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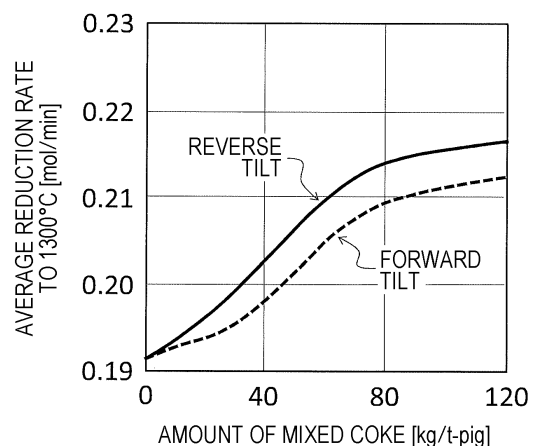
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(54) **METHOD FOR CHARGING RAW MATERIAL INTO BLAST FURNACE**

(57) Provided is a method for charging raw material into a blast furnace which enables the formation of coke-mixed ore layers for securing gas permeability in the furnace and maintaining high reduction reactivity.

The method for charging raw material into a blast furnace in which a mixture of ore and mixing coke is charged into the blast furnace in two or more separated batches by using a bell-less charging equipment with a charging chute, includes classifying the ore into coarse grain ore and fine grain ore having a smaller average grain diameter than the coarse grain ore, mixing the coarse grain ore with the mixing coke to prepare coke-mixed coarse grain ore, and mixing the fine grain ore with the mixing coke to prepare coke-mixed fine grain ore; and charging, at least in a first batch, the entirety or a part of the coke-mixed coarse grain ore into the blast furnace by tilting the charging chute from a position closer to a center of the blast furnace than a midpoint between the center of the blast furnace and a wall of the blast furnace in a radial direction of the blast furnace toward the wall of the blast furnace.

FIG. 2



EP 4 083 235 A1

Description

Technical Field

5 **[0001]** The present invention relates to a method for charging raw material into a blast furnace.

Background Art

10 **[0002]** Ore layers and coke layers are alternately stacked in a blast furnace by alternately charging raw materials of a certain amount of ore and a certain amount of coke from a furnace top. The amount of ore or coke per layer is referred to as a charge of ore or coke. The flow of gas in the blast furnace is controlled by adjusting the ratio between the thicknesses of the ore and coke layers in the furnace in the radial direction of the furnace. In a blast furnace provided with a bell-less charging equipment with a charging chute, the tilt angle of the charging chute is changed while the raw materials are charged into the furnace to form an appropriate layer thickness ratio distribution to enable a stable operation of the blast furnace and to lower the reducing agent ratio. There has also been an attempt to charge ore or coke for each charge to a blast furnace separately in a plurality of batches to control the flow of a gas in the blast furnace.

15 **[0003]** There has been a demand for a reduction in CO₂ emissions to prevent global warming. Approximately 70% of CO₂ emissions in the steel industry is from blast furnaces, and a reduction of CO₂ emissions from blast furnaces has been required. The reduction of CO₂ emissions from blast furnaces can be achieved by reducing the amount of the reducing agents (such as coke, pulverized coal, and natural gas) used in the blast furnaces. A known approach to the reduction of the amount of reducing agents is a coke-mixing technique in ore layers. Non Patent Literature 1 discloses that the ratio of the reducing agent used in the operation of a blast furnace can be lowered by mixing 50 kg/t-pig of small lumps of coke in ore layers.

25 **[0004]** Patent Literature 1 discloses a coke-mixing technique in ore layers in which each ore layer is formed by separated two batch charges and a mixture of ore and coke is charged in the first batch. In the technique, the first half of the first batch charge is performed by a forward tilt charge of tilting a charging chute from the furnace wall-side toward the furnace center-side. In the second half, the charge is performed by a reverse tilt charge of tilting the charging chute from the furnace center-side toward the furnace wall-side. According to Patent Literature 1, the charges performed in above-described manner enable to control the coke mixing ratio and thereby improve reducibility of ore. Patent Literature 2 discloses a method in which small lumps of coke are mixed in a part of ore which is to be charged in the vicinity of a furnace center and the mixture is charged into the furnace by forward tilt charge.

30 **[0005]** Since the productivity of a blast furnace depends on the amount of air that can be blown into the blast furnace, it is also important to secure gas permeability in the blast furnace. Non Patent Literature 2 discloses a technique for securing gas permeability in a blast furnace in which a sintered ore is classified into coarse and fine grains, the coarse grains are charged in the vicinity of the furnace center, and the fine grains are charged in the vicinity of the periphery of the blast furnace.

Citation List

40 Patent Literature

[0006]

PTL 1: Japanese Patent No. 6260288

45 PTL 2: Japanese Patent No. 6167829

Non Patent Literature

[0007]

50 NPL 1: Kuniyoshi ANAN and 5 others, "High Productivity Operation with Low Fuel Rate Using a large amount of Nut Coke", Current advances in materials and processes, Volume 12 (1999), pp. 234
NPL 2: Yoshio OKUNO and 5 others, "Improvement of Oilless Blast Furnace Operation by Applying Size-segregated Sinter Charging", Tetsu to Hagane (Iron and Steel), Vol. 69 (1983), No. 14, pp. 1578-1584

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Summary of Invention

Technical Problem

[0008] Although it is understood that the charge of coarse grain ore in the vicinity of the center of a blast furnace improves the gas permeability in the blast furnace, the reactivity of coarse grain ore in the furnace is poor due to its small specific surface area, and this may disadvantageously raise the ratio of the reducing agent used in the blast furnace. A way to compensate the low reduction reactivity of coarse grain ore is a use of a coke-mixing technique. However, in the forward tilt charges as disclosed in Patent Literatures 1 and 2, a mixture of ore and coke is charged into a blast furnace to flow from the position of charge toward the furnace center, and the coke which has a lower specific gravity than ore may be separated from the mixture to be segregated in the vicinity of the furnace center. The segregation of coke in the vicinity of the furnace center lowers the ratio of coke effectively mixed with ore, not to achieve improvement of reduction reactivity.

[0009] The present invention was made in view of the above issues of the related art. An object of the present invention is to provide a method for charging raw material into a blast furnace which enables the formation of coke-mixed coarse grain ore layers for securing gas permeability in the blast furnace and maintaining high reduction reactivity.

Solution to Problem

[0010] The means for addressing the above issues is as follows.

(1) A method for charging raw material into a blast furnace in which a mixture of ore and mixing coke is charged into the blast furnace in two or more separated batches by using a bell-less charging equipment with a charging chute, the method including classifying the ore into coarse grain ore and fine grain ore having a smaller average grain diameter than the coarse grain ore, mixing the coarse grain ore with the mixing coke to prepare coke-mixed coarse grain ore, and mixing the fine grain ore with the mixing coke to prepare coke-mixed fine grain ore; and charging, at least in a first batch, the entirety or a part of the coke-mixed coarse grain ore into the blast furnace by tilting the charging chute from a position closer to a center of the blast furnace than a midpoint between the center of the blast furnace and a wall of the blast furnace in a radial direction of the blast furnace toward the wall of the blast furnace.

(2) The method for charging raw material into a blast furnace described in (1), wherein, in a final batch, the entirety or a part of the coke-mixed fine grain ore is charged into the blast furnace by tilting the charging chute from a position closer to the wall of the blast furnace than the midpoint between the center of the blast furnace and the wall of the blast furnace in the radial direction of the blast furnace toward the center of the blast furnace. Advantageous Effects of Invention

[0011] The use of the method for charging raw material into a blast furnace according to the present invention suppresses the coke-mixed coarse grain ore from flowing toward the furnace center to restrain segregation of coke in the vicinity of the furnace center. This enables the formation of a coke-mixed coarse grain ore layer for securing gas permeability in the blast furnace and maintaining high reduction reactivity, to lowers the ratios of the reducing agent and coke used in the operations of the blast furnace.

Brief Description of Drawings

[0012]

[Fig. 1] Fig. 1 is a schematic cross-sectional view of a coke-mixed coarse grain ore layer 12 including and a coke-mixed fine grain ore layer 14 which are formed by a method for charging raw material into a blast furnace according to this embodiment.

[Fig. 2] Fig. 2 is a graph showing the relationship between the amount of mixing coke mixed in a coarse grain ore used in a first batch and a reduction rate.

Description of Embodiments

[0013] In order to secure gas permeability in the blast furnace and to maintain high reducing ability, ore is classified into coarse and fine grain ores, and each of the coarse and fine grain ores is mixed with mixing coke to prepare coke-mixed coarse grain ore and coke-mixed fine grain ore. The inventors of the present invention have confirmed that, when the coke-mixed coarse grain ore is charged into a blast furnace by forwardly tilting a charging chute, the coarse grain

ore flows toward the furnace center and the coke mixed in the coarse grain ore is separated due to the differences in specific gravity and grain diameter between coke and ore, to be segregated in the vicinity of the furnace center. In order to address the above issues, the inventors have also found that the segregation of the mixing coke mixed in the coarse grain ore can be suppressed by charging the coke-mixed coarse grain ore into a blast furnace by reversely tilting the charge chute, to enable the formation of a coke-mixed coarse grain ore layer for securing gas permeability in the blast furnace and maintaining high reduction reactivity, and has accomplished the present invention. The present invention is described below with reference to an embodiment thereof.

[0014] In the description of this embodiment, the coke mixed with ore is referred to as "mixing coke" to be distinguished from the coke for forming coke layers in a blast furnace. The grain diameter of the mixing coke is 5 to 40 mm. The ore is sintered ore produced in sintering plants. The coarse grain ore and the fine grain ore having a smaller average grain diameter than the coarse grain ore are separated from each other by screening the sintered ore with a sieve having openings of 4 to 10 mm. The sieve may be selected from various types of sieves commonly used for screening ores, such as a mesh, a punching metal, and a grizzly bar. It is preferable to use a grizzly bar sieve because a large amount of ore is used in a blast furnace.

[0015] Using a sieve having openings of 4 to 10 mm for classifying a sintered ore makes it possible to classify the sintered ore into coarse and fine grain ores at an appropriate mass ratio and limits a reduction in the reactivity of the coarse grain ore. When a sieve having openings of less than 4 mm is used, the amount of the resulting fine grain ore is excessively reduced, that is, most of the sintered ore is classified as a coarse grain ore, and, consequently, it becomes difficult to perform charges by using the classification of ore in terms of grain diameter. Thus, it is not preferable to use a sieve having openings of less than 4 mm. When a sieve having openings of more than 10 mm is used, the average grain diameter of the resulting coarse grain ore is excessively increased and, consequently, the reactivity of the ore may be reduced. Thus, it is not preferable to use a sieve having openings of more than 10 mm.

[0016] Specifically, a sintered ore is screened with a sieve having openings of 4 to 10 mm. A part of the sintered ore which remains on the sieve is a coarse grain ore, while the other part of the sintered ore which passes through the sieve is a fine grain ore. The mass ratio between the coarse and fine grain ores varies with the grain diameter distribution of the ore and the size of the openings used for the screening. It is preferable to select a sieve having openings such that the mass ratio between the coarse and fine grain ores falls within the range of 50:50 to 90:10. Classifying the ore into coarse and fine grain ores with respect to a predetermined grain diameter in the above-described manner and charging the coarse and fine grain ores into a blast furnace in different batches enhances the controllability of the grain diameters of the ore in the radial direction of the furnace. It is more preferable to use a sieve having openings of 5 to 8 mm for classifying a sintered ore into coarse and fine grain ores.

[0017] The grain diameter distribution of a sintered ore may vary by the conditions under which a sintering machine is operated. In such a case, for example, coarse and fine grain ores are separated from each other with a sieve having openings adjusted such that the mass ratio between the coarse and fine grain ores is about 50:50 and the coarse and fine grain ores may be mixed with each other appropriately in accordance with the balance between the coarse and fine grain ores used in a blast furnace. Specifically, in the case where the amount of the coarse grain ore used in a blast furnace is insufficient, a part of the fine grain ore may be mixed with the coarse grain ore. In the case where the amount of the fine grain ore used in a blast furnace is insufficient, a part of the coarse grain ore may be mixed with the fine grain ore.

[0018] In the method for charging raw material into a blast furnace according to this embodiment, the ore used for forming coke-mixed ore layers is classified into coarse and fine grain ores in accordance with the above-described procedures. Each of the coarse and fine grain ores is mixed with mixing coke to prepare coke-mixed coarse grain ore and coke-mixed fine grain ore. The amounts of mixing coke mixed to the coarse and fine grain ores can be 30 kg/t-pig or more and 100 kg/t-pig or less, and more preferably 40 kg/t-pig or more and 80 kg/t-pig or less. The unit "kg/t-pig" refers to the mass (kg) of mixing coke relative to the mass (t) of hot pig iron produced by melting and reducing coke-mixed coarse or fine grain ore.

[0019] The mixing coke and the coarse grain ore may be mixed with each other by, for example, stacking the mixing coke on a conveyer on which the coarse grain ore has been deposited. The coke-mixed coarse grain ore is charged into a furnace top hopper by the conveyor and then charged into a blast furnace through a charging chute.

[0020] Similarly to the above, the mixing coke and the fine grain ore may be mixed with each other by, for example, stacking the mixing coke on a conveyer on which the fine grain ore has been deposited. The coke-mixed fine grain ore is charged into a furnace top hopper by the conveyor and then charged into a blast furnace through a charging chute.

[0021] Fig. 1 is a schematic cross-sectional view of a coke-mixed coarse grain ore layer 12 and a coke-mixed fine grain ore layer 14 which are formed by the method for charging raw material into a blast furnace according to this embodiment. In Fig. 1, the horizontal axis represents a dimensionless throat radius, which is the quotient of a distance from the furnace center divided by the throat radius; and the vertical axis represents a height relative to a reference height. In the example shown in Fig. 1, coke-mixed ores are charged into a blast furnace in two batches; a coke-mixed coarse grain ore layer 12 is formed by the first batch charge, and a coke-mixed fine grain ore layer 14 is formed by the second batch charge.

[0022] In the method for charging raw material into a blast furnace according to this embodiment, in the first batch, the coke-mixed coarse grain ore is charged into a blast furnace to form a coarse grain ore layer 12 on a coke layer 10 by tilting a charging chute from a position closer to the furnace center than the midpoint between the furnace center and the furnace wall in the radial direction of the blast furnace toward the furnace wall (hereinafter, this action is referred to as "reverse tilt"). As shown in Fig. 1, the depositional surface of the coke layer 10 is inclined such that the height of the surface reduces toward the furnace center, that is, in the direction in which the dimensionless throat radius decreases, and increases toward the furnace wall. Therefore, when the coke-mixed coarse grain ore is charged into the furnace by reversely tilting the charging chute, the coke-mixed coarse grain ore becomes deposited on the inclined depositional surface of the coke layer 10 so as to accumulate on the depositional surface in order from lower. This restrains the coarse grain ore from being spread in the radial direction of the throat. As a result, the coke-mixed coarse grain ore is suppressed from flowing toward the furnace center. This reduces the segregation of mixing coke in the vicinity of the furnace center. Consequently, a coke-mixed coarse grain ore layer for securing gas permeability in the blast furnace and maintaining high reduction reactivity can be formed. This lowers the ratio of the reducing agent used in the operation of the blast furnace.

[0023] On the other hand, when, in the first batch, the coke-mixed coarse grain ore is charged into the furnace by tilting the charging chute from a position closer to the furnace wall than the midpoint between the furnace center and the furnace wall toward the furnace center (hereinafter, this action is referred to as "forward tilt"), the coarse grain ore is charged into the furnace so as to flow in the direction from the upper to lower parts of the inclined surface, that is, in the direction from the furnace wall to the furnace center. When the charging is performed in the above manner, the coarse grain ore may flow toward the furnace center and become deposited to be spread toward the furnace center. When the coarse grain ore is deposited to be spread toward the furnace center, the mixing coke mixed in the coarse grain ore may become separated due to the differences in specific gravity and grain diameter between mixing coke and ore and segregate in the vicinity of the furnace center. When the mixing coke segregates in the vicinity of the furnace center, the amount of mixing coke effectively mixed in the ore is reduced. This makes it impossible to maintain high reduction reactivity and raises the ratio of the reducing agent used in the operation of the blast furnace.

[0024] Fig. 2 is a graph showing the relationship between the amount of mixing coke mixed in the coarse grain ore used in the first batch and the average reduction rate to 1300°C. In Fig. 2, the horizontal axis represents the amount of mixing coke (kg/t-pig), and the vertical axis represents the average reduction rate to 1300°C (mol/min). The average reduction rate is an average reduction rate determined when 1550 g of ore is heated from 1000°C to 1300°C at 5 °C/min under respective coke mixing conditions and subsequently reduced with a CO gas, and is expressed by the number of moles of the amount of oxygen removed as a result of the reduction. In Fig. 2, the solid line represents the relationship that holds in the case where the coke-mixed coarse grain ore is charged into the furnace by reversely tilting the charging chute. The dotted line in Fig. 2 represents the relationship that holds in the case where the coke-mixed coarse grain ore is charged into the furnace by forwardly tilting the charging chute.

[0025] As shown in Fig. 2, the increase in the reduction rate relative to the amount of mixing coke is greater in the case where the coarse grain ore is charged into the furnace by reversely tilting the charging chute than in the case where the coarse grain ore is charged into the furnace by forwardly tilting the charging chute. From the above results it is confirmed that the charge of the coke-mixed coarse grain ore for the first batch into the furnace by reversely tilting the charging chute restrains segregation of the mixing coke in the vicinity of the furnace center, to enable the formation of a coke-mixed coarse grain ore layer for maintaining high reduction reactivity.

[0026] Referring again to Fig. 1, the coke-mixed fine grain ore is charged into the blast furnace in the second batch, which is the final batch subsequent to the charge of the coarse grain ore. As a result, a fine grain ore layer 14 is formed on the coarse grain ore layer 12. As shown in Fig. 1, the coarse grain ore layer 12 is inclined such that the surface thereof mildly descends from the midpoint between the furnace center and the furnace wall toward the furnace wall. Therefore, it is preferable to charge the coke-mixed fine grain ore into the blast furnace by forwardly tilting the charging chute. Charging the fine grain ore into the furnace in the above-described manner enables the fine grain ore to be deposited so as to accumulate in order from the lower part of the inclined coarse grain ore layer 12 and restrains the charged coarse grain ore from being spread in the radial direction of the throat. This suppresses the coke-mixed fine grain ore from flowing toward the furnace wall to restrain segregation of the mixing coke in the vicinity of the furnace wall. Consequently, a coke-mixed fine grain ore layer which enables high reduction reactivity to be maintained can be formed. This may further lower the reducing agent ratio.

[0027] On the other hand, when the fine grain ore for the second batch is charged by reversely tilting the charging chute, the fine grain ore is charged into the furnace so as to flow from the upper part of the inclined surface, that is, the furnace center-side, toward the lower part of the inclined surface, that is, the furnace wall-side. Consequently, the fine grain ore may become deposited to be spread toward the furnace wall. When the fine grain ore is deposited to be spread toward the furnace wall, the mixing coke mixed in the fine grain ore may segregate in the vicinity of the furnace wall due to the differences in specific gravity and grain diameter between coke and ore. The segregation of the mixing coke in the vicinity of the furnace wall reduces the amount of mixing coke effectively mixed in the ore. As a result, compared

with the case where the fine grain ore for the second batch is charged into the furnace by forwardly tilting the charging chute, high reduction reactivity may fail to be maintained in the vicinity of the furnace wall and the ratio of the reducing agent used in the operation of the blast furnace may become relatively high.

[0028] As described above, in the method for charging raw material into a blast furnace according to this embodiment, ore is classified into coarse and fine grain ores, each of the coarse and fine grain ores is mixed with mixing coke, and, in the first batch, the coke-mixed coarse grain ore is charged into the blast furnace by reversely tilting a charging chute. This restrains the mixing coke mixed in the coarse grain ore from segregating in the vicinity of the furnace center. As a result, a coke-mixed coarse grain ore layer which enables certain gas permeability in the blast furnace and high reduction reactivity to be maintained can be formed. This lowers the ratio of the reducing agent used in the operation of the blast furnace.

[0029] In this embodiment, an example where ore is classified into coarse and fine grain ores, each of the coarse and fine grain ores is mixed with mixing coke, the coke-mixed coarse grain ore is charged into the furnace in the first batch, and the coke-mixed fine grain ore is charged into the furnace in the second batch, which is the final batch, is described. However, the present invention is not limited to this. For example, a mixture of ore and mixing coke may be classified into three or more batches. Even in such a case, segregation of the mixing coke in the vicinity of the furnace center can be restrained by charging the entirety or a part of the coke-mixed coarse grain ore into the furnace by reversely tilting the charging chute at least in the first batch. Therefore, the ratio of the reducing agent used in the operation of the blast furnace can be lowered compared with the case where the coke-mixed coarse grain ore is charged into the furnace by forwardly tilting the charging chute in the first batch. Furthermore, charging the entirety or a part of the coke-mixed fine grain ore into the furnace by forwardly tilting the charging chute in the final batch enables high reduction reactivity to be maintained in the vicinity of the furnace wall and lowers the ratio of the reducing agent used in the operation of the blast furnace.

[0030] In the case where a mixture of ore and mixing coke is charged into the furnace in three or more separated batches, in an ore batch other than the first or final batch, either the coke-mixed coarse grain ore or the coke-mixed fine grain ore may be charged into the furnace. In such a batch, it is more preferable to charge the coarse grain or coke-mixed fine grain ore into the furnace by reverse tilt charging. Charging the raw materials into the furnace by reverse tilt charge suppresses the raw materials from flowing toward the furnace center together with a part of the mixing coke that has been charged into the furnace in the previous batch to restrain segregation of the mixing coke in the vicinity of the furnace center.

EXAMPLE 1

[0031] Examples in which a blast furnace was operated while coke-mixed coarse and fine grain ores were charged into the blast furnace by the method for charging raw material into a blast furnace according to this embodiment and reductions in the reducing agent and coke ratios were confirmed are described below. First, coke was charged into a blast furnace provided with a bell-less charging equipment with a charging chute and had an inner capacity of 5000 m³ to form a coke layer. Subsequently, ore was charged into the furnace with the bell-less charging equipment to form an ore layer. The blast furnace was operated while the above-described steps were repeated to alternately form coke layers and ore layers in the furnace.

[0032] In Example 1, the ratios of the reducing agent and coke used in the operation of the blast furnace were measured under the same conditions except that the ratio of the average grain diameter of the coarse grain ore to that of the fine grain ore, the direction of tilt of the charging chute in the first batch, the direction of tilt of the charging chute in the second batch, and the use of the mixing coke were changed. Table 1 lists the measurement conditions and results of Comparative examples 1 to 5 and Invention examples 1 to 3. The mixing ratio of the mixing coke was 60 kg/t-pig.

[Table 1]

	Comparative example 1	Comparative example 2	Comparative example 3	Comparative example 4	Comparative example 5	Invention example 1	Invention example 2	Invention example 3
First batch ore average grain diameter/ second batch ore average grain diameter	1.00	1.35	1.35	1.85	1.85	1.35	1.85	1.85
O1 tilt direction (forward/reverse)	Forward	Forward	Forward	Forward	Forward	Reverse	Reverse	Reverse
O2 tilt direction (forward/reverse)	Forward	Forward	Forward	Forward	Forward	Forward	Reverse	Forward
Mixing coke (Yes/No)	No	No	Yes	No	Yes	Yes	Yes	Yes
Productivity (t/m ³ /day)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Reducing agent ratio (kg/t-pig)	505	504	503	504	503	500	499	497
Coke ratio (kg/t-pig)	357	356	355	356	355	352	351	349
Pulverized coal ratio (kg/t-pig)	148	148	148	148	148	148	148	148
Rate of gas use (%)	48.6	48.7	48.8	48.8	48.9	49.6	49.4	49.6
Pressure loss in packed bed (kPa/(Nm ³ /min))	21.7	21.1	21.0	20.5	20.5	20.4	20.0	20.0

[0033] The sieves used for separating the coarse and fine grain ores from each other were a sieve having openings of 10 mm (average grain diameter ratio: 1.85) and a sieve having openings of 14 mm (average grain diameter ratio: 1.35). The average grain diameter ratio is the quotient of the average grain diameter of the coarse grain ore obtained by the screening using the sieve divided by that of the fine grain ore.

[0034] The average grain diameter of the fine grain ore obtained by the screening using the sieve having openings of 10 mm was 8 mm, while the average grain diameter of the coarse grain ore was 14.8 mm. The mass ratio between the coarse and fine grain ores was 66:34.

[0035] The average grain diameter of the fine grain ore obtained by the screening using the sieve having openings of 14 mm was 12 mm, while the average grain diameter of the coarse grain ore was 16.2 mm. The mass ratio between the coarse and fine grain ores was 58:42. The average grain diameter of the mixing coke was 25 mm.

[0036] The average grain diameter of ore and coke was determined by performing screening using sieves having nominal openings of 1 mm or more which are specified in JIS Z 8801-2019. Specifically, the characteristic diameter of grains that passed through a sieve of 1 mm was considered 0.5 mm. The characteristic diameters of the other grains were each considered the average of the major dimension of openings of the corresponding sieve and a sieve having next larger openings. The above characteristic diameters were weight-averaged in accordance with the masses of the classified grains.

[0037] In Table 1, the term "O1 tilt direction" refers to the direction of tilt of the charging chute when the ore was charged in the first batch, while the term "O2 tilt direction" refers to the direction in which the charging chute was tilted when the ore was charged in the second batch. In Comparative examples 2 to 5 and Invention examples 1 to 3, the coarse grain ore was charged in the first batch, while the fine grain ore was charged in the second batch. The term "Forward" used when referring to tilt direction means that the ore was charged into the furnace by forwardly tilting the charging chute, while the term "Reverse" means that the ore was charged into the furnace by reversely tilting the charging chute.

[0038] In Invention example 1, ore was classified into coarse and fine grain ores (grain diameter ratio: 1.35), each of the coarse and fine grain ores was mixed with mixing coke, and the coarse grain ore was charged into the furnace by reverse tilt charge in the first batch. As a result, in Invention example 1, the rate of gas use was increased, the pressure loss in the packed bed was reduced, and the ratios of the reducing agent and coke were reduced compared with Comparative example 3, where the same conditions as in Invention example 1 were used except that the coarse grain ore was charged into the furnace by forward tilt charge in the first batch. Similarly, in Invention example 3, ore was classified into coarse and fine grain ores (grain diameter ratio: 1.83), each of the coarse and fine grain ores was mixed with mixing coke, and the coarse grain ore was charged into the furnace by reverse tilt charge in the first batch. As a result, in Invention example 3, the rate of gas use was increased, the pressure loss in the packed bed was reduced, and the ratios of the reducing agent and coke were lowered compared with Comparative example 5, where the same conditions as in Invention example 3 were used except that the coarse grain ore was charged into the furnace by forward tilt charge in the first batch.

[0039] It was confirmed from a comparison between Invention examples 2 and 3 and Comparative example 5 that reverse tilt charge of the coarse grain ore in the first batch reduces the reducing agent and coke ratios compared with the case of forward tilt charge of the coarse grain ore in the first batch, regardless of whether the fine grain ore was charged into the furnace by forward or reverse tilt charge in the second batch. It was confirmed from the above results that the ratios of the reducing agent and coke used in the operation of the blast furnace can be lowered by classifying ore into coarse and fine grain ores, mixing each of the coarse and fine grain ores with mixing coke, and charging the coke-mixed coarse grain ore by reverse tilt charge.

[0040] In Invention example 3, where the coke-mixed fine grain ore was charged into the furnace by forward tilt charge in the second batch, the reducing agent and coke ratios were lowered compared with Invention example 2, where the same conditions as in Invention example 3 were used except that the coke-mixed fine grain ore was charged into the furnace by forward tilt charge in the second batch. It was confirmed from the above results that reverse tilt charge of the coke-mixed fine grain ore in the second batch further lowers the ratios of the reducing agent used and coke in the operation of the blast furnace.

[0041] In Comparative examples 2 and 4, where ore was classified into coarse and fine grain ores and the coarse and fine grain ores were charged into the furnace in the first and second batches, respectively, the reducing agent and coke ratios were lowered compared with Comparative example 1, where ore was not classified into coarse and fine grain ores before being charged into the furnace. However, in Comparative examples 2 and 4, since the ores were not mixed with the mixing coke, reduction reactivity was poor and the reducing agent and coke ratios were higher than in Comparative example 3 or 5.

EXAMPLE 2

[0042] Table 2 lists examples in which the same blast furnace as that used in Example 1 was operated at a productivity

EP 4 083 235 A1

of 2.0 while ore was charged into the furnace in three batches. The classification into coarse and fine grain ores was performed similarly to Example 1 under the two conditions: average grain diameter ratios of 1.35 and 1.85. Table 2 lists the measurement conditions and results of Comparative example 11 and Invention examples 11 to 24.

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[Table 2]

	Compara- tive example 11	Invention example 11	Invention example 12	Invention example 13	Invention example 14	Invention example 15	Invention example 16	Invention example 17	Invention example 18	Invention example 19	Invention example 20	Invention example 21	Invention example 22	Invention example 23	Invention example 24
First batch ore average grain diam- eter/ third batch ore average grain diam- eter	1.35	1.35	1.35	1.00	1.00	1.00	1.00	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85
Second batch ore average grain diam- eter/ third batch ore average grain diam- eter	1.35	1.35	1.00	1/1.85	1/1.85	1/1.85	1/1.85	1.85	1.85	1.85	1.85	1.00	1.00	1.00	1.00
O1 tilt direc- tion (for- ward/re- verse)	Forward	Reverse	Reverse	Reverse	Reverse	Reverse	Reverse	Reverse	Reverse	Reverse	Reverse	Reverse	Reverse	Reverse	Reverse
O2 tilt direc- tion (for- ward/re- verse)	Forward	Reverse	Forward	Reverse	Reverse	Forward	Forward	Reverse	Reverse	Forward	Forward	Reverse	Reverse	Forward	Forward
O3 tilt direc- tion (for- ward/re- verse)	Forward	Forward	Forward	Reverse	Forward	Reverse	Forward	Reverse	Forward	Reverse	Forward	Reverse	Forward	Reverse	Forward
Use of mix- ing coke	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

(continued)

	Comparative example 11	Invention example 11	Invention example 12	Invention example 13	Invention example 14	Invention example 15	Invention example 16	Invention example 17	Invention example 18	Invention example 19	Invention example 20	Invention example 21	Invention example 22	Invention example 23	Invention example 24
Productivity (t/m ³ /day)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Reducing agent ratio (kg/t-pig)	503	500	501	498	497	498	499	497	496	497	497	497	497	498	498
Coke ratio (kg/t-pig)	355	352	353	350	349	350	351	349	348	349	349	349	349	350	350
Pulverized coal ratio (kg/t-pig)	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148
Rate of gas use (%)	48.8	49.6	49.4	49.4	49.5	49.3	49.2	49.6	49.7	49.5	49.6	49.5	49.6	49.4	49.4
Pressure loss in packed bed (kPa/(Nm ³ /min))	21.0	20.4	20.5	20.3	20.2	20.2	20.2	20.3	20.2	20.4	20.3	20.4	20.3	20.5	20.4

[0043] In Table 2, the term "O1 tilt direction" refers to the direction of tilt of the charging chute when the ore was charged in the first batch; the term "O2 tilt direction" refers to the direction of tilt of the charging chute when the ore was charged in the second batch; and the term "O3 tilt direction" refers to the direction of tilt when the ore was charged into the furnace in the third batch, which was the final batch. The term "Forward" in tilt direction means that the ore was charged into the furnace by forwardly tilting the charging chute, while the term "Reverse" means that the ore was charged into the furnace by reversely tilting the charging chute.

[0044] In Comparative example 11 and Invention examples 11 and 12, ore was classified into coarse and fine grain ores (grain diameter ratio: 1.35) and each of the coarse and fine grain ores was mixed with mixing coke. In Comparative example 11, the coarse grain ore was charged into the furnace in the first and second batches and the fine grain ore was charged into the furnace in the third batch. Both coarse and fine grain ores were charged by forward tilt charge. On the other hand, in Invention example 11, the coarse grain ore was charged into the furnace by reverse tilt charge in the first batch, the coarse grain ore was charged into the furnace by reverse tilt charge in the second batch, and the fine grain ore was charged into the furnace by forward tilt charge in the third batch. In Invention example 12, the coarse grain ore was charged into the furnace by reverse tilt charge in the first batch, the fine grain ore was charged into the furnace by forward tilt charge in the second batch, and the fine grain ore was charged into the furnace by forward tilt charge in the third batch. In Invention examples 11 and 12, the rate of gas use was increased, the pressure loss in the packed bed was reduced, and the ratios of the reducing agent and coke were lowered compared with Comparative example 11. In particular, it was confirmed that Invention example 11, where the ore was charged into the furnace by reverse tilt charge in the second batch, is more preferable than Invention example 12, where the ore was charged into the furnace by forward tilt charge in the second batch, because, in Invention example 11, the reducing agent and coke ratios were lowered compared with Invention example 12.

[0045] In Invention examples 13 to 24, the classification into coarse and fine grain ores was performed using a sieve having openings of 10 mm (average grain diameter ratio: 1.85). In all of Invention examples 13 to 24, the coarse grain ore was charged into the furnace by reverse tilt charge in the first batch.

[0046] In Invention examples 13 to 16, the fine and coarse grain ores were charged in the second and third batches, respectively, and the raw materials were charged into the furnace while the directions in which the charging chute was tilted in the second and third batches were changed to forward or reverse, that is, in four patterns. In all of Invention examples 13 to 16, the rate of gas use was increased, the pressure loss in the packed bed was reduced, and the ratios of reducing agent and coke were lowered compared with Comparative example 11.

[0047] In Invention examples 17 to 20, the coarse and fine grain ores were charged in the second and third batches, respectively, and the raw materials were charged into the furnace while the directions in which the charging chute was tilted in the second and third batches were changed to forward or reverse, that is, in four patterns. In all of Invention examples 17 to 20, the rate of gas use was increased, the pressure loss in the packed bed was reduced, and the ratios of reducing agent and coke were lowered compared with Comparative example 11. In particular, it was confirmed that Invention examples 18 and 20, where the ore was charged into the furnace by forward tilt charge in the third batch, is more preferable than Invention examples 17 and 19, where the ore was charged into the furnace by reverse tilt charge in the third batch, because, in Invention examples 18 and 20, the rate of gas use was increased and the pressure loss in the packed bed was reduced compared with Invention examples 17 and 19.

[0048] In Invention examples 21 to 24, the fine grain ore was charged in the second and third batches and the raw materials were charged into the furnace while the directions in which the charging chute was tilted in the second and third batches were changed to forward or reverse, that is, in four patterns. In all of Invention examples 21 to 24, the rate of gas use was increased, the pressure loss in the packed bed was reduced, and the ratios of reducing agent and coke were lowered compared with Comparative example 11. In particular, it was confirmed that Invention examples 22 and 24, where the ore was charged into the furnace by forward tilt charge in the third batch, is more preferable than Invention examples 21 and 23, where the ore was charged into the furnace by reverse tilt charge in the third batch, because, in Invention examples 22 and 24, the rate of gas use was comparable to or higher than that of Invention examples 21 and 23 and the pressure loss in the packed bed was reduced compared with Invention examples 21 and 23.

Reference Signs List

[0049]

- 10 COKE LAYER
- 12 COARSE GRAIN ORE LAYER
- 14 FINE GRAIN ORE LAYER

Claims

1. A method for charging raw material into a blast furnace in which a mixture of ore and mixing coke is charged into the blast furnace in two or more separated batches by using a bell-less charging equipment with a charging chute, the method comprising:

classifying the ore into coarse grain ore and fine grain ore having a smaller average grain diameter than the coarse grain ore, mixing the coarse grain ore with the mixing coke to prepare coke-mixed coarse grain ore, and mixing the fine grain ore with the mixing coke to prepare coke-mixed fine grain ore; and charging, at least in a first batch, the entirety or a part of the coke-mixed coarse grain ore into the blast furnace by tilting the charging chute from a position closer to a center of the blast furnace than a midpoint between the center of the blast furnace and a wall of the blast furnace in a radial direction of the blast furnace toward the wall of the blast furnace.

2. The method for charging raw material into a blast furnace according to Claim 1, wherein, in a final batch, the entirety or a part of the coke-mixed fine grain ore is charged into the blast furnace by tilting the charging chute being a position closer to the wall of the blast furnace than the midpoint between the center of the blast furnace and the wall of the blast furnace in the radial direction of the blast furnace toward the center of the blast furnace.

FIG. 1

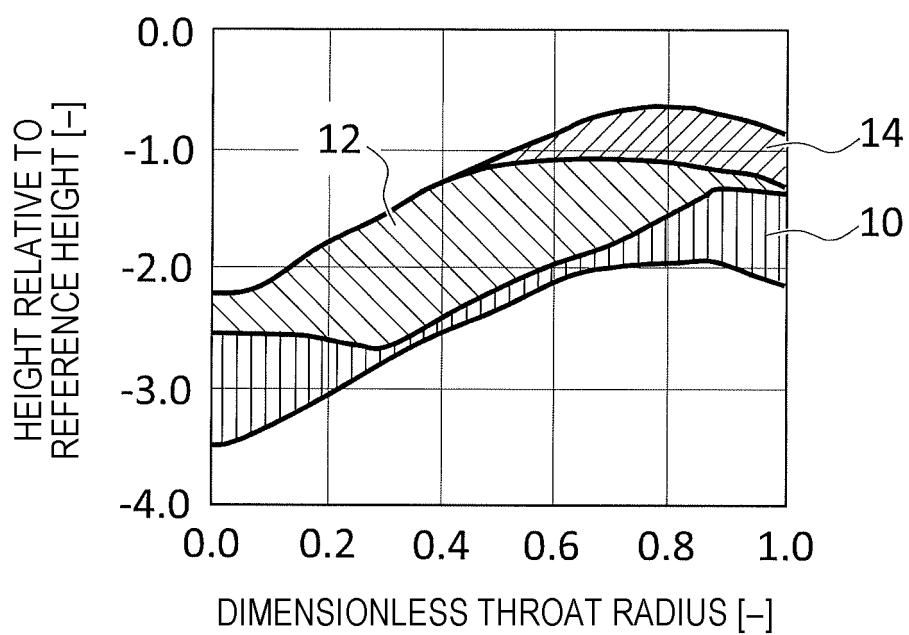
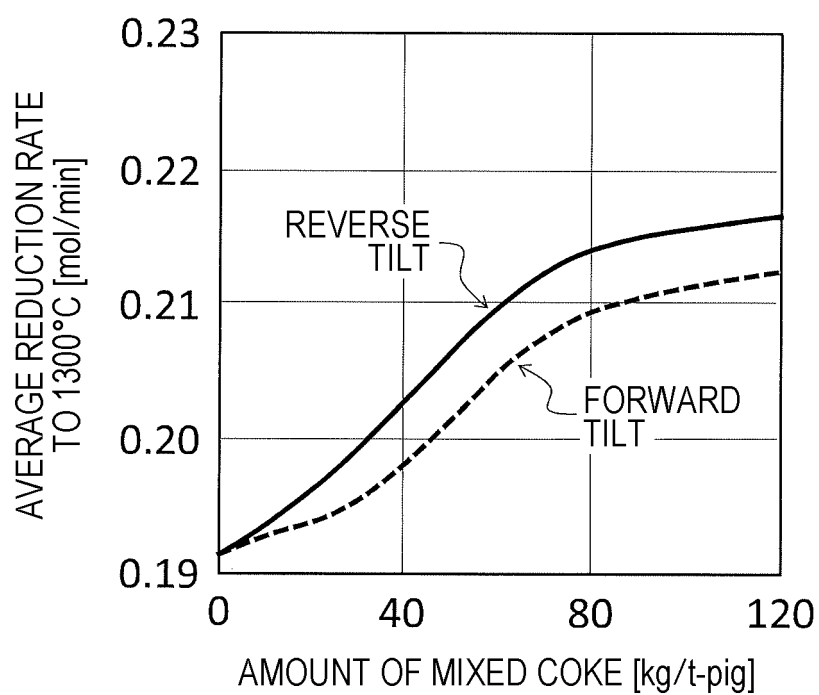


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/044357

A. CLASSIFICATION OF SUBJECT MATTER

C21B 5/00 (2006.01) i

FI: C21B5/00 311

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

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2020

Registered utility model specifications of Japan 1996-2020

Published registered utility model applications of Japan 1994-2020

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	JP 63-140006 A (KAWASAKI STEEL CORP.) 11 June 1988 (1988-06-11) entire text	1-2
A	JP 08-120311 A (NIPPON STEEL CORP.) 14 May 1996 (1996-05-14) entire text	1-2
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A	JP 02-305911 A (NIPPON STEEL CORP.) 19 December 1990 (1990-12-19) entire text	1-2
A	JP 2018-024914 A (KOBE STEEL, LTD.) 15 February .2018 (2018-02-15) entire text	1-2
A	JP 07-054023 A (SUMITOMO METAL INDUSTRIES, LTD.) 28 February 1995 (1995-02-28) entire text	1-2



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"&" document member of the same patent family

Date of the actual completion of the international search
09 December 2020 (09.12.2020)Date of mailing of the international search report
22 December 2020 (22.12.2020)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/044357

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	JP 2001-064705 A (KAWASAKI STEEL CORP.) 13 March 2001 (2001-03-13) entire text	1-2
A	JP 2015-199979 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 12 November 2015 (2015-11-12) entire text	1-2
A	WO 2013/172046 A1 (JFE STEEL CORPORATION) 21 November 2013 (2013-11-21) entire text	1-2

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/JP2020/044357

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REFERENCES CITED IN THE DESCRIPTION

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