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(54) METHOD FOR LOADING RAW MATERIAL INTO BLAST FURNACE

VERFAHREN ZUM LADEN EINES ROHMATERIALS IN EINEN HOCHOFEN

PROCÉDÉ POUR LE CHARGEMENT DE MATIÈRE PREMIÈRE DANS UN HAUT-FOURNEAU

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Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a method for loading (charging) raw material into a blast furnace by charging the 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 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 bottom of
15 the shaft of the blast furnace, gas permeability resistance grows extremely large, forming a cohesive layer where nearly no gas flows.

[0003] Conventionally, 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
20 along with a coke slit, derived from coke, with a relatively small gas permeability resistance.

[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. Furthermore, when performing a low coke operation, the amount of coke that is used is reduced, which is considered to cause unlimited 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.

[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 the furnace top bunker and mixing the coke and ore while charging them simultaneously in order to yield three batches at the same time: a batch for regularly
30 charged coke, a batch for mainly charging coke, and a batch for mixed charging.

[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 raw material into a blast furnace whereby
35 all of the ore and all of the coke are charged into the furnace after being completely mixed.

[0009] In addition, EP 1 445 334 A1 discloses a method for charging material in a bell-less blast furnace comprising the steps of: storing coke in at least one of furnace top bunkers; storing ore in at least one of furnace top bunkers; charging the stored cokes into the blast furnace while rotating a chute of the bell-less charging device and varying a inclination angle thereof; and charging the stored ore while rotating the chute of the bell-less charging device and varying
40 the inclination angle thereof. Discharging of the stored in the at least one furnace top bunkers commences when the discharging amount of the coke stored in the at least furnace top bunker is 5 to 50 mass% relative to a coke amount of one batch. A mixed material of ore and coke is stored in one of furnace top bunkers, and the mixed material stored in the furnace top bunker is charged in the blast furnace while rotating the charging chute and changing a inclination angle of the charging chute.

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CITATION LIST

Patent Literature

50 **[0010]**

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)

[0011] In order to improve the gas permeability resistance of the cohesive zone, mixing coke into the ore layer as in the technique disclosed in PTL 3 is known to be effective.

[0012] In the disclosure in PTL 3, however, the representative mean particle size of coke is approximately 40 mm to 50 mm, and the mean particle size of ore is approximately 15 mm. The particle sizes thus greatly differ, and simply mixing the coke and ore may lead to problems such as a great reduction in the void ratio, worsening of gas permeability in the furnace, blowout of gas, and improper descent of raw material.

[0013] Even if ore and coke are simultaneously ejected from two bunkers and mixed when charging, large size coke rolls further due to the tilt of the charging surface, leading to the problem of the coke separating easily.

[0014] One possible method for avoiding these problems is to form a layer of only coke near the center of the furnace shaft. With this method, a path for gas is ensured by the coke layer near the center of the furnace shaft, allowing for improvement of gas permeability. It is also known that when simultaneously ejecting ore and coke to mix and charge the ore and coke, charging by reverse tilting to load the charged raw material from the center is effective for avoiding the above problem.

[0015] In cases such as when the raw material charging interval is small in the blast furnace radial direction, however, or there is too much charged raw material per rotation, the pile of raw material charged during a given rotation is exceeded by the pile of raw material charged upon the next rotation. In this case, the raw material flows to the center of the blast furnace, and the mixed coke separates, triggering the problems of worsened mixing ratio controllability, a drop in the coke mixing ratio, and the like. Normally, when mixing and charging with simultaneous discharge that uses reverse tilting, particularly when the raw material charging interval is narrow, the charged raw material exceeds the pile of raw material spread immediately before and flows towards the center, and the mixed coke separates. This triggers the problems of worsened mixing ratio controllability, a drop in the coke mixing ratio, and the like.

[0016] The present invention has been conceived in light of the above circumstances, and it is an object thereof to provide a method for charging raw material into a blast furnace that, even when the raw material charging interval is narrow, can ensure mixing in the mixed layer, stabilize blast furnace operations, and improve thermal efficiency, and that, when charging by reverse tilting during mixing and charging while simultaneously discharging coke and ore, adjusts the amount of raw material charged per rotation or the charging interval to prevent the newly charged raw material from exceeding the pile of previously charged raw material and flowing towards the center, thereby ensuring mixing in the mixed layer, stabilizing blast furnace operations, and improving reaction efficiency.

(Solution to Problem)

[0017] Specifically, main features of the present invention are as follows.

1. A method for charging raw material including coke and ore into a blast furnace using a rotating chute, with one charge of the raw material being divided into two or more batches of the coke and two or more batches of the ore, the method comprising:

when simultaneously charging the coke and the ore, setting an average layer thickness L_{av1} at each rotation of the rotating chute, calculated by Expression 1, to be smaller than a thickness h of coke charged into a shaft central portion of the blast furnace:

$$L_{av1} = V_n / ((R_n^2 - R_{n-1}^2) \pi) \quad \text{Expression 1}$$

where V_n is a charged volume (t) per rotation at an n^{th} rotation / (apparent density (t/m^3) of a mixed layer of coke and ore), and

R_n is a falling radius (m) of charged raw material at the n^{th} rotation.

2. A method for charging raw material including coke and ore into a blast furnace using a rotating chute, with one charge of the raw material being divided into two or more batches of the coke and two or more batches of the ore, the method comprising:

when simultaneously charging the coke and the ore, setting an average layer thickness $L_{av2}(n)$ at an n^{th} rotation of the rotating chute, calculated by Expression 2, and an average layer thickness $L_{av2}(n+1)$ at an $(n+1)^{\text{th}}$ rotation,

calculated by Expression 3, to satisfy Expression 4, where n is any natural number:

$$L_{av2}(n) = V_n / ((R_n^2 - R_{n-1}^2) \pi) \quad \text{Expression 2}$$

$$L_{av2}(n+1) = V_{n+1} / ((R_{n+1}^2 - R_n^2) \pi) \quad \text{Expression 3}$$

$$L_{av2}(n+1) < L_{av2}(n) \quad \text{Expression 4}$$

where V_n is a charged raw material volume (m^3) per rotation at the n^{th} rotation,
 R_{n-1} is a falling radius (m) of charged raw material at an $(n-1)^{th}$ rotation,
 R_n is a falling radius (m) of charged raw material at the n^{th} rotation,
 V_{n+1} is a charged raw material volume (m^3) per rotation at the $(n+1)^{th}$ rotation, and
 R_{n+1} is a falling radius (m) of charged raw material at the $(n+1)^{th}$ rotation.

(Advantageous Effect of Invention)

[0018] According to the present invention, when charging ore material and coke into a blast furnace, the charged raw material is spread at a predetermined position, and the mixed coke does not separate. Therefore, gas permeability is improved dramatically at the bottom of the furnace, reducibility of ore is greatly improved, and the blast furnace can be operated stably even when the raw material charging interval is narrow, or when charging by reverse tilting during mixing and simultaneously charging coke and ore.

BRIEF DESCRIPTION OF DRAWINGS

[0019] The present invention will be further described below with reference to the accompanying drawings, wherein:

FIG. 1 is a schematic diagram illustrating the way of charging ore material into a blast furnace;
 FIGS. 2(a) and 2(b) respectively illustrate a state of raw material charging by a conventional method and according to the present invention;
 FIGS. 3(a) and 3(b) respectively illustrate another state of raw material charging by a conventional method and according to the present invention;
 FIG. 4 is a schematic diagram illustrating a comparison of a state of raw material charging into a blast furnace according to the present invention and a state of raw material charging into a regular blast furnace;
 FIG. 5 is a schematic diagram illustrating a comparison of another state of raw material charging into a blast furnace according to the present invention and a state of raw material charging into a regular blast furnace;
 FIG. 6 illustrates a comparison of a state of raw material charging into a blast furnace according to the present invention and a state of raw material charging into a regular blast furnace, showing the reduction state, gas permeability/thermal conductivity state, and molten carburizing state in the upper, middle, and lower sections; and
 FIG. 7 schematically illustrates a laboratory device for measuring high temperature properties of ore material.

DESCRIPTION OF EMBODIMENTS

[0020] The following describes a representative embodiment of the present invention with reference to the drawings.

[0021] The specific way of charging ore material and coke into a blast furnace is described based on FIG. 1.

[0022] In the following description, it is assumed that only coke is stored in a furnace top bunker 12a, and that ore material is stored in furnace top bunkers 12b and 12c.

[0023] FIG. 1 illustrates the following: a blast furnace 10, furnace top bunkers 12a to 12c, flow regulating gates 13, a collecting hopper 14, a bell-less charging device 15, and a rotating chute 16. Furthermore, θ indicates the angle of the rotating chute with respect to a vertical direction.

[0024] The order for charging raw material from the furnace top bunkers is as follows. First, when forming a central coke layer at the central portion of the blast furnace, the rotating chute 16 is set to charge raw material into the inner peripheral region of the blast furnace wall, and by charging only coke from the furnace top bunker 12a, into which only coke has been charged, a central coke layer can be formed in the central portion of the blast furnace. A peripheral coke layer may also be formed in the inner peripheral region of the furnace wall.

[0025] In other words, with the rotating chute 16 set to charge raw material into the blast furnace wall region, 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 is formed in the central portion of the blast furnace.

[0026] Coke charging and ore charging are performed by simultaneous discharge from the furnace top bunkers 12a, 12b, or 12c. The order for charging is as follows. The rotating chute 16 successively moves upwards from a position near the central shaft of the blast furnace, i.e. a position with a small angle θ , subsequently moves away from the central shaft of the blast furnace towards the outside, i.e. in the direction of a larger angle θ , and finally the upper edge of the inclined sidewall is charged.

[0027] In the present invention, it is important that an average layer thickness L_{av1} at each rotation of the rotating chute, calculated by Expression 1 below, be set smaller than a thickness h of central coke charged into a shaft central portion of the blast furnace:

$$L_{av1} = V_n / ((R_n^2 - R_{n-1}^2) \pi) \quad \text{Expression 1}$$

where V_n is a charged volume (t) per rotation at an n^{th} rotation / (apparent density (t/m³) of a mixed layer of coke and ore), and

R_n is a falling radius (m) of charged raw material at the n^{th} rotation.

$$(L_{av1} < h)$$

[0028] When ore material and coke are segregated at, for example, a facility for transport to the furnace top bunkers, only ore material or coke is charged and is mixed in the collecting hopper 14 with the coke and ore material charged from the other furnace top bunkers 12a, 12b, and 12c. In this case, however, the ratio of ore material or coke increases, and the mixing ratio of the mixed layer of ore material and coke formed by the rotating chute 16 becomes uneven.

[0029] Therefore, in the present invention, as illustrated in FIGS. 2(a) and 2(b), by setting L_{av1} calculated by Expression 1 to be smaller than the thickness h of central coke charged into the shaft central portion of the blast furnace, the above unevenness of the mixed layer is eliminated. As a result, gas permeability and stability in the blast furnace can be ensured even when the amount of coke is small or an operation to blow in a large amount of pulverized coal is performed.

[0030] Furthermore, L_{av1} is preferably in a range of approximately 0.7 to 0.95 times the value of h .

[0031] The reason is to prevent a situation whereby the charged raw material exceeds the pile of raw material spread immediately before and flows towards the center, the mixed coke separates, the mixing ratio controllability worsens, and the coke mixing ratio drops.

[0032] In the present invention, it is important for the relationship $L_{av1} < h$ to be satisfied. As specific values, preferable approximate ranges are 0.90 m to 1.35 m for L_{av1} and 1.20 m to 1.50 m for h .

[0033] In other words, in the present invention, as illustrated in FIGS. 2(a) and 2(b), the mixed layers 12e are formed by setting the average layer thickness L_{av1} at each rotation of the rotating chute, calculated by Expression 1, to be smaller than the thickness h of central coke.

[0034] Furthermore, in the present invention, it is important that an average layer thickness $L_{av2}(n)$ at the n^{th} rotation of the rotating chute, calculated by Expression 2 below, and an average layer thickness $L_{av2}(n+1)$ at the $(n+1)^{\text{th}}$ rotation, calculated by Expression 3 below, satisfy Expression 4 below, where n is any natural number. When $n = 1$, R_{n-1} is 0. When forming central coke, the equation $L_{av2}(1) = h$ may be used, where h is the height of the central coke. Of course, the layer for the first rotation may be formed regardless of the height of the central coke, and when $n = 1$, R_{n-1} may be 0, and $L_{av2}(1)$ may be calculated:

$$L_{av2}(n) = V_n / ((R_n^2 - R_{n-1}^2) \pi) \quad \text{Expression 2}$$

$$L_{av2}(n+1) = V_{n+1} / ((R_{n+1}^2 - R_n^2) \pi) \quad \text{Expression 3}$$

$$L_{av2}(n+1) < L_{av2}(n) \quad \text{Expression 4}$$

where V_n is a charged raw material volume (m³) per rotation at the n^{th} rotation,

R_{n-1} is a falling radius (m) of charged raw material at an $(n-1)^{\text{th}}$ rotation,
 R_n is a falling radius (m) of charged raw material at the n^{th} rotation,
 V_{n+1} is a charged raw material volume (m^3) per rotation at the $(n+1)^{\text{th}}$ rotation, and
 R_{n+1} is a falling radius (m) of charged raw material at the $(n+1)^{\text{th}}$ rotation.

$$(L_{av2}(n+1) < L_{av2}(n))$$

[0035] The coke and ore materials that are simultaneously discharged from the furnace top bunkers 12a, 12b, or 12c converge in the collecting hopper 14 and are charged through the charging chute. At that point, when the pile of raw material charged in a ring shape at the $(n+1)^{\text{th}}$ rotation of the charging chute is higher than the pile of raw material charged in a ring shape at the n^{th} rotation, the charged raw material may exceed the n^{th} pile and flow towards the center. In this case, since the coke separates as the raw material at the $(n+1)^{\text{th}}$ rotation flows along the tilted surface, the coke mixing ratio drops, preventing the effect of improving gas permeability from being sufficiently achieved.

[0036] Therefore, in the present invention, as illustrated in FIGS. 3(a) and 3(b), by setting the average layer thickness $L_{av2}(n)$ at the n^{th} rotation calculated by Expression 2 to be larger than the average layer thickness $L_{av2}(n+1)$ at the $(n+1)^{\text{th}}$ rotation calculated by Expression 3, the above unevenness of the mixed layer is eliminated. As a result, gas permeability and stability in the blast furnace can be ensured even when the amount of coke is small or an operation to blow in a large amount of pulverized coal is performed.

[0037] Furthermore, the ratio between $L_{av2}(n)$ and $L_{av2}(n+1)$, i.e. $(L_{av2}(n+1)/L_{av2}(n))$, is preferably in a range of approximately 0.5 to 0.9. The reason is that when the ratio is 0.9 or greater, the probability of the raw material charged at the $(n+1)^{\text{th}}$ rotation exceeding the pile of raw material charged at the n^{th} rotation and flowing towards the center increases, whereas when the ratio is 0.5 or less, controlling the shape of the raw material deposit becomes difficult due to an increase in the charging interval or a reduction of charged raw material.

[0038] In the present invention, it is important for Expression 4 to be satisfied. As specific values, preferable approximate ranges are 2 m^3 to 7 m^3 for V_n , 1 m to 2 m for R_1 , and 0.2 m to 0.5 m for ΔR .

[0039] The above-described central coke layer and mixed layer 12e are formed sequentially inside the blast furnace 10 from the bottom to the top.

[0040] In accordance with these methods, by sequentially layering the coke layers and the mixed layers 12e that are formed by simultaneous discharge, coke layers 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 and the furnace wall portion inside the blast furnace 10. Therefore, even when the raw material charging interval is narrow, the mixed layers 12e in which the coke and ore material are completely mixed can be formed therebetween, and moreover, worsening of gas permeability at the top of the blast furnace caused by a drop in void ratio due to coke mixing can be prevented. Additionally, since the mixed layers 12e in which the coke and ore material are completely mixed can be formed between coke layers, the effect of improving gas permeability at the bottom of the blast furnace can be maximized.

[0041] Therefore, as illustrated in the right half of FIGS. 4 and 5, by injecting high-temperature gas having CO as the main constituent through a blast tube 21 of a tuyere disposed in a basin at the bottom of the blast furnace 10, a gas flow that traverses the coke layers and rises is formed, and a gas flow that traverses the mixed layers and rises is also formed. The coke is combusted by the high-temperature gas injected through the blast tube 21, and the ore material is subjected to reductive dissolution.

[0042] FIGS. 4 and 5 show the flow of gas in the blast furnace at this time. High-temperature air is blown from the blast tube 21 provided at the bottom of the blast furnace 10 through the tuyere, and by combusting the coke and the pulverized coal near the tuyere, high-temperature CO_2 gas is generated. The CO_2 gas reacts with the coke at the bottom of the blast furnace to yield CO, subjecting the ore material to reductive dissolution.

[0043] In this way, the ore material at the bottom of the blast furnace 10 dissolves, 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.

[0044] 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.

[0045] At this time, as illustrated in the right half of FIG. 6, 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, and high-temperature gas passes directly between ore materials, allowing for improvement of heat-transfer properties without delay in heat transfer.

[0046] Additionally, 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.

[0047] The reduction reaction at this time is represented by $\text{FeO} + \text{CO} = \text{Fe} + \text{CO}_2$.

[0048] The gasification reaction is represented by $\text{C} + \text{CO}_2 = 2\text{CO}$.

[0049] On the other hand, in the above-described conventional example in which ore and coke are stacked as layers, ore and coke are alternately charged into the blast furnace so that ore layers and coke layers are formed in the blast furnace, as illustrated in the left half of FIGS. 4 and 5. In this case, when injecting high-temperature gas having CO as the main constituent through the blast tube 21 of the tuyere, gas permeability is restricted by the reduction in the coke slit at the bottom of the cohesive zone and the pressure drop increases, as illustrated in the left half of FIG. 6, leading to the problem of a reduction in the area of contact between the ore and the high-temperature gas and restriction of carburizing.

[0050] 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.

[0051] In the present invention, however, as described above, charging layers are stacked by forming coke layers and mixed layers 12e in which coke and ore material are completely mixed. Therefore, no coke slit is formed in the mixed layers and gas flow becomes uniform. Good thermal conductivity can also be ensured, as can stable improvement in gas permeability, thus resolving the problems in the above conventional example.

[0052] Note that conventionally, in order to produce 1 t of hot metal, the necessary amount of coke (kg), i.e. the coke ratio is 320 kg/t to 350 kg/t, yet by charging raw material in accordance with the present invention, the coke ratio can be reduced to approximately 270 kg/t to 320 kg/t.

EXAMPLES

(Example 1)

[0053] In order to prove the effects of the present invention, the laboratory device illustrated in FIG. 7 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.

[0054] 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.

[0055] Gas adjusted by a gas mixing device 40 is sent to the crucible 35 through the cylindrical body 34 below the crucible 35. Subsequently, gas that has passed through the charged raw material 36 in the crucible 35 is analyzed in 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.

[0056] As the charged raw material 36 charged into the crucible 35, the following materials were used.

[0057] A high pulverized coal ratio operation with a pulverized coal ratio of 180 kg/t was performed when not mixing coke into the ore layer at all (Comparative Example 1) and for the various charging conditions listed in Table 1, with an average layer thickness L_{av1} and thickness of central coke h . The productivity as listed in Table 1 is the amount of metal produced per day in the blast furnace (t/d) divided by the volume of the blast furnace (m^3).

[0058] The charged volume of the charged raw material per rotation V_n , the initial falling radius of the charged raw material R_1 , and the radial increase in the falling radius of the charged raw material per rotation ΔR were as listed in Table 1. Note that $R_n - R_{n-1} = \Delta R$ (n being any natural number).

[0059] Furthermore, the operation results for each case are also listed in Table 1 for comparison.

[Table 1]

[0060]

Table 1

	Comparative Example 1-1	Comparative Example 1-2	Comparative Example 1-3	Inventive Example 1-1	Inventive Example 1-2
productivity (t/m ³ /day)	2	2	2	2	2
coke ratio (kg/t)	342	335	330	312	300
pulverized coal ratio (kg/t)	180	180	180	180	180
reducing agent ratio (kg/t)	522	515	510	492	480
gas utilization rate (%)	48.1	49.6	50.5	52.6	54.5
ΔP_N (Pa/m ³ /min)	21.8	20.5	22.6	20.5	20.1
mixing ratio (%)	0	34	69	69	84
number of batches of coke charging (number of times)	2	2	2	2	2
number of batches of ore charging (number of times)	2	2	2	2	2
charged volume per rotation V_n (t)	10	10	10	10	10
initial falling radius of charged raw material R_1 (m)	2	2	2	2	2
radial increase in the falling radius of the charged raw material per rotation ΔR (m)	0.3	0.3	0.3	0.35	0.45
average layer thickness L_{av1} (m)	1.30	1.30	1.30	0.86	0.81
thickness of central coke h (m)	1.42	1.42	1.42	1.15	0.81

[0061] In Table 1, the coke ratio and the pulverized coal ratio are the coke volume and pulverized coal volume (kg) used when producing 1 t of hot metal.

[0062] The reducing agent ratio is the sum of the coke ratio and the pulverized coal ratio.

[0063] 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 [%].

$\Delta P/V$ 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).

[0064] As is clear from Table 1, the coke ratio in Comparative Example 1 was 342 kg/t, yet charging raw material in accordance with the present invention, such as by setting L_{av1} to be in a range of approximately 0.7 to 0.95 times the

value of h , L_{av1} to be approximately 0.90 m to 1.35 m, and h to be in a range of approximately 1.20 m to 1.50 m, allowed for a reduction of the coke ratio to 312 kg/t in Inventive Example 1 and approximately 300 kg/t in Inventive Example 2.

[0065] For the low reducing agent ratio with a low coke ratio as well, it was proven that gas permeability resistance can be reduced.

[0066] In the above embodiment, the charged volume per rotation V_n and the radial increase in the falling radius of the charged raw material per rotation ΔR were fixed for each example, yet as long as the relationship $L_{av1} < h$ is satisfied, the effects of the present invention can be achieved without any problem even when V_n and ΔR change with each rotation.

[0067] In the above embodiment, the central coke layer and mixed layer are described as being formed by tilting of the rotating chute and control to open and close the flow regulating gates of the furnace top bunkers, yet formation is not limited in this way. A dedicated coke chute that discharges coke directly into the shaft central portion of the blast furnace may be provided at a position that does not interfere with the rotating chute, and with this dedicated coke chute, coke may be charged directly into the shaft central portion of the blast furnace in order to form the central coke layer. Accordingly, by setting L_{av1} to be in a range of approximately 0.7 to 0.95 times the value of h , L_{av1} to be approximately 0.90 m to 1.35 m, and h to be in a range of approximately 1.20 m to 1.50 m, it was proven that for the low reducing agent ratio with a low coke ratio as well, the gas permeability resistance can be reduced.

(Example 2)

[0068] Furthermore, in an actual blast furnace with a 4000 mm³ class volume, a raw material charging experiment was performed, and operating conditions were compared. This blast furnace, as illustrated in FIG. 1, had three independent bunkers at the top of the blast furnace, and coke or ore material was charged from each bunker. During regular charging, for each charge, two batches of ore material were charged after charging two batches of coke, whereas during mixed charging (120 kg/t), after charging one batch of coke, coke was charged into the furnace central region in the first half of coke discharge for the second batch to form the central coke layer. Thereafter, ore material was simultaneously discharged from another bunker, and by reverse tilting during mixing and charging, raw material was charged to form a coke mixed layer.

[0069] Table 2 lists the test results in accordance with the above procedure.

[Table 2]

[0070]

Table 2

	Comparative Example 2-1	Comparative Example 2-2	Inventive Example 2-1	Inventive Example 2-2	Inventive Example 2-3
charging method	regular charging	mixed charging	mixed charging	mixed charging	mixed charging
productivity (t/m ³ /day)	1.95	2.0	2.0	2.0	2.0
coke ratio (kg/t)	365	350	345	330	310
pulverized coal ratio (kg/t)	165	165	165	165	185
reducing agent ratio (kg/t)	530	515	505	495	495
gas utilization rate (%)	48.5	49.3	50.8	51.0	51.8
$\Delta P/V$ (Pa/m ³ /min)	24.05	24.25	22.50	23.35	24.25
coke mixing ratio (kg/t)	60	120	180	180	180
number of batches of coke charging (number of times)	2	2	2	2	2
number of batches of ore charging (number of times)	2	2	2	2	2
charged volume per rotation by simultaneous discharge V_n (m ³)	-	6.3	6.3	6.3	6.3

(continued)

	Comparative Example 2-1	Comparative Example 2-2	Inventive Example 2-1	Inventive Example 2-2	Inventive Example 2-3
initial falling radius of mixed charged raw material R_1 (m)	1.749	2.385	1.815	1.815	1.815
radial increase in falling radius of the charged raw material per rotation ΔR (m)	-	-	0.2	0.4	0.4

[0071] In Table 2, the coke ratio and the pulverized coal ratio are the coke volume and pulverized coal volume (kg) used when producing 1 t of hot metal.

[0072] The reducing agent ratio is the sum of the coke ratio and the pulverized coal ratio.

[0073] The gas utilization rate is the ratio of the concentrations of CO_2 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 CO_2 is the furnace top CO_2 concentration [%], and

CO is the furnace top CO concentration [%].

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

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

where BP is the blast pressure [Pa],

TP is the furnace top pressure [Pa], and

BGV is the Bosch gas volume (m^3 (standard temperature and pressure)/min).

[0074] As is clear from Table 2, Inventive Examples 1 and 2 exhibit even lower $\Delta P/V$ than Comparative Examples 1 and 2, which have a high coke ratio. In Inventive Example 3 with an even lower coke ratio of 310 kg/t, the same $\Delta P/V$ as Comparative Example 2 with a coke ratio of 350 kg/t was obtained.

[0075] Based on the above results, it was proven that for a low reducing agent ratio with a low coke ratio as well, gas permeability resistance can be reduced.

[0076] In the above embodiment, the charged volume per rotation V_n and the radial increase in the falling radius of the charged raw material per rotation ΔR were fixed for each example, yet as long as the relationship $L_{av2}(n+1) < L_{av2}(n)$ is satisfied, the effects of the present invention can be achieved without any problem even when V_n and ΔR are changed as appropriate with each rotation.

REFERENCE SIGNS LIST

[0077]

10: Blast furnace

12a to 12c: Furnace top bunker

13: Flow regulating gate

14: Collecting hopper

15: Bell-less charging device

16: Rotating chute

31: Furnace body

32: Furnace core tube

33: Heater

34: Cylindrical body

35: Graphite crucible
 36: Charged raw material
 37: Punch rod
 38: Load application device
 39: Device for sampling drops
 40: Gas mixing device
 41: Gas analysis device
 42: Thermocouple

Claims

1. A method for charging raw material including coke and ore into a blast furnace using a rotating chute, with one charge of the raw material being divided into two or more batches of the coke and two or more batches of the ore, the method comprising:
 when simultaneously charging the coke and the ore, setting an average layer thickness L_{av1} at each rotation of the rotating chute, calculated by Expression 1, to be smaller than a thickness h of coke charged into a shaft central portion of the blast furnace:

$$L_{av1} = V_n / ((R_n^2 - R_{n-1}^2) \pi) \quad \text{Expression 1}$$

where V_n is a charged volume (t) per rotation at an n^{th} rotation / (apparent density (t/m^3) of a mixed layer of coke and ore), and

R_n is a falling radius (m) of charged raw material at the n^{th} rotation.

2. A method for charging raw material including coke and ore into a blast furnace using a rotating chute, with one charge of the raw material being divided into two or more batches of the coke and two or more batches of the ore, the method comprising:
 when simultaneously charging the coke and the ore, setting an average layer thickness $L_{av2}(n)$ at an n^{th} rotation of the rotating chute, calculated by Expression 2, and an average layer thickness $L_{av2}(n+1)$ at an $(n+1)^{\text{th}}$ rotation, calculated by Expression 3, to satisfy Expression 4, where n is any natural number:

$$L_{av2}(n) = V_n / ((R_n^2 - R_{n-1}^2) \pi) \quad \text{Expression 2}$$

$$L_{av2}(n+1) = V_{n+1} / ((R_{n+1}^2 - R_n^2) \pi) \quad \text{Expression 3}$$

$$L_{av2}(n+1) < L_{av2}(n) \quad \text{Expression 4}$$

where V_n is a charged raw material volume (m^3) per rotation at the n^{th} rotation,

R_{n-1} is a falling radius (m) of charged raw material at an $(n-1)^{\text{th}}$ rotation,

R_n is a falling radius (m) of charged raw material at the n^{th} rotation,

V_{n+1} is a charged raw material volume (m^3) per rotation at the $(n+1)^{\text{th}}$ rotation, and

R_{n+1} is a falling radius (m) of charged raw material at the $(n+1)^{\text{th}}$ rotation.

Patentansprüche

1. Verfahren zum Beschicken eines Hochofens mit Rohmaterial, das Koks und Erz enthält, unter Verwendung einer rotierenden Rutsche, wobei eine Charge des Rohmaterials in zwei oder mehr Teilmengen des Kokes und zwei oder mehr Teilmengen des Erzes aufgeteilt wird, wobei das Verfahren umfasst:
 bei gleichzeitiger Beschickung des Kokes und des Erzes, Einstellen einer mittleren Schichtdicke L_{av1} bei jeder Umdrehung der rotierenden Rutsche, berechnet durch Ausdruck 1, um kleiner als eine Dicke h von Koks, mit dem ein Schachtmittelbereich des Hochofens beschickt wird, zu sein:

$$L_{av1} = V_n / ((R_n^2 - R_{n-1}^2) \pi) \quad \text{Ausdruck 1}$$

wobei V_n ein beschicktes Volumen (t) pro Umdrehung bei einer n-ten Umdrehung / (Schüttdichte (t/m³) einer gemischten Schicht aus Koks und Erz) ist, und R_n ein fallender Radius (m) von beschicktem Rohmaterial bei der n-ten Umdrehung ist.

2. Verfahren zum Beschicken eines Hochofens mit Rohmaterial, das Koks und Erz enthält, unter Verwendung einer rotierenden Rutsche, wobei eine Charge des Rohmaterials in zwei oder mehr Teilmengen des Kokes und zwei oder mehr Teilmengen des Erzes aufgeteilt wird, wobei das Verfahren umfasst:
beim gleichzeitigen Beschicken des Kokes und des Erzes, Einstellen einer mittleren Schichtdicke $L_{av2}(n)$ bei einer n-ten Umdrehung der rotierenden Rutsche, berechnet durch Ausdruck 2, und einer mittleren Schichtdicke $L_{av2}(n+1)$ bei einer (n+1)-ten Umdrehung, berechnet durch Ausdruck 3, um Ausdruck 4 zu erfüllen, wobei n eine beliebige natürliche Zahl ist:

$$L_{av2}(n) = V_n / ((R_n^2 - R_{n-1}^2) \pi) \quad \text{Ausdruck 2}$$

$$L_{av2}(n+1) = V_{n+1} / ((R_{n+1}^2 - R_n^2) \pi) \quad \text{Ausdruck 3}$$

$$L_{av2}(n+1) < L_{av2}(n) \quad \text{Ausdruck 4}$$

wobei V_n ein beschicktes Rohmaterialvolumen (m³) pro Umdrehung bei der n-ten Umdrehung ist, R_{n-1} ein fallender Radius (m) von beschicktem Rohmaterial bei einer (n-1)-ten Umdrehung ist, R_n ein fallender Radius (m) von beschicktem Rohmaterial bei der n-ten Umdrehung ist, V_{n+1} ein beschicktes Rohmaterialvolumen (m³) pro Umdrehung bei der (n+1)-ten Umdrehung ist, und R_{n+1} ein fallender Radius (m) von beschicktem Rohmaterial bei der (n+1)-ten Umdrehung ist.

Revendications

1. Procédé de chargement de matière première incluant du coke et du minerai dans un haut fourneau utilisant une goulotte rotative, avec une charge de la matière première qui est divisée en deux lots ou plus de coke et deux lots ou plus du minerai, le procédé comprenant :
en chargeant simultanément le coke et le minerai, régler une épaisseur de couche moyenne L_{av1} à chaque rotation de la goulotte rotative, calculée par l'Expression 1, pour qu'elle soit inférieure à une épaisseur h du coke chargé dans une partie centrale de l'axe du haut fourneau :

$$L_{av1} = V_n / ((R_n^2 - R_{n-1}^2) \pi) \quad \text{Expression 1}$$

où V_n est un volume chargé (t) par rotation à une n^{ième} rotation / (densité apparente (t/m³) d'une couche mixte de coke et de minerai) ; et R_n est un rayon de chute (m) de matière première chargée à la n^{ième} rotation.

2. Procédé de chargement de matière première incluant du coke et du minerai dans un haut fourneau à l'aide d'une goulotte rotative, avec une charge de la matière première qui est divisée en deux lots ou plus de coke et deux lots ou plus de minerai, le procédé comprenant :
en chargeant simultanément le coke et le minerai, régler une épaisseur de couche moyenne $L_{av2}(n)$ à une n^{ième} rotation de la goulotte rotative, calculée par l'Expression 2, et une épaisseur de couche moyenne $L_{av2}(n+1)$ à une (n+1)^{ième} rotation, calculée par l'Expression 3, pour satisfaire l'Expression 4, où n est un nombre naturel quelconque :

$$L_{av2}(n) = V_n / ((R_n^2 - R_{n-1}^2) \pi) \quad \text{Expression 2}$$

$$L_{av2}(n+1) = V_{n+1} / ((R_{n+1}^2 - R_n^2) \pi) \quad \text{Expression 3}$$

$$L_{av2}(n+1) < L_{av2}(n) \quad \text{Expression 4}$$

où V_n est un volume de matière première chargée (m^3) par rotation à la $n^{ième}$ rotation ;
 R_{n-1} est un rayon de chute (m) de matière première chargée à une $(n-1)^{ième}$ rotation ;
 R_n est un rayon de chute (m) de matière première chargée à la $n^{ième}$ rotation ;
 V_{n+1} est un volume de matière première chargée (m^3) par rotation à la $(n+1)^{ième}$ rotation ; et
 R_{n+1} est un rayon de chute (m) de matière première chargée à la $(n+1)^{ième}$ rotation.

FIG. 1

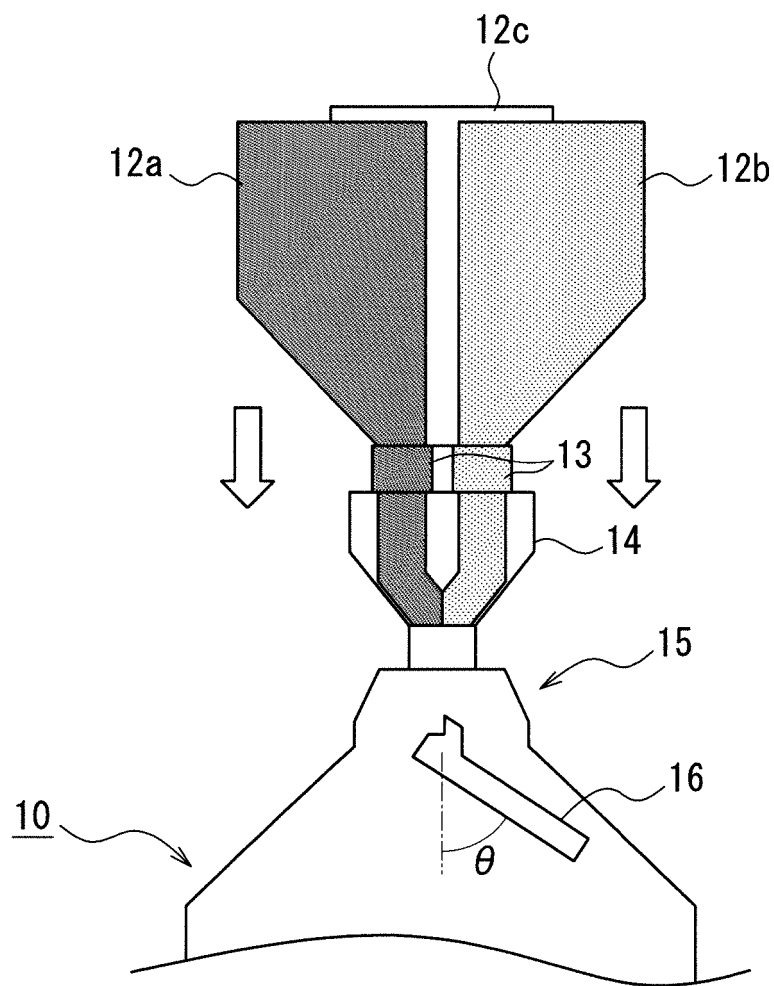
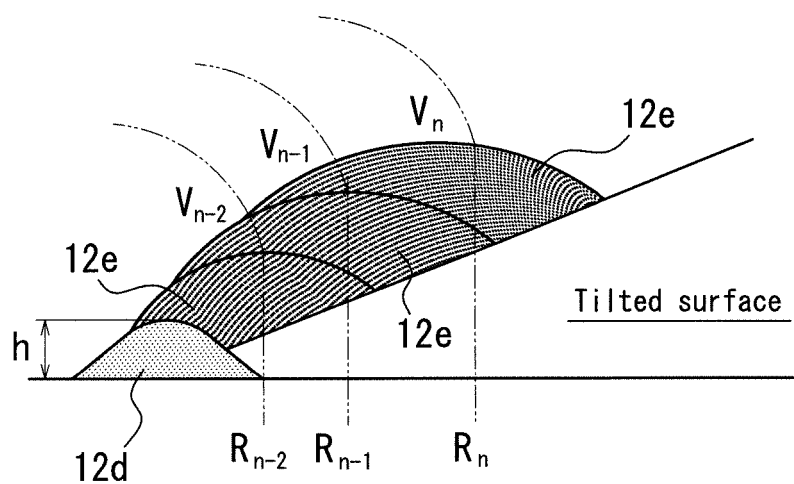


FIG. 2

(a)



(b)

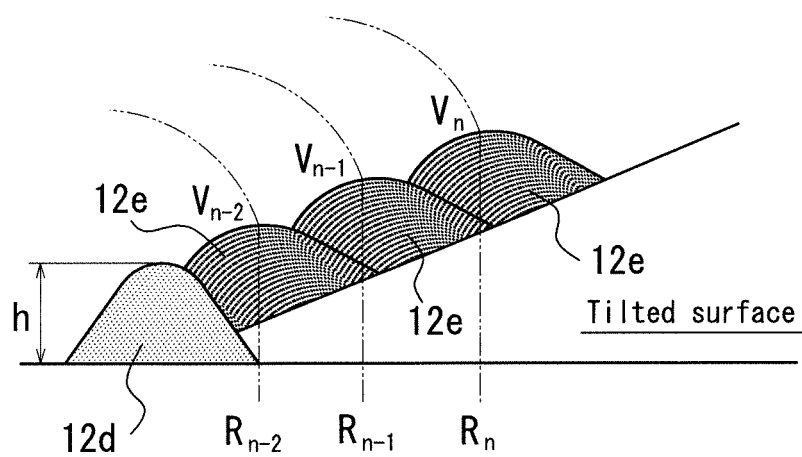
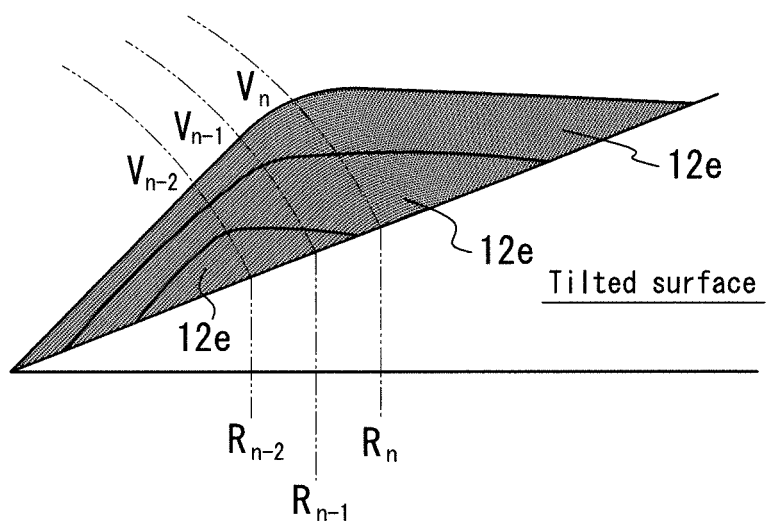


FIG. 3

(a)



(b)

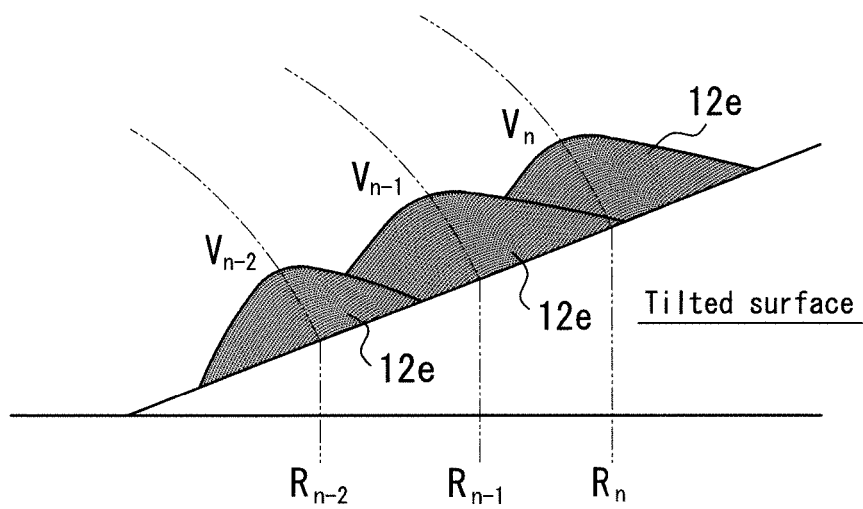


FIG. 4

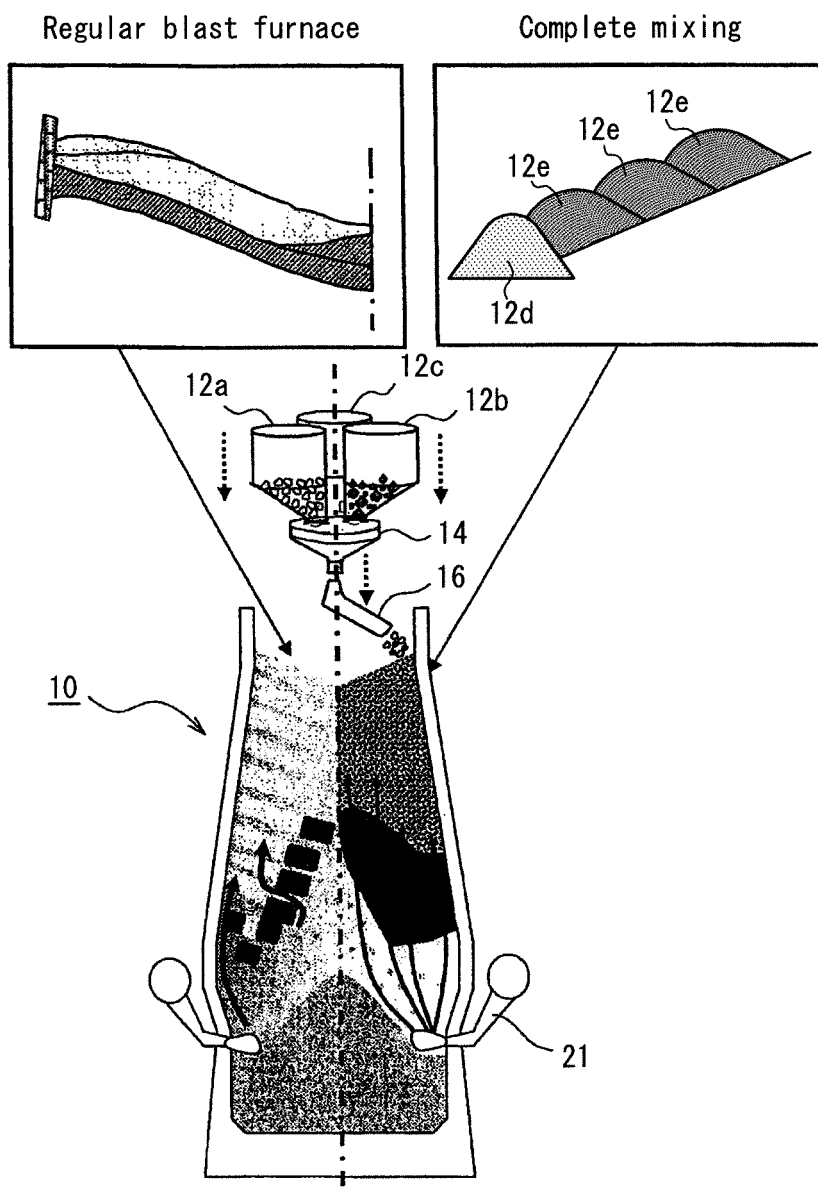


FIG. 5

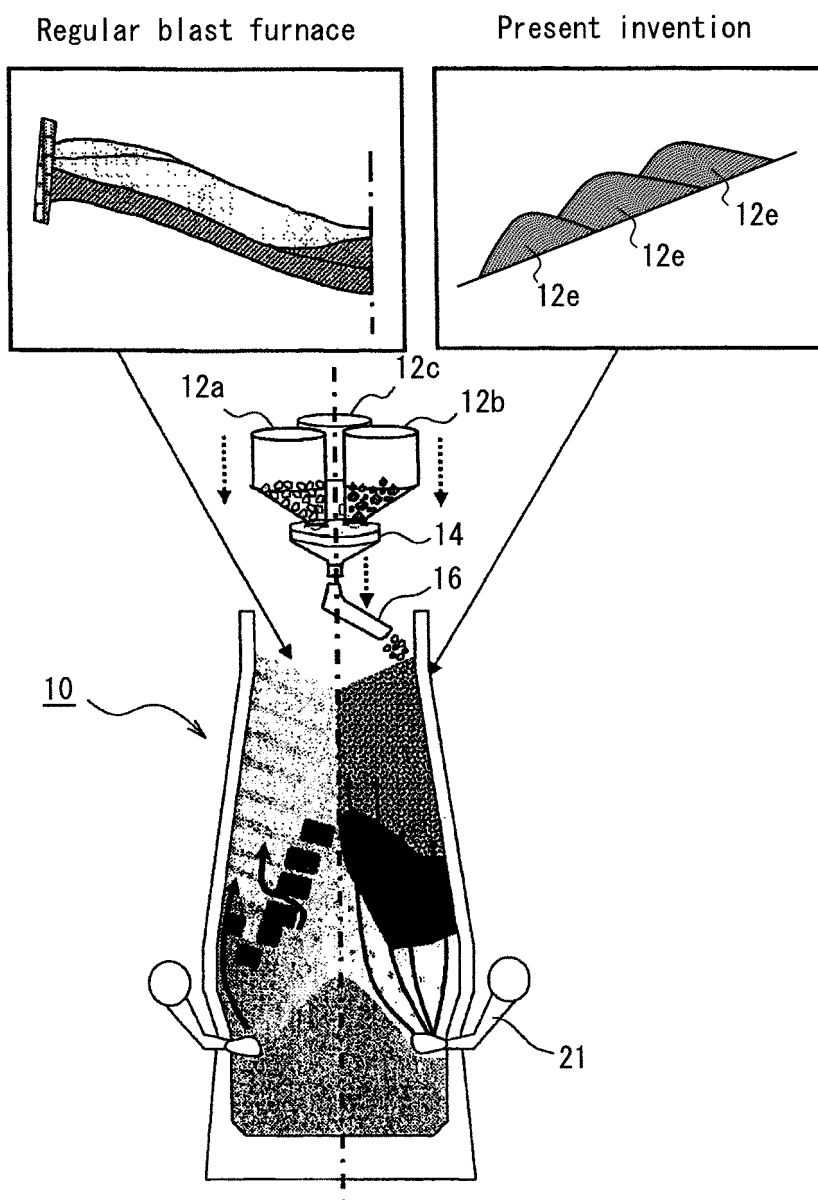


FIG. 6

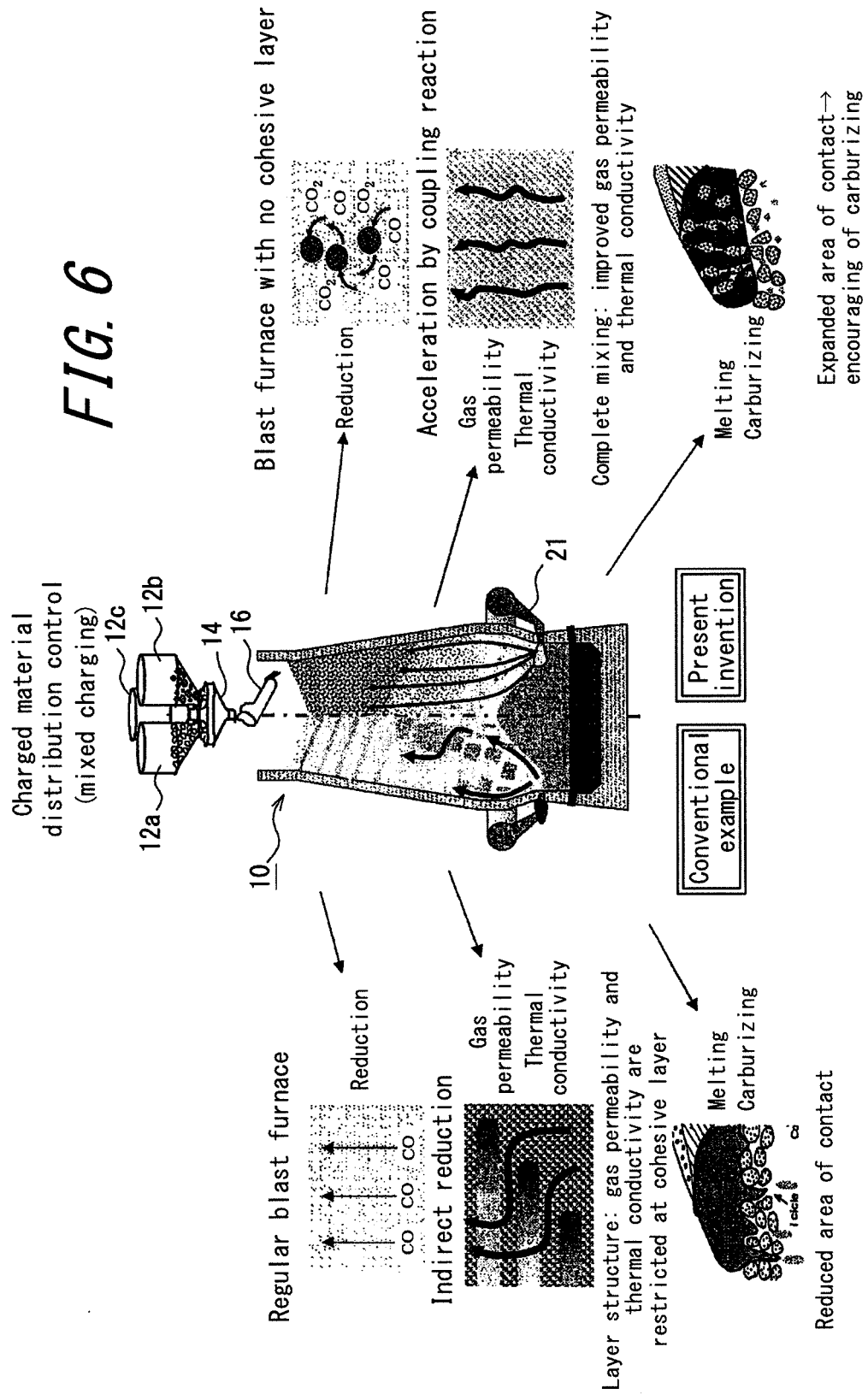
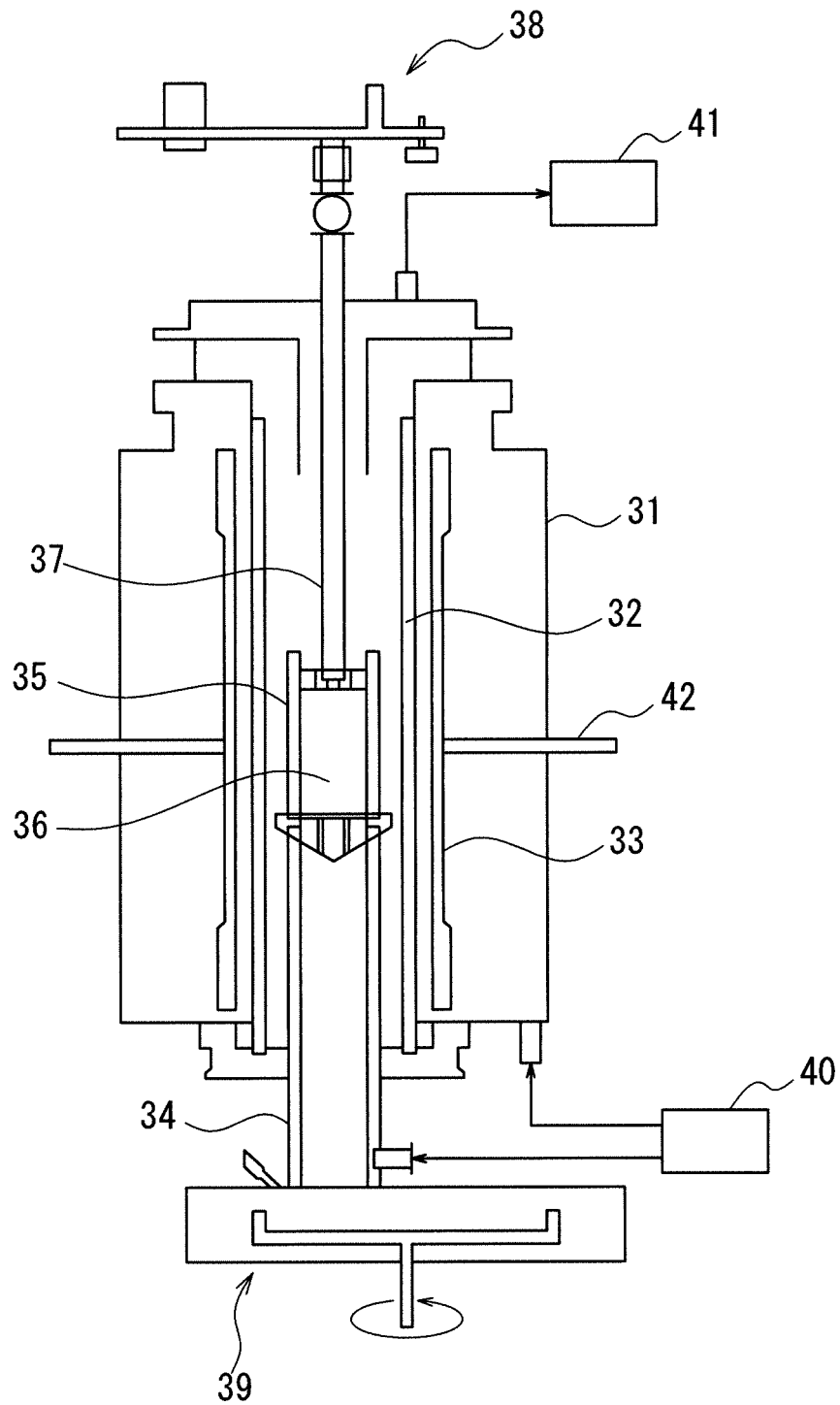


FIG. 7



REFERENCES CITED IN THE DESCRIPTION

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