



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
07.08.2024 Bulletin 2024/32

(21) Application number: **22876452.8**

(22) Date of filing: **29.09.2022**

(51) International Patent Classification (IPC):
C22B 1/16 ^(2006.01) **C21B 5/00** ^(2006.01)
C21C 5/52 ^(2006.01) **C22B 1/14** ^(2006.01)

(52) Cooperative Patent Classification (CPC):
C21B 5/00; C21C 5/52; C22B 1/14; C22B 1/16

(86) International application number:
PCT/JP2022/036451

(87) International publication number:
WO 2023/054588 (06.04.2023 Gazette 2023/14)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **29.09.2021 JP 2021159551**

(71) Applicant: **NIPPON STEEL CORPORATION**
Chiyoda-ku
Tokyo 100-8071 (JP)

(72) Inventor: **MIZUTANI, Moritoshi**
Tokyo 100-8071 (JP)

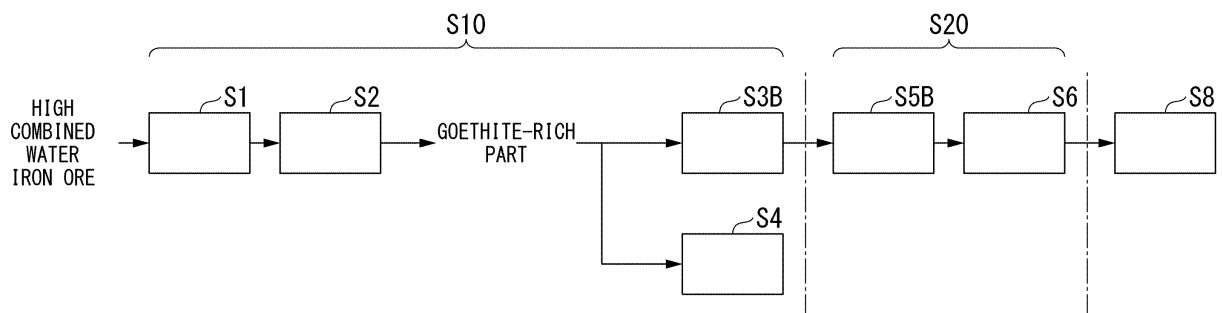
(74) Representative: **Vossius & Partner**
Patentanwälte Rechtsanwälte mbB
Siebertstrasse 3
81675 München (DE)

(54) **IRONMAKING METHOD**

(57) This ironmaking method includes an ore beneficiation step in which a high combined water content iron ore having a loss of ignition of 3 to 12 mass% is beneficiated into a goethite-rich part having at least a loss of ignition of 4 mass% or more and an iron content of 55 mass% or more; a first agglomeration processing step in which the goethite-rich part is agglomerated into first fired

pellets in a pellet induration furnace; and a first reduction step in which the first fired pellets are charged into a shaft furnace while the first fired pellets have a surface temperature of 600°C or higher, and directly reduced using a reducing gas containing 60 volume% or more of hydrogen.

FIG. 1



Description

[Technical Field]

5 **[0001]** The present invention relates to an ironmaking method. Priority is claimed on Japanese Patent Application No. 2021-159551, filed September 29, 2021, the content of which is incorporated herein by reference.

[Background Art]

10 **[0002]** A direct reduction ironmaking method is known as one of ironmaking methods for obtaining iron from raw materials containing iron oxide (reducing iron oxide). The direct reduction ironmaking method has continued to develop based on the background such as low construction cost of plants for performing this method, ease of operation, and operability in small-scale plants. Particularly, in the shaft furnace type direct reduction ironmaking method, various improvements have been made to effectively utilize the reducing gas in the furnace.

15 **[0003]** Furthermore, recently, in order to reduce the carbon dioxide emission amount from the steel industry, the development of direct reduction ironmaking methods in which hydrogen is used as a reducing gas has progressed. As typical examples, HYBRIT and MIDREX+H₂ in which hydrogen obtained by water electrolysis is used in a shaft furnace type direct reduction ironmaking method are known.

20 **[0004]** Reduced iron (hereinafter referred to as direct reduction iron (DRI)) produced by the direct reduction ironmaking method is used as a raw material for blast furnaces or electric furnaces. When DRI is used as a replacement for scrap in an electric furnace, if the metallization degree of DRI is low or the amount of gangue such as SiO₂ or Al₂O₃ is large, the energy consumption rate during electric furnace operation increases and the production cost increases (for example, Non-Patent Document 1). On the other hand, in the blast furnace, since unreduced iron ore, sintered ore, and pellets with large gangue contents are used, even if DRI with a low metallization degree or a high gangue content is used, the
25 energy consumption rate of the blast furnace does not increase. On the other hand, if iron ore, sintered ore, and pellets are replaced with DRI, the energy consumption rate decreases (for example, Non-Patent Document 2).

[Citation List]

30 [Non-Patent Document]

[0005]

[Non-Patent Document 1]

35 Joseph J Poveromo, 2013 World DRI & Pellet Congress, Abu Dhabi, DR Pellet Quality & MENA Applications

[Non-Patent Document 2]

Kunitomo et al., Nippon Steel Technical Report No. 384, P. 121-P. 126

[Summary of the Invention]

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[Problems to be Solved by the Invention]

45 **[0006]** As described above, if the gangue content in DRI is high, the energy consumption rate increases when used in an electric furnace. Therefore, in the direct reduction ironmaking method, DR pellets with a low gangue content are used. DR pellets are produced using iron ore (concentrate) enriched by magnetic separation or gravity separation as raw materials, but DR pellet concentrates can only be produced from raw ore that has favorable gangue separation properties and is produced in specific regions.

50 **[0007]** Iron ore produced in Australia is not beneficiated because it is difficult to separate gangues, and as a result, the gangue content is high. In addition, in recent years, the quality of iron ore raw materials, not just those produced in Australia, has deteriorated. Accordingly, the gangue content of iron ore has increased, and it is estimated that it will become increasingly difficult to produce DR pellets in the future. Here, poor-quality iron ore, including iron ore produced in Australia, contains large amounts of combined water.

55 **[0008]** The present invention has been made in view of the above circumstances and an object of the present invention is to provide a novel and improved ironmaking method in which it is possible to efficiently agglomerate and reduce poor-quality iron ore raw materials.

[Means for Solving the Problem]

[0009] In order to achieve the above object, the gist of the present invention is as follows.

(1) An ironmaking method according to Aspect 1 of the present invention includes an ore beneficiation step in which a high combined water content iron ore having a loss of ignition of 3 to 12 mass% is beneficiated into a goethite-rich part having at least a loss of ignition of 4 mass% or more and an iron content of 55 mass% or more; a first agglomeration processing step in which the goethite-rich part is agglomerated into first fired pellets in a pellet induration furnace; and a first reduction step in which the first fired pellets are charged into a shaft furnace while the first fired pellets have a surface temperature of 600°C or higher, and directly reduced using a reducing gas containing 60 volume% or more of hydrogen.

In Aspect 2 of the present invention, in the ironmaking method according to Aspect 1, the first fired pellets may be directly reduced to a metallization degree of 60% to 95%.

(3) Aspect 3 of the present invention may further include a second agglomeration processing step in which a hematite-rich part is agglomerated into second fired pellets in a pellet induration furnace in the ironmaking method according to Aspect 1 or 2, wherein, in the ore beneficiation step, the hematite-rich part having a loss of ignition of less than 4 mass% and an iron content of 55 mass% or more is additionally beneficiated.

(4) Aspect 4 of the present invention may further include a second reduction step in which the second fired pellets are directly reduced in a shaft furnace using a reducing gas containing 60 volume% or more of hydrogen to produce direct reduction iron having a metallization degree of 90% or more in the ironmaking method according to Aspect 3.

(5) Aspect 5 of the present invention may further include a water washing step in which tailings are removed from the high combined water content iron ore before the ore beneficiation step in the ironmaking method according to any one of Aspects 1 to 4.

[Effects of the Invention]

[0010] According to the above aspects of the present invention, it is possible to efficiently agglomerate and reduce poor-quality iron ore raw materials.

[Brief Description of Drawings]

[0011]

FIG. 1 is a flowchart showing a procedure of an ironmaking method according to the present embodiment.

FIG. 2 is a flowchart showing another procedure of the ironmaking method according to the present embodiment.

[Embodiment(s) for implementing the Invention]

[0012] Hereinafter, the present embodiment will be described in detail with reference to the drawings. Here, when a numerical value range is expressed using "to," the range includes both stated numerical values.

[0013] The percentage (%) of each component of iron ore and the like in the text and tables is mass% with respect to a total mass of iron ore and the like. Here, the iron content is measured according to JIS M 8212: 2005 iron ore total iron determination method. In addition, the loss of ignition (LOI) is regarded as the combined water content. The loss of ignition (LOI) is the mass reduction rate when iron ore is left at 1,000°C for 60 minutes.

<1. Overview of present embodiment>

[0014] An agglomeration method and a reduction method according to the present embodiment are ironmaking methods using iron ore containing a large amount of combined water, for example, goethite-containing iron ore produced in Australia, of which reserves are abundant. In the ironmaking method according to the present embodiment, first, according to ore beneficiation, iron ore raw materials are separated into a goethite-rich part mainly composed of goethite. In the ore beneficiation, iron ore raw materials may be separated into a hematite-rich part mainly composed of hematite, a goethite-rich part mainly composed of goethite, and a gangue-rich part mainly composed of gangue. Here, the hematite-rich part is a part having an LOI of less than 4 mass% and an iron content of 55 mass% or more, the goethite-rich part is a part having an LOI of 4 mass% or more and an iron content of 55 mass% or more, and the gangue-rich part is a part having an iron content of less than 55 mass%. The hematite-rich part is a part mainly composed of hematite within the high combined water content iron ore and is a part of the high combined water content iron ore in which the LOI is less than 4 mass% and the iron content is 55 mass% or more. Here, the part mainly composed of hematite is a part in

which the amount of hematite is 50 mass% or more based on the total mass of the part. In addition, the goethite-rich part is a part mainly composed of goethite within the high combined water content iron ore and is a part of the high combined water content iron ore in which the LOI is 4 mass% or more and the iron content is 55 mass% or more. The part mainly composed of goethite is a part in which the amount of goethite is 50 mass% or more based on a total mass of the part. The gangue-rich part is a part mainly composed of gangue within the high combined water content iron ore and is a part of the high combined water content iron ore in which the iron content is less than 55 mass%. The part mainly composed of gangue is a part in which the amount of gangue is 50 mass% or more based on a total mass of the part. Subsequently, the hematite-rich part and the goethite-rich part are separately agglomerated and reduced, and thus the hematite-rich part is processed into a raw material for electric furnaces and the goethite-rich part is processed into a raw material for blast furnaces.

[0015] The inventors analyzed an iron ore containing a large amount of combined water (here, the LOI is regarded as the content thereof) (hereinafter also referred to as "high combined water content iron ore") by an EDS (energy dispersive X-ray analysis method), identified the mineral phase, and analyzed the composition of each phase. Here, the high combined water content iron ore is an iron ore containing 3 to 12 mass% of combined water. That is, in this specification, the loss of ignition of the high combined water content iron ore is 3 to 12 mass%. As a result, it became clear that the high combined water content iron ore contains a hematite-rich part mainly composed of hematite, a goethite-rich part mainly composed of goethite, and a gangue-rich part mainly composed of gangue, and most of gangue components such as Si, Al, and P are present in the goethite-rich part and the gangue-rich part.

[0016] Therefore, the inventors came up with the following idea. That is, the high combined water content iron ore is subjected to ore-beneficiation based on specific gravity, and it is determined whether separated parts are a hematite-rich part, the goethite-rich part, or the gangue-rich part, and the hematite-rich part and the goethite-rich part are agglomerated and reduced by a method suitable for each part. Here, since the hematite-rich part contains a large iron content, it can be agglomerated into fired pellets and directly reduced in the shaft furnace to produce reduction iron, which can be effectively used as a raw material for electric furnaces, with the same quality as conventional DR pellets, but the goethite-rich part has a relatively low iron content, and thus it is treated as semi-reduction iron and used as a raw material for blast furnaces. As described above, when the high combined water content iron ore is separated into the hematite-rich part and the goethite-rich part, and agglomerated and reduced, Steelmaking can be efficiently made with the high combined water content iron ore.

[0017] Here, fired pellets derived from the goethite-rich part are inferior to conventional fired pellets derived from hematite or magnetite in terms of strength and reduction disintegration due to the effect of release of combined water, and are easily pulverized in the shaft furnace. When pellets are pulverized in the shaft furnace, permeability increases, which not only reduces the productivity of the shaft furnace, but also causes failure of descending of iron oxide raw material, and leads to production failure. Therefore, in the present embodiment, furthermore, after fired pellets derived from the goethite-rich part are preheated (or while maintaining the temperature of the produced high-temperature pellets), they are charged into the shaft furnace. Thereby, it is possible to improve the thermal history received during the reduction process in the shaft furnace and avoid the above problem.

[0018] In addition, the goethite-rich part may be used as a sintered ore raw material. Accordingly, it is possible to avoid the above problems resulting from use of the shaft furnace for pellets produced from the goethite-rich part.

<2. Details of present embodiment>

(2-1. Iron ore to be processed)

[0019] Next, an ironmaking method according to the present embodiment will be described in detail. The iron ore (iron ore raw material) to be processed in the present embodiment is the above high combined water content iron ore. The high combined water content iron ore contains 3 to 12 mass% of combined water. Here, the mass% of combined water is measured as the loss of ignition (LOI). The high combined water content iron ore contains 55 to 67 mass% of the iron content in many cases. Examples of high combined water content iron ore include Brockman iron ore produced in Australia, which has components shown in Table 1.

[0020] The particle size of the high combined water content iron ore is not particularly limited. Raw high combined water content iron ore mined from deposits is first coarsely crushed. When lump ore for blast furnaces is collected, it is crushed to particles having a particle size of 50 mm or less, that having a particle size of 50 mm to 10 mm is recovered as lump ore, and that having a particle size of less than 10 mm is recovered as powder ore. The high combined water content iron ore used as a starting raw material in the embodiment of the present invention may be either a coarsely crushed ore from which lump ore is not collected or a powder ore.

[Table 1]

Iron ore sample produced in Australia					
Component	P	Fe	SiO ₂	Al ₂ O ₃	LOI _{1000°C}
Proportion (%)	0.12	61.0	3.99	2.89	3.73

(2-2. Processes of agglomeration methods S10 and S10A)

[0021] FIG. 1 shows an overall flow of an agglomeration method S10 and a reduction method S20 in the ironmaking method according to the present embodiment. FIG. 2 shows an overall flow of another agglomeration method S10A and reduction method S20A in the ironmaking method according to the present embodiment. The agglomeration method S10 includes a water washing step S1, an ore beneficiation step S2, and a first agglomeration processing step S3B. The agglomeration method S10 may further include a sintered ore producing step S4. The agglomeration method S10A in which the hematite-rich part is also subjected to ore-beneficiation and agglomerated includes the water washing step S1, the ore beneficiation step S2, the first agglomeration processing step S3B and a second agglomeration processing step S3A.

[0022] The high combined water content iron ore, which is an iron ore raw material, is separated into a plurality of parts using a specific gravity separation method. Then, in the separated parts, the goethite-rich part is determined based on the iron content and LOI. It may be determined whether the separated part is the hematite-rich part, the goethite-rich part or the gangue-rich part based on the iron content and LOI. Here, the hematite-rich part is a part having an LOI of less than 4 mass% and an iron content of 55 mass% or more, the goethite-rich part is a part having an LOI of 4 mass% or more and the iron content of 55 mass% or more, and the gangue-rich part is a part having an iron content of less than 55 mass%.

[0023] The separated goethite-rich part is agglomerated according to the flow shown in FIG. 1. Each of the separated parts may be separately agglomerated according to the flow shown in FIG. 2. In the second agglomeration processing step S3A, the hematite-rich part is agglomerated into second fired pellets in a pellet induration furnace. In the first agglomeration processing step S3B, the goethite-rich part is agglomerated into first fired pellets in the pellet induration furnace. Here, the goethite-rich part may be converted into a sintered ore in a sintering machine. The gangue-rich part is preferably discarded or used as a sintered ore raw material depending on the iron content thereof.

(2-2-1. Water washing step)

[0024] In the water washing step S1, it is preferable to wash the iron ore raw material with water before ore beneficiation. Clay minerals (tailings) can be removed from the high combined water content iron ore by washing with water. Specifically, for example, the iron ore raw material is washed with water using a drum type scrubber, a washing sieve or the like. Thereby, clay minerals (so-called tailings) having a particle size of 20 to 45 μm or less which are adhered to the surface of the iron ore raw material can be washed away. Tailings are preferably discarded because they have a low iron content.

[Table 2]

(Effect of washing raw ore with water)								
Component	P (%)	Fe (%)	SiO ₂ (%)	Al ₂ O ₃ (%)	CaO (%)	MgO (%)	LOI (%)	Proportion (%)
Before washing with water	0.129	58.79	4.91	3.69	0.14	0.016	4.71	100
After washing with water	0.123	61.01	3.99	2.89	0.11	0.013	4.58	90.5
Tailings	0.186	37.74	13.67	11.31	0.43	0.04	5.95	9.5

[0025] Table 2 shows an example of the results of washing with water. As can be clearly understood from Table 2, when clay minerals are removed in advance, it is possible to increase the iron content in the iron ore raw material and reduce the amount of gangue components.

(2-2-2. Ore beneficiation step)

[0026] Next, in the ore beneficiation step S2, the washed iron ore raw material is subjected to ore-beneficiation and separated into a plurality of parts. In the ore beneficiation step S2, the high combined water content iron ore is beneficiated

into a goethite-rich part having an iron content of at least 55 mass% or more. In the ore beneficiation step S2, the high combined water content iron ore may be ore-beneficiated into a hematite-rich part having a loss of ignition LOI of less than 4 mass% and an iron content of 55 mass% or more and a goethite-rich part having a loss of ignition LOI of 4 mass% or more and an iron content of 55 mass% or more. In the ore beneficiation step S2, the high combined water content iron ore may be additionally ore-beneficiated into a gangue-rich part having an iron content of less than 55 mass%. Then, the LOI and iron content of the separated parts are analyzed and it is determined whether the separated part belongs to the hematite-rich part, the goethite-rich part or the gangue-rich part. Here, since the specific gravity of each mineral phase is 5.3 g/cm³ for hematite, 3.8 g/cm³ for goethite, and 2.7 g/cm³ for gangue, the iron ore raw material can be separated into the hematite-rich part, the goethite-rich part, and the gangue-rich part by so-called gravity separation (specific gravity separation processing). Magnetic separation may be performed together with gravity separation.

[0027] First, the iron ore raw materials are classified according to a particle size of about 3 mm. Classification may be performed using a sieve. The iron ore raw materials plus mesh and minus mesh are preferably subjected to gravity separation by the following methods.

plus mesh: JIG or heavy liquid separation

minus mesh: spiral, Up-current classifiers (UCC), Wet High Intensity Magnetic Separation (WHIMS) or heavy liquid separation

[0028] The reason why the classification particle size is set to 3 mm is that the particle size range in which ore beneficiation can be efficiently performed by JIG is 3.0 mm or more, and the particle size range in which classification can be efficiently performed by spiral is 3.0 mm or less. Hereinafter, an overview of each ore beneficiation method will be described.

(JIG)

[0029] JIG is a type of gravity separation, and is a method for separating mineral particles using a difference in specific gravity. Mineral particles are supplied into a particle bed with a net at the bottom. Next, water flows intermittently from the bottom to the top to raise the water level. This causes the mineral particles to be swept up into water and to float temporarily. Subsequently, the water flow is stopped. Thereby, the mineral particles precipitate again on the net as the water level falls and returns to its original level. When mineral particles float in water and precipitate on the net again, since the mineral particles fall faster as the specific gravity of the mineral particles is higher, mineral particles with a higher specific gravity gather at the bottom of the particle bed after precipitation. Accordingly, the mineral particles can be concentrated by the specific gravity. That is, when desired mineral particles are extracted from each formed particle bed, the mineral particles can be separated by the specific gravity.

(Spiral)

[0030] Spiral is a type of gravity separation, and is an ore beneficiation method using a centrifugal force that is generated in a slurry (mixture of water and mineral particles) that flows through a spiral (helical) gutter. When a slurry is poured from the top of the tower, mineral particles with a low specific gravity gather on the outside due to a centrifugal force as the slurry descends in a spiral, and can be separated from other mineral particles. Mineral particles with a high specific gravity, which are hardly affected by the centrifugal force, gather on the inner periphery of the gutter and are extracted. The ore beneficiation efficiency is controlled by adjusting the ore supply size and the amount of water in the gutter.

(UCC)

[0031] UCC is also a type of gravity separation. In the UCC, a slurry (mixture of water and mineral particles) is supplied from the upper part of the device, and a rising water flow is supplied from the lower part. Then, these components interact and come into contact with each other in the device, and mineral particles with a low specific gravity ride the rising water flow and thus can be separated from other mineral particles. Mineral particles with a high specific gravity are hardly affected by the rising water flow and discharged from the lower part of the device. The ore beneficiation efficiency is controlled by adjusting the ore supply size and the amount of water in the rising water flow.

(WHIMS)

[0032] WHIMS is an ore beneficiation method using a magnetic force of 8,000 to 12,000 Gauss or more. A rotating rotor and a magnet disposed in the rotor are disposed in the device. When a slurry (mixture of water and mineral particles) is supplied into the device, since non-magnetic particles do not stick to a magnet, they fall directly and are collected in

a fixed tray of the rotating lower part. Paramagnetic particles are captured according to a high magnetic force/high gradient magnetic field, and are discharged at a part in which the magnetism weakens as the rotor rotates. Ferromagnetic particles move as the rotor rotates and are discharged at a part without the magnetic field.

(Heavy liquid separation)

[0033] Heavy liquid separation is a type of gravity separation. Heavy liquid separation is also called heavy liquid ore beneficiation, heavy liquid coal dressing, or floatation separation. Heavy liquid separation is a method for separating beneficial minerals and waste stones using a liquid (heavy liquid) with a high specific gravity as a medium. A heavy liquid can be obtained by finely crushing a heavy liquid material (magnetite, slag, barite, etc.) that has a specific gravity 2 to 3 times that of a heavy liquid to be produced, is hard and difficult to refine, has favorable chemical stability, and is easy to purify and recover and suspending it water. Mineral particles with a higher specific gravity than the heavy liquid sink into the heavy liquid, and mineral particles with a lower specific gravity float on the upper surface of the heavy liquid, and thus mineral particles with a desired specific gravity are separated.

[0034] When control conditions for the above gravity separation (and magnetic separation) are appropriately adjusted, the iron ore raw material (high combined water content iron ore) can be beneficiated into a hematite-rich part having at least a loss of ignition LOI of less than 4 mass% and an iron content of 55 mass% or more and a goethite-rich part having a loss of ignition LOI of 4 mass% or more and an iron content of 55 mass% or more. The iron ore raw material can be separated into the hematite-rich part, the goethite-rich part, and the gangue-rich part.

[0035] The following Table 3 shows examples of the results obtained by specific gravity separation of the iron ore raw material (high combined water content iron ore) by UCC. As can be clearly understood from Table 3, the iron ore raw material can be separated into the hematite-rich part, the goethite-rich part, and the gangue-rich part by

UCC.

[0036]

[Table 3]

(Test results)									
Component	Fe (%)	SiO ₂ (%)	Al ₂ O ₃ (%)	CaO (%)	MgO (%)	P (%)	LOI (%)	Specific gravity (-)	Proportion (%)
After washing with water	61.01	3.99	2.89	0.11	0.013	0.123	4.58	4.41	100
Goethite-rich part	58.35	5.13	4.11	0.18	0.014	0.195	7.89	3.91	47
Hematite-rich part	66.5	2.31	1.15	0.05	0.011	0.053	1.2	5.03	46
Gangue-rich part	42.79	7.38	6.13	0.03	0.019	0.100	4.57	3.73	7

(2-2-3. Pellet producing step)

[0037] Next, in the pellet producing step, the goethite-rich part and the hematite-rich part are separately agglomerated using a pellet induration furnace and used as raw materials for direct reduction. In the second agglomeration processing step S3A, the hematite-rich part is agglomerated using the pellet induration furnace. In the first agglomeration processing step S3B, the goethite-rich part is agglomerated using the pellet induration furnace. A specific method for the pellet producing step is not particularly limited, and the step may be performed according to a general pellet production method. An example of the pellet producing step is described in Non-Patent Document 3 (KOBE STEEL ENGINEERING REPORTS/Vol. 60 No. 1 (Apr. 2010)). In the present embodiment, the pellet producing step is performed according to the method described in the above document, but the production method is not limited to the method described in this non-patent document.

[0038] Table 4 shows an example of compositions of pellets. Since fired pellets derived from the hematite-rich part (second fired pellets) have a low gangue content, they can be directly reduced and used as raw materials for electric furnaces. Since fired pellets derived from the goethite-rich part (first fired pellets) have a relatively high gangue content and are not suitable as raw materials for electric furnaces, they can be used as raw materials for blast furnaces. In Table

4, goethite-rich pellets are first fired pellets and hematite-rich pellets are second fired pellets.

(2-2-4. Sintered ore producing step)

[0039] In the sintered ore producing step S4, in place of the above pellet producing step, the goethite-rich part may be agglomerated using a sintering machine and used as a raw material for blast furnaces. Here, conditions for producing sintered ore are not particularly limited. The fired pellets derived from the goethite-rich part may have problems in strength and reduction disintegration during reduction. This problem can be avoided by agglomerating them as a sintered ore.

[0040] The gangue-rich part is preferably discarded or agglomerated as a sintered ore using a sintering machine depending on the iron content thereof.

[Table 4]

Component	Fe (%)	SiO ₂ (%)	Al ₂ O ₃ (%)	CaO (%)	MgO (%)	P (%)
Goethite-rich pellet	63.35	5.57	4.46	0.20	0.02	0.21
Hematite-rich pellet	67.31	2.34	1.16	0.05	0.01	0.05

(2-3. Reduction step)

[0041] A flowchart of a reduction step is shown on the right side of FIG. 1. The reduction method S20 includes a first reduction step S5B. The reduction method S20 may include a blast furnace step S6. The reduction method S20A for further reducing the fired pellets derived from the hematite-rich part includes a first reduction step S5B and a second reduction step S5A.

[0042] In the second reduction step S5A, the fired pellets derived from the hematite-rich part (second fired pellets) are directly reduced using a shaft furnace to produce direct reduction iron having a metallization degree of 90% or more. The obtained direct reduction iron can be used as a reduction iron raw material for electric furnaces. As the reducing gas, a natural gas, a synthetic gas (Syn-gas), H₂ gas or the like can be used. The reducing gas preferably contains 60 volume% or more of hydrogen gas. Operation conditions for the shaft furnace, for example, as follows. In an electric furnace step S7, molten steel is obtained using reduction iron for electric furnaces obtained in the second reduction step S5A.

- a reducing gas temperature of 700 to 1,000°C
- a reducing gas flow rate of 1,000 to 2,200 Nm³/t-DRI (flow rate per ton of reduction iron)
- a metallization degree of 90% or more

[0043] Here, the metallization degree is defined as the metallic iron concentration/total iron concentration×100. The method for measuring the metallic iron concentration is specified in ISO 5416 in the bromine methanol titration method for measuring metallic iron in reduction iron. The total iron concentration is determined according to JIS M 8212: 2005 iron ore total iron determination method.

[0044] In the first reduction step S5B, the fired pellets derived from the goethite-rich part (first fired pellet) are charged into a shaft furnace while the first fired pellets have a surface temperature of 600°C or higher, and directly reduced using a reducing gas containing 60 volume% or more of hydrogen. The upper limit of the surface temperature of the first fired pellets is not particularly limited, and is, for example, 800°C. In the first reduction step S5B, the first fired pellets may be directly reduced to a semi-reduced state with a metallization degree of 60 to 95% to obtain semi-reduced fired pellets. The metallization degree after direct reduction is more preferably 60 to 90%. The semi-reduced state is a state with a metallization degree of 60 to 95%. The obtained semi-reduced fired pellets can be used as raw materials for blast furnaces if the metallization degree is high. The semi-reduced fired pellets are fired pellets having a metallization degree of 60% to 95%. As the reducing gas, a natural gas, a synthetic gas (Syn-gas), H₂ gas or the like can be used. The reducing gas preferably contains 60 volume% or more of hydrogen gas. Operation conditions for the shaft furnace are, for example, as follows. The upper limit of hydrogen gas is not particularly limited, and is, for example, 100 volume%.

- a reducing gas temperature of 700 to 1,000°C
- a reducing gas flow rate of 1,000 to 2,200 Nm³/t-DRI (flow rate per ton of reduction iron)
- metallization degree 60% to 95%

[0045] Here, if the temperature of the fired pellets derived from the goethite-rich part (first fired pellet) when charged into a shaft furnace is lower than 600°C, the first fired pellets are pulverized in the shaft furnace, and the raw materials

clog the shaft furnace, which results in poor discharge. Therefore, the temperature of the first fired pellets when charged into the shaft furnace is 600°C or higher. The temperature of the first fired pellets when charged into the shaft furnace is preferably 650°C or higher.

[0046] Since the gangue-rich part is agglomerated as a sintered ore as described above, it is preferable to use it as a raw material for blast furnaces.

[0047] As described above, according to the present embodiment, the high combined water content iron ore is beneficiated into the hematite-rich part, the goethite-rich part, and the gangue-rich part, and reduced by a method suitable for each part. Therefore, it is possible to efficiently reduce the poor-quality iron ore raw material.

(2-4. Recycling of dust)

[0048] Dust and DRI powder generated according to a direct reduction ironmaking method are preferably treated using the same route in accordance with the goethite-rich part. Dust and DRI powder have an effect of improving the strength of pellets, and can improve the strength when used with goethite-rich pellets having low strength.

(2-5. Other)

[0049] In the blast furnace step S6, of the hematite-rich part or goethite-rich part beneficiated in the ore beneficiation step, a part having a particle size that can be used as a lump ore in the blast furnace may be directly used in the blast furnace, or the fired pellets derived from the goethite-rich part may be directly charged into the blast furnace. In the blast furnace step S6, pig iron can be obtained. In a converter step S8, steel can be obtained from the pig iron obtained in the blast furnace step S6.

[Examples]

[0050] Next, examples of the present embodiment will be described. Here, examples to be described below are examples of the present invention, and the present invention is not limited to the following examples.

(Example 1)

[0051] In Example 1, fired pellets derived from a goethite-rich part having a composition shown in Table 4 were charged into a shaft furnace to produce semi-reduction iron. A natural gas or a synthetic gas was used as a reducing gas. Production conditions are as follows. The temperature of the raw material was a temperature of the fired pellets when charged into the shaft furnace.

- raw materials used: fired pellets derived from the goethite-rich part shown in the above Table 4
- a raw material temperature of 650°C
- a reducing gas temperature of 950°C
- a reducing gas flow rate of 1,200 Nm³/t-DRI
- a metallization degree of 82%
- product applications semi-reduction iron for blast furnaces
- composition of reducing gas, as shown in Table 5 (showing a composition in which Inlet indicates an input gas, Outlet indicates an output gas (exhaust gas), the numerical value of each component indicates volume%, and the column Temp shown in Table 5 indicates the temperature of the input gas (Inlet) or the temperature (°C) of the output gas (Outlet))

[Table 5]

	H ₂	H ₂ O	CO	CO ₂	N ₂	Temp.
	vol%	vol%	vol%	vol%	vol%	°C
Outlet	40	33	14	13	0	680
Inlet	70	0	25	5	0	950

[0052] According to Example 1, it was possible to produce semi-reduction iron having a metallization degree of 82%. As described above, since semi-reduction iron derived from the goethite-rich part contained a large amount of gangue

components, it was suitable as a raw material for blast furnaces.

(Example 2)

[0053] In Example 2, fired pellets derived from the hematite-rich part having a composition shown in Table 4 were charged into a shaft furnace to produce reduction iron. Hydrogen gas was used as the reducing gas. Production conditions are as follows.

· raw materials used hematite-rich pellets shown in Table 4

· a raw material temperature of 650°C

· a reducing gas temperature of 1,020°C

· a reducing gas flow rate of 1,400 Nm³/t-DRI

· a metallization degree of 94%

· product applications reduction iron for electric furnaces

· composition of reducing gas, as shown in Table 6 (showing a composition in which Inlet indicates an input gas, Outlet indicates an output gas (exhaust gas), the numerical value of each component indicates volume%, and the column Temp shown in Table 6 indicates the temperature of the input gas (Inlet) or the temperature (°C) of the output gas (Outlet))

[Table 6]

	H ₂	H ₂ O	CO	CO ₂	N ₂	Temp.
	vol%	vol%	vol%	vol%	vol%	°C
Outlet	40	33	14	13	0	630
Inlet	70	0	25	5	0	1020

[0054] According to Example 2, it was possible to produce reduction iron having a metallization degree of 94%. As described above, since the reduction iron derived from the hematite-rich part contained a small amount of gangue components, it was suitably used as a raw material for electric furnaces.

(Example 3)

[0055] In Example 3, fired pellets derived from the goethite-rich part having a composition shown in Table 4 were charged into a shaft furnace to produce semi-reduction iron. Hydrogen was used as the reducing gas. Production conditions are as follows.

· raw materials used: fired pellets derived from the goethite-rich part shown in the above Table 4

· a raw material temperature of 600°C

· a reducing gas temperature of 1,050°C

· a reducing gas flow rate of 1,250 Nm³/t-DRI

· a metallization degree of 85%

· product applications semi-reduction iron for blast furnaces

· composition of reducing gas, as shown in Table 7 (showing a composition in which Inlet indicates an input gas, Outlet indicates an output gas (exhaust gas), the numerical value of each component indicates volume%, and the column Temp shown in Table 7 indicates the temperature of the input gas (Inlet) or the temperature (°C) of the output gas (Outlet))

[Table 7]

	H ₂	H ₂ O	CO	CO ₂	N ₂	Temp.
	vol%	vol%	vol%	vol%	vol%	°C
Outlet	55	40	0	0	5	625
Inlet	95	0	0	0	5	1050

[0056] According to Example 3, it was possible to produce semi-reduction iron having a metallization degree of 84%. As described above, since semi-reduction iron derived from the goethite-rich part contained a large amount of gangue components, it was suitable as a raw material for blast furnaces.

(Example 4)

[0057] In Example 4, fired pellets derived from the goethite-rich part having a composition shown in Table 4 were charged into a shaft furnace to produce semi-reduction iron. Hydrogen was used as the reducing gas. Production conditions are as follows.

- raw materials used: fired pellets derived from the goethite-rich part shown in the above Table 4
- a raw material temperature of 650°C
- a reducing gas temperature of 1,020°C
- a reducing gas flow rate of 1,580 Nm³/t-DRI
- a metallization degree of 92%
- product applications semi-reduction iron for blast furnaces or reduction iron for electric furnaces
- composition of reducing gas, as shown in Table 8 (showing a composition in which Inlet indicates an input gas, Outlet indicates an output gas (exhaust gas), the numerical value of each component indicates volume%, and the column Temp shown in Table 8 indicates the temperature of the input gas (Inlet) or the temperature (°C) of the output gas (Outlet))

[Table 8]

	H ₂	H ₂ O	CO	CO ₂	N ₂	Temp.
	vol%	vol%	vol%	vol%	vol%	°C
Outlet	59	33	0	0	8	600
Inlet	192	0	0	0	8	1020

[0058] According to Example 4, it was possible to produce semi-reduction iron having a metallization degree of 92%. As described above, since semi-reduction iron derived from the goethite-rich part contained a large amount of gangue components, it was suitable as a raw material for blast furnaces. On the other hand, it could be used as reduction iron for electric furnaces due to its high metallization degree.

(Example 5)

[0059] In Example 5, fired pellets derived from the goethite-rich part having a composition shown in Table 4 were charged into a shaft furnace to produce semi-reduction iron. Hydrogen was used as the reducing gas. Production conditions are as follows.

- raw materials used: fired pellets derived from the goethite-rich part shown in the above Table 4
- a raw material temperature of 620°C
- a reducing gas temperature of 980°C
- a reducing gas flow rate of 1,700 Nm³/t-DRI
- a metallization degree of 95%
- product applications semi-reduction iron for blast furnaces or reduction iron for electric furnaces
- composition of reducing gas, as shown in Table 9 (showing a composition in which Inlet indicates an input gas, Outlet indicates an output gas (exhaust gas), the numerical value of each component indicates volume%, and the column Temp shown in Table 9 indicates the temperature of the input gas (Inlet) or the temperature (°C) of the output gas

(Outlet))

[0060]

[Table 9]

	H ₂	H ₂ O	CO	CO ₂	N ₂	Temp.
	vol%	vol%	vol%	vol%	vol%	°C
Outlet	58	32	0	0	10	600
Inlet	90	0	0	0	10	1020

[0061] According to Example 5, it was possible to produce semi-reduction iron having a metallization degree of 95%. As described above, since semi-reduction iron derived from the goethite-rich part contained a large amount of gangue components, it was suitable as a raw material for blast furnaces. On the other hand, it could be used as reduction iron for electric furnaces due to its high metallization degree.

[0062] An attempt was made to produce reduction iron by charging fired pellets derived from the goethite-rich part into a shaft furnace at a raw material temperature of 550°C. However, the fired pellets derived from goethite were pulverized in the shaft furnace, and the raw materials clog the shaft furnace, which results in poor discharge. Accordingly, it was found that the temperature of the raw material when charged into the shaft furnace needs to be 600°C or higher.

[0063] While preferable embodiments of the present invention have been described above in detail with reference to the appended drawings, the present invention is not limited to these examples. It can be clearly understood that those skilled in the art can implement various alternations or modifications within the scope of technical ideas of the present disclosure, and of course these also belong to the technical scope of the present invention.

Claims

1. An ironmaking method, comprising:

an ore beneficiation step in which a high combined water content iron ore having a loss of ignition of 3 to 12 mass% is beneficiated into a goethite-rich part having at least a loss of ignition of 4 mass% or more and an iron content of 55 mass% or more;

a first agglomeration processing step in which the goethite-rich part is agglomerated into first fired pellets in a pellet induration furnace; and

a first reduction step in which the first fired pellets are charged into a shaft furnace while the first fired pellets have a surface temperature of 600°C or higher, and directly reduced using a reducing gas containing 60 volume% or more of hydrogen.

2. The ironmaking method according to claim 1,

wherein, in the first reduction step, the first fired pellets are directly reduced to a metallization degree of 60% to 95%.

3. The ironmaking method according to claim 1, further comprising

a second agglomeration processing step in which a hematite-rich part is agglomerated into second fired pellets in a pellet induration furnace,

wherein, in the ore beneficiation step, the hematite-rich part having a loss of ignition of less than 4 mass% and an iron content of 55 mass% or more is additionally beneficiated.

4. The ironmaking method according to claim 3, further comprising

a second reduction step in which the second fired pellets are directly reduced in a shaft furnace using a reducing gas containing 60 volume% or more of hydrogen to produce direct reduction iron having a metallization degree of 90% or more.

5. The ironmaking method according to any one of claims 1 to 4, further comprising

a water washing step in which tailings are removed from the high combined water content iron ore before the ore beneficiation step.

FIG. 1

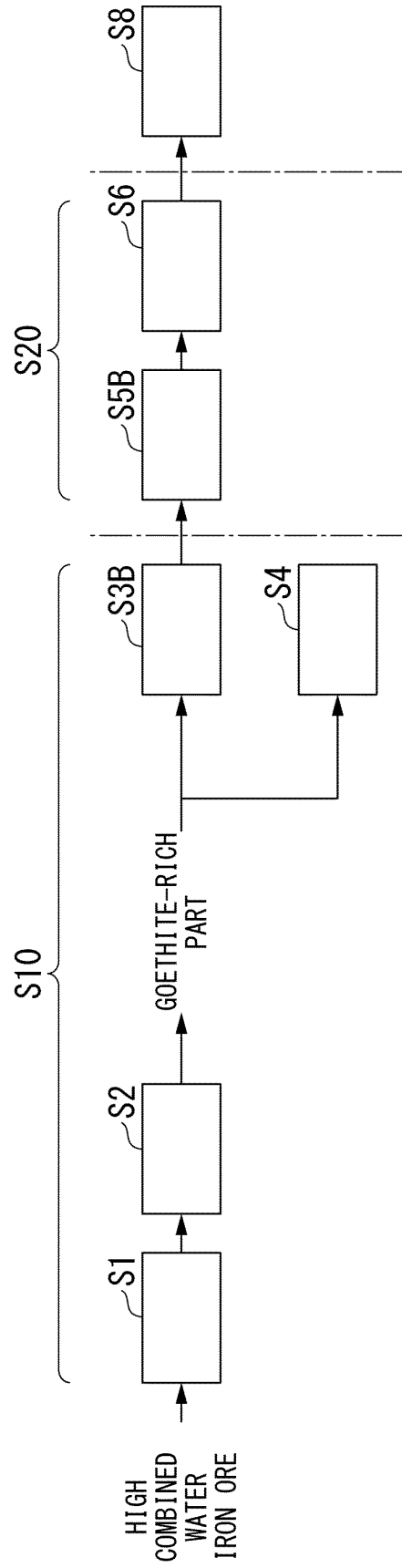
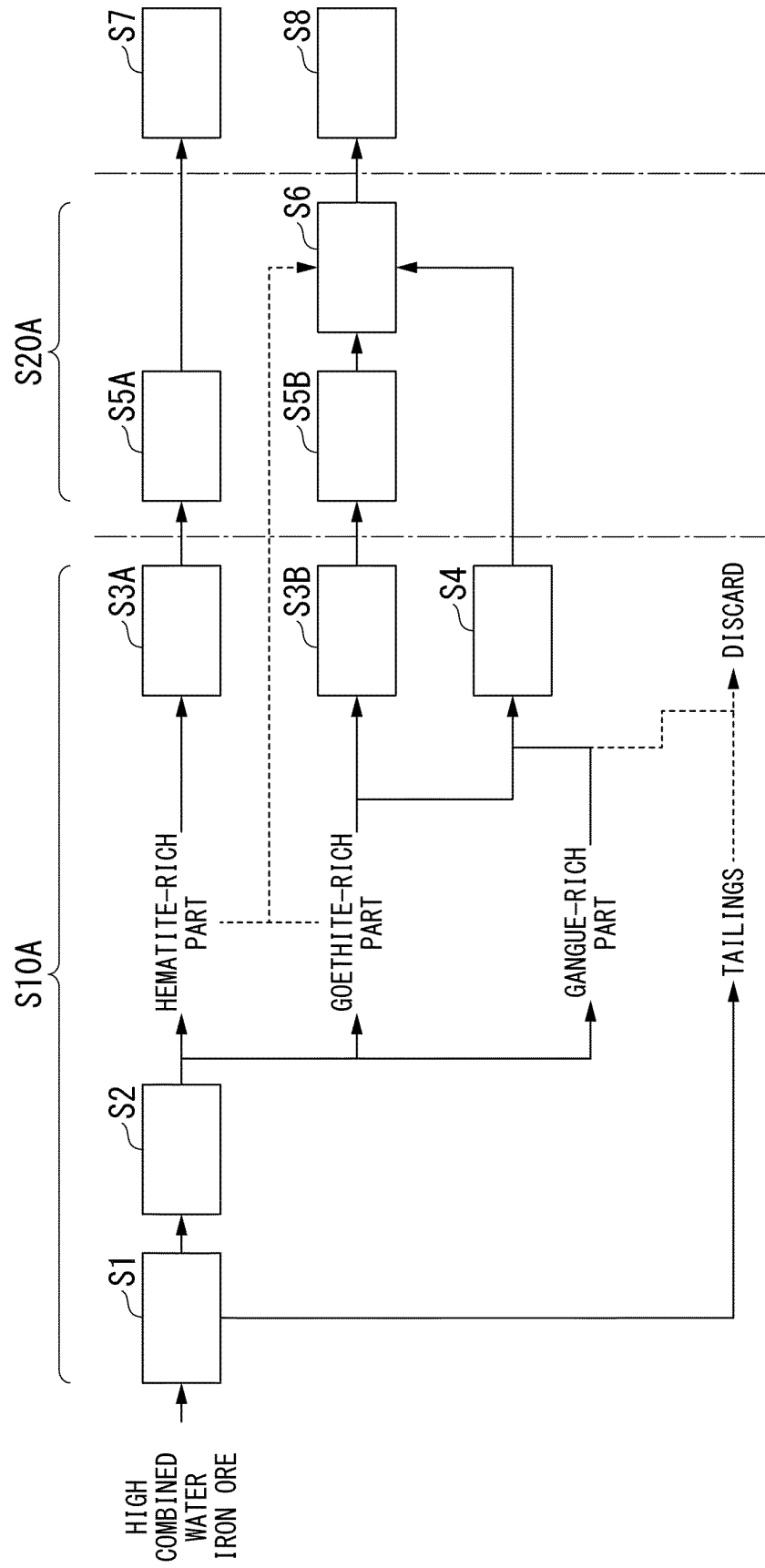


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/036451

A. CLASSIFICATION OF SUBJECT MATTER C22B 1/16 (2006.01)i; C21B 5/00 (2006.01)i; C21C 5/52 (2006.01)i; C22B 1/14 (2006.01)i FI: C22B1/16 C; C22B1/16 101; C21B5/00 302; C21C5/52; C22B1/14 According to International Patent Classification (IPC) or to both national classification and IPC																					
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C22B1/16; C21B5/00; C21C5/52; C22B1/14 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Published examined utility model applications of Japan 1922-1996 Published unexamined utility model applications of Japan 1971-2022 Registered utility model specifications of Japan 1996-2022 Published registered utility model applications of Japan 1994-2022 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)																					
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>JP 2020-20010 A (NIPPON STEEL CORP.) 06 February 2020 (2020-02-06) claim 4, paragraphs [0044]-[0058], [0075]-[0079], [0091]-[0093], fig. 5</td> <td>1-5</td> </tr> <tr> <td>A</td> <td>JP 2012-102371 A (NIPPON STEEL CORP.) 31 May 2012 (2012-05-31) claims, paragraphs [0015]-[0035], fig. 1-8</td> <td>1-5</td> </tr> <tr> <td>A</td> <td>JP 46-18841 B1 (NIPPON STEEL CORP.) 26 May 1971 (1971-05-26) column 2, line 27 to column 7, line 6, fig. 1, 2</td> <td>1-5</td> </tr> <tr> <td>A</td> <td>JP 3-10027 A (NIPPON STEEL CORP.) 17 January 1991 (1991-01-17) page 2, upper left column, line 17 to page 4, upper right column, line 16, fig. 1</td> <td>1-5</td> </tr> <tr> <td>A</td> <td>JP 7-166248 A (NKK CORP.) 27 June 1995 (1995-06-27) abstract, paragraphs [0001]-[0010]</td> <td>1-5</td> </tr> <tr> <td>A</td> <td>JP 2013-133512 A (JFE STEEL CORP.) 08 July 2013 (2013-07-08) abstract, paragraphs [0001]-[0030]</td> <td>1-5</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	A	JP 2020-20010 A (NIPPON STEEL CORP.) 06 February 2020 (2020-02-06) claim 4, paragraphs [0044]-[0058], [0075]-[0079], [0091]-[0093], fig. 5	1-5	A	JP 2012-102371 A (NIPPON STEEL CORP.) 31 May 2012 (2012-05-31) claims, paragraphs [0015]-[0035], fig. 1-8	1-5	A	JP 46-18841 B1 (NIPPON STEEL CORP.) 26 May 1971 (1971-05-26) column 2, line 27 to column 7, line 6, fig. 1, 2	1-5	A	JP 3-10027 A (NIPPON STEEL CORP.) 17 January 1991 (1991-01-17) page 2, upper left column, line 17 to page 4, upper right column, line 16, fig. 1	1-5	A	JP 7-166248 A (NKK CORP.) 27 June 1995 (1995-06-27) abstract, paragraphs [0001]-[0010]	1-5	A	JP 2013-133512 A (JFE STEEL CORP.) 08 July 2013 (2013-07-08) abstract, paragraphs [0001]-[0030]	1-5
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Date of the actual completion of the international search 02 December 2022	Date of mailing of the international search report 13 December 2022																				
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2022/036451

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2020-20010 A	06 February 2020	(Family: none)	
JP 2012-102371 A	31 May 2012	(Family: none)	
JP 46-18841 B1	26 May 1971	(Family: none)	
JP 3-10027 A	17 January 1991	(Family: none)	
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REFERENCES CITED IN THE DESCRIPTION

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