



(11) **EP 4 553 175 A1**

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

- (43) Date of publication:
14.05.2025 Bulletin 2025/20

(21) Application number: **22953910.1**

(22) Date of filing: **01.08.2022**
- (51) International Patent Classification (IPC):
C21B 13/02 (2006.01) **C21B 13/08** (2006.01)

(52) Cooperative Patent Classification (CPC):
C21B 13/02; C21B 13/08

(86) International application number:
PCT/JP2022/029418

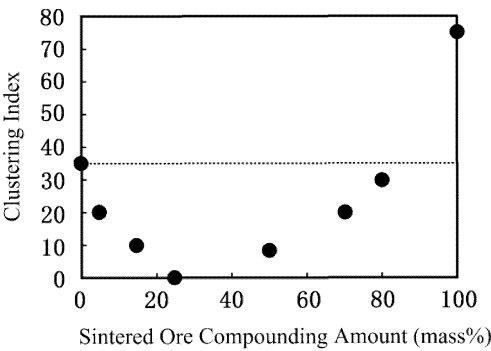
(87) International publication number:
WO 2024/028919 (08.02.2024 Gazette 2024/06)

(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 (71) Applicant: JFE Steel Corporation Tokyo 100-0011 (JP) (72) Inventors: • FUJIWARA Shohei Tokyo 100-0011 (JP) • TAKEHARA Kenta Tokyo 100-0011 (JP) • HORITA Kenya Tokyo 100-0011 (JP)	• MORITA Yuya Tokyo 100-0011 (JP) • YAMAMOTO Tetsuya Tokyo 100-0011 (JP) • HIGUCHI Takahide Tokyo 100-0011 (JP) • HIROSAWA Toshiyuki Tokyo 100-0011 (JP) • IWAMI Yuji Tokyo 100-0011 (JP) • IGAWA Daisuke Tokyo 100-0011 (JP) (74) Representative: Grünecker Patent- und Rechtsanwälte PartG mbB Leopoldstraße 4 80802 München (DE)
--	--

(54) **PRODUCTION METHOD FOR REDUCED IRON**

(57) Provided is a production method for direct reduced iron capable of preventing the occurrence of clustering when producing direct reduced iron by reducing a raw material for reduction with a reducing gas, using a shaft furnace or a kiln furnace. The production method for direct reduced iron includes producing direct reduced iron by reducing the raw material for reduction with the reducing gas, using the shaft furnace or kiln furnace. The raw material for reduction contains a sintered ore, and is preferably composed of 80% by mass or less of the sintered ore; and a remainder made up of at least one of lump ore and pellets.

[Fig. 2]



Description

Technical field

- 5 **[0001]** The present invention relates to a direct reduced iron production method for producing direct reduced iron by reducing a raw material for reduction with a reducing gas, using a shaft furnace or a kiln furnace.

Background Art

- 10 **[0002]** Conventionally, there are known various direct reduced iron production methods for producing direct reduced iron by reducing a raw material for reduction with a reducing gas, using a shaft furnace or a kiln furnace. Further, in an operation involving a shaft furnace or a kiln furnace, as a raw material(s) for reduction, there have been mainly used, for example, lump ore and pellets prepared by granulating and sintering a powder ore (e.g., see Patent Literature 1).

15 Citation List

Patent Literature

- 20 **[0003]** Patent Literature 1: Japanese Patent No.4427295

Summary of Invention

Technical Problem

- 25 **[0004]** However, in the case of the reduction method of Patent Literature 1 for producing direct reduced iron, no mention is made on clustering in which the raw material(s) for reduction bind together in a reduction furnace, which leaves a possibility that direct reduced iron may not be able to be discharged from inside the furnace.

- 30 **[0005]** Further, in a conventional direct reduced iron production (e.g., MIDREX: registered trademark) using a shaft furnace or a kiln furnace, a hydrogen gas and carbon monoxide are used as a reducing gas. There, while the hydrogen gas in the reducing gas is usually of an amount of about 60 vol.%, a method of increasing such amount to 67 to 100 vol.% (called hydrogen-direct reduced iron making) has gained attention as it is capable of reducing CO₂ discharge amount. If increasing the amount of the hydrogen gas in the reducing gas to 67 to 100 vol.%, there may be employed a higher temperature inside the shaft furnace or kiln furnace for the purpose of ensuring a reaction speed therein, which requires clustering to be prevented in a more reliable manner.

- 35 **[0006]** The present invention was made in view of these circumstances. It is an object of the present invention to provide a production method for direct reduced iron capable of preventing the occurrence of clustering when producing direct reduced iron by reducing a raw material for reduction with a reducing gas, using a shaft furnace or a kiln furnace.

Solution to Problem

- 40 **[0007]** The present invention is a production method for direct reduced iron that includes: producing direct reduced iron by reducing a raw material for reduction with a reducing gas, using a shaft furnace or a kiln furnace, wherein the raw material for reduction contains a sintered ore.

- 45 **[0008]** Here, as for the production method for direct reduced iron of the present invention that is configured in the above manner, it is considered that more preferable resolutions can be brought when:

- (1) the raw material for reduction is composed of 80% by mass or less of the sintered ore; and a remainder made up of at least one of lump ore and pellets;
- 50 (2) the raw material for reduction is composed of 5 to 70% by mass of the sintered ore; and a remainder made up of at least one of lump ore and pellets;
- (3) the raw material for reduction is composed of 15 to 50% by mass of the sintered ore; and a remainder made up of at least one of lump ore and pellets;
- (4) the RDI of the sintered ore is 54% by mass or less;
- (5) a total iron content of the sintered ore is smaller than 65% by mass;
- 55 (6) the reducing gas contains 60 vol.% or more of a hydrogen gas; and
- (7) the reducing gas contains 67 vol.% or more of a hydrogen gas.

Advantageous Effects of Invention

[0009] According to the present invention configured in the above manner, when producing direct reduced iron with a shaft furnace or a kiln furnace, the occurrence of clustering in the direct reduced iron produced can be prevented by using, as a raw material for reduction, a sintered ore, preferably a sintered ore satisfying given conditions.

Brief Description of Drawings

[0010]

[Fig.1] is a graph explaining a correlation between a sintered ore compounding ratio; and contact ratios between sintered ores themselves and between pellets themselves.

[Fig.2] is a graph showing a correlation between the sintered ore compounding amount and a clustering index.

[Fig.3] is a graph showing a correlation between a sintered ore RDI and the clustering index.

[Fig.4] is a graph showing a correlation between a total iron content (T.Fe) of the sintered ore and the clustering index.

Description of Embodiments

[0011] An embodiment of the present invention is described in detail hereunder. Here, the following embodiment is a set of examples of a device and/or method embodying the technical concept of the present invention and is not to limit the configuration of the present invention to those shown below. That is, various modifications can be made to the technical concept of the present invention within the technical scope described in the claims.

<Idea of the present invention; and configuration of the present invention with which the idea is realized>

[0012] Conventionally, it is known that the higher the iron content in a raw material for reduction is, the more likely clustering will occur. Thus, the present invention was made based on an idea that it may be possible to suppress clustering by reducing the iron content in a raw material for reduction as a result of adding a low-iron-content sintered ore to the raw material for reduction.

[0013] That is, since a sintered ore uses a coagulating material and a lime-based auxiliary raw material, it has a higher slag component content and a lower iron content as compared to pellets. While a low iron content is advantageous in terms of suppressing clustering, a sintered ore alone resulted in an increased clustering index. It was considered that this was because while the iron content was low, fusion was incurred as a melt was generated by the slag component.

[0014] In this way, as for the causes that trigger clustering, it was made clear that the mechanism by which clustering occurs in the case of pellets and the mechanism by which clustering occurs in the case of sintered ores differ from each other in that while clustering is attributed to iron fusion between pellets themselves in the case of pellets, it is attributed to slag fusion between sintered ores themselves in the case of sintered ores. This indicates that while clustering is easy to occur with pellets themselves coming into contact with one another and with sintered ores themselves coming into contact with one another, clustering is not easy to occur with pellets and sintered ores coming into contact with each other.

[0015] The inventors concluded that a frequency at which a particle comes into contact with the same kind of particle is the product of an existence ratio of such kind of particles and an existence ratio of the particles coming into contact therewith, and this is the square of a compounding ratio of such kind of particles. Thus, the inventors arrived at an idea that the clustering index as a whole could be reduced by moderately adding a sintered ore (see Fig.1).

[0016] The production method for direct reduced iron of the present invention that was made based on the above idea is a production method for producing direct reduced iron by reducing a raw material for reduction with a reducing gas, using a shaft furnace or a kiln furnace, and this production method is characterized in that the raw material for reduction contains a sintered ore. Preferably, the raw material for reduction is characterized by being composed of 80% by mass or less of the sintered ore; and a remainder made up of at least one of lump ore and pellets. More preferably, the raw material for reduction is characterized by being composed of 5 to 70% by mass of the sintered ore; and a remainder made up of at least one of lump ore and pellets. Even more preferably, the raw material for reduction is characterized by being composed of 15 to 50% by mass of the sintered ore; and a remainder made up of at least one of lump ore and pellets. Further, the production method for direct reduced iron of the present invention is characterized in that the RDI of the sintered ore is 54% by mass or less, the total iron content of the sintered ore is smaller than 65% by mass, and the reducing gas contains 60 vol.% or more, more preferably 67 vol.% or more of a hydrogen gas.

[0017] Here, the expression that "the reducing gas contains 60 vol.% or more of a hydrogen gas" is defined as follows. That is, it means that of the gases supplied into the shaft furnace or kiln furnace, when a proportion excluding gases having no reduction action such as a nitrogen gas and a CO₂ gas is regarded as 100%, a volume ratio of the hydrogen gas is 60 vol.% or more. For example, there is a hypothetical case where the composition of the gases supplied into the shaft furnace

or kiln furnace is: hydrogen gas 50 vol.%; carbon monoxide gas 30 vol.%; carbon dioxide gas 10 vol.%; and nitrogen gas 10 vol.%. In such case, the reducing gas contains the hydrogen gas at a ratio of 62.5 vol.% which is calculated by: hydrogen gas volume concentration $\div$ (hydrogen gas volume concentration + carbon monoxide gas volume concentration) = $50 \div (50+30) = 62.5$ vol.%.

Examples

[0018] Examples of the present invention are described in detail hereunder. At first, a sintered ore having given properties was produced in a manner described below. The sintered ore produced and pellets were combined together by changing the additive amount of the sintered ore, thereby obtaining raw materials for reduction of Examples 1 to 9 and Comparative Examples 1 to 4 as shown in the following Table 1.

[0019] Next, with regard to the obtained raw materials for reduction of Examples 1 to 9 and Comparative Examples 1 to 4, according to a cluster strength measurement described below, direct reduced iron production was simulated from the raw materials for reduction, and the condition of clustering was evaluated via clustering indexes. The results are shown in the following Table 1 and Figs.2 to 4.

<Production of sintered ore>

[0020] The sintered ore was prepared in such a manner that after mixing iron ore and an auxiliary raw material(s) so that given properties are satisfied, a drum mixer was then used to perform granulation together with water, followed by producing the sintered ore with a cylindrical sintering test pot simulating a sintering machine. Of the sintered ore(s) obtained, those with a size of 5 mm or larger were collected via sieving and were treated as a raw material subjected to the cluster strength measurement. Further, in the present invention, a sintered ore with a given RDI was able to be produced by adjusting a suction negative pressure at the time of sintering and a coagulating material ratio. Moreover, in the present invention, a sintered ore with a given iron content was able to be produced by adjusting the type of the iron ore added and the amount of the auxiliary raw material. Here, RDI refers to reduction disintegration index as provided by JIS M 8720. However, if subjected to hydrogen-direct reduced iron making where a hydrogen gas is contained at 67 vol.% or more in the reducing gas, measurement may be performed by substituting part of or all the CO gas of the reducing gas as set forth in JIS M 8720 with a hydrogen gas.

<Cluster strength measurement>

[0021] Here, 500 g of a sample were loaded into a vertical cylindrical furnace having a diameter of 100 mm. The temperature of the sample was raised to 1,000°C in a N₂ atmosphere by the vertical cylindrical furnace; once the temperature of the sample had reached 1,000°C, the sample was then held for 3 hours under conditions of: reducing gas 24 L/min, H₂:N₂=20:80 (vol%), and load 1 kg/cm². Later, the sample was cooled in a N₂ atmosphere. Next, sieving was performed using a sieve with an opening of 16 mm which is the largest size of a single pellet, after which the weight was measured (Wa (g)). Later, the sample on the sieve was put into a type I testing machine (cylindrical container (diameter 132 mm; capacity 700 mL)), and was rotated at a rotation speed of 30 rpm for 5 min, followed by evaluating an amount Wb (g) sieved by the sieve with the opening of 16 mm. From this test, the result of a calculation of uncrushed clustering ratio (Wb/Wa)×100 was used as a clustering index for evaluation.

[Table 1]

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Example 9	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4
Sintered ore compounding amount (mass%)	5	15	25	50	70	80	70	70	70	0	100	70	70
Sintered ore RDI (mass%)	50	50	50	50	50	50	45	54	50	50	50	55	50
Sintered ore T.Fe (mass%)	63	63	63	63	63	63	63	63	55	63	63	63	65
Clustering index	20	10	0	8	20	30	10	34	0	35	76	40	37

[0022] Here, based on the results shown in Table 1, Fig.2 is a graph showing a correlation between a sintered ore compounding amount and the clustering index; Fig.3 is a graph showing a correlation between the sintered ore RDI and the clustering index; and Fig.4 is a graph showing a correlation between the total iron content (T.Fe) of the sintered ore and the clustering index.

[0023] Based on the correlation between the sintered ore compounding amount and the clustering index, as shown in Fig.2 (data of Examples 1 to 6 and Comparative Examples 1 and 2 were used), the following facts were made clear about adding the sintered ore into the raw material for reduction. First of all, by adding the sintered ore in an amount of not more than 80% by mass into the raw material for reduction, the clustering index decreased (improved) to less than 35. Further, by adding the sintered ore in an amount of 5 to 70% by mass into the raw material for reduction, the clustering index further decreased to 20 or lower. Moreover, by adding the sintered ore in an amount of 15 to 50% by mass into the raw material for reduction, the clustering index further decreased to 10 or lower. From the above facts, it was made clear that in order to prevent clustering from occurring, it is effective to add a sintered ore into a raw material for removal and reduction, and it is particularly effective to add a sintered ore in an amount of 80% by mass or less into a raw material for reduction. Further, as for the additive amount of the sintered ore, it was made clear that it is preferable to add the sintered ore in an amount of 5 to 70% by mass into the raw material for reduction, and it is more preferable to add the sintered ore in an amount of 15 to 50% by mass into the raw material for reduction.

[0024] From the correlation between the sintered ore RDI and the clustering index as shown in Fig.3 (there were used data of Examples 5, 7 and 8; and data of Comparative Example 3), there was assumed a case where the sintered ore was added in an amount of 70% by mass into the raw material for reduction. In such case, it was made clear that the clustering index further decreased by lowering the RDI of the sintered ore to 54% by mass or less. This indicates that in order to prevent clustering from occurring, it is preferable to lower the RDI of the sintered ore to 54% by mass or less.

[0025] From the correlation between the total iron content (T.Fe) of the sintered ore and the clustering index as shown in Fig.4 (there were used data of Examples 5 and 9; and data of Comparative Example 4), there was assumed a case where a sintered ore with a RDI of 50% by mass was added in an amount of 70% by mass into the raw material for reduction. In such case, it was made clear that the clustering index further decreased by lowering the total iron content (T.Fe) of the sintered ore to smaller than 65% by mass. This indicates that in order to prevent clustering from occurring, it is preferable to lower the total iron content (T.Fe) of the sintered ore to smaller than 65% by mass.

Industrial Applicability

[0026] The production method for direct reduced iron of the present invention is such that the occurrence of clustering can be reduced when producing direct reduced iron by reducing the raw material for reduction with the reducing gas, using a shaft furnace or a kiln furnace. Thus, the present invention is industrially useful as it contributes to CO₂ reduction, is also useful in a method using a hydrogen gas and carbon monoxide as a reducing gas, and is particularly useful when applied to a method using 67 vol.% or more of a hydrogen gas as a reducing gas (the method is called hydrogen-direct reduced iron making).

Claims

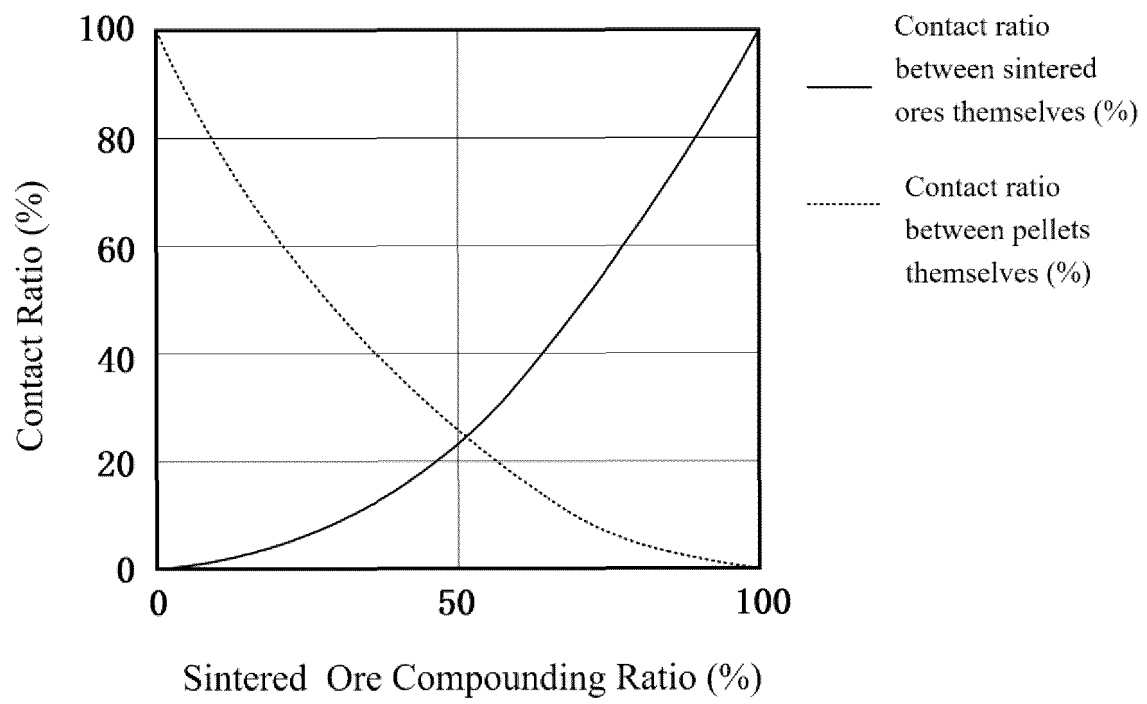
1. A production method for direct reduced iron comprising:
producing direct reduced iron by reducing a raw material for reduction with a reducing gas, using a shaft furnace or a kiln furnace,
wherein the raw material for reduction contains a sintered ore.
2. The production method for direct reduced iron according to claim 1, wherein the raw material for reduction is composed of 80% by mass or less of the sintered ore; and a remainder made up of at least one of lump ore and pellets.
3. The production method for direct reduced iron according to claim 1, wherein the raw material for reduction is composed of 5 to 70% by mass of the sintered ore; and a remainder made up of at least one of lump ore and pellets.
4. The production method for direct reduced iron according to claim 1, wherein the raw material for reduction is composed of 15 to 50% by mass of the sintered ore; and a remainder made up of at least one of lump ore and pellets.
5. The production method for direct reduced iron according to any one of claims 1 to 4, wherein the RDI of the sintered ore is 54% by mass or less.
6. The production method for direct reduced iron according to any one of claims 1 to 5, wherein a total iron content of the

sintered ore is smaller than 65% by mass.

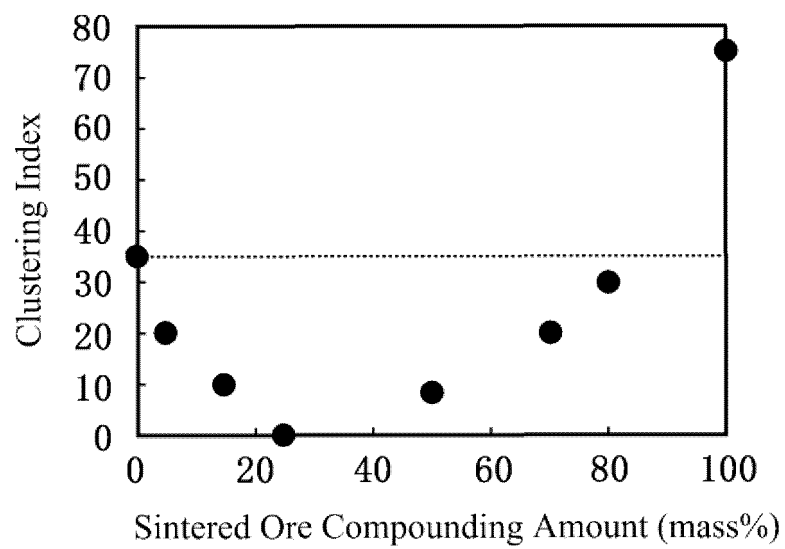
7. The production method for direct reduced iron according to any one of claims 1 to 6, wherein the reducing gas contains 60 vol.% or more of a hydrogen gas.

8. The production method for direct reduced iron according to any one of claims 1 to 6, wherein the reducing gas contains 67 vol.% or more of a hydrogen gas.

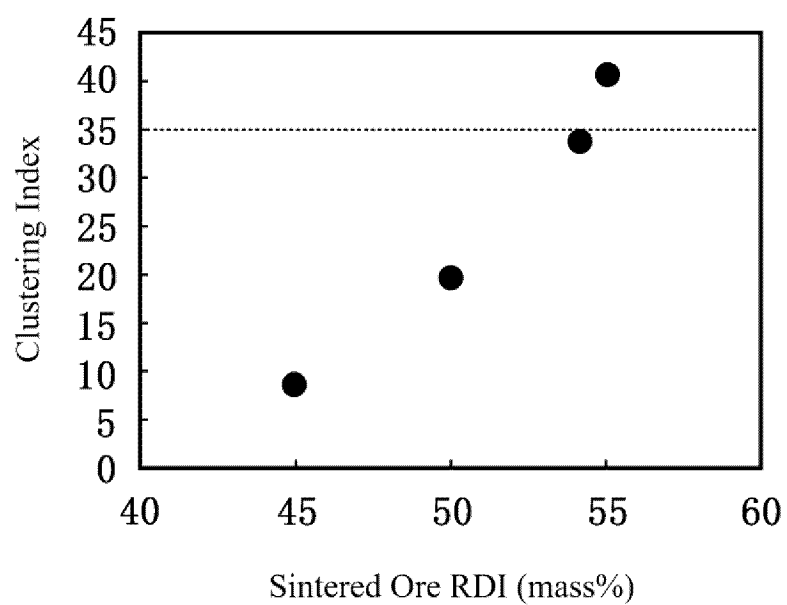
[Fig. 1]



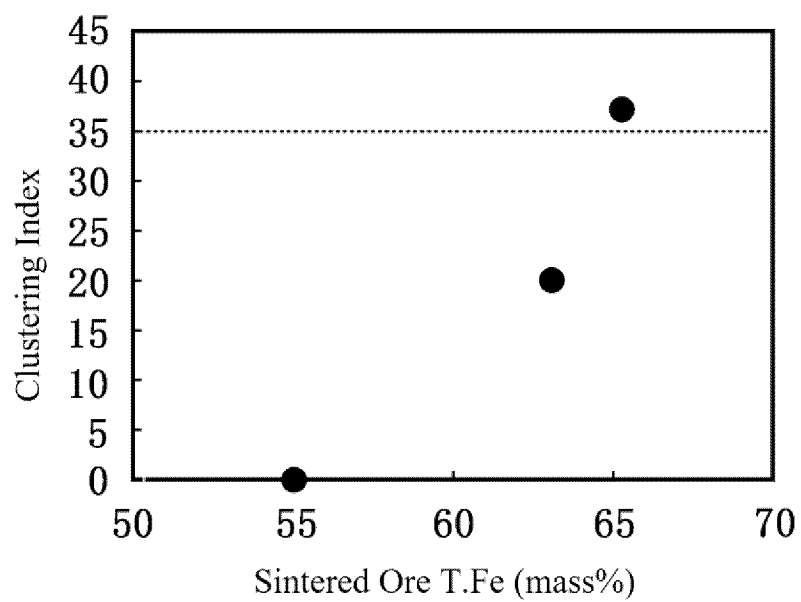
[Fig. 2]



[Fig. 3]



[Fig. 4]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/029418

A. CLASSIFICATION OF SUBJECT MATTER

C21B 13/02(2006.01)i; *C21B 13/08*(2006.01)i

FI: C21B13/02; C21B13/08

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C21B13/02; C21B13/08

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2011/099070 A1 (NIPPON STEEL CORP.) 18 August 2011 (2011-08-18) paragraphs [0001], [0066]-[0090], [0110]-[0129], fig. 4-8, tables 2, 4	1-5, 7
A		6, 8

☐ 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

02 September 2022

Date of mailing of the international search report

13 September 2022

Name and mailing address of the ISA/JP

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

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/029418

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2011/099070 A1	18 August 2011	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 4427295 B [0003]