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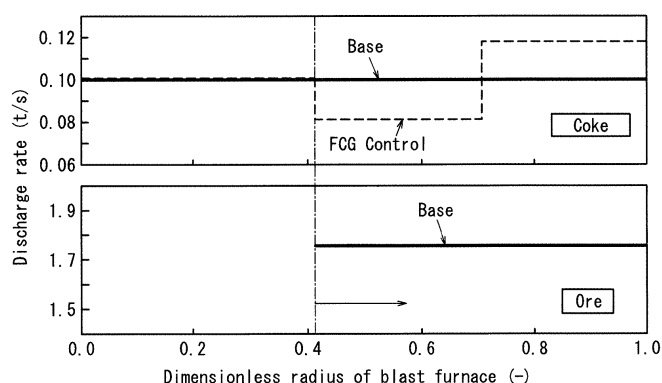
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(54) **METHOD FOR CHARGING STARTING MATERIAL INTO BLAST FURNACE**

(57) A method for charging blast furnace raw material into a blast furnace, comprising, when charging blast furnace raw material including coke and ore material such as sinter, pellet, or lump ore into the blast furnace using a rotating chute, forming a central coke layer at a shaft central portion of the blast furnace; and forming a mixed layer of the coke and the ore material on the outside of

the central coke layer with a coke mixing ratio varying in a continuous or stepwise manner from the shaft of the blast furnace towards the furnace wall in the blast furnace radial direction. The method ensures gas permeability in the blast furnace, stabilizes blast furnace operations, and improves thermal efficiency even when an operation to blow in a large amount of pulverized coal is performed.

FIG. 7



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a method for charging starting material (blast furnace raw material) into a blast furnace by charging blast furnace raw material into the furnace with a rotating chute.

BACKGROUND ART

10 **[0002]** Generally, ore material such as sintered ore, pellet, lump ore, and the like and coke are charged into a blast furnace from the furnace top in a layer state, and combustion gas is injected through a tuyere to yield pig iron. The coke and ore material that constitute the blast furnace raw material charged into the blast furnace descend from the furnace top to the furnace bottom, the ore reduces, and the temperature of the raw material rises. The ore material layer gradually deforms due to the temperature rise and the load from above while filling the voids between ore materials, and at the
15 bottom of the shaft of the blast furnace, gas permeability resistance grows extremely large, forming a cohesive layer where nearly no gas flows.

[0003] Conventionally, blast furnace raw material is charged into a blast furnace by alternately charging ore material and coke. In the furnace, ore material layers and coke layers form alternately. At the bottom of the blast furnace, in the so-called cohesive zone, ore material layers with a large gas permeability resistance, where ore has softened and cohered, exist along with a coke slit, derived from coke, with a relatively small gas permeability resistance.
20 **[0004]** The gas permeability of the cohesive zone greatly affects the gas permeability of the blast furnace as a whole and limits the rate of productivity in the blast furnace. When performing a low coke operation, the amount of coke that is used is reduced, which is considered to cause significant thinning of the coke slit.

[0005] In order to improve the gas permeability resistance of the cohesive zone, mixing coke into the ore material layer is known to be effective, and much research has been reported for achieving an appropriate mixing state.
25 **[0006]** For example, JP H3-211210 A (PTL 1) discloses charging, in a bell-less blast furnace, coke into an ore hopper that is downstream among the ore hoppers, layering coke onto the ore on a conveyor, and charging the ore and coke into the furnace top bunker and then into the blast furnace via a rotating chute.

[0007] JP 2004-107794 A (PTL 2) discloses separately storing ore and coke in furnace top bunkers and mixing the coke and ore while charging them simultaneously in order to yield three batches at the same time: a batch for regularly charged coke, a batch for mainly charging coke, and a batch for mixed charging.
30 **[0008]** Furthermore, in order to prevent the cohesive zone shape from becoming unstable during blast furnace operation, to prevent a reduction in the gas utilization rate near the central region, and to improve operation safety and thermal efficiency, JP S59-10402 B2 (PTL 3) discloses a method for charging blast furnace raw material into a blast furnace whereby all of the ore and all of the coke are charged into the furnace after being completely mixed.

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CITATION LIST

Patent Literature

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[0009]

PTL 1: JP H3-211210 A

PTL 2: JP 2004-107794 A

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PTL 3: JP S59-10402 B2

SUMMARY OF INVENTION

(Technical Problem)

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[0010] In order to improve the gas permeability resistance of the cohesive zone, mixing coke into the ore layer as in the conventional example disclosed in PTL 3 is known to be effective.

[0011] However, as the amount of coke mixed into the ore material layer is increased in order to improve the gas permeability of the blast furnace, the coke slit is reduced and eventually lost locally. The ore material layer provides a gas permeability improving effect at the time of softening that more than offsets such local loss of the coke slit, thereby improving the gas permeability of the cohesive zone as a whole.
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[0012] On the other hand, during blast furnace operation, it is important to balance the reduction efficiency of ore material using a reducing gas with the gas permeability of the reducing gas. Accordingly, in conventional blast furnace

operation, ore material layers and coke layers are formed with different thickness ratios (which will be referred to hereinafter as " L_O/L_C ," where L_O is the thickness of ore material layers and L_C is the thickness of coke layers) in the blast furnace radial direction to control the gas flow in the blast furnace.

[0013] As mentioned above, however, where the coke slit is very thin or locally lost, it is impossible to control L_O/L_C in the blast furnace radial direction.

[0014] The present invention has been developed in light of the above circumstances, and it is an object thereof to provide a method for charging blast furnace raw material into a blast furnace that can stabilize blast furnace operations and improve thermal efficiency by controlling the gas flow in the blast furnace without having to provide a coke slit therein.

(Solution to Problem)

[0015] Specifically, main features of the present invention are as follows.

[1] A method for charging blast furnace raw material into a blast furnace, comprising, when charging blast furnace raw material including coke and ore material such as sintered ore, pellet, or lump ore into the blast furnace using a rotating chute:

forming a central coke layer at a shaft central portion of the blast furnace; and
forming a mixed layer of the coke and the ore material on the outside of the central coke layer with a coke mixing ratio varying in a continuous or stepwise manner in the blast furnace radial direction.

[2] The method for charging blast furnace raw material into a blast furnace according to the aspect [1] above, further comprising:

providing at least two furnace top bunkers at a top of the blast furnace;
storing, in either one or two of the furnace top bunkers, either one or both of the ore material and mixed material obtained by mixing the ore material with the coke with a mixing amount of coke being 30 mass% or less of a total amount of coke;
storing only coke in one of the remaining furnace top bunkers;
receiving the raw material discharged from each of the furnace top bunkers in a collecting hopper; and
then feeding the raw material to the rotating chute to charge the blast furnace raw material into the blast furnace, wherein

(1) the rotating chute is set to charge blast furnace raw material into the shaft central portion of the blast furnace, and by discharging only coke from the furnace top bunker, into which only coke has been charged, a central coke layer is formed in the shaft central portion of the blast furnace, and
(2) the rotating chute is then set to charge blast furnace raw material to the outside of the central coke layer, and by simultaneously discharging the coke and the ore material and/or the mixed material from the furnace top bunkers at an adjusted discharge rate, mixing the discharged coke with the discharged ore material and/or mixed material in the collecting hopper to form a mixture, and feeding the mixture to the rotating chute, a mixed layer is formed on the outside of the central coke layer with a coke mixing ratio varying in a continuous or stepwise manner in the blast furnace radial direction.

(Advantageous Effect of Invention)

[0016] According to the present invention, gas flow in a blast furnace can be controlled without a coke slit and the blast furnace can maintain good gas permeability, which allows for stabilizing blast furnace operation and improving reduction efficiency, and as a result, yielding high productivity and enabling operation with a low reducing agent ratio. This may result in reduced CO emission and contribute to tackling global environmental issues. In addition, according to the present invention, even if the coke distribution in the blast furnace radial direction in a mixed layer deviates from an adequate range due to the segregation of the mixed material in the furnace top bunker, and causes a defect in the gas flow in the blast furnace, a mixed layer having a coke ratio that compensates the deviation of the coke distribution may be formed thereon to prevent deterioration of the gas flow in the blast furnace.

BRIEF DESCRIPTION OF DRAWINGS

[0017] The present invention will be further described below with reference to the accompanying drawings, wherein:

FIG. 1 schematically illustrates an embodiment of a method for charging blast furnace raw material into a blast furnace according to the present invention;

FIG. 2 is a diagram illustrating the order for charging blast furnace raw material from the furnace top bunkers;

FIG. 3 schematically illustrates the raw material charging condition including the furnace top bunkers;

FIG. 4 is a schematic configuration diagram of an experimental device for measuring high temperature properties of the ore material;

FIG. 5 is a graph showing the relationship between the ratio of mixed coke to ore material and maximum pressure drop, using the sintered ore ratio as parameters;

FIG. 6 is a graph showing the relationship between the mixed coke ratio and the gas permeability resistance ($\Delta P/V$) of the mixed coke packed layer, plotting parameters of the ratio of the particle diameter of coke to the particle diameter of sintered ore;

FIG. 7 is a graph showing an example where the mixed coke ratio varies in the blast furnace radial direction, with varying discharge rates of coke and of ore material over time according to the present invention;

FIG. 8 is a graph showing the temporal change of the discharge rates of coke and of ore material in Example 1;

FIG. 9 is a graph showing the temporal change of the discharge rates of coke and of ore material in Example 2;

FIG. 10 is a graph showing the temporal change of the discharge rates of coke and of ore material in Example 3; and

FIG. 11 is a graph showing the temporal change of the discharge rates of coke and of ore material in Example 4.

DESCRIPTION OF EMBODIMENTS

[0018] The following describes an embodiment of the present invention with reference to the drawings.

[0019] FIG. 1 schematically illustrates an embodiment of a method for charging blast furnace raw material into a blast furnace according to the present invention.

[0020] FIG. 1 illustrates the following: an ore material hopper 1 for storing ore material 2 composed of at least one of sintered ore, pellet, and lump ore; and a coke hopper 3 for storing coke 4. Ore material 2 and coke 4 that have been discharged from the ore material hopper 1 and from the coke hopper 3 in predetermined proportions are transported upwardly by an ore conveyor 5, then mixed and stored in a reserving hopper 6 as blast furnace raw material 7. Blast furnace raw material 7 that has been discharged from the reserving hopper 6 is transported to the top of the blast furnace 10 by a charging conveyor 8, then charged via a receiving chute 11, and stored in one furnace top bunker, e.g., 12b among, e.g., three furnace top bunkers 12a to 12c. Note that the mixed material of ore material and coke is stored in the furnace top bunker 12b while adjusting the mixing amount of coke to be 30 mass% or less of a total amount of coke.

[0021] Here, the mixing amount of coke is adjusted to be 30 mass% or less of the total amount of coke for the following reasons. Ore material 2 and coke 4 that have been discharged from the ore material hopper 1 and the coke hopper 3 are transported on the ore conveyor 5 with the coke 4 being layered onto the ore material 2, charged into the reserving hopper 6, where the ore material 2 and the coke 4 are mixed to form mixed material. However, since coke 4 and ore material 2 are different in specific gravity and particle size, the mixed material stored in the reserving hopper 6 may segregate during transport to the receiving chute 11 on the charging conveyor 8, and furthermore, during charging via the receiving chute 11 into the furnace top bunker 12b.

[0022] At this point, if the amount of coke mixed with ore material is 30 mass% or less of the total amount of coke, coke and ore material are not significantly segregated when stored in the furnace top bunker 12b, and consequently, the mixing ratio of the mixed layer of ore material and coke formed by the rotating chute 16 may become substantially even.

[0023] In contrast, if the mixing amount of coke is more than 30 mass% of the total amount of coke, coke and ore material are more prone to segregation due to the differences in specific gravity and particle size and are largely segregated when stored in the furnace top bunker 12b, which causes regions where either one of ore material or coke alone is present.

[0024] Moreover, the mixed material is discharged from the furnace top bunker 12b in the order of, as shown in FIG. 2, upwards from a position near the outlet 12g close to the central shaft of the blast furnace, subsequently away from the central shaft of the blast furnace towards the outside, and finally the upper edge of the inclined sidewall 12h is discharged.

[0025] Thus, when either one of ore material or coke alone lies directly on the outlet 12g or on the upper end of the inclined sidewall 12h, only ore material or coke is discharged. In this case, although the ore material or coke will be mixed with coke and ore material to be discharged from the other furnace top bunkers 12a and 12c in the collecting hopper 14 to be stated later, the proportion of ore material or coke will increase, and the mixing ratio of the mixed layer of ore material and coke formed by the rotating chute 16 will be uneven.

[0026] The specific way of charging ore material and coke into a blast furnace is described based on FIG. 3.

[0027] In this example, it is assumed that the furnace top bunker 12b stores mixed material of ore material and coke, the furnace top bunker 12a stores coke alone, and the furnace top bunker 12c stores ore material alone.

[0028] In addition, the following describes raw material charging using a so-called reverse tilting control scheme, where

the rotating chute 16 is controlled to be tilted from the shaft central portion of the blast furnace 10 towards the furnace wall, while simultaneously rotating about the shaft center of the blast furnace 10.

[0029] The order for charging blast furnace raw material from the furnace top bunkers is as follows. First, the rotating chute 16 is set to charge blast furnace raw material into the shaft central portion of the blast furnace, and by discharging only coke from the furnace top bunker 12a, into which coke alone has been charged, a central coke layer 12d is formed in the shaft central portion of the blast furnace.

[0030] In other words, with the rotating chute 16 set to tilt in substantially vertical direction, the flow regulating gates 13 of the furnace top bunkers 12b and 12c are closed, the flow regulating gate 13 of only the furnace top bunker 12a is opened, and only the coke stored in the furnace top bunker 12a is fed to the rotating chute 16. In this way, a central coke layer 12d is formed in the shaft central portion of the blast furnace, as shown in FIG. 3.

[0031] At this point, it is desirable that coke falls at a position having a dimensionless radius of the blast furnace of 0 or more to 0.3 or less, in relation to the raw material stock line level, when 0 is the shaft central portion of the blast furnace and 1 is the furnace wall. The reason is that collecting some of coke in the shaft central portion of the furnace may be effective for improving the gas permeability at the shaft central portion, and thus the gas permeability of the blast furnace as a whole.

[0032] Note that the amount of coke charged to form a central coke layer is preferably approximately 5 mass% to 30 mass% of the amount of coke charged per charge. This is because if the amount of coke charged into the shaft central portion is less than 5 mass%, the gas permeability around the shaft central portion improves insufficiently, and if coke is collected in the shaft central portion by more than 30 mass%, not only does the amount of coke used to form a mixed layer decrease, but also too much gas passes through the shaft central portion, leading to increased heat removal from the furnace body. Preferably, the amount of coke charged into the shaft central portion is 10 mass% to 20 mass%.

[0033] Then, after the formation of the central coke layer 12d, coke and ore material and/or mixed material are discharged simultaneously from each furnace top bunker, while gradually tilting the rotating chute 16 towards the horizontal direction, mixed in the collecting hopper 14, and then fed to the rotating chute 16 to form a mixed layer 12e of ore material and coke on the outside of the central coke layer 12d.

[0034] In other words, with the rotating chute set to charge blast furnace raw material to the outside of the central coke layer, not only the flow regulating gate 13 of the furnace top bunker 12a but also the flow regulating gates 13 of the remaining two furnace top bunkers 12b and 12c are opened to predetermined opening positions, and coke discharged from the furnace top bunker 12a, mixed material discharged from the furnace top bunker 12b, and ore material discharged from the furnace top bunker 12c are simultaneously fed to the collecting hopper 14, where the coke and the ore material are completely mixed and fed to the rotating chute 16. As a result, a mixed layer 12e is formed on the outside of the central coke layer 12d in the blast furnace 10, where coke and ore material are mixed with a substantially even mixing ratio and no coke slit is formed.

[0035] In this case, the proportion of coke in the mixed layer is preferably approximately 7 mass% to 25 mass%, more preferably approximately 10 mass% to 15 mass%, in terms of the ratio of (amount of coke / amount of ore material). If the ratio of (amount of coke / amount of ore material) deviates from the aforementioned range, in either case, the gas permeability in the mixed layer deteriorates. Note that the proportion of coke in the mixed layer is preferably about 20 % to 95 % in terms of a percentage of the total amount of coke.

[0036] It is also desirable that ore material has a particle diameter of 5 mm to 35 mm, preferably 10 mm to 30 mm, and coke has a particle diameter of 10 mm to 60 mm, preferably 30 mm to 55 mm. Moreover, the ratio of the particle diameters (the particle diameter of coke / the particle diameter of ore material) is preferably approximately 1.0 to 5.5.

[0037] Meanwhile, as mentioned above for conventional blast furnace operation, for balancing the reduction efficiency of ore material with a reducing gas and the gas permeability of the reducing gas, it is important to control the gas flow in the blast furnace by changing the ratio of the amount of ore material to the amount of coke as appropriate in the blast furnace radial direction.

[0038] Therefore, in the present invention, the ratio of the amount of ore material to the amount of coke in the mixed layer is adjusted as appropriate in the blast furnace radial direction so as to control the gas flow in the blast furnace, rather than adjusting the ratio of the thickness of an ore material layer to the thickness of a coke layer (L_O/L_C) as done in conventional methods.

[0039] In other words, according to the present invention, the following furnace top bunkers are preferably provided: the furnace top bunker 12a for storing coke, the furnace top bunker 12c for storing ore material, and the furnace top bunker 12b for storing mixed material of ore material and coke, and furthermore, the raw material discharge rate from each furnace top bunker may be changed in any desired manner by adjusting the opening position of the flow regulating gate 13 disposed at the bottom of each furnace top bunker 12.

[0040] Accordingly, the opening position of each flow regulating gate 13 may be adjusted to control the discharge rate of coke and ore material, and thus change the ratio of the amount of ore material to the amount of coke in the mixed layer to be deposited in the furnace in a continuous or stepwise manner in the blast furnace radial direction.

[0041] Generally, a gas flow is formed in the blast furnace radial direction depending on the ratio of the gas permeability

resistance in the radial direction of the packed layer and the cohesive zone in the furnace, the gas permeability resistance is determined by the particle diameter of particles constituting the layer and the void ratio among particles, and those factors of the mixed layer are mainly determined by the amount of coke mixed in the mixed layer.

[0042] Therefore, the gas flow in the blast furnace radial direction may be controlled by adjusting the amount of coke contained in the mixed layer.

[0043] The laboratory device illustrated in FIG. 4 was used to simulate the raw material reduction and elevated temperature process in a blast furnace and to test the change in gas permeability resistance.

[0044] In the laboratory device, a furnace core tube 32 is disposed on the inner peripheral surface of a cylindrical furnace body 31, and a cylindrical heater 33 is disposed on the outside of the furnace core tube 32. On the inside of the furnace core tube 32, a graphite crucible 35 is disposed at the upper edge of a cylindrical body 34 constituted by refractory material, and charged raw material 36 is charged inside the crucible 35. A load is applied to the charged raw material 36 from above by a load application device 38 connected via a punch rod 37, so that the charged raw material 36 adopts approximately the same state as the cohesive layer at the bottom of the blast furnace. A device 39 for sampling drops is provided at the bottom of the cylindrical body 34.

[0045] The gas adjusted by a gas mixing device 40 is fed to the crucible 35 through the cylindrical body 34 provided on its underside, and the gas passing through the charged raw material 36 in the crucible 35 is analyzed by a gas analysis device 41. A thermocouple 42 for controlling the heating temperature is provided in the heater 33, and by having a control device (not illustrated) control the heater 33 while measuring the temperature with the thermocouple 42, the crucible 35 is heated to 1200 °C to 1500 °C.

[0046] As the charged raw material 36, samples were prepared by mixing, in different proportions, coke with ore material formed from sinter and iron ore mixed in a predetermined ratio.

[0047] FIG. 5 is a graph showing the results of the aforementioned experiments and the relationship between the ratio of mixed coke to ore material and maximum pressure drop, using the sinter ratio as parameters.

[0048] It can be seen from FIG. 5 that the maximum pressure drop becomes less significant with increasing mixed coke ratio, independently of the type of ore material.

[0049] The reason seems to be that mixing with coke suppressed deformation of ore, preserved voids near the mixed coke, and accordingly prevented the occurrence of a phenomenon that would otherwise cause a decrease in the amount of voids among particles and an increase in gas permeability resistance due to deformation of ore.

[0050] Then, FIG. 6 is a graph showing the results of studies conducted separately to examine the relationship between the mixed coke ratio and the gas permeability resistance ($\Delta P/V$) of the mixed coke packed layer, plotting parameters of the ratio of the particle diameter of coke to the particle diameter of sintered ore.

[0051] Note that $\Delta P/V$ is an index yielded by indexation of the gas permeability resistance in the blast furnace and is calculated by the following equation:

$$\Delta P/V = (BP - TP)/BGV$$

where BP is the blast pressure [Pa],

TP is the furnace top pressure [Pa], and

BGV is the Bosch gas volume (m³ (standard temperature and pressure)/min).

[0052] As shown in FIG. 6, the gas permeability resistance of the mixed coke packed layer rises with increasing mixed coke ratio. It can also be seen that this tendency grows more pronounced with a higher ratio of the particle diameter of coke to the particle diameter of sinter.

[0053] In the cohesive zone, however, the gas permeability resistance significantly decreases significantly with increasing mixed coke ratio as well as increasing ratio of the particle diameter of coke to the particle diameter of sinter. Thus, an increase in the amount of coke causes a rise in gas permeability resistance in the packed layer, yet, in the cohesive zone, provides an advantage that more than offsets the disadvantage, and thus is effective, as a whole, for reducing gas permeability resistance.

[0054] Therefore, according to the present invention, by adjusting the ratio of mixed coke to ore material, as well as the ratio of the particle diameter of coke to the particle diameter of sintered ore, the mixed coke ratio in the blast furnace radial direction may be appropriately controlled to be a predetermined value, with the result that the gas flow in the blast furnace may be controlled as appropriate.

[0055] In addition, as shown in FIG. 2, even if the coke distribution in the blast furnace radial direction in the mixed layer deviates from an adequate range due to the segregation of the mixed material in the furnace top bunker 12b, and causes a defect in the gas flow in the blast furnace, a mixed layer having a coke ratio that compensates the deviation of the coke distribution may be formed thereon to prevent deterioration of the gas flow in the blast furnace.

[0056] Then, FIG. 7 is a graph showing an example where the mixed coke ratio varies in the blast furnace radial direction, with varying raw material discharge rates over time for discharge from the furnace top bunker 12a for storing coke and for discharge from the furnace top bunker 12c for storing ore material, according to the present invention.

[0057] In this example, to form a central coke layer 12d, only coke is charged at a discharge rate of 0.10 t/s into a region having a dimensionless radius of the blast furnace in a range of 0 to 0.4. Then, to form a mixed layer on the periphery of the central coke layer, ore material is charged at a constant discharge rate of 1.75 t/s, while coke is charged at a discharge rate of 0.08 t/s into a region having a dimensionless radius of the blast furnace in a range of 0.4 to 0.7, and subsequently at a raised discharge rate of 0.12 t/s into a region having a dimensionless radius of the blast furnace in a range of 0.7 to 1.0.

[0058] For raw material charging into the blast furnace, the above-described central coke layer 12d and mixed layer 12e are formed sequentially inside the blast furnace 10 from the bottom to the top.

[0059] In this way, by sequentially layering central coke layers 12d and mixed layers 12e, the central coke layers 12d with small gas permeability resistance are formed from the bottom of the blast furnace towards the top of the blast furnace at the shaft central portion inside the blast furnace 10, and the mixed layers 12e in which coke and ore material are completely mixed are formed on the outside thereof.

[0060] Therefore, by blowing high-temperature gas having CO as the main constituent into the furnace through a blast tube of a tuyere disposed in a basin at the bottom of the blast furnace 10, a gas flow that traverses the central coke layers 12d at the shaft central portion and rises is formed, and a gas flow that traverses the mixed layers 12e and rises is also formed. Then, the coke is combusted by the high-temperature gas blown through the blast tube of tuyere, and the ore material is subjected to reductive dissolution.

[0061] In this way, the ore material at the bottom of the blast furnace 10 dissolves, with the result that the coke and ore material charged into the blast furnace 10 descend from the furnace top to the furnace bottom, and the ore material is reduced and rises in temperature.

[0062] Therefore, at the top of the melt layer, a cohesive zone in which the ore material is softened forms, and the ore material is reduced at the top of this cohesive zone.

[0063] At this time, at the bottom of the blast furnace 10 in the mixed layer 12e, the ore material and the coke are completely mixed, with coke penetrating between the ore materials. The gas permeability improves by virtue of the absence of a coke slit, and high-temperature gas passes directly between ore materials, allowing for improvement of heat-transfer properties without delay in heat transfer.

[0064] Therefore, at the bottom of the cohesive zone in the blast furnace 10, the area of contact between the ore material and the high-temperature gas expands, encouraging carburizing. In the cohesive zone, gas permeability and thermal conductivity can also be improved. Furthermore, at the top of the blast furnace 10 as well, ore material and coke are provided near each other. Hence, due to a coupling reaction, which is a reciprocal activation phenomenon between a reduction reaction of the ore material and a gasification reaction (carbon solution loss reaction), reduction proceeds well without a reduction delay.

[0065] The reduction reaction at this time is represented by $\text{FeO} + \text{CO} = \text{Fe} + \text{CO}_2$. The gasification reaction is represented by $\text{C} + \text{CO}_2 = 2\text{CO}$.

[0066] On the other hand, in the above-described conventional example in which ore and coke are layered, ore and coke are alternately charged into the blast furnace so that ore layers and coke layers are charged into the blast furnace in a layer state. In this case, when injecting high-temperature gas having CO as the main constituent through the blast tube of the tuyere, at the bottom of the cohesive zone gas permeability is restricted by the reduction in the coke slit and the pressure drop increases, leading to the problem of a reduction in the area of contact between the ore and the high-temperature gas and restriction of carburizing.

[0067] At the top of the cohesive zone, a coke slit is formed, and heat is conducted to the ore mainly through this coke slit. Therefore, a delay in heat transfer occurs, causing insufficient heat transfer. Furthermore, since a coke layer with good gas permeability and an ore layer with poor gas permeability are stacked at the top of the blast furnace 10, not only does the rate of temperature increase drop, but also the reduction reaction alone occurs, so that the above coupling reaction cannot be expected. The problem of reduction delay thus occurs.

[0068] In the present invention, however, as described above, charging layers are stacked by forming central coke layers 12d, into which coke alone has been charged, and mixed layers 12e, in which coke and ore material are completely mixed. Therefore, no coke slit is formed in the mixed layers 12e. In addition, by adjusting the coke mixing ratio in the mixed layers 12e as appropriate in the blast furnace radial direction, gas flow in the blast furnace radial direction can be precisely controlled. Therefore, gas flow in the blast furnace becomes uniform and good thermal conductivity can also be ensured, as can stable improvement in gas permeability, thus resolving the problems in the above conventional example.

[0069] FIG. 7 shows a case where the discharge rate of coke is switched in one step, yet the discharge rate may be switched in more than one step, and even changed in a continuous manner.

[0070] For example, the following describes a case where the discharge rate is switched in two steps.

[0071] In this case, only coke is charged at a discharge rate of 0.10 t/s into those regions with a dimensionless radius of the blast furnace from 0 to 0.4 to form a central coke layer. Then, to form a mixed layer, ore material may be charged at a constant discharge rate of 1.75 t/s, while coke may be charged at a discharge rate of 0.2 t/s into a region having a blast furnace dimensionless radius from 0.4 to 0.6, at a discharge rate of 0.17 t/s into a region having a blast furnace dimensionless radius from 0.6 to 0.8, and at a discharge rate of 0.15 t/s into a region having a blast furnace dimensionless radius from 0.8 to 1.0.

[0072] Note that an advantageous operation is as follows: when a shaft pressure anomaly is detected while monitoring shaft pressure during blast furnace operation, in the course of continuous blast furnace charging according to the present invention, the raw material charging should be switched to a normal mode in which ore material layers and a coke slit are separately formed and, when the shaft pressure anomaly is resolved later, switched back to the charging scheme according to the present invention.

EXAMPLES

[0073] In this embodiment, for a mixed layer 12e, coke mixing ratio is the amount of coke mixed in the mixed layer 12e, based on the total amount of coke, and productivity is the amount of metal produced per day in the blast furnace (t/d) divided by the volume of the blast furnace (m^3). Example 1 has a coke mixing ratio of 40 mass% and productivity of 2.2, Example 2 has a coke mixing ratio of 69 mass% and productivity of 2.2, Example 3 has a coke mixing ratio of 84 mass% and productivity of 2.2, and Example 4 has a coke mixing ratio of 84 mass% and productivity of 2.6. In addition, as comparative examples, Comparative Example 1 has a coke mixing ratio of 0 mass% and productivity of 2.2, Comparative Example 2 has a coke mixing ratio of 32 mass% and productivity of 2.2, Comparative Example 3 has a coke mixing ratio of 32 mass% and productivity of 2.6, and Comparative Example 4 has a coke mixing ratio of 84 mass% and productivity of 2.6.

[0074] In Examples 1 to 4, blast furnace raw material was charged with the mixed coke ratio in the mixed layer varying in a stepwise manner in the blast furnace radial direction, as shown in FIGS. 8 to 11.

[0075] Blast furnace operations were performed under different conditions, the results of which are shown in Table 1.

[0076] [Table 1]

Table 1

	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Inventive Example 1	Inventive Example 2	Inventive Example 3	Inventive Example 4
Productivity (t/m ³ /day)	2.2	2.2	2.4	2.4	2.2	2.2	2.2	2.4
Coke ratio (kg/t)	362	360	361	350	345	343	341	339
Pulverized coal ratio (kg/t)	148	148	148	148	148	148	148	148
Reducing agent ratio (kg/t)	510	508	509	498	493	491	489	487
Gas utilization rate (%)	48.1	48.5	48.4	50.2	50.7	50.9	51.1	51.5
$\Delta P/V$ (kPa/(Nm ³ /min))	25.8	24.6	25.0	23.8	24.0	23.5	23.2	23.1
Coke mixing ratio (mass%)	0	32	32	84	40	69	84	84
Mixed coke ratio in blast furnace radial direction	-	constant	constant	constant	FIG. 8	FIG. 9	FIG. 10	FIG. 11

[0077] In Table 1, the coke ratio and the pulverized coal ratio are the coke volume and pulverized coal volume (kg) used when producing 1t of hot metal. The reducing agent ratio is the sum of the coke ratio and the pulverized coal ratio.

[0078] The gas utilization rate is the ratio of the concentrations of CO₂ and CO at the furnace top and is calculated by the following equation:

$$\text{gas utilization rate} = \text{CO}_2 / (\text{CO}_2 + \text{CO}) \times 100$$

where CO₂ is the furnace top CO₂ concentration[%], and

CO is the furnace top CO concentration[%].

[0079] ΔP/V is an index yielded by indexation of the gas permeability resistance in the blast furnace and is calculated by the following equation:

$$\Delta P/V = (BP - TP)/BGV$$

where BP is the blast pressure[Pa],

TP is the furnace top pressure [Pa], and

BGV is the Bosch gas volume (m³ (standard temperature and pressure)/min).

[0080] As shown in Table 1, Examples 1 to 4 each yielded a significant drop in the reducing agent ratio, which is the sum of the coke ratio and the pulverized coal ratio, and an improvement in gas utilization rate, as compared with Comparative Examples 1 to 4. Moreover, Examples 1 to 4 each showed a drastic reduction in ΔP/V, which is an index of gas permeability resistance, and offered considerably improved gas permeability in the blast furnace.

REFERENCE SIGNS LIST

[0081]

- | | |
|------------|---|
| 1 | Ore powder hopper |
| 2 | Ore material |
| 3 | Coke hopper |
| 4 | Coke |
| 5 | Ore conveyor |
| 6 | Reserving hopper |
| 7 | Blast furnace raw material |
| 8 | Charging conveyor |
| 10 | Blast furnace |
| 11 | Receiving chute |
| 12a to 12c | Furnace top bunker |
| 12d | Central coke layer |
| 12e | Mixed layer |
| 12g | Outlet of furnace top bunker |
| 12h | Inclined sidewall of furnace top bunker |
| 13 | Flow regulating gate |
| 14 | Collecting hopper |
| 15 | Bell-less charging device |
| 16 | Rotating chute |
| 31 | Cylindrical furnace body |
| 32 | Furnace core tube |
| 33 | Cylindrical heater |
| 34 | Cylindrical body |
| 35 | Graphite crucible |
| 36 | Charged raw material |
| 37 | Punch rod |
| 38 | Load application device |

40 Mixing device
41 Gas analysis device
42 Thermocouple

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Claims

1. A method for charging blast furnace raw material into a blast furnace, comprising, when charging blast furnace raw material including coke and ore material such as sintered ore, pellet, or lump ore into the blast furnace using a rotating chute:

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forming a central coke layer at a shaft central portion of the blast furnace; and
forming a mixed layer of the coke and the ore material on the outside of the central coke layer with a coke mixing ratio varying in a continuous or stepwise manner in the blast furnace radial direction.

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2. The method for charging blast furnace raw material into a blast furnace according to claim 1, further comprising:

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providing at least two furnace top bunkers at a top of the blast furnace;
storing, in either one or two of the furnace top bunkers, either one or both of the ore material and mixed material obtained by mixing the ore material with the coke with a mixing amount of coke being 30 mass% or less of a total amount of coke;

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storing only coke in one of the remaining furnace top bunkers;
receiving the raw material discharged from each of the furnace top bunkers in a collecting hopper; and
then feeding the raw material to the rotating chute to charge the blast furnace raw material into the blast furnace, wherein

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(1) the rotating chute is set to charge blast furnace raw material into the shaft central portion of the blast furnace, and by discharging only coke from the furnace top bunker, into which only coke has been charged, a central coke layer is formed in the shaft central portion of the blast furnace, and

(2) the rotating chute is then set to charge blast furnace raw material to the outside of the central coke layer, and by simultaneously discharging the coke and the ore material and/or the mixed material from the furnace top bunkers at an adjusted discharge rate, mixing the discharged coke with the discharged ore material and/or mixed material in the collecting hopper to form a mixture, and feeding the mixture to the rotating chute, a mixed layer is formed on the outside of the central coke layer with a coke mixing ratio varying in a continuous or stepwise manner in the blast furnace radial direction.

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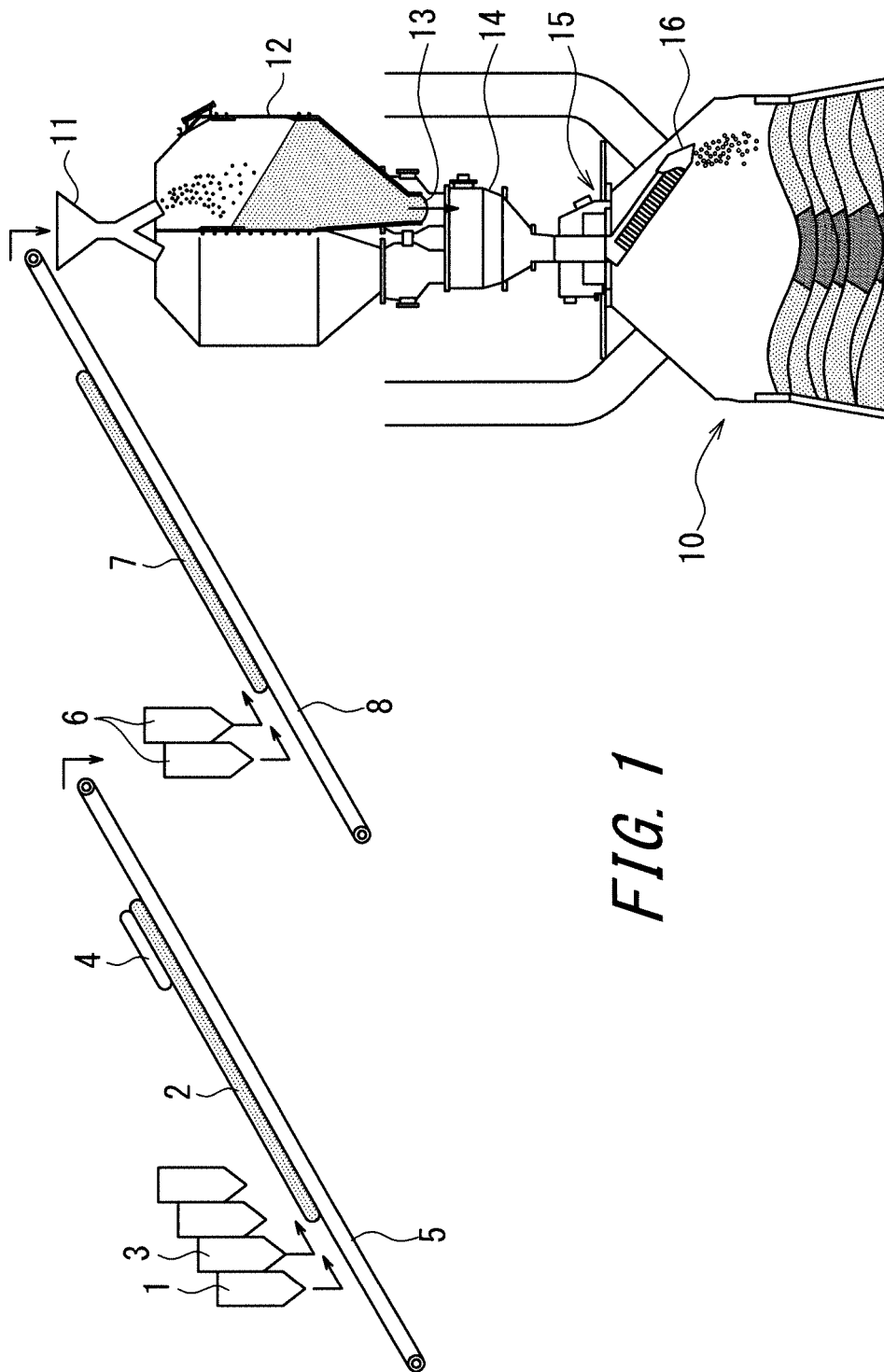


FIG. 1

FIG. 2

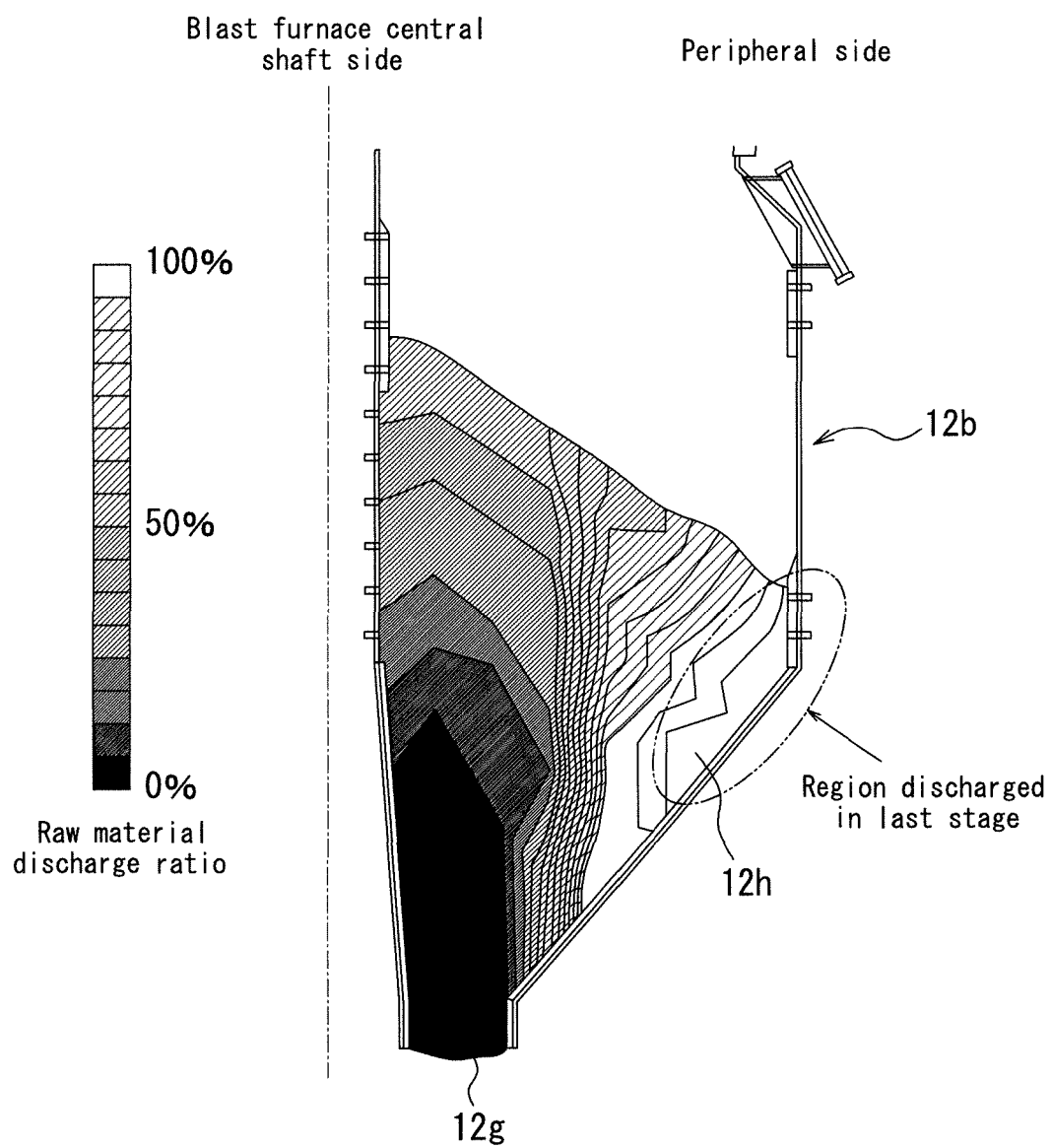


FIG. 3

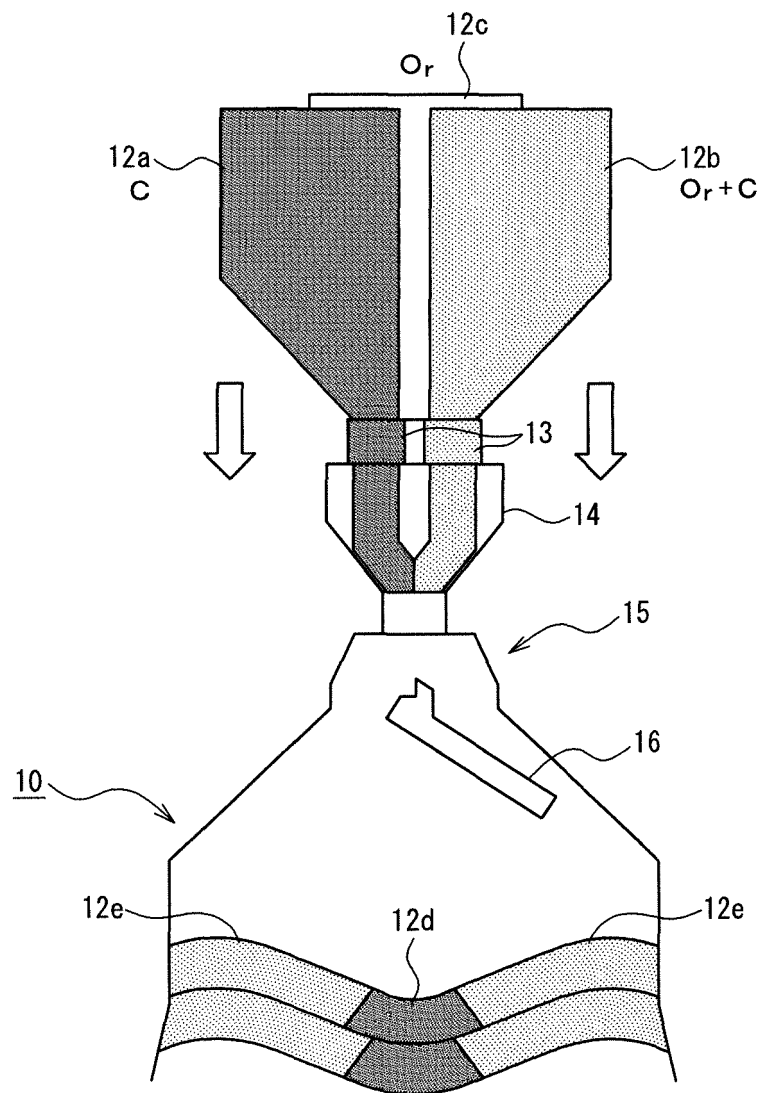


FIG. 4

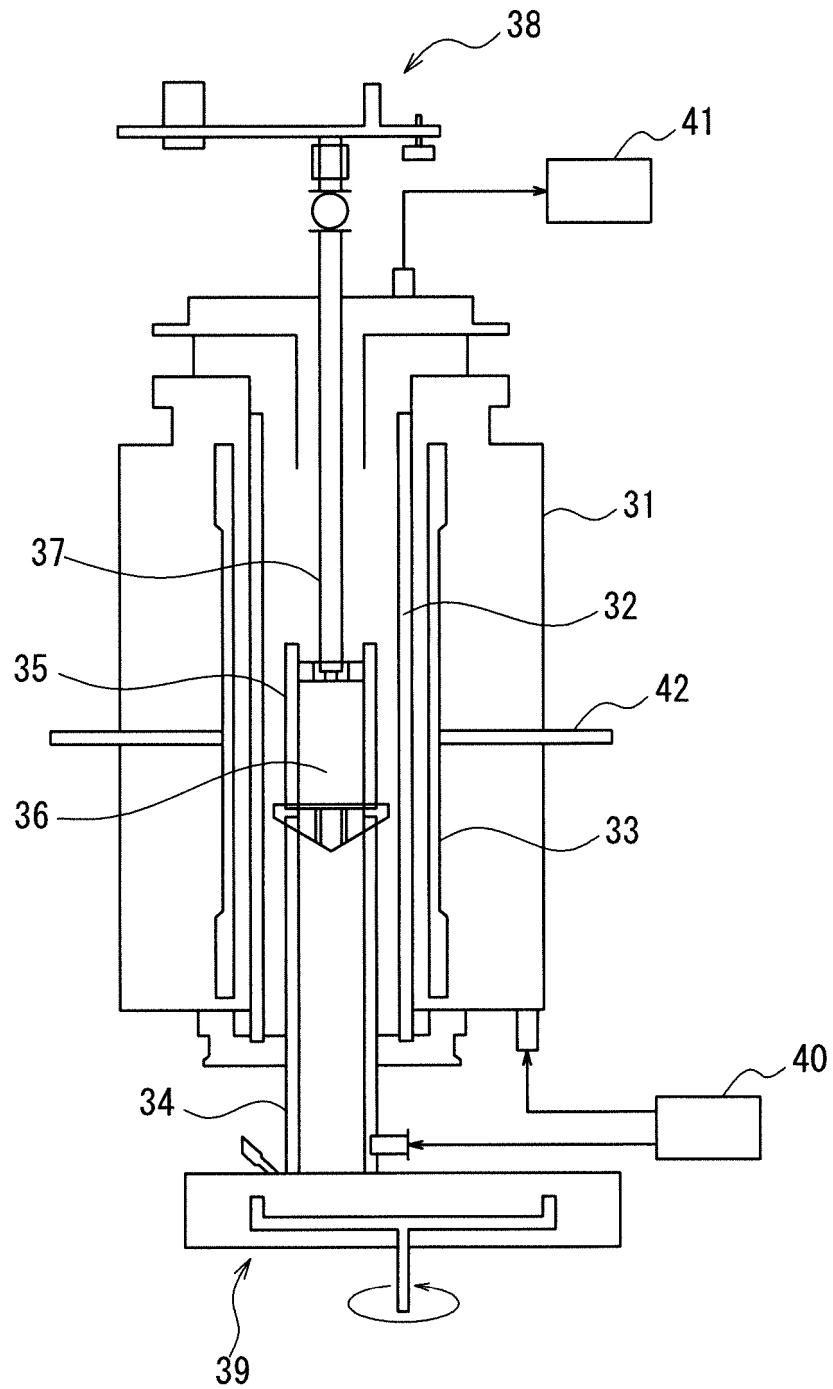


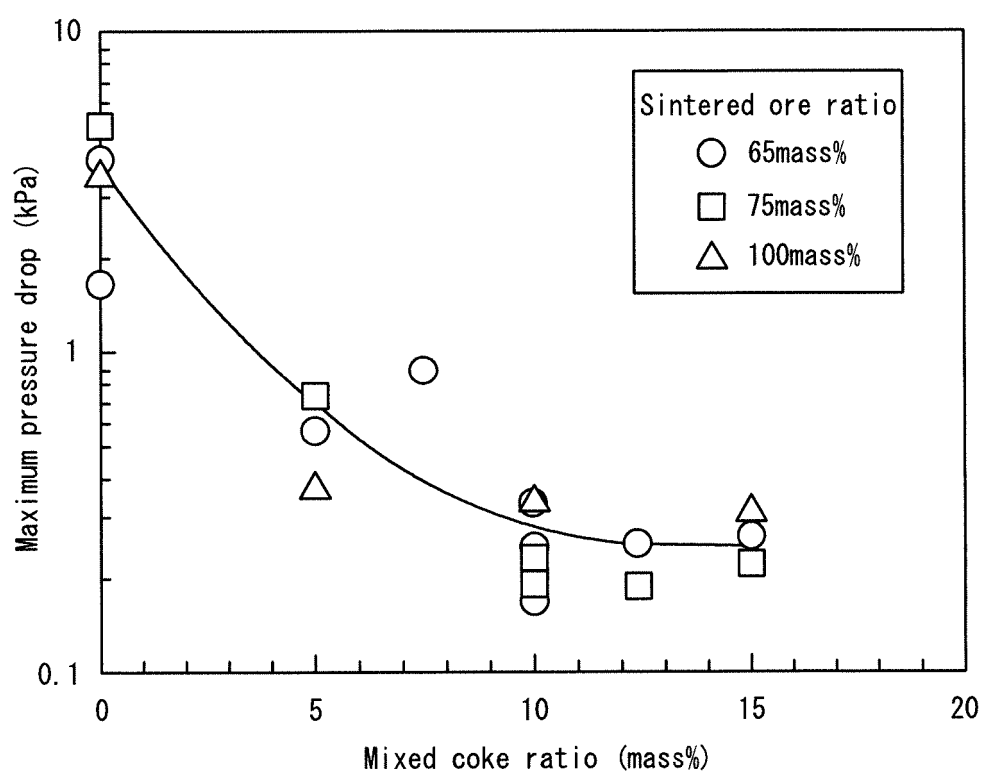
FIG. 5

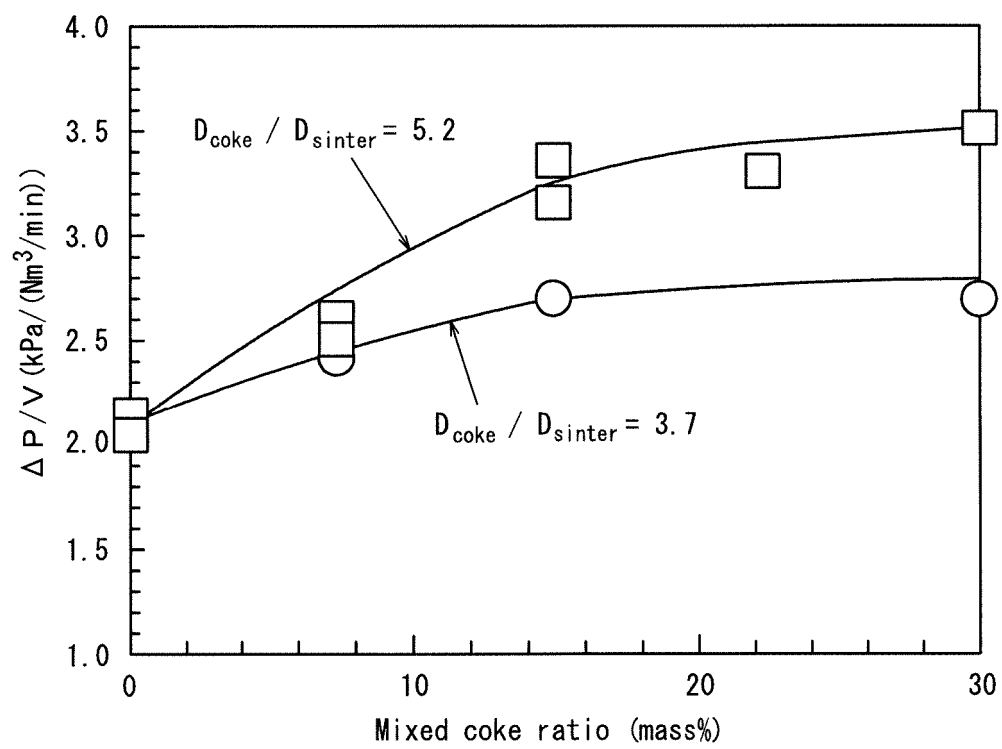
FIG. 6

FIG. 7

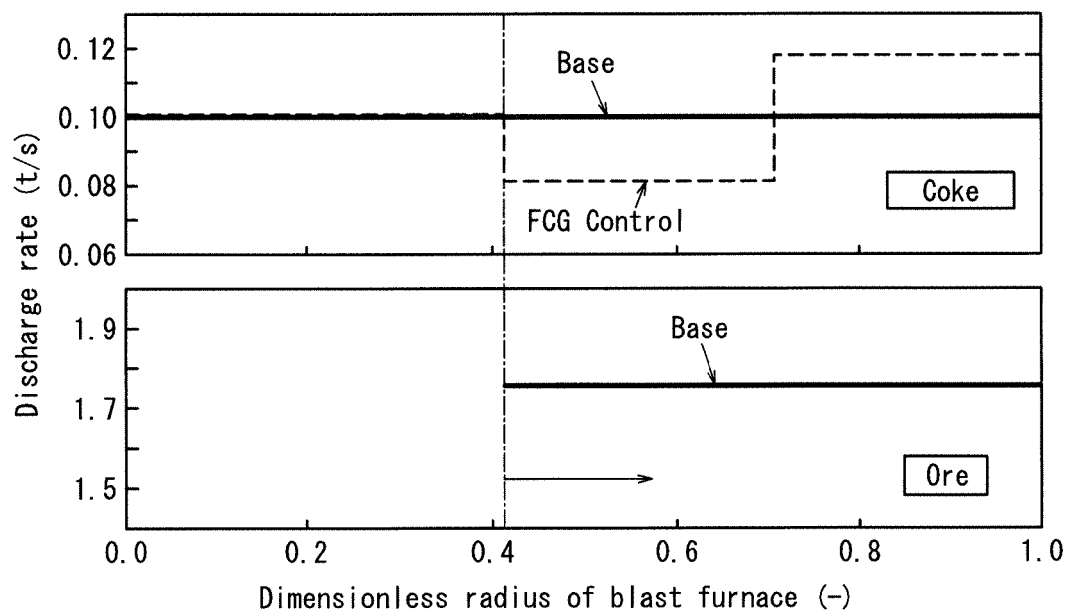


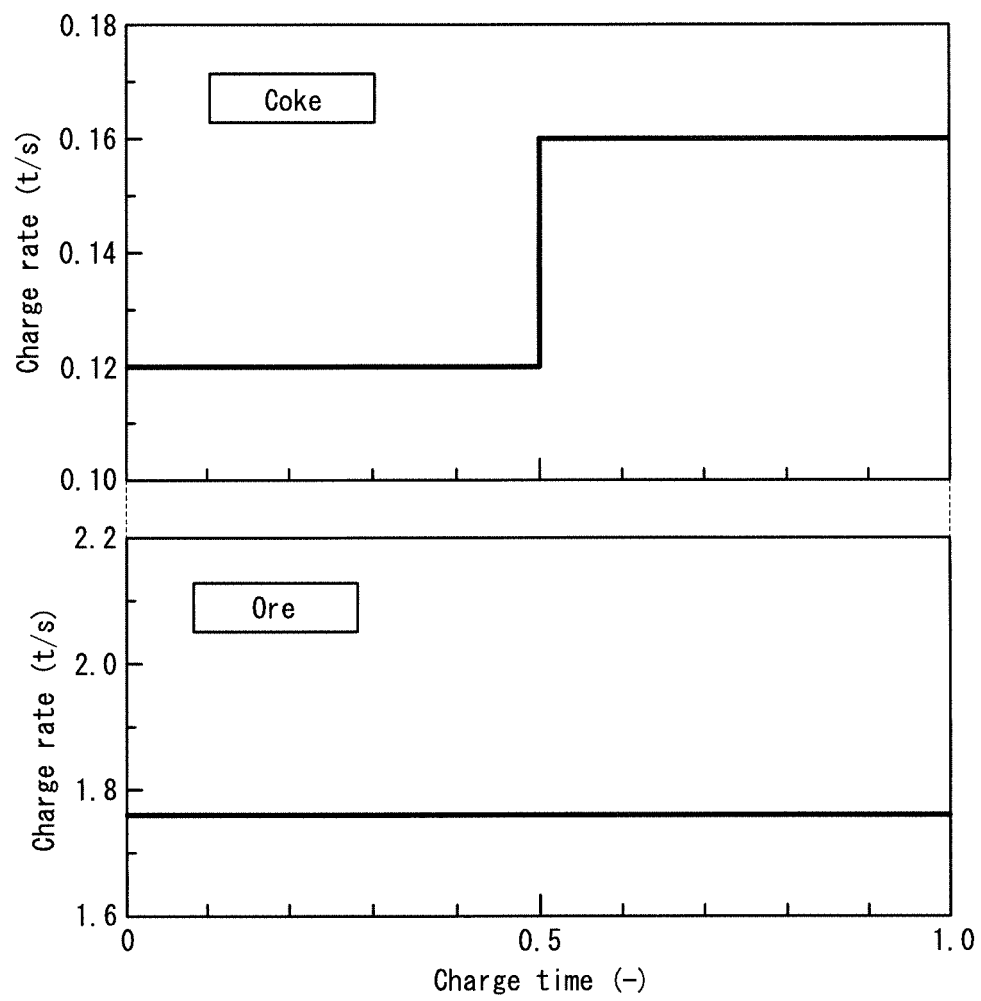
FIG. 8

FIG. 9

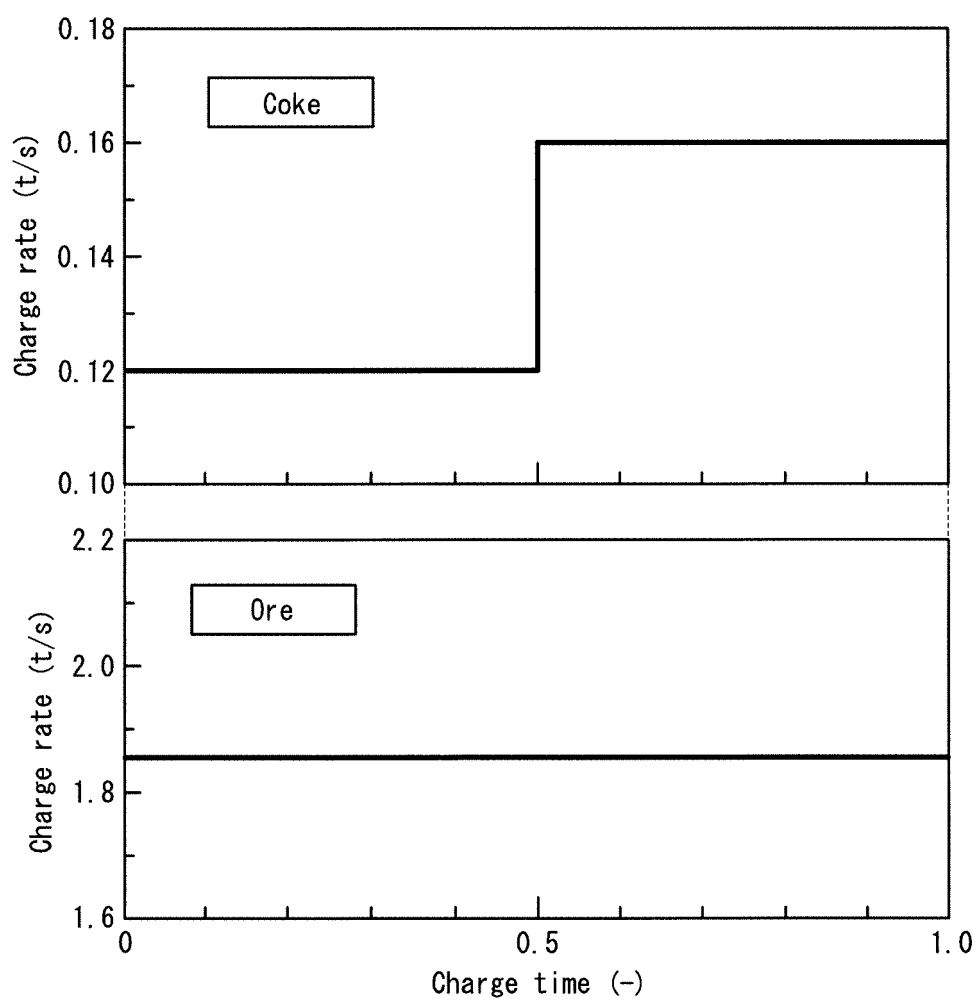


FIG. 10

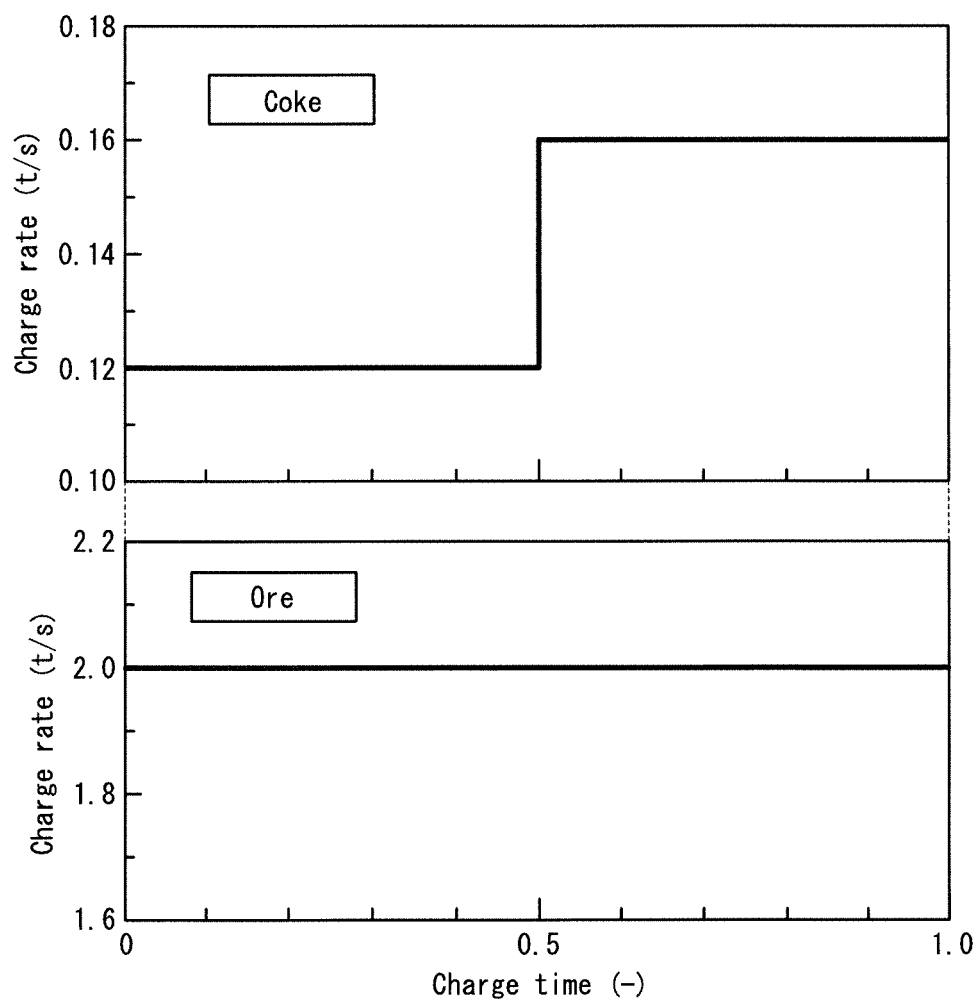
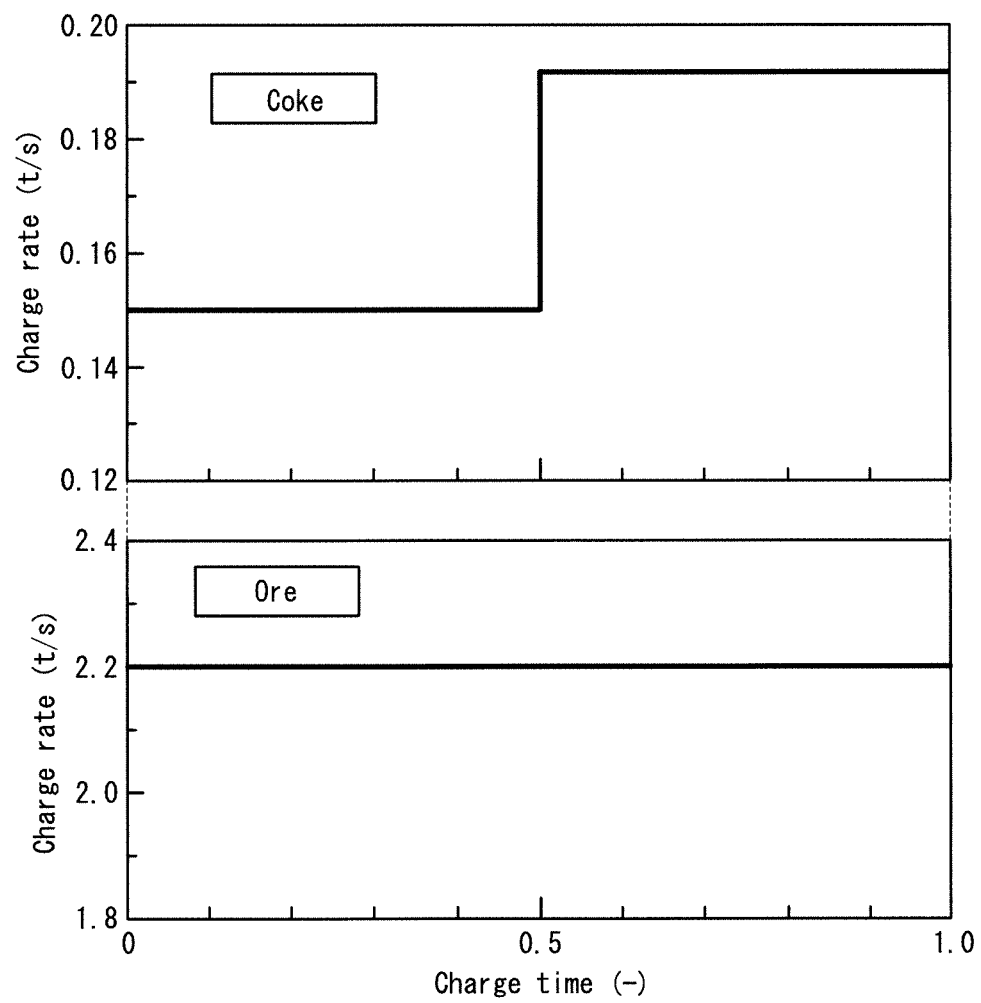


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/003171

A. CLASSIFICATION OF SUBJECT MATTER

C21B5/00 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C21B5/00

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2013
 Kokai Jitsuyo Shinan Koho 1971-2013 Toroku Jitsuyo Shinan Koho 1994-2013

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.
Y	JP 2004-107794 A (JFE Steel Corp.), 08 April 2004 (08.04.2004), paragraphs [0010] to [0028]; fig. 1, 2 & EP 1445334 A1 & WO 2004/027097 A1 & BR 306185 A & TW 239355 B & CN 1596315 A	1, 2
Y	JP 2010-100915 A (JFE Steel Corp.), 06 May 2010 (06.05.2010), paragraphs [0013] to [0033], fig. 5 (Family: none)	1, 2
Y	JP 2005-213579 A (JFE Steel Corp.), 11 August 2005 (11.08.2005), paragraphs [0019] to [0038]; fig. 1, 7 (Family: none)	1, 2



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search
12 August, 2013 (12.08.13)Date of mailing of the international search report
20 August, 2013 (20.08.13)Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/003171

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2005-264292 A (JFE Steel Corp.), 29 September 2005 (29.09.2005), paragraphs [0013] to [0026]; fig. 6 (Family: none)	1, 2
Y	JP 2010-150646 A (JFE Steel Corp.), 08 July 2010 (08.07.2010), paragraph [0017]; fig. 2, 3 (Family: none)	2
Y	JP 2012-21227 A (JFE Steel Corp.), 02 February 2012 (02.02.2012), paragraph [0021] (Family: none)	2
P, Y	JP 2012-97301 A (JFE Steel Corp.), 24 May 2012 (24.05.2012), paragraphs [0022] to [0045]; fig. 1 to 6 (Family: none)	1, 2

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP H3211210 A [0006] [0009]
- JP 2004107794 A [0007] [0009]
- JP S5910402 B [0008] [0009]