



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

(43) Date of publication:
08.04.2015 Bulletin 2015/15

(51) Int Cl.:
C21B 5/00 (2006.01) C21B 7/20 (2006.01)

(21) Application number: **13797875.5**

(86) International application number:
PCT/JP2013/001857

(22) Date of filing: **19.03.2013**

(87) International publication number:
WO 2013/179541 (05.12.2013 Gazette 2013/49)

(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

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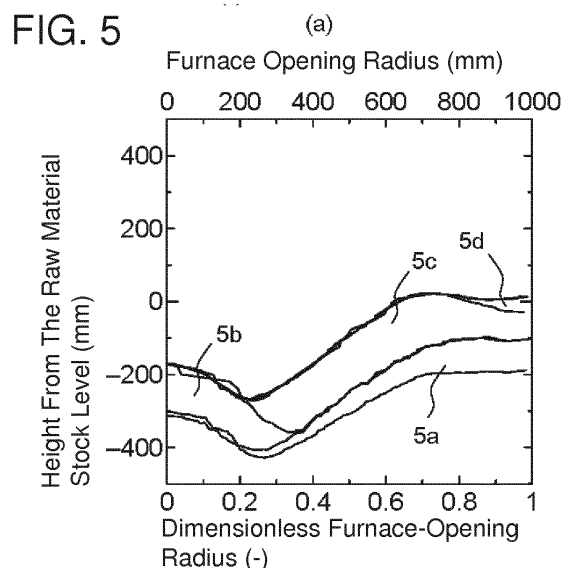
(30) Priority: **28.05.2012 JP 2012120631**

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(54) **METHOD FOR CHARGING RAW MATERIAL INTO BELL-LESS BLAST FURNACE**

(57) With respect to raw material charging from a furnace intermediate portion to a furnace wall, a coke batch (first charging batch 5a) is piled up such that a coke surface has a piled-up peak in a range of dimensionless furnace-opening radius of 0.6 to 0.8, and forms a raw material piled-up slope which is inclined toward a furnace center and toward the furnace wall; a mixture batch of ore and coke (third charging batch 5c) is charged such that its fall point of charging is on the furnace wall side from the piled-up peak of coke; and an ore batch (fourth charging batch 5d) is charged such that its fall point of charging is in a range of dimensionless furnace-opening radius of 0.5 to 0.9. This makes it possible to independently control and decrease O/C in the vicinity of the furnace wall without requiring a new ancillary facility, and to prevent formation of furnace wall deposits without significantly increasing reducing material ratio of the blast furnace. It is desirable that the charging amount of the mixture batch of ore and coke is less than that of the ore batch.



Description

TECHNICAL FIELD

[0001] The present invention relates to a method for charging raw material into a Bell-less blast furnace, which is capable of controlling gas flow in the vicinity of a furnace wall without significantly increasing a reducing material ratio of the blast furnace.

BACKGROUND ART

[0002] A bell-less blast furnace is a blast furnace which is provided with a bell-less type charging apparatus having a swivel chute as a raw material charging apparatus in a furnace top portion.

[0003] FIG. 1 is a diagram schematically illustrating the apparatus configuration of a furnace top portion of a bell-less blast furnace, and a piled-up state of raw material in the blast furnace. As shown in FIG 1, in the bell-less blast furnace, iron sources such as sintered ore, lump ore, pellets, scrap, and reduced iron (hereinafter these are generically referred to as "ore") and coke, which is a reducing material (ore and coke are generically referred to as "raw material") are piled up alternately in layers in a furnace of a blast furnace 2 by means of a swivel chute 1, and auxiliary fuel such as pulverized coal is blown into the furnace along with hot air from a tuyere in a furnace bottom portion. A charging raw material (charging material) which is the raw material charged into the blast furnace is heated and reduced by rising hot gas and the coke in the charging material while gradually descending in the furnace from the furnace top so that the ore is melted to become pig iron and is discharged from a tap hole in a side wall of a furnace bottom portion.

[0004] Operation to distribute charging material in the bell-less blast furnace is performed by turning the swivel chute 1 while being in tilting motion, thereby charging coke and ore into the furnace, and controlling a fall position of coke and ore in the direction of a furnace opening radius 4 at a raw material stock level 3. Where, tilting motion means that an angle formed between a central axis 1a of the swivel chute and a central axis 2a in the vertical direction of the blast furnace is changed during turning. In general, the swivel chute is disposed in a furnace wall side at the start of charging, and is then actuated to gradually tilt toward a furnace center side.

[0005] In the blast furnace, a series of charging operations to form a coke layer and an ore layer (which consists mainly of ore, but may include a small or medium lump coke) are referred to as "charge". Conventionally, one charge of raw material is charged by continuously charging one batch of coke and one batch of ore respectively from the furnace wall side toward the center side while the swivel chute is in tilting motion.

[0006] For stable operation of the blast furnace, it is important to stabilize the descent of the charging material and the gas flow in the furnace, thereby maintaining good

air permeability. To that end, along with adjustment of condition of air draft from the tuyere, operation is performed to control the distribution of mass ratio between ore and coke (hereinafter referred to as "O/C") and particle size distribution of the raw material to be piled up in the furnace in a furnace radial direction. Since the average particle size of the coke to be charged into the furnace is larger than that of the ore, it is possible to control the distribution of gas flow from a furnace lower portion toward a furnace upper portion by controlling the O/C distribution and particle size distribution of the ore and coke in the furnace radial direction (that is, by adjusting the distribution of the charging material).

[0007] To ensure a stable gas flow, it is preferable to keep the O/C of the central portion at a low level (that is, to increase the proportion of coke). Further, to improve the reaction efficiency of the entire furnace, it is preferable to keep the O/C in a range from a furnace intermediate portion (a portion between the region near the central portion and the region near the furnace wall in the furnace), which occupies a large proportion of the furnace opening sectional area, to the furnace wall side at a high level.

[0008] To make such O/C distribution easy to obtain, it is common practice to separate coke and ore and charge them individually. FIG. 1 shows a piled-up state 5 of one charge of raw material, in which coke and ore are divided into 2 batches respectively, and a total of 4 batches are charged.

[0009] A first batch of coke (hereafter, referred to as a "first charging batch") 5a is charged in a range from the furnace wall portion to the intermediate portion, and a second batch of coke (hereafter, referred to as a "second charging batch") 5b is charged in the vicinity of the center of the furnace so as to have a larger thickness than that of the first charging batch 5a. A first batch of ore (hereafter, referred to as a "third charging batch") 5c is charged over the first and second charging batches 5a and 5b in a range from the furnace wall to the furnace intermediate portion, and a second batch of ore (hereafter, referred to as a "fourth charging batch") 5d is charged in the furnace wall side. Owing to the relation between the thickness of the coke layer, which consists of the first and second charging batches 5a and 5b, and the thickness of the ore layer, which consists of the third and fourth charging batches 5c and 5d, the O/C of the central portion of the furnace is kept at a low level, thereby ensuring a stable gas flow, and the O/C in a range from the furnace intermediate portion to the furnace wall side is kept at a high level, thereby improving the reaction efficiency of the entire furnace.

[0010] Generally, so-called small-and-middle lump coke, which has a particle size smaller than that of the coke to be charged in the coke batch, is mixed in the ore batch. This is because it can be expected that the reaction between ore and coke is facilitated by disposing them in proximity, and the air permeability is improved as a result of coke serving as an aggregate (spacer) when the ore

is softened and fused together. The particle size of the small-and-middle lump coke has a lower limit of about 5 mm, and an upper limit of about 35 to 40 mm, although it varies depending on the particle size of coke to be charged in the coke batch.

[0011] Meanwhile, in a blast furnace, zinc-containing compounds may solidify and form deposits on the inner wall of a furnace upper portion, and metallic iron and slag on the inner wall in a range from a furnace belly portion to a furnace lower portion. If such furnace wall deposits grow excessively, the descent of charging material and the gas flow may become unstable, thereby hindering stable operation of the blast furnace. Further, if furnace wall deposits fall off irregularly and descend to the furnace lower portion, the furnace may lose heat due to the fallen-off deposits, thereby even causing serious operation troubles such as cool down of furnace etc. For this reason, to maintain stable operation of the blast furnace, it is important to suppress the formation of furnace wall deposits.

[0012] To suppress the formation of furnace wall deposits, it is generally attempted to perform operation to distribute charging material to control the O/C of the furnace wall side to be relatively low. Since such control enhances the gas flow in the furnace wall side, thereby maintaining the heat level at a high level, the formation of deposits can be suppressed.

[0013] On the other hand, however, since the time for reaction between the gas moving up in the furnace and the charging material decreases as the gas flow becomes enhanced, a decrease of O/C leads to a decrease in reaction efficiency. When the charging amount of coke to the furnace wall side is increased for the purpose of controlling the formation of furnace wall deposits in the conventional raw material charging method using a swivel chute, it is difficult to independently control only the O/C in the vicinity of the furnace wall. This is because O/C will decrease not only in the vicinity of the furnace wall, but also over a wide range including the furnace intermediate portion which occupies a large proportion of the furnace opening sectional area. Since, for this reason, the reaction efficiency as the entire furnace decreases, thereby increasing the latent heat of the gas to be discharged from a furnace top to outside of the furnace, the reducing material ratio will increase to make up for the heat, thus increasing the production cost of pig iron. It is also not preferable in the viewpoint of reduction of CO₂ emission amount.

[0014] Therefore, to realize operation at a lower reduction material ratio while suppressing formation of furnace wall deposits, a technique for independently control the O/C only in the vicinity of the furnace wall is necessary, and for example, Patent Literatures 1 to 3 disclose methods therefor.

[0015] Patent Literature 1 makes it possible to control the O/C in the vicinity of the furnace wall without requiring a new ancillary facility, by charging small lump coke, preferably as a mixture with fine particle sintered ore having

a particle size of 1 to 5 mm, on the ore layer in a range of 500 mm from the furnace wall. However, it is difficult to make small lump coke stably pile up on a terrace in a range of 500 mm from the furnace wall.

[0016] Patent Literature 2 makes it possible to independently control the O/C in the vicinity of the furnace wall by charging raw material in a state that a cylindrical member is placed along a furnace opening outer periphery. However, since control range is fixed by the placement position of the cylindrical member, the degree of freedom in operation is small.

[0017] Patent Literature 3 makes it possible to independently control the O/C in the vicinity of the furnace wall by providing a raw material charging system different from a normal route and a supplemental bunker, and discharging coke from the supplemental bunker in conjunction with ore discharge from the normal bunker. However, since it is necessary in this method to control the coke discharge from the supplemental bunker in accordance with the ore discharge from the normal bunker and the tilting position of the swivel chute, its control becomes complicated.

CITATION LIST

PATENT LITERATURE

[0018]

- Patent Literature 1: Japanese Patent Application Publication No. 8-239705
- Patent Literature 2: Japanese Patent Application Publication No. 2005-314771
- Patent Literature 3: Japanese Patent Application Publication No. 2009-62576

NON PATENT LITERATURE

- [0019]** Non Patent Literature 1: Kaoru Nakano, Kohei Sunahara, and Takanobu Inada, "Advanced Supporting System for Burden Distribution Control at Blast Furnace Top," ISIJ International, 45(2005), p. 538 to 543.

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0020] Since if it is attempted to increase the charging amount of coke to the vicinity of the furnace wall by an ordinary operation to distribute charging material to suppress the formation of furnace wall deposits, O/C decreases not only in the vicinity of the furnace wall but also in a wide range including the furnace intermediate portion, it becomes difficult to concurrently achieve operation at a low reduction material ratio. To achieve these at the same time, it is necessary to independently control only the O/C in the vicinity of the furnace wall.

[0021] Since both the methods according to Patent Lit-

eratures 2 and 3 described above require a new ancillary facility to be installed in an ordinary bell-less charging apparatus, and are disadvantageous in terms of installation cost and maintenance cost, a charging method which does not require a new ancillary facility is desirable.

[0022] Moreover, although, in the method according to Patent Literature 1 described above, a range of 500 mm from the furnace wall is specified as a charging range of small lump coke, the relative position in radial direction in the furnace of small lump coke will vary depending on the furnace opening radius of the blast furnace. For example, although it depends on the furnace volume of the blast furnace and charging conditions thereof, generally, the width of raw material flow to be charged via a swivel chute often becomes 500 mm or more at a stock level, and therefore it is difficult to make the raw material to be stably piled up on the terrace in a range of 500 mm from the furnace wall. Since the raw material is made up of small lump coke and fine particle sintered ore, if part of the raw material overflows from the terrace and flows into the center side, there is risk that it hinders the gas flow in the central portion, or causes fluctuation of the gas flow.

[0023] The present invention has been made in view of the above described circumstances, and has its object to provide a method for charging raw material into a bell-less blast furnace, which can independently control O/C only in the vicinity of the furnace wall without requiring a new ancillary facility.

SOLUTION TO PROBLEM

[0024] Generally in many blast furnaces, to enhance gas flow in the central portion for continuing stable operation, it is attempted to reduce the reducing material ratio by maintaining the O/C in a range from the furnace intermediate portion, which occupies a large proportion of the furnace opening sectional area, to the furnace wall side at a high level while keeping the O/C of the center side at a low level.

[0025] On the other hand, under a condition in which furnace wall deposits have excessively grown and thereby may hinder stable operation of the blast furnace, it is effective to decrease the O/C in the vicinity of the furnace wall as the method for suppressing the formation of deposits or removing deposits. However, as described above, it is difficult to independently control only the O/C in the vicinity of the furnace wall by an ordinary method of continuously charging raw material from the furnace wall side toward the center side while the swivel chute is in tilting motion, and the O/C will decrease in a wide range including the furnace intermediate portion. Therefore, although the formation of furnace wall deposits is suppressed by enhancing gas flow of the furnace wall side, the reaction efficiency as the entire furnace decreases, thereby resulting in significant increase in the reduction material ratio.

[0026] Therefore, if it is possible to independently control and decrease the O/C only in the vicinity of the furnace

wall without significantly changing ordinary O/C distribution in the furnace radial direction from the furnace center to the intermediate portion, it becomes possible to suppress both of formation of furnace wall deposits and significant increase of the reducing material ratio.

[0027] Accordingly, the present inventors have conducted various studies on the method of charging raw material for a bell-less blast furnace, which can independently control and decrease the O/C in the vicinity of the furnace wall. As a result of that, they have found a method for charging raw material, which can independently control only the O/C in the vicinity of the furnace wall without requiring a new ancillary facility by charging raw material from a chute, thereby forming a piled-up layer of the raw material having a peak in the furnace intermediate portion, and taking advantage of a segregation effect by a raw material slope in a range from that peak (hereafter, referred to as a "piled-up peak") to the furnace wall.

[0028] The present invention has been made based on such a study result, and its gist is the following method for charging raw material into a bell-less blast furnace.

[0029] That is, a method for charging raw material into a bell-less blast furnace such that a coke layer and an ore layer are alternately piled up, characterized in that a coke batch, a mixture batch of ore and coke, and an ore batch are charged in this order with respect to raw material charging from a furnace intermediate portion to a furnace wall;

the coke batch is piled up such that a coke surface has a piled-up peak in a range of dimensionless furnace-opening radius of 0.6 to 0.8, and forms a raw material piled-up slope which is inclined from the piled-up peak to a furnace center and to the furnace wall;

the mixture batch of ore and coke is charged such that a fall point of charging is on the furnace wall side from the piled-up peak of coke; and

the ore batch is charged such that the fall point of charging is in a range of dimensionless furnace-opening radius of 0.5 to 0.9.

[0030] The above described "dimensionless furnace-opening radius" is an index to represent a position with respect to the furnace center in a raw material charging plane (raw material stock level), and also an index normalized by dividing a distance from the furnace center to the relevant position by the furnace opening radius. The furnace center is represented by 0 and the furnace wall by 1.

[0031] Moreover, the above described "furnace intermediate portion" here refers to a range of dimensionless furnace-opening radius of 0.5 to 0.8.

[0032] In the method for charging raw material into a bell-less blast furnace of the present invention, it is desirable to take on an embodiment in which charging is performed such that a charging amount of the above described mixture batch of ore and coke is less than that of the ore batch, and the fall point of charging of the mixture batch of ore and coke is on the furnace wall side from the piled-up peak formed by the charging of the coke

batch, and in a range of dimensionless furnace-opening radius of not more than 0.9.

[0033] Moreover, in the method for charging raw material into a bell-less blast furnace of the present invention, it is possible to take on an embodiment in which a batch of coke alone is charged in place of the mixture batch of ore and coke.

ADVANTAGEOUS EFFECTS OF INVENTION

[0034] According to the method of the present invention for charging raw material into a bell-less blast furnace, it is possible to independently control and decrease O/C only in the vicinity of the furnace wall without requiring a new ancillary facility. This makes it possible to enhance the gas flow of the furnace wall side, thereby suppressing formation of furnace wall deposits, or removing deposits. Since this method for charging raw material does not significantly increase the reducing material ratio of the blast furnace, it can suppress decrease in productivity, increase in pig iron production cost, and increase in the amount of CO₂ emission.

BRIEF DESCRIPTION OF DRAWINGS

[0035]

[FIG. 1] FIG. 1 is a schematic view showing apparatus configuration of a furnace top portion of a bell-less blast furnace and a raw material piled-up state in the blast furnace.

[FIG. 2] FIG. 2 is a diagram showing a calculation result by a simulation model of raw material piled-up profile, in which (a) is Comparative Example and (b) is Inventive Example of the present invention.

[FIG. 3] FIG. 3 is a diagram showing a calculation result by a simulation model of O/C distribution in the furnace radial direction.

[FIG. 4] FIG. 4 is a diagram showing calculation results by a simulation model of in-furnace distribution of ore and coke in an ore batch according to the method of the present invention for charging raw material.

[FIG. 5] FIG. 5 is a diagram showing raw material piled-up profiles in a model experiment, in which (a) is Comparative Example, and (b) is Inventive Example of the present invention.

[FIG. 6] FIG. 6 is a diagram showing an O/C distribution in the furnace radial direction in a model experiment.

DESCRIPTION OF EMBODIMENTS

[0036] The method for charging raw material according to the present invention is premised on a method for charging raw material in which coke layers and ore layers are charged to be alternately piled up, which are commonly practiced in a bell-less blast furnace as described

above.

[0037] In the method for charging raw material according to the present invention, upon alternately piling up coke layers and ore layers, a coke batch, a mixture batch of ore and coke, and an ore batch are charged in this order with respect to raw material charging from the furnace intermediate portion to the furnace wall. The statement "with respect to raw material charging from the furnace intermediate portion to the furnace wall" intends to focus on raw material charging in an in-furnace region excluding the center of the furnace and the furnace intermediate portion. For example, coke can be charged into the vicinity of the center of the furnace as a second charging batch 5b after being charged into a range from the furnace wall portion to the intermediate portion as a first charging batch 5a as in the past (see FIG. 1).

[0038] First, the coke batch is charged to pile up a coke layer such that the coke layer surface has a piled-up peak in a range of dimensionless furnace-opening radius of 0.6 to 0.8 at the end of coke charging, and forms a raw material piled-up (coke layer) slope which is inclined from the piled-up peak to a furnace center and to the furnace wall. Next, a mixture batch of ore and coke is charged such that the fall point of charging of the mixture batch is on the furnace wall side from the piled-up peak of the coke layer.

[0039] The reason why the coke layer is piled up such that the coke layer surface has a piled-up peak in the predetermined range of dimensionless furnace-opening radius at the end of coke charging, and forms a raw material piled-up slope which is inclined from the piled-up peak to the furnace center is because it is intended to enhance central gas flow by facilitating particle size segregation on the slope and causing raw material having larger particle sizes to be piled up in the furnace center side. Moreover, the reason why a slope which is inclined from the piled-up peak to the furnace wall is formed is to cause particles of larger sizes to be piled up in the vicinity of the furnace wall by taking advantage of a phenomenon of particle size segregation on the slope.

[0040] For that reason, it is not preferable that the piled-up peak on the coke layer surface is formed to be excessively close to the center. Further, it is preferable to prevent the raw material of the mixture batch of ore and coke to be charged after the formation of the coke layer from flowing into the center side, and to effectively take advantage of the particle segregation on the slope from the piled-up peak to the furnace wall. From these viewpoints, the piled-up peak of the coke layer is formed to be in a range of dimensionless furnace-opening radius of 0.6 to 0.8. Generally, small-and-middle lump coke is mixed in the mixture batch of ore and coke. In this case, ore and coke are separated because of differences in particle size and density so that coke which has a larger particle size and a lower density with respect to ore is piled up in the vicinity of the furnace wall. This makes it possible to decrease the O/C in the vicinity of the furnace wall.

[0041] Therefore, the charging position of the mixture

batch of ore and coke onto the coke slope is important. This charging position is made to be on the furnace wall side from the piled-up peak of the coke layer. However, since it is not possible to take advantage of the segregation effect and therefore not possible to decrease the O/C in the vicinity of the furnace wall if the charging position is too close to the furnace wall, the charging position is desirably in a range of dimensionless furnace-opening radius of not more than 0.9 as described below.

[0042] It is noted that while in the method according to Patent Literature 1 described above, a mixture of ore and coke is charged onto an ore layer which is formerly formed, in the method for charging raw material according to the present invention, a mixture of ore and coke is charged onto a coke layer, for example, as a second batch. Therefore, in the method for charging raw material according to the present invention, ore which has a smaller average particle size compared with coke, is more likely to stay at the fall point of charging in a form to fill a vacant space in the coke layer, and coke, which has a larger average particle size than that of ore, becomes more likely to be piled up in the furnace wall side away from the fall point due to the segregation on the slope.

[0043] Next, an ore batch is charged. This ore batch is charged as usual while a swivel chute is in tilting motion from the furnace wall side to the center side such that the fall point of charging is in a range of dimensionless furnace-opening radius of 0.5 to 0.9. Since charging raw material of the mixture batch of ore and coke which is piled up in the furnace wall side acts as a barrier against the ore batch piling up in the furnace wall side, the O/C in the vicinity of the furnace wall will not excessively increase, and will be kept at a low level.

[0044] In the method for charging raw material according to the present invention, it is desirable to take on an embodiment in which a charging amount of the above described mixture batch of ore and coke is less than that of the ore batch, and the fall point of charging of the mixture batch of ore and coke is on the furnace wall side from the piled-up peak after completion of charging of coke, and in a range of dimensionless furnace-opening radius of not more than 0.9.

[0045] The reason why the charging amount of the mixture batch of ore and coke is set to be less than that of the ore batch is to prevent the raw material to be charged in the mixture batch of ore and coke from flowing over to the furnace center side from the piled-up peak of the coke layer.

[0046] The reason why the mixture batch of ore and coke is charged is for the purpose of bringing ore and coke into contact not as layers but as grains (that is, by disposing ore and coke in proximity), thereby facilitating reaction, and also making the coke function as an aggregate (spacer), thereby enhancing the gas flow in the furnace wall side and more effectively suppressing the formation of furnace wall deposits. The above described effect can be equally obtained in both cases where the coke to be mixed with ore in the mixture of ore and coke

is small-and-middle lump coke and large lump coke (coke having a particle size which is charged in an ordinary coke batch).

[0047] Moreover, since charging a mixture of ore and coke makes it possible to control the O/C in the vicinity of the furnace wall by adjusting the amount of coke, the degree of freedom in operation is ensured as well.

[0048] The reason why the mixture batch of ore and coke is charged with its fall point of charging being on the furnace wall side from the piled-up peak after completion of coke charging, and in a range of dimensionless furnace-opening radius of not more than 0.9 is because if the charging position in the furnace of the mixture batch of ore and coke is too close to the furnace wall, segregation effect on the coke slope cannot be obtained, and ore as well as coke is piled up in the vicinity of the furnace wall, thereby increasing the O/C.

[0049] Moreover, in the method for charging raw material into a bell-less blast furnace according to the present invention, it is possible to take on an embodiment in which a batch made up of coke alone is charged in place of the mixture batch of ore and coke.

[0050] In this case, since there is no need to take consideration of the separation of ore and coke by particle size segregation effect on the piled-up slope when charging the mixture batch of ore and coke, charging can be performed with relative ease, and further can be made to concentrate in the vicinity of the furnace wall. The controllability of the O/C in the vicinity of the furnace wall and the degree of freedom in operation based thereon can be equally maintained as in the case where the mixture batch of ore and coke is charged.

[0051] Moreover, since only coke is charged, the effect of facilitating reaction by disposing ore and coke in proximity cannot be expected, but the effect of suppressing the formation of furnace wall deposits by the enhancement of gas flow in the furnace wall side, or immediate effect of removing the deposits can be expected.

[0052] As so far described, according to the method for charging raw material of the present invention, it is possible to independently control and decrease the O/C in the vicinity of the furnace wall without requiring installment of new facility and maintenance cost associated therewith. Decrease of the O/C in the vicinity of the furnace wall makes it possible to enhance the gas flow in the furnace wall side, thereby suppressing the formation of furnace wall deposits or removing the deposits. Further, since it becomes possible to decrease the OC only in the vicinity of the furnace wall, there is no need to significantly increase the reducing material ratio of the blast furnace, and therefore it is possible to suppress decrease in productivity, increase in pig iron production cost, and increase in the amount of CO₂ emission.

EXAMPLES

[0053] The advantageous effects of the method for charging raw material according to the present invention

was verified by using a simulation model for charging material distribution of a bell-less blast furnace according to Non Patent Literature 1 described above, and a bell-less charging model apparatus.

(Example 1)

[Charging material distribution simulation]

[0054] The subject blast furnace was a bell-less blast furnace having a furnace volume of 5,370 m³, and one charge was made up of a total of 4 batches including 2 batches of coke and 2 batches of ore based on charging record of a real furnace. The charging amount per one charge was assumed to be 25.7 ton in total of coke batch, and 140.7 ton in total of ore batch including 4.1 ton of coke (of a particle size of 6 to 50 mm). One batch out of the two batches of coke corresponds to a coke batch ("first charging batch 5a" of FIG. 2 to be described below, hereafter referred to by this term) to be charged in a range from the furnace intermediate portion to the furnace wall. Moreover, 2 batches of ore were the mixture batch of ore and coke (hereafter, referred to as "third charging batch 5c") and an ore batch (hereafter, referred to as "fourth charging batch 5d"). The mass ratio between the third charging batch 5c and the fourth charging batch 5d in Example of the present invention was assumed to be 10:90.

[0055] FIG. 2 is a diagram showing calculation results of a simulation model of raw material piled-up profile. Where, (a) is Comparative Example in which raw material charging was conducted by an ordinary operation, and (b) is Inventive Example of the present invention in which raw material charging was conducted by the above described method of the present invention. FIG. 2 shows one charge of raw material piled-up profile (that is, first and second charging batches 5a, 5b of coke, and third and fourth charging batches 5c, 5d of ore, where the third charging batch 5c includes coke).

[0056] In the raw material piled-up profile of Comparative Example shown in FIG. 2(a), the O/C in a range from the furnace intermediate portion to the furnace wall side was kept at a high level while keeping the O/C in the center portion at a low level to aim at stabilizing the central gas flow and improving reaction efficiency in a range from the furnace intermediate portion to the furnace wall side.

[0057] In contrast to this, in Inventive Example of the present invention shown in FIG. 2(b), the coke layer was piled up such that the coke layer (first charging batch 5a), which was formed before the charging of ore, had a piled-up peak 6 at a dimensionless furnace-opening radius of 0.7, and formed a raw material slope which was inclined from the piled-up peak to the furnace center and to the furnace wall. The raw material of the third charging batch 5c to be charged after the formation of the coke layer was assumed to be a mixture of ore and coke, and from the viewpoint of preventing the raw material of the afore-

mentioned batch from flowing to the center portion, the tilting angle of the swivel chute was adjusted such that the raw material supplied from the swivel chute was charged at a position of a dimensionless furnace-opening radius of 0.9 which was on the furnace wall side from the piled-up peak of the coke layer. Adopting such a charging method would result in that ore and coke were separated due to particle segregation on the slope of the coke layer in a range from the piled-up peak in the furnace intermediate portion to the furnace wall, and coke was piled up in the vicinity of the furnace wall.

[0058] Then, the fourth charging batch 5d to be charged next was charged with the fall point of charging being in a range of dimensionless furnace-opening radius of about 0.6 to 0.8, while the swivel chute is in tilting motion from the furnace wall side to the furnace intermediate portion. Since the raw material of the third charging batch 5c which was piled up in the furnace wall side would act as a barrier against the raw material of the fourth charging batch 5d being piled up in the furnace wall side, the O/C in the vicinity of the furnace wall was kept a low level.

[0059] FIG. 3 is a diagram showing calculation results by the simulation model of the O/C distribution in the furnace radial direction, in which the radial distribution of O/C of a furnace top portion of the blast furnace by the method for charging raw material in an ordinary operation (Comparative Example) as shown in FIG. 2(a) is compared with the radial distribution of O/C by the method for charging raw material according to the present invention shown in FIG. 2(b). FIG. 3 reveals that in the method for charging raw material according to the present invention in which the piled-up peak position of the coke layer was at a dimensionless furnace-opening radius of 0.7, and the raw material charging position of the third charging batch was at a dimensionless furnace-opening radius of 0.9, the O/C from the furnace center to the furnace intermediate portion did not change significantly compared with the case of the method for charging raw material in an ordinary operation, and thus the O/C in the vicinity of the furnace wall decreased, thus realizing a desired O/C distribution state.

[0060] FIG. 4 is a diagram showing calculation results by a simulation model of in-furnace distribution of ore and coke in an ore batch in the method for charging raw material according to the present invention, in which the piled-up peak position of the coke layer was at a dimensionless furnace-opening radius of 0.7, and the in-furnace charging position of the third charging batch was at a dimensionless furnace-opening radius of 0.9. This figure reveals that a large amount of coke was piled up in the vicinity of the furnace wall as a result of particle size segregation on the coke slope.

[0061] The results of above described verification using the simulation model for charging material distribution of a bell-less blast furnace confirmed advantageous effects (that is, effects that the O/C in the vicinity of the furnace wall can be controlled independently) of the

method for charging raw material according to the present invention.

(Example 2)

[Bell-less charging model experiment]

[0062] The effects of the method for charging raw material according to the present invention was verified by using a bell-less charging model apparatus which is a 1/5.6 scale model of a furnace volume of 5,370 m³.

[0063] The particle size of the raw material used in the experiment was about 1/5.6 of the real furnace particle size, and the charging amount per one charge was determined according to the similarity rule as: 146 kg in total of coke batches (the first and second charging batches) and 801 kg in total of ore batches (the third and fourth charging batches) including 23 kg of coke (of a particle size of 1 to 10 mm). The mass ratio between the third charging batch and the fourth charging batch in Example of the present invention was set to be 10:90.

[0064] In the model experiment, when performing raw material charging according to the method of the present invention, the piled-up peak position of the coke layer was at a dimensionless furnace-opening radius of 0.7, and the raw material charging position of the third charging batch was at a dimensionless furnace-opening radius of 0.9 as in Example 1.

[0065] FIG. 5 is a diagram showing raw material piled-up profiles in the model experiment. Where, (a) shows Comparative Example in which raw material charging was conducted by an ordinary operation, and (b) shows Inventive Example of the present invention in which raw material charging was conducted by the above described method of the present invention. The raw material piled-up profile in the furnace was continuously measured by using a laser range meter. It is noted that FIG. 5 shows a raw material piled-up profile of one charge.

[0066] FIG. 5 reveals that in both of the case (Comparative Example) in which raw material charging was conducted by an ordinary operation, and the case in which raw material charging was conducted by the method of the present invention, the raw material piled-up profiles were substantially the same as those of the calculation results by the above described simulation model for charging material distribution.

[0067] FIG. 6 is a diagram showing the O/C distribution in the furnace radial direction in the model experiment, in which the radial distribution of O/C of a furnace top portion of the blast furnace by the method for charging raw material in an ordinary operation (Comparative Example) as shown in (a) of FIG. 5 is compared with the radial distribution of O/C by the method for charging raw material according to the present invention as shown in (b). FIG. 6 reveals that when raw material charging was conducted by the method for charging raw material according to the present invention, the O/C from the furnace center to the furnace intermediate portion did not change

significantly compared with the case of the method for charging raw material by an ordinary operation, and the O/C in the vicinity of the furnace wall decreased as in the calculation results by the simulation model (see FIG. 3).

[0068] The results of above described verification by using the bell-less charging model apparatus confirmed advantageous effects (that is, effects that the O/C in the vicinity of the furnace wall can be controlled independently) of the method for charging raw material according to the present invention.

INDUSTRIAL APPLICABILITY

[0069] According to the method of the present invention for charging raw material to a bell-less blast furnace, it is possible to independently control and decrease the O/C only in the vicinity of the furnace wall. Further, since this method can prevent the formation of furnace wall deposits without significantly increasing the reducing material ratio of the blast furnace, it is possible to suppress decrease in productivity, increase in pig iron production cost, and the like. Therefore, the present invention can be effectively used at the time of raw material charging into a bell-less blast furnace.

REFERENCE SIGNS LIST

[0070]

- 1: Swivel chute, 1a: Central axis of swivel chute,
- 2: Blast furnace, 2a: Central axis of blast furnace,
- 3: Raw material stock level, 4: Furnace opening radius,
- 5: One charge of raw material, 5a: First charging batch,
- 5b: Second charging batch, 5c: Third charging batch,
- 5d: Fourth charging batch,
- 6: Piled-up peak of coke layer

Claims

1. A method for charging raw material into a bell-less blast furnace such that a coke layer and an ore layer are alternately piled up, **characterized in that** a coke batch, a mixture batch of ore and coke, and an ore batch are charged in this order with respect to raw material charging from a furnace intermediate portion to a furnace wall;
the coke batch is piled up such that a coke surface has a piled-up peak in a range of dimensionless furnace-opening radius of 0.6 to 0.8, and forms a raw material piled-up slope which is inclined from the piled-up peak to a furnace center and to the furnace wall;
the mixture batch of ore and coke is charged such that a fall point of charging is on the furnace wall side from the piled-up peak of coke; and

the ore batch is charged such that the fall point of charging is in a range of dimensionless furnace-opening radius of 0.5 to 0.9.

2. The method for charging raw material into a bell-less blast furnace according to claim 1, **characterized in that** charging is performed such that a charging amount of the mixture batch of ore and coke is less than that of the ore batch, and the fall point of charging of the mixture batch of ore and coke is on the furnace wall side from the piled-up peak formed by the charging of the coke batch, and in a range of dimensionless furnace-opening radius of not more than 0.9.
3. The method for charging raw material into a bell-less blast furnace according to claim 1 or 2, **characterized in that** a batch of coke alone is charged in place of the mixture batch of ore and coke.

FIG. 1

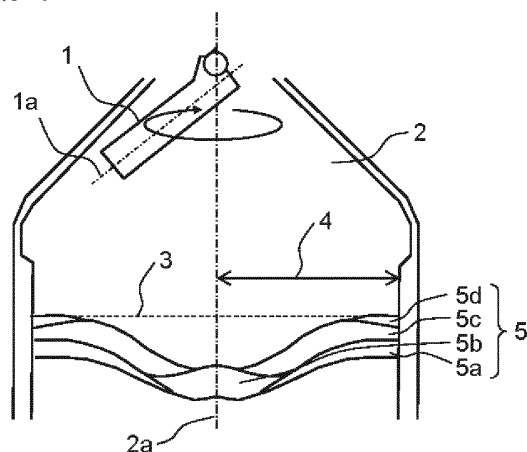


FIG. 2

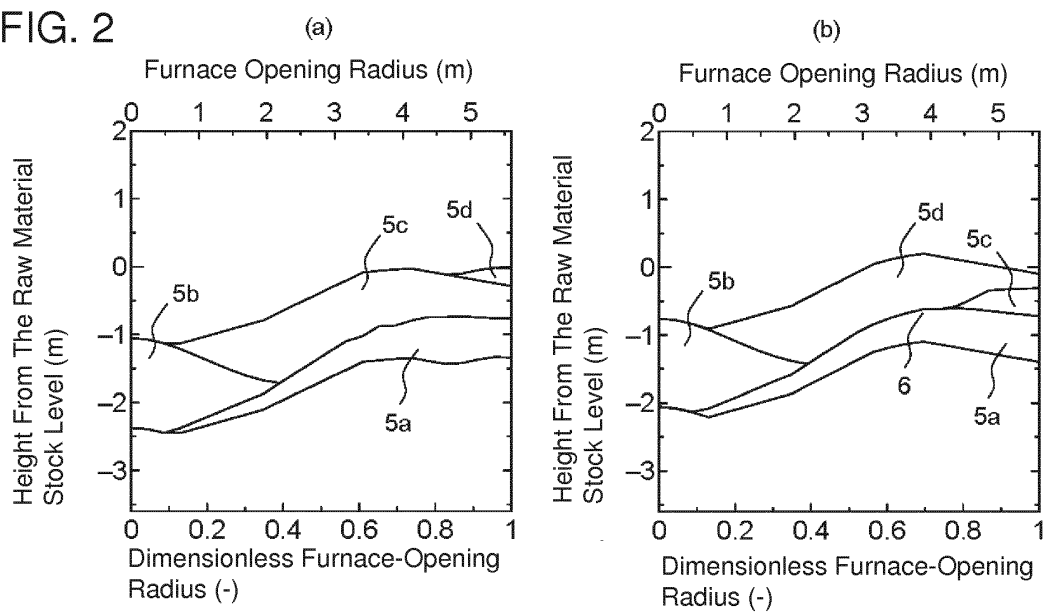


FIG. 3

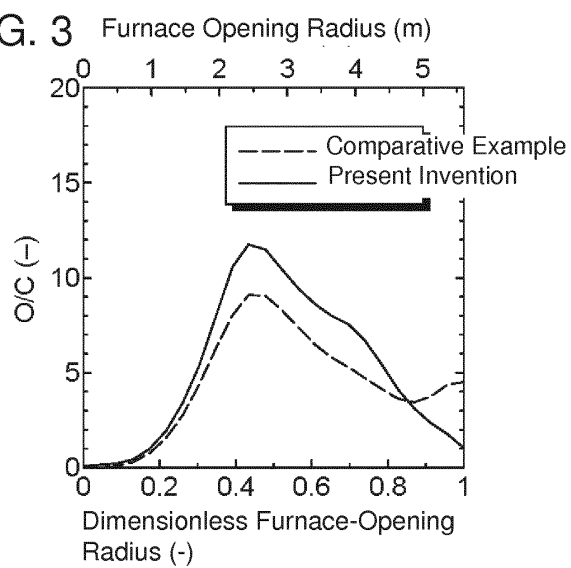


FIG. 4

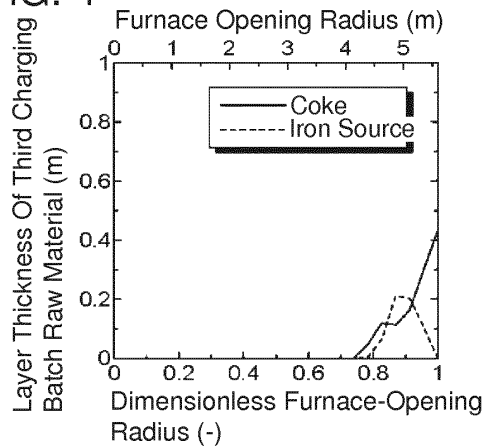


FIG. 5

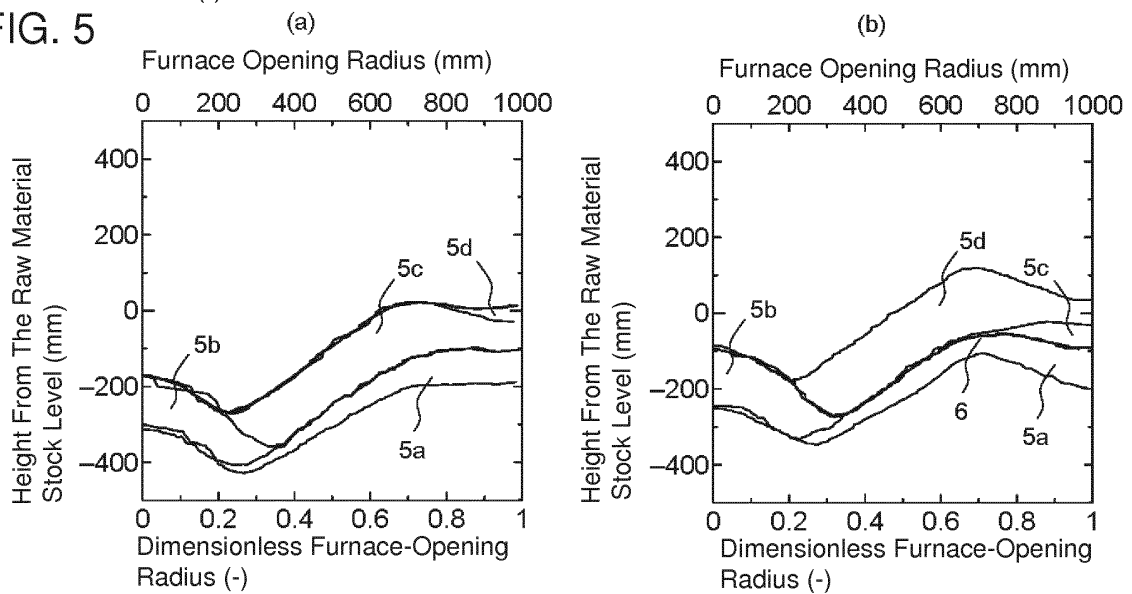
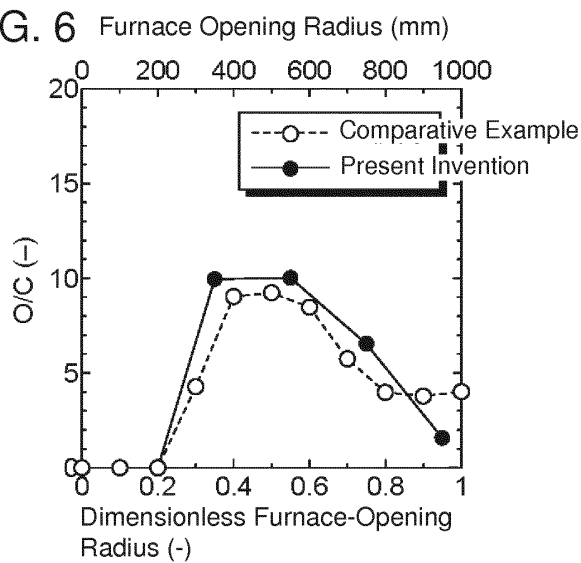


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/001857

A. CLASSIFICATION OF SUBJECT MATTER

C21B5/00(2006.01)i, C21B7/20(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, C21B7/20

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.
A	JP 2001-140009 A (Kawasaki Steel Corp.), 22 May 2001 (22.05.2001), paragraphs [0016] to [0035]; fig. 1 to 4 (Family: none)	1-3
A	JP 8-239705 A (Nippon Steel Corp.), 17 September 1996 (17.09.1996), paragraphs [0006] to [0021]; fig. 1 to 3 (Family: none)	1-3
A	JP 7-268413 A (Kawasaki Steel Corp.), 17 October 1995 (17.10.1995), paragraphs [0010] to [0037]; fig. 1 to 4 (Family: none)	1-3

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search
03 June, 2013 (03.06.13)Date of mailing of the international search report
11 June, 2013 (11.06.13)Name and mailing address of the ISA/
Japanese Patent Office

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Facsimile No.

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REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- KAORU NAKANO ; KOHEI SUNAHARA ; TAKANOBU INADA. Advanced Supporting System for Burden Distribution Control at Blast Furnace Top. *ISIJ International*, 2005, vol. 45, 538-543 [0019]