(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 357 465 A1

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

(43) Date of publication:
24.04.2024 Bulletin 2024/17

(21) Application number: **22858193.0**

(22) Date of filing: **06.07.2022**

(51) International Patent Classification (IPC):
C21B 5/00 *(2006.01)* ***C21B 7/24*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
C21B 5/00; C21B 7/24

(86) International application number:
PCT/JP2022/026800

(87) International publication number:
WO 2023/021870 (23.02.2023 Gazette 2023/08)

(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: **17.08.2021 JP 2021132661**

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

(72) Inventors:
- **MATSUNAGA, Ryotaro**
Tokyo 100-0011 (JP)
- **MORIYA, Kota**
Tokyo 100-0011 (JP)
- **ICHIKAWA, Kazuhira**
Tokyo 100-0011 (JP)
- **YAMAMOTO, Tetsuya**
Tokyo 100-0011 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) METHOD FOR ESTIMATING DEPOSITIONAL SHAPE OF BLAST FURNACE FILLING AND METHOD FOR SUBSTITUTING BLAST FURNACE COKE

(57) Provided is, in a blast furnace in a blowing down with lowering stock level, an estimation method of the depositional shape of a charged material inside the blast furnace formed after coke inside the blast furnace is consumed by using a burner when the blast furnace is caused to start up.

In the estimation method of a depositional shape of a charged material inside a blast furnace, when a blast furnace in a blowing down with lowering stock level is caused to start up, there is estimated the depositional shape of a charged material inside the blast furnace formed after a burner is inserted into the blast furnace through a tap hole of the blast furnace and is used to consume coke inside the blast furnace, and the estimation method includes the steps of: estimating the depositional shape of a charged material inside a blast furnace in a blowing down with lowering stock level; estimating a charged region of coke inside the blast furnace from the depositional shape of the charged material inside the blast furnace estimated through the previous step and from the shape of a solidified layer on a bottom part inside the blast furnace; estimating an amount of coke inside the blast furnace that is consumed by using the burner; and estimating, from the amount of the coke inside the blast furnace, the depositional shape of a charged material inside the blast furnace formed after consumption of the coke inside the blast furnace.

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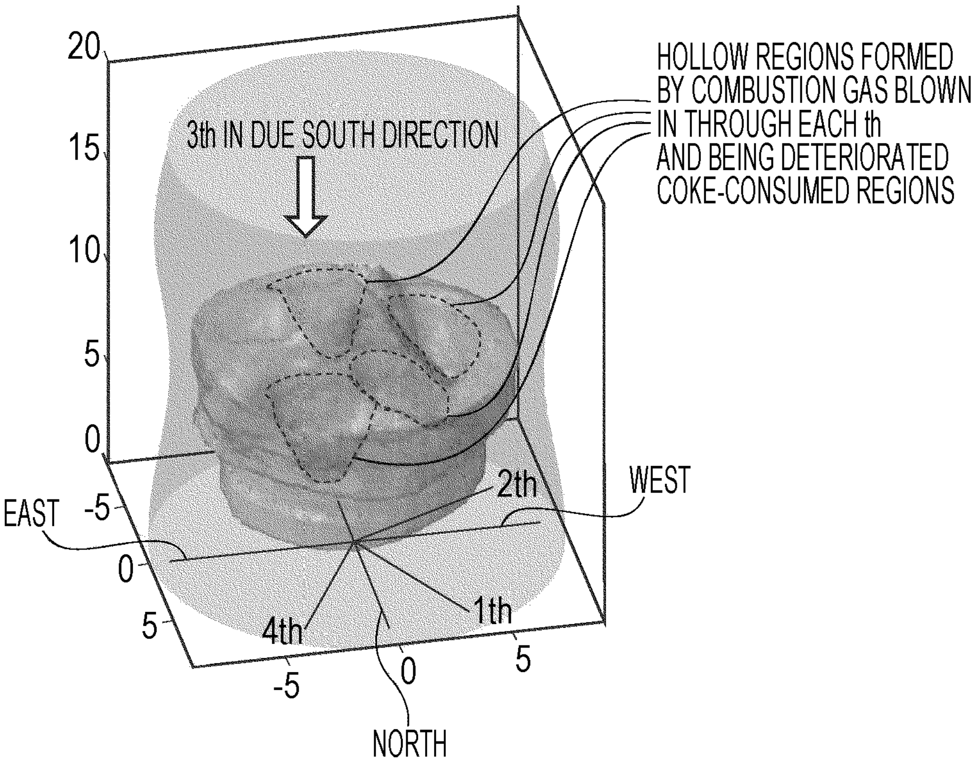
FIG. 3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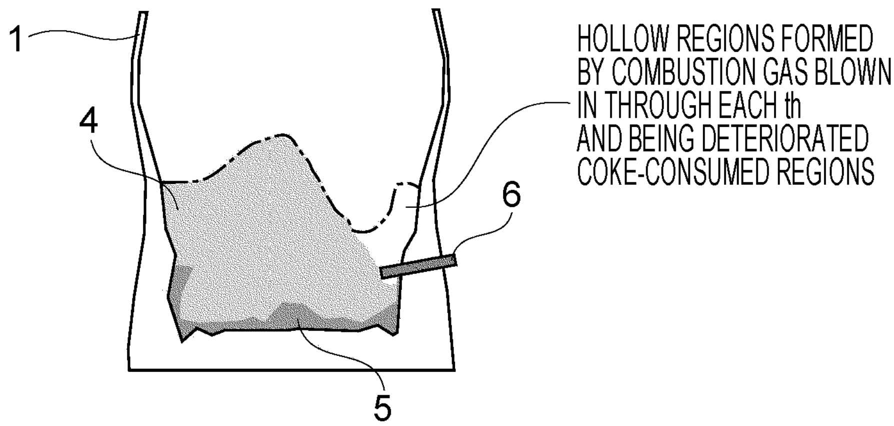
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HOLLOW REGIONS FORMED BY COMBUSTION GAS BLOWN IN THROUGH EACH th AND BEING DETERIORATED COKE-CONSUMED REGIONS
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(b)

Description

Technical Field

[0001] The present invention relates to an estimation method of the depositional shape of the charged material inside a blast furnace and a replacement method of the coke inside the blast furnace.

Background Art

[0002] A blast furnace is operated as follows. Iron ore and coke are charged from a furnace top, high-temperature air is blown in through tuyeres provided in a furnace lower part, and molten pig iron and slag are discharged through tap holes. In a process of the upward movement, inside the furnace, of high-temperature reducing gases such as CO and H_2 generated in regions ahead of the tuyeres, molten pig iron is produced by heating, reducing, and melting the iron ore that moves downward inside the furnace. The high-temperature air continues to be blown into the furnace during a steady operation; however, there may be taken a measure referred to as blowing down under which air-blowing into the blast furnace is temporarily stopped due to non-steady events such as a repair of a furnace body and addressing an operational trouble. In such a case, the temperature of the charged material inside the furnace is decreased due to heat removal from the furnace body and air suction from the tuyeres.

[0003] When the temperature inside the furnace is decreased, the molten material inside the furnace is increased in viscosity and further solidifies, thereby becoming difficult to be discharged through the tap holes. When air-blowing is performed through the tuyeres in such a situation, the molten pig iron and slag subjected to reduction melting are not discharged, and the build-up amount of the molten pig iron and slag in the furnace lower part is thereby increased. There is also a case in which the molten pig iron and slag that have built up in the furnace lower part become able to be discharged with the heating of the furnace lower part by dripping molten pig iron and slag. However, when the temperature increase of the furnace lower part is insufficient, the situation in which there is a difficulty in discharging the molten pig iron and slag continues, and the build-up amount of the molten pig iron and slag further increases. When the level of the molten pig iron and slag (the height of a surface of the molten pig iron and slag) reaches a tuyere due to a remarkable increase in the build-up amount, troubles such as erosion of a tuyere and blockage of a blast pipe will be caused. In such a case, air-blowing into the furnace cannot be performed; thus, heat input into the furnace ceases, which leads to a hearth chilling accident.

[0004] The hearth chilling accident here refers to an event in which the molten pig iron and slag cannot be discharged through the tap holes due to a remarkable decrease of the heat level inside the blast furnace, and a steady operation becomes difficult to be continued. When such an accident occurs, the following measures are taken to recover the furnace condition. That is, a solidified material positioned between one tap hole and tuyeres just above the tap hole is melted by a technique, such as oxygen-blowing, and is discharged to ensure an outlet for the molten material. Subsequently, air-blowing is performed through the tap hole and the two to three tuyeres just above the tap hole, and, while a solidified layer therearound is melted gradually by using the generated molten material, the numbers of tap holes and tuyeres in use are raised nearly to those in the steady operation. Because a recovery from the hearth chilling accident to the steady operation usually takes two to three months, the production amount of molten pig iron is understandably remarkably decreased during the recovery. In addition to that, there is a great danger that an operator is exposed to a high-temperature molten material and a poisonous gas in the process of the recovery work. Thus, such a hearth chilling accident can be considered as an operational trouble that entails huge loss and risk in economic and safety terms.

[0005] As described above, because the heat level inside the furnace is low at the time of a startup operation after the blowing down, the risk of the hearth chilling accident is increased. Thus, in the existing art, the coke ratio is increased to increase the heat level inside the furnace before the blowing down, and the risk of a hearth chilling accident is reduced. However, with an increase in the time period of the blowing down, the heat level inside the furnace gradually becomes unable to be maintained by such heat compensation due to the increase in the coke ratio. In such a case, as Fig. 1 illustrates, there is used a method in which air-blowing is suspended after the charged material inside the furnace is reduced in volume from the upper end of a bosh part of the blast furnace to the level of the tuyeres on condition of the high coke ratio, a raw material is charged, again on condition of the high coke ratio before the startup from the blowing down, and air-blowing into the furnace is then resumed. Such an blowing down is referred to as blowing down with lowering stock level. Such a blowing down with lowering stock level, which is conducted in the case of a large-scale facility repair or a long-term suspension of a blast furnace operation, is an blowing down continuing over a time period longer than a usual blowing down, thereby having a further increased risk of furnace cooling at the time of startup.

[0006] As a measure to reduce the furnace-cooling risk during such an blowing down or a blowing down with lowering stock level, there is proposed a method in which, as Fig. 1 illustrates, before air-blowing, a burner is inserted into a tap hole and is caused to blow in oxygen and fuel, the heat level in a region from the tuyere to the tap hole is raised sufficiently, and air-blowing is then started (Patent Literature 1). In addition, to improve the gas and molten-material permeability in the furnace lower part, there is proposed a method in which a portion of the coke, in the furnace lower part, pulverized and decreased in strength (deteriorated coke) is removed and replaced by new coke (Patent Literature 2).

Citation List

Patent Literature

[0007]

Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2016-30833

Patent Literature 2: Japanese Unexamined Patent Application Publication No. 5-295415

Non Patent Literature

[0008] Non Patent Literature 1: Yoshikawa Fumiaki and five others, "Estimation of Refractory Wear and Solidified Layer Distribution in the Blast Furnace Hearth and Its Application to the Operation", Tetsu-to-Hagane, Vol. 73 (1987) No. 15, p. 2068-2075

Summary of Invention

Technical Problem

[0009] The approach described in Patent Literature 1 is effective for improving the heat level in the furnace lower part of the blast furnace. In view of the purpose of reducing the risk of a hearth chilling accident, it is considered that simultaneously adopting, in combination, an approach of replacing deteriorated coke that is pulverized and decreased in strength with new coke, as in Patent Literature 2, can ensure far better gas and molten-material permeability in the furnace lower part and can thus reduce the risk of a hearth chilling accident. However, by partially removing the coke in the furnace lower part by half measures, the charged material above the consumed portion locally moves down, and the layering structure of the raw material to be subsequently charged will become nonuniform; thus, there is concern about a manifestation of adverse effects on the operation, such as lowered gas permeability in the furnace upper part and reduction failure of the raw material.

[0010] The present invention provides, in a blast furnace in a blowing down with lowering stock level, an estimation method of a depositional shape of a charged material inside the blast furnace formed after coke inside the blast furnace is consumed by using a burner when the blast furnace is caused to start up.

[0011] The present invention further provides a replacement method of coke inside the blast furnace using the estimation method.

Solution to Problem

[0012] The subject matter of the present invention is as follows.

[1] An estimation method of a depositional shape of a charged material inside a blast furnace, in which, when a blast furnace in a blowing down with lowering stock level is caused to start up, there is estimated a depositional shape of a charged material inside the blast furnace formed after a burner is inserted into the blast furnace through a tap hole of the blast furnace and is used to consume coke inside the blast furnace, the estimation method including the steps of:

- estimating a depositional shape of a charged material inside a blast furnace in a blowing down with lowering stock level;
- estimating a charged region of coke inside the blast furnace from the depositional shape of the charged material inside the blast furnace estimated through the previous step and from a shape of a solidified layer on a bottom part inside the blast furnace;
- estimating an amount of coke inside the blast furnace that is consumed by using the burner; and
- estimating, from the amount of the coke inside the blast furnace, a depositional shape of a charged material inside the blast furnace formed after consumption of the coke inside the blast furnace.

[2] A replacement method of coke inside a blast furnace using the estimation method of the depositional shape of the charged material inside the blast furnace according to the previous article [1], the replacement method including:
charging coke into the blast furnace so as to reduce a change between the depositional shape of the charged material inside the blast furnace in the blowing down with lowering stock level and the depositional shape of the charged material inside the blast furnace formed after the consumption of the coke inside the blast furnace.

Advantageous Effects of Invention

[0013] According to the present invention, in the blast furnace in the blowing down with lowering stock level, it is possible to estimate the depositional shape of the charged material inside the blast furnace formed after the coke inside the blast furnace (deteriorated coke) is consumed by using the burner when the blast furnace is caused to start up.

[0014] According to the present invention, a change in the depositional shape of the charged material inside the blast furnace with the consumption of the deteriorated coke is estimated, and coke is charged into the blast furnace with reference to the estimation result. Thus, while a change in the depositional shape of the charged material inside the blast furnace with the replacement of the coke inside the blast furnace is reduced, the coke inside the blast furnace in the blowing down with lowering stock level (deteriorated coke) is replaced by new coke, and the gas and molten-material permeability in the furnace lower part can thereby be improved. As a result, the blast furnace in a state of blowing down can be caused to start up stably to reach a state of steady operation.

Brief Description of Drawings

[0015]

[Fig. 1] Fig. 1 is a schematic view illustrating an example of a depositional shape of charged material inside a blast furnace in a blowing down with lowering stock level and a state in which a burner is inserted into the furnace through a tap hole of the blast furnace.

[Fig. 2] Fig. 2 illustrates a charged region of the coke inside the furnace that is estimated in the present example.

[Fig. 3] Fig. 3 illustrates the depositional shape of the charged material inside the furnace formed after consumption of the coke inside the furnace that is estimated in the present example.

Description of Embodiments

[0016] The present invention is implemented for a blast furnace. The blast furnace refers to an industrial furnace for producing molten pig iron by using a main raw material such as iron ore and sintered ore, including iron oxide and a reducing material such as coke, including carbon or hydrogen. The main raw material and the reducing material are charged, in layers, from a furnace top, and a blast of hot air containing oxygen and the reducing material such as powdered coal are delivered into the furnace through tuyere parts. Through a process in which CO and H_2 generated through gasification of the reducing material in the vicinity of each of the tuyeres flow to a furnace upper part, the main raw material charged from the furnace top is heated, reduced, and melted, and molten pig iron is thus generated. Inside the furnace, the generated molten pig iron drips to be collected on a furnace hearth part and is discharged through tap holes provided in a side face of the lower part of the blast furnace. Although the facility design of a blast furnace including, for example, the inner capacity of a blast furnace, a raw material charging mechanism, and the number of tuyeres often varies from one furnace body to another, the present invention is applicable regardless of such differences in the facility design.

[0017] In addition, in the operation of the blast furnace, various materials are used as the main raw material and the reducing material that are charged from the furnace top and as the reducing material that is blown into through the tuyere parts. Examples of the main raw material include iron ore, sintered ore, pellet, scrap, and reduced iron. Examples of the reducing material that is charged from the furnace top include lump coke, and smaller coke such as coke granules and ferrocoke. Examples of the reducing material that is blown into through the tuyere parts include: powdered coal; coke breeze; plastic; a combustible gas, such as a natural gas, including at least one kind of carbon atoms and hydrogen atoms; and liquid fossil fuel. The present invention is applicable regardless of types of the raw material and the reducing material to be used.

[0018] In the present invention, it is found that a change in the depositional shape of the charged material inside the furnace before and after the consumption of deteriorated coke can be estimated by estimating the depositional shape of the charged material inside the blast furnace in a blowing down with lowering stock level (hereinafter, referred to also as an initial depositional shape), the shape of a solidified layer on a bottom part inside the furnace (solidified layer shape), the consumption behavior of the coke inside the furnace (deteriorated coke), and the depositional shape of the charged material inside the furnace formed after the consumption of the deteriorated coke. It is also found that, by appropriately determining, for example, the amount and a charging position of the coke to be charged anew based on the estimation result of the depositional shape change, there can be reduced a change in the depositional shape of the charged material inside the furnace before and after the charged coke inside the furnace under the blowing down with lowering stock level is replaced by the coke to be charged anew when the furnace is caused to start up from the blowing down with lowering stock level.

<Estimation Method of Depositional Shape of Charged Material Inside Blast Furnace>

[0019] An estimation method of a depositional shape of a charged material inside a blast furnace of the present invention includes the steps of: estimating a depositional shape of a charged material inside a blast furnace in a blowing down with lowering stock level; estimating a charged region of coke inside the blast furnace from the depositional shape of the charged material inside the blast furnace estimated through the previous step and from a shape of a solidified layer on a bottom part inside the blast furnace; estimating an amount of coke inside the blast furnace that is consumed by using a burner; and estimating, from the amount of the coke inside the blast furnace, a depositional shape of a charged material inside the blast furnace formed after consumption of the coke inside the blast furnace.

(Step of Estimating Depositional Shape of Charged Material Inside Blast Furnace in Blowing Down with Lowering Stock Level)

[0020] In the step of estimating a depositional shape of a charged material inside a blast furnace in a blowing down with lowering stock level, the depositional shape (initial depositional shape) of the charged material inside the blast furnace in a blowing down with lowering stock level is estimated. Examples of the estimation method of the initial depositional shape include a method in which the initial depositional shape is estimated from the results obtained by measuring, with a rangefinder, distances from the furnace top of the blast furnace in a blowing down with lowering stock level to several spots on the surface of the charged material inside the furnace. Examples of the rangefinder include, but not particularly limited to, a noncontact rangefinder such as a laser rangefinder. The depositional shape can be estimated three-dimensionally by measuring, with the rangefinder, the distances to several spots on the surface of the charged material inside the furnace.
However, the estimation method of the initial depositional shape is not limited thereto, and the technique of the present invention can be implemented regardless of the estimation method of the initial depositional shape.

(Step of Estimating Charged Region of Coke Inside Blast Furnace)

[0021] In the step of estimating a charged region of coke inside the blast furnace, a charged region of the coke inside the blast furnace is estimated from the depositional shape (initial depositional shape) of the charged material inside the furnace estimated by the step of estimating the initial depositional shape described above and from the shape of a solidified layer on the bottom part inside the furnace. The blast furnace in a blowing down with lowering stock level includes a solidified layer that has increased in size on the bottom part inside the furnace. In the present step, the shape of the solidified layer on the bottom part inside the furnace is estimated. Examples of the estimation method of the shape of the solidified layer on the bottom part inside the furnace include an approach using the boundary element method, such as an approach described in Non Patent Literature 1. In the approach described in Non Patent Literature 1, a heat transfer calculation using the boundary element method is performed on the assumption that the interface of the solidified layer coincides with the isotherm of the solidification temperature (1150° C) of pig iron. This approach is a method in which sequential calculation is performed to determine the solidification interface such that the error between the value of a temperature of the furnace bottom in an actual furnace actually measured by a thermocouple and the calculation result of a temperature obtained by using the boundary element method is minimized. The shape of the solidified layer on the bottom part inside the furnace can be estimated from the solidification interface determined as described above. Note that thermocouples are usually provided in the furnace bottom part of the blast furnace below the tuyeres, at plural positions in the circumferential direction and the height direction of the blast furnace.

[0022] After the shape of the solidified layer on the bottom part inside the furnace is estimated as described above, a charged region of the coke inside the furnace is estimated. As for the estimation method of the charged region of the coke inside the furnace, by using the initial depositional shape and the shape of the solidified layer on the bottom part inside the furnace that are estimated as described above, a region other than the region of the shape of the solidified layer can be estimated as the charged region of the coke inside the furnace.

(Step of Estimating Amount of Coke Inside Blast Furnace That IS Consumed by Using Burner and Estimating, From the Amount of Coke Inside Blast Furnace, Depositional Shape of Charged Material Inside Blast Furnace Formed After Consumption of Coke Inside Blast Furnace)

[0023] In the step of estimating an amount of coke inside the blast furnace that is consumed by using a burner, there is estimated the amount of the coke inside the blast furnace that is consumed by using a burner inserted into the furnace through a tap hole of the blast furnace. Examples of this estimation method include a method in which estimation is performed by using: a flow passage, in a coke-charged layer (the charged region of the coke inside the furnace), of a combustion gas that is blown into the furnace from the burner; and the composition of the combustion gas, on the assumption that all of the combustion gas blown from the burner reacts with coke. However, the temperature of the combustion gas decreases gradually while the combustion gas moves upward inside the furnace, thereby there is a probability of becoming lower than a temperature at which a reaction proceeds in the coke-charged layer. In addition, even if the temperature of the combustion gas is a temperature at which a reaction proceeds, the reaction speed varies depending on the temperature. Thus, it is preferable that the consumption behavior of the coke inside the furnace (deteriorated coke) is estimated in consideration of the heat transfer between the combustion gas and the coke inside the furnace and the temperature dependence of the reaction speeds of various reactions.

[0024] As for the gas used for the burner inserted through a tap hole, a gas as it is or after its burning that reacts with and consumes the coke inside the furnace may be used. Although the inventors of the present invention used LNG and oxygen as the gas, the type of the gas usable in the technique described in the present invention is not limited thereto.

[0025] After the amount of the coke inside the furnace that is consumed by using the burner (a consumption region of the coke inside the furnace) is estimated as described above, and, in the step of estimating a depositional shape of a charged material inside the blast furnace formed after consumption of the coke inside the blast furnace, the depositional shape of the charged material inside the blast furnace formed after consumption of the coke inside the blast furnace is estimated based on the estimated amount of the coke inside the furnace. Regarding the depositional shape formed after the consumption of the coke inside the furnace, as Fig. 3 illustrates, based on hollow regions generated by consuming the coke inside the furnace (deteriorated coke) with the combustion gas, a region other than the hollow regions can be estimated as the depositional shape of the charged material inside the furnace formed after the consumption of the coke inside the furnace.

<Replacement Method of Coke Inside Blast Furnace>

[0026] For a replacement method of coke inside a blast furnace of the present invention, the above-described estimation method of the depositional shape of the charged material inside the blast furnace is used. Specifically, based on the depositional shape (initial depositional shape) of the charged material inside the furnace in the blowing down with lowering stock level and the depositional shape of the charged material inside the furnace formed after the consumption of the coke inside the furnace, new coke is charged into the blast furnace so as to reduce a change between the depositional shapes, and the coke inside the furnace in the blowing down with lowering stock level is thus replaced by the new coke. That is, regarding the amount of the coke to be charged anew and a position at which the coke is charged, it is desirable that the coke is charged so as to reproduce the initial depositional shape of the charged material inside the furnace. Examples of the method for charging coke anew include a method in which coke is charged from the furnace top as in a normal operation and a method in which a conveyor belt is inserted into the furnace through a tuyere part, and charging is performed by using the conveyor belt. The larger the difference in height between a position at which new coke is charged and the charged material inside the furnace, the higher the possibility that the charged new coke increasingly becomes granular. Thus, new coke is preferably charged into the furnace at a position whose difference in height from the charged material inside the furnace is minimized.

[0027] As described above, with the approach of the present invention, a change in the depositional shape with the consumption of the coke inside the blast furnace in a blowing down with lowering stock level (deteriorated coke) is estimated, and coke is charged into the blast furnace with reference to the estimation result. Thus, while a change in the depositional shape of the charged material inside the blast furnace with the replacement of the coke inside the furnace is reduced, the deteriorated coke is replaced by new coke, and the gas and molten-material permeability of the furnace lower part can thereby be improved. As a result, the blast furnace in a state of blowing down can be caused to start up further stably to reach a state of steady operation.

EXAMPLE

[0028] Hereinafter, the present invention will specifically be described with an example. However, the present invention is not limited to the example below.

[0029] In the present example, in a commercial blast furnace in a long-term blowing down with lowering stock level, after the depositional shape of the charged material inside the furnace formed after consumption of deteriorated coke was estimated based on the above-described embodiment, new coke was charged, air-blowing through tuyeres was then started, and a startup operation of the blast furnace was performed.

[0030] First, the initial depositional shape of the charged material inside the furnace was estimated from the data of distances from the furnace top of the blast furnace in the blowing down with lowering stock level to the charged material inside the furnace measured by using a noncontact rangefinder (in the present example, a laser rangefinder). Further, by using the data given by thermometers provided in the furnace bottom part of the blast furnace, a solidified layer shape on the bottom part inside the blast furnace was estimated by the approach described in the embodiment using the boundary element method. The result of estimating a charged region of the coke inside the furnace through such approaches is illustrated in Fig. 2. Note that Fig. 2(a) illustrates, from diagonally above, the estimated charged region of the coke inside the furnace, and Fig. 2(b) is a vertical sectional view (schematic view) of a tap hole (2th) in Fig. 2(a).

[0031] Subsequently, on the assumption that a burner is inserted through a tap hole of the furnace bottom part of the blast furnace and is caused to blow a combustion gas into the furnace, a change in the depositional shape of the charged material inside the furnace with the consumption of the coke inside the furnace (deteriorated coke) by the blowing-in of the combustion gas was estimated by the approach described in the above-described embodiment. The estimation result of the depositional shape of the charged material inside the furnace formed after the consumption of the deteriorated coke is illustrated in Fig. 3. Note that Fig. 3(a) illustrates, from diagonally above, the estimated depositional shape of the charged material inside the furnace formed after the consumption of the deteriorated coke, and Fig. 3(b) is a vertical sectional view (schematic view) of the tap hole (2th) in Fig. 3(a). The comparison between Fig. 2 and Fig. 3 reveals that, from the vicinity of a tap hole toward the upper side, the deteriorated coke was consumed, and cone-shaped hollows were formed. In addition, the weight of new coke required to be charged in the hollows was calculated from the volume of the hollows obtained through the comparison between the estimation results of Fig. 2 and Fig. 3.

[0032] Based on the calculation result of the weight described above, the burner was inserted through a tap hole, the deteriorated coke inside the furnace was consumed, the new coke was charged into the hollows though tuyeres, and coke and a main raw material were then charged from the furnace top to an upper part relative to the tuyere level. Subsequently, when air-blowing was started through the tuyeres to perform the startup operation, molten pig iron and slag were smoothly discharged through the tap holes, and the blast furnace was able to be returned to the state of steady operation, without a serious trouble such as a trouble that the molten pig iron and slag are prevented from being discharged, and the remaining pig iron and slag inside the furnace thus build up to the tuyere level (the height of the tuyeres).

[0033] The above-described result has revealed that, with the present invention, while a change in the depositional shape of the charged material inside the blast furnace with the replacement of the coke inside the furnace is reduced, the gas and molten-material permeability of the furnace lower part can be improved by replacing deteriorated coke with new coke, and the blast furnace in the state of blowing down with lowering stock level can be caused to start up stably to reach the state of steady operation.

Reference Signs List

[0034]

1 blast furnace body
2 tuyere (air-blowing tuyere)
3 tap hole
4 coke
5 solidified layer
6 burner

Claims

1. An estimation method of a depositional shape of a charged material inside a blast furnace, wherein, when a blast furnace in a blowing down with lowering stock level is caused to start up, there is estimated a depositional shape of a charged material inside the blast furnace formed after a burner is inserted into the blast furnace through a tap hole of the blast furnace and is used to consume coke inside the blast furnace, the estimation method comprising the steps of:

    estimating a depositional shape of a charged material inside a blast furnace in a blowing down with lowering stock level;
    estimating a charged region of coke inside the blast furnace from the depositional shape of the charged material inside the blast furnace estimated through the previous step and from a shape of a solidified layer on a bottom part inside the blast furnace;
    estimating an amount of coke inside the blast furnace that is consumed by using the burner; and
    estimating, from the amount of the coke inside the blast furnace, a depositional shape of a charged material inside the blast furnace formed after consumption of the coke inside the blast furnace.

2. A replacement method of coke inside a blast furnace using the estimation method of the depositional shape of the charged material inside the blast furnace according to Claim 1, the replacement method comprising:
    charging coke into the blast furnace so as to reduce a change between the depositional shape of the charged material inside the blast furnace in the blowing down with lowering stock level and the depositional shape of the charged material inside the blast furnace formed after the consumption of the coke inside the blast furnace.

FIG. 1

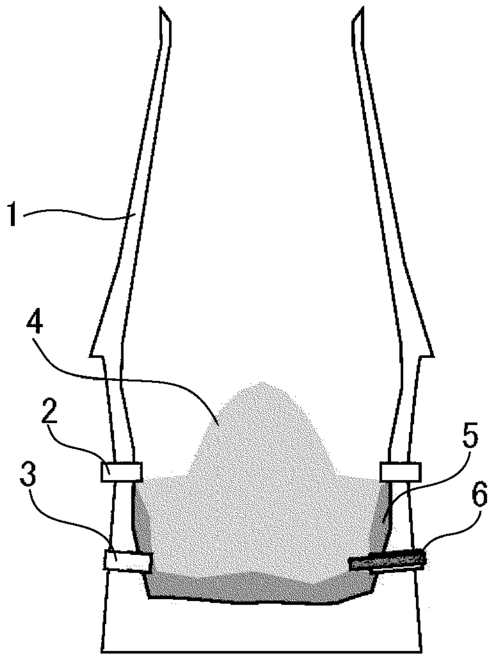
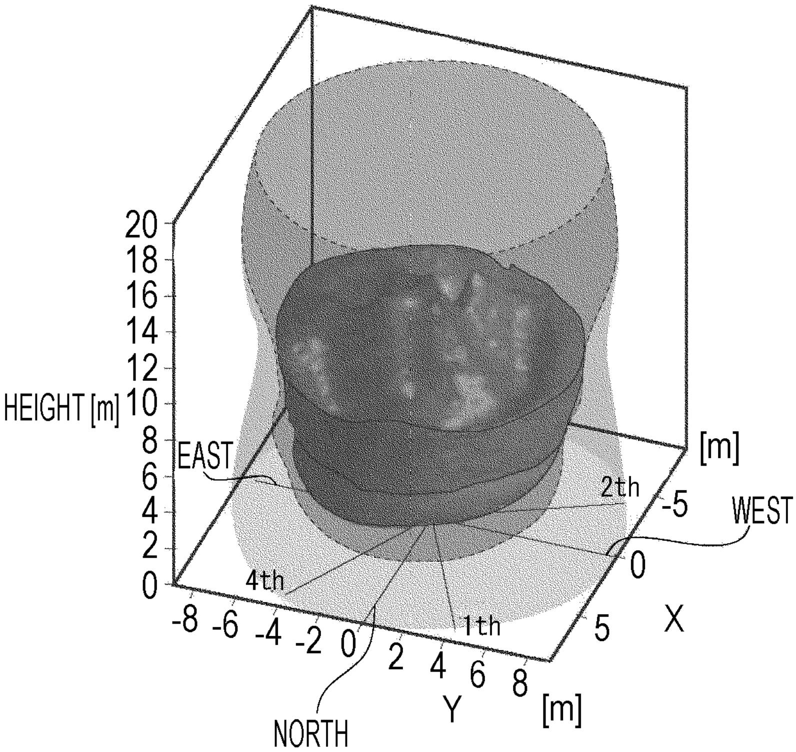


FIG. 2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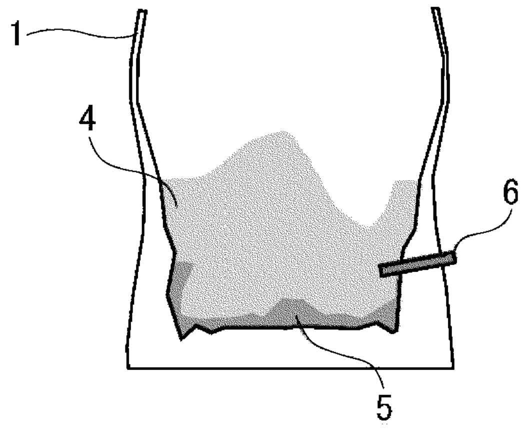
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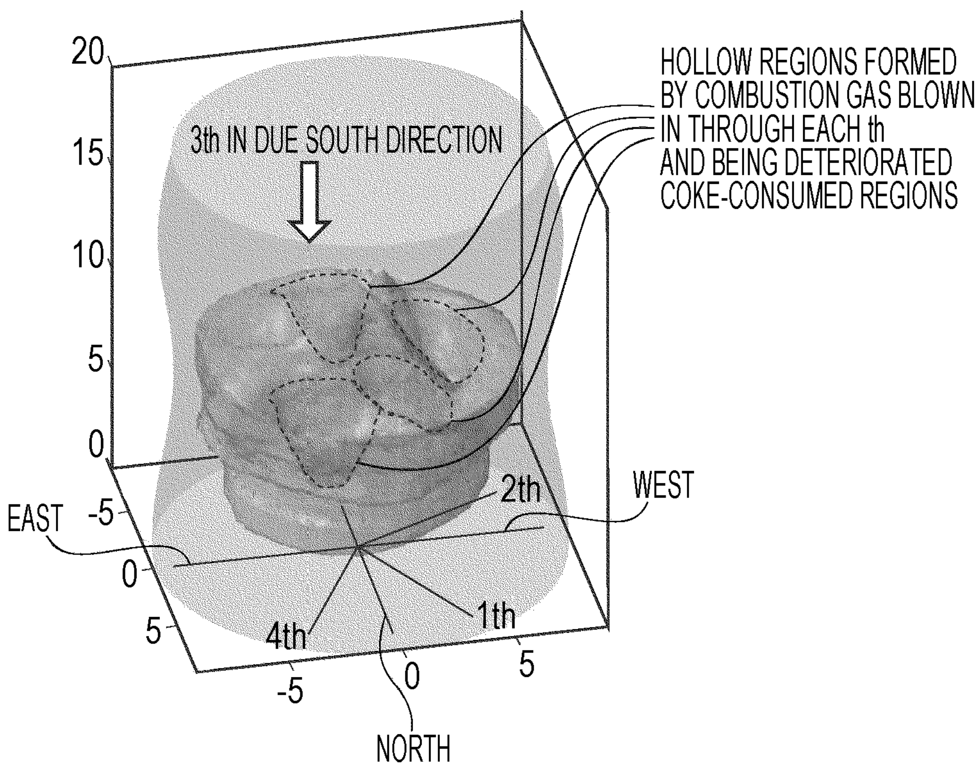
(b)

FIG. 3


20
15
10
5
0
3th IN DUE SOUTH DIRECTION
HOLLOW REGIONS FORMED BY COMBUSTION GAS BLOWN IN THROUGH EACH th AND BEING DETERIORATED COKE-CONSUMED REGIONS
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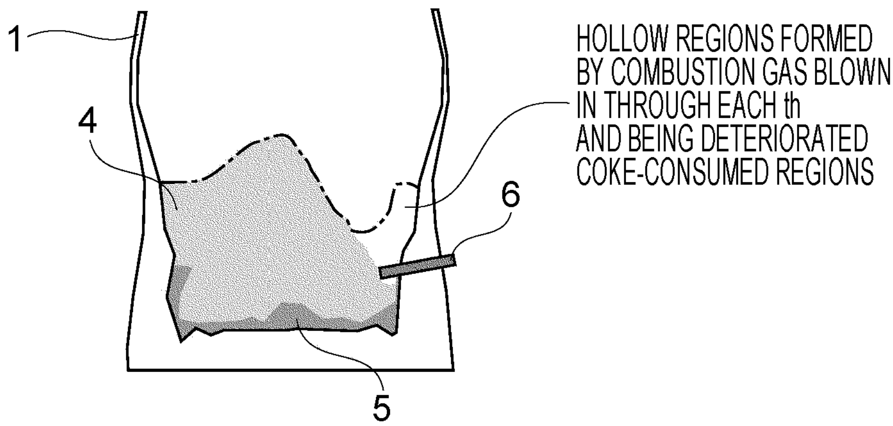
WEST
NORTH
2th
1th
4th
-5
0
5
-5
0
5

(a)


1
4
5
6
HOLLOW REGIONS FORMED BY COMBUSTION GAS BLOWN IN THROUGH EACH th AND BEING DETERIORATED COKE-CONSUMED REGIONS

(b)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/026800

A. CLASSIFICATION OF SUBJECT MATTER

C21B 5/00(2006.01)i; ***C21B 7/24***(2006.01)i
FI: C21B5/00 315; C21B7/24

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)

C21B5/00; C21B7/24

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.
A	JP 2014-047397 A (NIPPON STEEL & SUMITOMO METAL CORP.) 17 March 2014 (2014-03-17) paragraphs [0001], [0041], [0042]	1-2
A	JP 64-065211 A (KOBE STEEL, LTD.) 10 March 1989 (1989-03-10) claims	1-2
A	JP 2018-003044 A (JFE STEEL CORP.) 11 January 2018 (2018-01-11) paragraph [0032]	1-2

☐ 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
08 August 2022	**23 August 2022**

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/JP2022/026800

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2014-047397 A	17 March 2014	(Family: none)	
JP 64-065211 A	10 March 1989	(Family: none)	
JP 2018-003044 A	11 January 2018	(Family: none)	

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 2016030833 A **[0007]**
- JP 5295415 A **[0007]**

Non-patent literature cited in the description

- **YOSHIKAWA FUMIAKI.** Estimation of Refractory Wear and Solidified Layer Distribution in the Blast Furnace Hearth and Its Application to the Operation. *Tetsu-to-Hagane,* 1987, vol. 73 (15), 2068-2075 **[0008]**