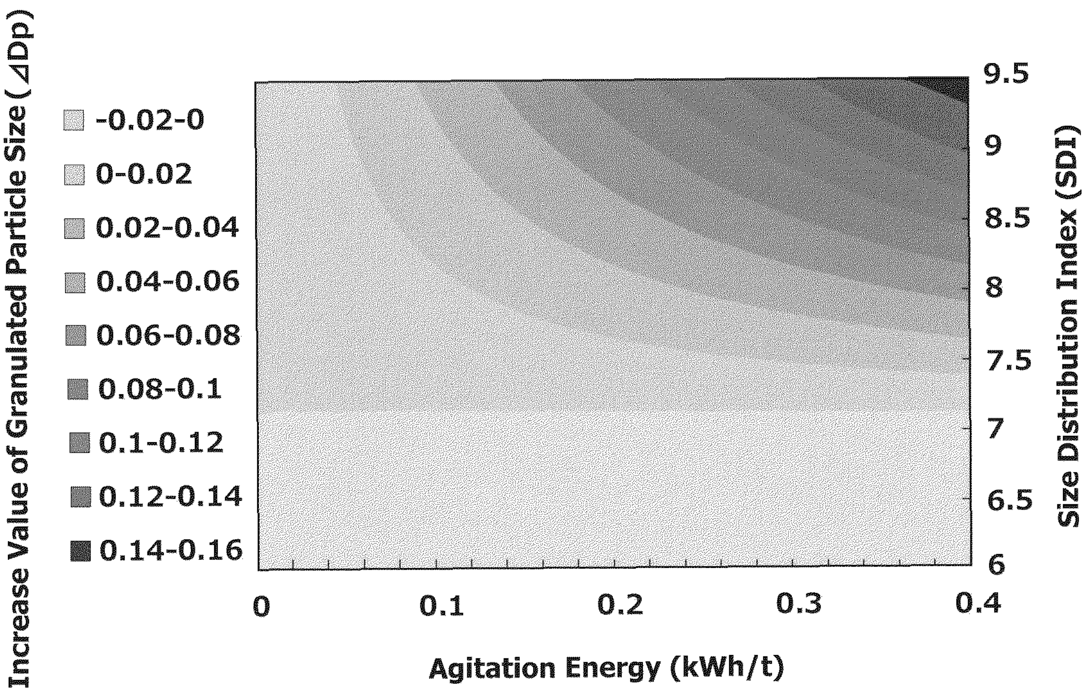
	Ore C		Ore D
Fine concentrate ratio	5.3	13.4	13.4
Conventional method	◇	△	□
High-speed agitation method	◆	▲	■



[Fig. 3]


y = 1.1174 x - 8.9509
Influence Coefficient (a)
1
0.5
0
-0.5
-1
-1.5
6
7
8
9
Size Distribution Index (SDI)

[Fig. 4]


Increase Value of Granulated Particle Size (⊿Dp)
-0.02-0
0-0.02
0.02-0.04
0.04-0.06
0.06-0.08
0.08-0.1
0.1-0.12
0.12-0.14
0.14-0.16
9.5
9
8.5
8
7.5
7
6.5
6
Size Distribution Index (SDI)
0
0.1
0.2
0.3
0.4
Agitation Energy (kWh/t)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/016288

A. CLASSIFICATION OF SUBJECT MATTER

C22B 1/16(2006.01)i
FI: C22B1/16 K

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

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 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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	WO 2017/026203 A1 (JFE STEEL CORP.) 16 February 2017 (2017-02-16) paragraphs [0008]-[0014], [0024]-[0031]	1
Y		4-5
A		2-3
X	WO 2017/094255 A1 (JFE STEEL CORP.) 08 June 2017 (2017-06-08) paragraphs [0032], [0033], [0041]-[0054]	1
Y		4-5
A		2-3
Y	WO 2013/175601 A1 (JFE STEEL CORP.) 28 November 2013 (2013-11-28) paragraph [0053], fig. 16	4-5
A		2-3

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 July 2023	**25 July 2023**

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.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/016288

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2017/026203 A1	16 February 2017	JP 2017-36480 A	
		CN 107849633 A	
		KR 10-2018-0030596 A	
		TW 201706417 A	
		TR 201801470 T	
WO 2017/094255 A1	08 June 2017	KR 10-2018-0072810 A	
		CN 108291270 A	
WO 2013/175601 A1	28 November 2013	CN 104334756 A	
		KR 10-2014-0147139 A	
		BR 112014028884 A	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP S6237325 A **[0010]**
- JP H01312036 A **[0010]**
- JP 2007247020 A **[0010]**
- JP H11061282 A **[0010]**
- JP H07331342 A **[0010]**
- JP H0748634 A **[0010]**
- JP 2005194616 A **[0010]**
- JP 2006063350 A **[0010]**
- JP 2003129139 A **[0010]**
- WO 2017094255 A **[0010]**
- WO 2017150428 A **[0010]**

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- **S. KAWACHI** ; **S. KASAMA**. *Tetsu-to-Hagane*, 2008, vol. 94, 475 **[0029]**