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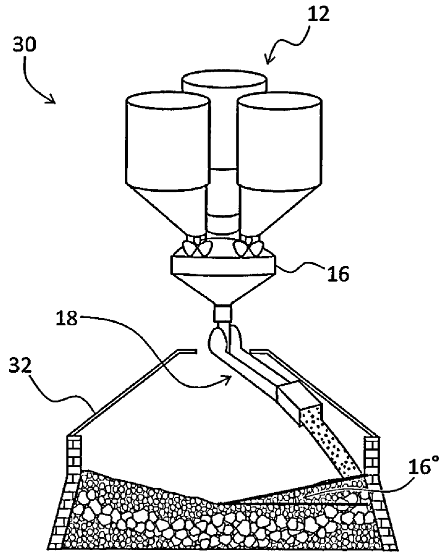
(54) METHOD FOR CHARGING RAW MATERIAL INTO BELL-LESS BLAST FURNACE, AND BLAST FURNACE OPERATION METHOD

(57) Provided are a method for charging raw materials into a bell-less blast furnace, the method enabling raw materials to be charged into a predetermined position in a furnace interior without compromising productivity, and a blast furnace operation method that uses the method for charging raw materials.

A method for charging raw materials into a bell-less blast furnace includes charging an iron source material and a carbonaceous material into a furnace interior of the blast furnace by rotating a distribution chute. The distribution chute includes a diversion plate at an end of the distribution chute, the diversion plate being inclined downward relative to a conveying direction of the distribution chute, and a rotational speed of the distribution chute is greater than 10 rpm.

FIG. 4



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Description

Technical Field

[0001] The present invention relates to a method for charging raw materials into a bell-less blast furnace, the method being designed to lower the reducing agent ratio of a blast furnace, and to a blast furnace operation method that uses the method for charging raw materials.

Background Art

[0002] In general, in a blast furnace operation, coke and iron source materials, which are burdens, are charged alternately from a furnace upper portion of the blast furnace. The coke is utilized as a reducing agent and fuel. The iron source materials are iron-containing oxides and include sintered ore, pellets, and lump ore. In the following description, these iron source materials will be collectively referred to as "ore". In the furnace interior of a blast furnace, coke layers and ore layers are alternately formed, and, accordingly, raw material deposition layers are formed. Hot air is blown through tuyeres disposed in a furnace lower portion of the blast furnace, and also, auxiliary fuel, such as pulverized coal and tar, is injected therethrough.

[0003] Maintaining the stable operation of a blast furnace requires ensuring that the raw material deposition layers have good gas permeability for the gas flowing from the furnace lower portion to the furnace upper portion, thereby stabilizing the gas flow in the furnace interior. The stabilizing of the gas flow in the furnace interior can be achieved by ensuring a stable central gas flow and a stable near-furnace-wall gas flow. The gas permeability of the raw material deposition layers is significantly affected, principally, by properties, particle sizes, and a charge amount of the coke and ore. In addition, the gas permeability is also significantly affected by the method used to charge the burdens from the furnace top, that is, by the state of distribution of the burdens charged in the furnace interior. In the following description, the burden distribution state will be referred to as a "burden distribution".

[0004] To date, for the controlling of the burden distribution, controlling of a mass-ratio-based distribution of the coke layers and the ore layers in a radial direction of a blast furnace has been most commonly employed. In the following description, the mass ratio between the coke layers and the ore layers will be referred to as "[Ore/Coke]". Blast furnaces can be classified into bell-less blast furnaces and bell blast furnaces, depending on the type of the raw material charging apparatus. Regardless of whether a bell-less blast furnace or a bell blast furnace is used, an effective way to achieve a particularly stable gas flow is to reduce the [Ore/Coke] value of a central portion of the furnace.

[0005] In recent years, operations with a high tapping ratio, a high pulverized coal ratio, and a low fuel ratio have been performed. In such operations, the operation conditions are such that an amount of ore is increased relative to an amount of coke that is charged. Such operation conditions will be referred to as "high O/C conditions" in the following description. In a blast furnace operation under high O/C conditions, the proportion of the ore layers, which have high gas permeation resistance, is increased in the raw material deposition layers, and, consequently, a pressure loss in the furnace upper portion increases. As a result, gas channeling tends to occur, and hanging, slipping, and/or the like tend to occur because the burdens do not stably fall. These phenomena significantly interfere with the stable operation of a blast furnace, which results in a noticeable decrease in productivity. Accordingly, the realization of stable operation under high O/C conditions requires more precise control of (Ore/Coke).

[0006] Patent Literature 1 discloses a method for performing control for achieving a charge distribution. The charge distribution is such that [Lo/(Lc+Lo)] (Lo is a thickness of the ore layers, and Lc is a thickness of the coke layers) satisfies the following conditions (a) to (d) provided that furnace interior regions in a furnace radial direction are designated as, starting from the furnace center side, a first region, in which $r/Rt \leq 0.20$, a second region, in which $0.20 < r/Rt \leq 0.80$, and a third region, in which $0.80 < r/Rt$, where r (m) is a distance from a furnace center in the furnace radial direction, and Rt (m) is a furnace interior radius at a throat portion.

(a) Average value in the first region: less than 0.5
(b) Average value in the second region: 0.6 or greater and less than 0.9
(c) Average value in the third region: 0.4 or greater and less than 0.8
(d) Average value in the first region < average value in the third region < average value in the second region

[0007] This method increases the reduction efficiency of an entire blast furnace by increasing [Lo/(Lc+Lo)] in the second region while ensuring the gas permeability of the furnace interior of the blast furnace in the first and third regions.

[0008] A widely used means for charging raw materials from the furnace top is a bell-less charging device provided with a distribution chute. With the bell-less charging device, a fall position and a deposition amount of the raw materials in the furnace radial direction can be adjusted by changing an inclination angle of the distribution chute and the number of rotations thereof, and, accordingly, [Ore/Coke] can be controlled. The "inclination angle of the distribution chute" is an angle between a vertical direction and an angle at which the raw materials on a chute surface of the distribution chute flow.

[0009] An effective way to deposit the raw materials in a predetermined position in a furnace interior is to reduce a deposition width of the raw materials that are charged into the furnace interior. Patent Literature 2 discloses a method for reducing the deposition width of matter that is to be deposited, which is achieved by ensuring that a linear velocity V of an end of a distribution chute is less than or equal to a predetermined value, which is determined based on a property of the raw materials to be charged.

Citation List

Patent Literature

[0010]

PTL 1: Japanese Unexamined Patent Application Publication No. 2018-193579
PTL 2: Japanese Unexamined Patent Application Publication No. 2003-328018

Summary of Invention

Technical Problem

[0011] For the operation under high O/C conditions, which has been employed in recent years, it is not sufficient to merely lower [Ore/Coke] of the central portion and thus form an inverted V-shape of a cohesive zone for the stabilization of the permeation of gas. It is necessary to lower [Ore/Coke] of a near-furnace-wall portion, too, thereby ensuring the permeation of gas, and to increase [Ore/Coke] of an intermediate portion, so that the reduction efficiency of the entire furnace can be increased. Achieving this requires depositing the raw materials stably and reliably from the furnace top through a distribution chute into a predetermined position in the furnace interior.

[0012] In depositing the raw materials in a predetermined position in the furnace interior, it is necessary not only to reduce the deposition width of the raw materials, as disclosed in Patent Literature 2, but also to inhibit collapsing of the raw materials deposited in a predetermined position. Accordingly, it is necessary to optimize a rotational speed of the distribution chute, which is a speed during the charging of the raw materials, so as to reduce the deposition width, while taking into account the inhibition of the collapsing of the raw materials deposited in a predetermined position.

[0013] Reducing a speed of the end of a distribution chute, as disclosed in Patent Literature 2, may compromise productivity because in such a case, the charge time needs to be extended. The present invention was made to solve the problems described above. Objects of the present invention are to provide a method for charging raw materials into a bell-less blast furnace, the method enabling raw materials to be charged into a predetermined position in the furnace interior without compromising productivity, and to provide a blast furnace operation method that uses the method for charging raw materials.

Solution to Problem

[0014] Features of the present invention for solving the problems described above are as follows.

[1] A method for charging raw materials into a bell-less blast furnace, the method including charging an iron source material and a carbonaceous material into a furnace interior of the blast furnace by rotating a distribution chute, wherein the distribution chute includes a diversion plate at an end of the distribution chute, the diversion plate being inclined downward relative to a conveying direction of the distribution chute, and a rotational speed of the distribution chute is greater than 10.0 rpm.

[2] The method for charging raw materials into a bell-less blast furnace according to [1], wherein the rotational speed of the distribution chute is greater than or equal to 12.0 rpm.

[3] The method for charging raw materials into a bell-less blast furnace according to [2], wherein an inclination angle of the distribution chute is greater than or equal to 1.36α, where α is an angle defined by a distance d, a throat radius Ro, and expression (1), shown below, and the distance d is a distance from a center of rotation of the distribution chute to a raw material deposition level of the furnace interior, the raw material deposition level being a level at a start of raw material charging.

$$\tan\alpha = Ro/d \quad ...(1)$$

[4] The method for charging raw materials into a bell-less blast furnace according to [1], wherein the rotational speed of the distribution chute is greater than or equal to 14.0 rpm.

[5] The method for charging raw materials into a bell-less blast furnace according to [4], wherein an inclination angle of the distribution chute is greater than or equal to 1.41α, where α is an angle defined by a distance d, a throat radius Ro, and expression (1), shown below, and the distance d is a distance from a center of rotation of the distribution chute to a raw material deposition level of the furnace interior, the raw material deposition level being a level at a start of raw material charging.

$$\tan\alpha = Ro/d \quad ...(1)$$

[6] A blast furnace operation method including charging an iron source material and a carbonaceous material into a furnace interior of the blast furnace by using the method for charging raw materials into a bell-less blast furnace according to any one of [1] to [5].

Advantageous Effects of Invention

[0015] In methods of the present invention for charging raw materials into a bell-less blast furnace, ore and a carbonaceous material are to be charged into a blast furnace in a manner in which a rotational speed of a distribution chute is greater than 10.0 rpm. Consequently, a deposition angle of the carbonaceous material in a region around the furnace wall is increased, and a deposition width of the carbonaceous material is reduced, without compromising productivity. As a result, an area of the region where [Ore/Coke] is lowered in the near-furnace-wall portion is reduced, and, therefore, a gas utilization ratio of the blast furnace is improved. Accordingly, low-reducing-agent-ratio/low-coke-ratio operation is realized.

Brief Description of Drawings

[0016]

[Fig. 1] Fig. 1 is a schematic diagram illustrating an overview of a model apparatus 10.

[Fig. 2] Fig. 2 presents a perspective view and a cross-sectional view of an end portion of a distribution chute 18, which includes a diversion plate 22.

[Fig. 3] Fig. 3 is a graph illustrating a weight distribution obtained in a charging experiment.

[Fig. 4] Fig. 4 is a schematic cross-sectional view of a model apparatus 30, which was used in a coke deposition angle measurement experiment.

[Fig. 5] Fig. 5 is a schematic diagram illustrating a state of a furnace interior, which is a state at the time at which the charging of raw materials was started. Description of Embodiments

[0017] The present inventors conducted a coke charging experiment by using a model apparatus 10, which has a scale factor of 1/17.8 with respect to a blast furnace having an internal volume of 5005 m^3 and a throat diameter of 11.2 m, to investigate the manner in which coke falls from a distribution chute in a bell-less blast furnace. Fig. 1 is a schematic diagram illustrating an overview of the model apparatus 10.

[0018] The model apparatus 10 includes a furnace top bunker 12, a collecting hopper 16, a distribution chute 18, and sample boxes 24. The furnace top bunker 12 includes three hoppers 14, in which coke and ore can be stored. A gate is disposed at a lower portion of each of the hoppers 14. The gate allows the stored raw materials to be discharged therethrough. The collecting hopper 16 feeds the raw materials discharged from the furnace top bunker 12 to the distribution chute 18. The distribution chute 18 includes a chute 20 and a diversion plate 22. The sample boxes 24 are disposed in four directions in a radial manner, with a center being a position corresponding to the center of rotation of the distribution chute 18. Each of the sample boxes 24 has a plurality of storage sections 26, which are divided sections disposed in a direction from the center side toward the outside, with spacings of 20 mm.

[0019] The sample boxes 24 are installed with a height such that the upper openings of the sample boxes 24 are positioned at a level 424 mm below a center position of inclination and rotation of the distribution chute 18 in a vertical direction. The difference in level corresponds to 0.67 times a throat diameter of the model apparatus 10, as the throat diameter is 630 mm.

[0020] Fig. 2 presents a perspective view and a cross-sectional view of an end portion of the distribution chute 18, which includes the diversion plate 22. Fig. 2(a) is the perspective view, and Fig. 2(b) is the cross-sectional view. Assuming that a conveying direction of the distribution chute 18 is the direction indicated by an arrow 21 in Fig. 2(b), the diversion plate 22 is disposed at an end of the distribution chute 18 in a manner such that the diversion plate 22 is inclined downward relative to the conveying direction.

[0021] The diversion plate 22 is disposed such that if the conveying direction of the chute 20 is parallel to a horizon, a distance (L in Fig. 2(b)) from an end of the chute 20 to the diversion plate 22 in a horizontal direction is 70 mm. A slope angle (θ in Fig. 2(b)) of the diversion plate 22 is 23° with respect to the horizontal direction. In instances where the angle of the diversion plate 22 is to be changed, a length of the diversion plate 22 is to be adjusted such that the distance from the chute 20 to the diversion plate 22 in the horizontal direction remains unchanged.

[0022] The coke charging experiment with the model apparatus 10 was conducted by the following procedure. First, 3 kg of coke having a particle diameter of 2.0 mm to 2.8 mm was charged into the furnace top bunker 12. An opening degree of the gate of the furnace top bunker 12 was adjusted such that the 3 kg of coke could be discharged in 17 seconds. Next, the gate was opened to discharge the coke into the collecting hopper 16 from the furnace top bunker 12, and the coke was allowed to fall through the distribution chute 18. The coke that fell from the distribution chute 18 was stored in the storage sections 26 of the sample boxes 24. The coke is an example of the carbonaceous material.

[0023] A weight of the coke stored in each of the storage sections 26 of the sample boxes 24 was measured, and the weight distribution of the fallen coke in a radial direction was calculated. Fig. 3 is a graph illustrating the weight distribution obtained in the charging experiment. In Fig. 3, the horizontal axis represents a position in the radial direction from the center (mm), and the vertical axis represents a cumulative weight frequency (%). The cumulative weight frequency is defined by using ratios of the weight of coke in regions associated with respective positions to the weight of the total coke; the respective positions are a predetermined distance away from the center, and the regions are closer to the center than the respective positions are.

[0024] In the charging experiment, the position corresponding to a cumulative weight frequency of 50% was designated as a predominant fall position, and a distance in the radial direction between the position corresponding to a cumulative weight frequency of 5% and the position corresponding to a cumulative weight frequency of 95% was designated as a fall width. The inclination angle of the distribution chute 18 was adjusted such that a near-furnace-wall position at a level 424 mm below the center of inclination and rotation in the vertical direction corresponded to the cumulative weight frequency of 95%, that is, the near-furnace-wall position was located 315 mm from the furnace center.

[0025] The charging experiment was conducted in a manner in which a length of the chute 20 of the distribution chute 18 was 240 mm, and a rotational speed of the distribution chute 18 was varied, that is, rotational speeds of 42.2, 50.6, and 59.1 rpm were used. The model apparatus 10 has a scale factor of 1/17.8 with respect to an actual blast furnace. Given the fact that a condition under which the trajectory of the raw materials that fall from the distribution chute 18 becomes similar to that of the actual blast furnace is having a constant Froude number, the rotational speed of 42.2 rpm of the model apparatus 10 corresponds to a rotational speed of 10.0 rpm of the actual blast furnace. The rotational speed of 50.6 rpm of the model apparatus 10 corresponds to a rotational speed of 12.0 rpm of the actual blast furnace. The rotational speed of 59.1 rpm of the model apparatus 10 corresponds to a rotational speed of 14.0 rpm of the actual blast furnace. The charging experiment was conducted for both the instance in which the diversion plate 22 was attached and the instance in which the diversion plate 22 was not attached. The conditions and the results of the experiment are shown in Table 1 below.

[Table 1]

Experiment No.	1	2	3	4	5	6
Rotational speed (rpm)	42.2	50.6	59.1	42.2	50.6	59.1
Chute length (mm)	240	240	240	240	240	240
Diversion plate		with			without	
Inclination angle (°)	54.5	52.5	50.5	52.5	50.5	48.5
Fall width (mm)	97	92	85	108	115	123

[0026] As shown in Table 1, in the instances where a distribution chute 18 with the diversion plate 22 attached to an end thereof was used, the coke fall width decreased as the rotational speed increased. On the other hand, in the instances where a distribution chute 18 without the diversion plate 22 attached to an end thereof was used, the coke fall width increased as the rotational speed increased. These results confirmed that in instances where coke is charged in a manner in which a distribution chute 18 with the diversion plate 22 attached to an end thereof is used, and a rotational speed of the distribution chute 18 is greater than 42.2 rpm, the coke fall width can be reduced.

[0027] Now, a coke deposition angle measurement experiment will be described. Fig. 4 is a schematic cross-sectional view of a model apparatus 30, which was used in the coke deposition angle measurement experiment. The model apparatus 30 includes a furnace top bunker 12, a collecting hopper 16, a distribution chute 18, and a model furnace 32, which has a throat diameter of 630 mm. The furnace top bunker 12, the collecting hopper 16, and the distribution chute 18 are the same as those used in the model apparatus 10. In the deposition angle measurement experiment, first, a deposition surface having a slope angle of 16° was prepared within the model furnace 32. Subsequently, by using the same procedure as that for the charging experiment, coke was dropped on the deposition surface through the distribution chute 18, and then a coke deposition angle, which is a deposition angle of coke deposited in a region near the furnace wall, was measured. The inclination angle of the distribution chute 18 was adjusted such that the predominant fall position at a level 424 mm below the center of inclination and rotation in the vertical direction was located 285 to 325 mm from the furnace center. The predominant fall position was measured by conducting a coke charging experiment with the model apparatus 10. The results are shown in Table 2 and Table 3 below.

[Table 2]

Experiment No.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Rotational speed (rpm)	42.2	42.2	42.2	42.2	42.2	50.6	50.6	50.6	50.6	50.6	59.1	59.1	59.1	59.1	59.1
Chute length (mm)	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240
Diversion plate (with/without)	with	with	with	with	with	with	with	with	with	with	with	with	with	with	with
Inclination angle (°)	52.5	53.5	54.5	55.5	56.5	50.5	51.5	52.5	53.5	54.5	48.5	49.5	50.5	51.5	52.5
Inclination angle/α (-)	1.43	1.46	1.49	1.52	1.54	1.38	1.41	1.43	1.46	1.49	1.32	1.35	1.38	1.41	1.43
Predominant fall position (mm)	285	295	305	315	325	285	295	305	315	325	285	295	305	315	325
Predominant fall position/Ro (-)	0.91	0.94	0.97	1.00	1.03	0.91	0.94	0.97	1.00	1.03	0.91	0.94	0.97	1.00	1.03
Deposition angle before charging of coke (°)	16.5	16.4	16.6	16.7	16.2	16.3	16.3	16.2	16.5	16.4	16.7	16.2	16.1	16.5	16.3
Deposition angle after charging of coke (°)	25.5	25.9	26.9	26.5	25.5	27.1	28.6	29.2	29.7	28.8	27.9	28.0	28.5	29.5	29.8
Δ Deposition angle (°)	9.0	9.5	10.3	9.8	9.3	10.8	12.3	13.0	13.2	12.4	11.2	11.8	12.4	13.0	13.5

[Table 3]

Experiment No.	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Rotational speed (rpm)	42.2	42.2	42.2	42.2	42.2	50.6	50.6	50.6	50.6	50.6	59.1	59.1	59.1	59.1	59.1
Chute length (mm)	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240
Diversion plate (with/without)	without	without	without	without	without	without	without	without	without	without	without	without	without	without	without
Inclination angle (°)	50.5	51.5	52.5	53.5	54.5	48.5	49.5	50.5	51.5	52.5	46.5	47.5	48.5	49.5	50.5
Inclination angle/α (-)	1.38	1.41	1.43	1.46	1.49	1.32	1.35	1.38	1.41	1.43	1.27	1.30	1.32	1.35	1.38
Predominant fall position (mm)	285	295	305	315	325	285	295	305	315	325	285	295	305	315	325
Predominant fall position/Ro (-)	0.91	0.94	0.97	1.00	1.03	0.91	0.94	0.97	1.00	1.03	0.91	0.94	0.97	1.00	1.03
Deposition angle before charging of coke (°)	16.5	16.4	16.6	16.7	16.2	16.3	16.3	16.2	16.5	16.4	16.7	16.2	16.1	16.5	16.3
Deposition angle after charging of coke (°)	24.7	25.0	25.6	26.2	25.3	24.1	24.3	24.7	25.4	25.7	23.9	23.5	23.8	24.5	24.7
Δ Deposition angle (°)	8.2	8.6	9.0	9.5	9.1	10.8	8.0	8.5	8.9	9.3	7.2	7.3	7.7	8.0	8.4

[0028] As shown in Table 2, in the instances where a distribution chute 18 with the diversion plate 22 attached to an end thereof is used, an inclination angle at which the coke deposition angle is a maximum existed for the cases in which the conditions of the rotational speed are the same. In instances where the predominant fall position is away from the wall surface and relatively close to the center, the number of coke particles that collide with the wall surface is small, and, consequently, the deposition angle is reduced. In instances where the predominant fall position is near the wall surface, the number of coke particles that collide with the wall surface is large, and thus, the bouncing from the wall surface is increased; consequently, the coke deposition angle is also reduced. As described, when the predominant fall position is away from the wall surface, the deposition angle is reduced, and, when the predominant fall position is near the wall surface, the coke deposition angle is also reduced. Accordingly, the slope angle at which the coke deposition angle is a maximum corresponds to a predominant fall position that exists therebetween.

[0029] When the rotational speed of the distribution chute 18 is increased, the predominant fall position associated with the inclination angle at which the deposition angle is a maximum is shifted to the furnace wall side. When the rotational speed is increased, the coke falls on a distant location compared with an instance in which the rotational speed is low, because a centrifugal force acts on the coke flowing through the distribution chute 18. As described above, for the cases where the predominant fall positions are the same, in the instance where the rotational speed is high, the fall width is reduced compared with the instance in which the rotational speed is low, and, accordingly, the number of coke particles that collide with the furnace wall before reaching the deposition surface is reduced. Accordingly, in the instance where the rotational speed is high, compared with the instance in which the rotational speed is low, the predominant fall position associated with the inclination angle at which the coke deposition angle is a maximum shifts to the furnace wall side.

[0030] In the instances where the rotational speed was increased, the coke deposition angle was increased even when the predominant fall position was relatively close to the furnace center. A reason for this is believed to be as follows. As a result of the increase in the rotational speed, a speed of the coke particles in the horizontal direction was also increased, and, consequently, even when the predominant fall position was relatively close to the furnace center, the coke particles that collided with the deposition surface was moved toward the furnace wall side, which resulted in an increase in the coke deposition angle. The maximum values of the coke deposition angle of cases with different rotational speeds were compared with one another, where each of the maximum values was the maximum for the cases with the same rotational speed. As a result, it was found that the maximum value of the deposition angle increased with the increase in the rotational speed.

[0031] On the other hand, as shown in Table 3, in the instances where a distribution chute without the diversion plate 22 attached to an end thereof was used, it was found that the maximum value of the deposition angle decreased with the increase in the rotational speed, the maximum value being the maximum for the cases with the same rotational speed. A reason for this is believed to be that as a result of the increase in the rotational speed, the fall width in the radial direction increased, and, therefore, coke was deposited at a low density.

[0032] As described above, it was confirmed that in instances where a distribution chute 18 with the diversion plate 22 attached to an end thereof is used, the coke deposition angle can be increased by increasing the rotational speed of the distribution chute 18. The result confirmed that the coke deposition angle in a region near the furnace wall can be increased by charging coke in a manner in which a distribution chute 18 with the diversion plate 22 attached to an end thereof is used, and the rotational speed of the distribution chute 18 is greater than 42.2 rpm.

[0033] Reasons for the increase in the coke deposition angle in a region near the furnace wall are believed to be as follows. As a result of the increase in the rotational speed of the distribution chute 18, the coke fall width in the radial direction was reduced, and, therefore, the coke was deposited at a high density on a particular region in the radial direction. In addition, because a coke falling speed in the rotational direction was increased, a direction in which the deposited coke might collapse was shifted from a furnace center direction to a rotational direction, compared with the instances in which the rotational speed was low, and consequently, collapsing of the deposited coke was less likely to occur.

[0034] Next, to investigate an influence of a chute length of the distribution chute 18, a similar charging experiment was conducted with various chute lengths of the distribution chute 18. The results are shown in Table 4 below. A condition of the inclination angle was such that the coke deposition angle was a maximum when the predominant fall position at a level 424 mm below the center of rotation and inclination in the vertical direction was located in a region 285 to 325 mm from the furnace center.

[Table 4]

Experiment No.	40	41	42	43	44	45
Rotational speed (rpm)	42.2	50.6	59.1	42.2	50.6	59.1
Chute length (mm)	220	220	220	260	260	260

(continued)

Experiment No.	40	41	42	43	44	45
Diversion plate (with/without)	with	with	with	with	with	with
Inclination angle (°)	56.5	55.0	53.5	53.0	51.5	50.0
Fall width (-)	112	105	101	87	82	77
Deposition angle before charging of coke (°)	16.3	16.5	16.7	16.4	16.2	16.6
Deposition angle after charging of coke (°)	25.8	28.7	28.0	26.7	29.3	29.5

[0035] As shown in Table 4, in the instances where the chute length of the distribution chute was reduced from 240 mm to 220 mm, the coke fall width was increased, and the coke deposition angle was reduced, compared with the instances in which the distribution chute having a chute length of 240 mm was used as shown in Table 1. However, even in the instances where the distribution chute having a chute length of 220 mm was used, when the rotational speed of the distribution chute was 50.6 rpm or greater, the coke fall width was reduced, and the coke deposition angle in a region near the furnace wall was increased, compared with the instance in which the rotational speed was 42.2 rpm.

[0036] In the instances where the chute length of the distribution chute was increased from 240 mm to 260 mm, the coke fall width was reduced, and the coke deposition angle was reduced, compared with the instances in which the distribution chute having a chute length of 240 mm was used. In the instances where the distribution chute having a chute length of 260 mm was used, when the rotational speed of the distribution chute was 50.6 rpm or greater, the coke fall width was also reduced, and the coke deposition angle in a region near the furnace wall was also increased, compared with the instance in which the rotational speed was 42.2 rpm. These results confirmed that although the coke fall width and the coke deposition angle are slightly affected by a change in the chute length of the distribution chute, there is a consistent tendency that when the rotational speed is greater than 42.2 rpm, the coke fall width is reduced, and the coke deposition angle is increased.

[0037] The methods of the present invention for charging raw materials into a bell-less blast furnace are methods designed in accordance with the results of the coke charging experiments described above. The rotational speeds of 42.2 rpm, 50.6 rpm, and 59.1 rpm of the distribution chute 18 of the model apparatus 10 and the model apparatus 30 correspond to rotational speeds of 10.0 rpm, 12.0 rpm, and 14.0 rpm, respectively, of a distribution chute of an actual blast furnace. Accordingly, in the method of the present embodiment for charging raw materials into a bell-less blast furnace, ore and a carbonaceous material are to be charged into the furnace interior of a blast furnace in a manner in which a distribution chute including a diversion plate at an end thereof is used, the diversion plate being inclined downward relative to the conveying direction of the distribution chute, and the rotational speed of the distribution chute is greater than 10.0 rpm. Consequently, the deposition angle of the carbonaceous material charged in a near-furnace-wall portion of the blast furnace is increased, and the fall width of the carbonaceous material is reduced, without compromising productivity. As a result, an area of the region where [Ore/Coke] is lowered is reduced in the near-furnace-wall portion of the blast furnace; hence, a gas utilization ratio of the blast furnace is improved, and, therefore, low-reducing-agent-ratio/low-coke-ratio operation is realized in the blast furnace.

[0038] It is preferable that the rotational speed of the distribution chute be greater than or equal to 12.0 rpm. In such a case, the coke deposition angle in a near-furnace-wall portion is increased compared with instances in which the rotational speed is less than 12.0 rpm, and, therefore, as described in the Examples section later, the reducing agent ratio and the coke ratio in a blast furnace operation can be further lowered.

[0039] It is more preferable that the rotational speed of the distribution chute be greater than or equal to 14.0 rpm. In such a case, the coke deposition angle in the near-furnace-wall portion is increased compared with instances in which the rotational speed is less than 14.0 rpm, and, therefore, the reducing agent ratio and the coke ratio in a blast furnace operation can be further lowered.

[0040] In addition, in a case where a distance from the center position of inclination and rotation of the distribution chute to a raw material deposition level of the furnace interior, which is a level at the start of raw material charging, is reduced, a distance from the end of the chute to the deposition surface is reduced, and, therefore, the coke fall width is further reduced. However, enabling the predominant fall position to reach the furnace wall requires increasing the inclination angle. In a case where the inclination angle is increased, the fall width of the predominant fall position on the furnace wall side is increased if the raw material deposition surface descends. Thus, it can be assumed that if the raw material deposition level of the furnace interior at the start of raw material charging changes in a blast furnace operation, an influence is more likely to be experienced. For this reason, it is preferable that the distance from the center position of inclination and rotation of the distribution chute to the raw material deposition level of the furnace interior at the start of raw material charging be greater than or equal to 0.60 times a throat radius. As referred to herein, the "raw material deposition level of the furnace interior at the start of raw material charging" is a level of the raw material deposition surface of the furnace interior at the time at which the charging of raw materials from the distribution chute is started.

[0041] Fig. 5 is a schematic diagram illustrating a state of a furnace interior, which is a state at the time at which the charging of raw materials was started. With reference to Fig. 5, the "level of the raw material deposition surface of the furnace interior at the start of raw material charging" will be described.

[0042] In blast furnaces, the raw material deposition surface is not horizontal. In blast furnace operations, in order to determine the time at which raw material charging is to be started, a detection means, such as a sounding meter, for detecting the level of the raw material deposition surface of a region near the furnace wall is used, for example. With the detection means, a decrease of the level of the deposition surface to a specific level is to be detected, and, at the time at which the detection is made, charging of a predetermined amount of raw materials is started. In this manner, management is performed such that the level of the deposition surface of the furnace interior is maintained within a predetermined range. Accordingly, in the present embodiment, the level of the raw material deposition surface of the furnace interior at the start of raw material charging is defined as a horizontal plane 40 at the level of the raw material deposition surface in a region near the furnace wall detected by a detection means. Furthermore, in Examples, which will be described below, the inclination angle of the distribution chute 18 is expressed by using a distance d, a throat radius Ro, and an angle α. The distance d is a distance from a center position 42 of inclination and rotation of the distribution chute to the horizontal plane 40, which is the level of the raw material deposition surface of the furnace interior at the start of raw material charging. The angle α is defined by expression (1) below. Furthermore, in the Examples, the inclination angle of the distribution chute is an angle between the raw material conveying direction of the distribution chute 18 and a vertically downward direction.

$$\tan\alpha = Ro/d \quad ...(1)$$

EXAMPLES

[0043] Now, the Examples will be described. A blast furnace with an internal volume of 5005 m^3 and a throat diameter of 11.2 m was used. Ore was discharged from an ore bin and stored in a furnace top hopper. Coke was discharged from a coke bin and stored in a different furnace top hopper. Subsequently, the ore and the coke were alternately discharged into a distribution chute including a diversion plate, and the ore and coke were deposited in the furnace interior of the blast furnace; thus, a blast furnace operation was performed.

[0044] In Comparative Example 1, ore and coke were deposited in the furnace interior of the blast furnace in a manner in which the chute length of the distribution chute including a diversion plate was 4.2 m, and a level 7.55 m below the center of rotation and inclination of the distribution chute in the vertical direction was designated as the raw material deposition level of the furnace interior at the start of raw material charging. In this instance, the angle α was 36.6°, the angle α being defined by the distance d from the center position of inclination and rotation of the distribution chute to the level of the raw material deposition surface of the furnace interior at the start of raw material charging, the throat radius Ro, and expression (1).

[0045] In the charging of coke, the charging was performed in a manner in which the inclination angle of the chute was set to be 54.5° before the charging was started, the rotational speed was 10.0 to 14.0 rpm, and the inclination angle was progressively reduced until coke was deposited on a furnace center.

[0046] In Invention Examples 1 to 15, ore and coke were deposited in the furnace interior of the blast furnace in a manner in which the chute length of the distribution chute including a diversion plate was 4.2 m, and a level 7.55 m below the center position of inclination and rotation of the distribution chute in the vertical direction was designated as the raw material deposition level of the furnace interior at the start of raw material charging; thus, a blast furnace operation was performed.

[0047] In Invention Examples 1 to 15, too, the angle α was 36.6°, the angle α being defined by the distance d from the center position of inclination and rotation of the distribution chute to the level of the raw material deposition surface of the furnace interior at the start of raw material charging, the throat radius Ro, and expression (1) .

[0048] In the charging of coke, the charging was performed in a manner in which the inclination angle of the distribution chute at the start of charging was progressively reduced with an increase in the rotational speed, and after the charging was started, the inclination angle was progressively reduced until coke was deposited on a furnace center. The rotational speed of the distribution chute was 10.5 to 14.0 rpm. The operation conditions and the results of the operation of the Examples and Comparative Example are shown in Table 5 and Table 6 below. The coke deposition angle in a near-furnace-wall portion was calculated from the slope angle of a region extending 1.8 m from the furnace wall; the slope angle was determined by profile data, which was burden profile data obtained after coke had been charged.

[Table 5]

	Invention example 1	Invention example 2	Invention example 3	Invention example 4	Invention example 5	Invention example 6	Invention example 7	Invention example 8
Throat radius (m)	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
Chute length (m)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Rotational speed of distribution chute (rpm)	10.5	11.0	11.5	12.0	12.0	12.0	12.5	12.5
Inclination angle of chute at start of coke charging (°)	54.0	53.5	53.0	49.5	51.0	52.5	49.0	50.5
Inclination angle/α (-)	1.48	1.46	1.45	1.35	1.39	1.44	1.34	1.38
Coke deposition angle in near-furnace-wall portion (°)	26.5	26.6	26.8	27.5	28.0	28.5	27.8	28.3
Reducing agent ratio (kg/t)	514	513	513	512	511	510	512	511
Coke ratio (kg/t)	332	332	331	331	331	329	330	330
Pulverized coal ratio (kg/t)	181	181	182	181	180	181	182	181
Tapping ratio (t/m^3/day)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2

[Table 6]

	Invention example 9	Invention example 10	Invention example 11	Invention example 12	Invention example 13	Invention example 14	Invention example 15	Comparative example 1
Throat radius (m)	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
Chute length (m)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Rotational speed of distribution chute (rpm)	12.5	13.0	13.0	13.0	14.0	14.0	14.0	10.0
Inclination angle of chute at start of coke charging (°)	52.0	47.5	50.0	51.5	48.5	50.0	52.5	54.5
Inclination angle/α (-)	1.42	1.30	1.37	1.41	1.33	1.37	1.44	1.49
Coke deposition angle in near-furnace-wall portion (°)	28.6	27.7	28.3	28.9	28.5	28.7	29.0	26.1
Reducing agent ratio (kg/t)	510	511	510	509	509	508	507	515
Coke ratio (kg/t)	329	331	329	328	329	328	326	335
Pulverized coal ratio (kg/t)	181	180	181	181	180	180	181	180
Tapping ratio (t/m^3/day)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2

In Comparative Example 1, regarding the raw material deposition level of the furnace interior at the start of raw material charging, the coke fall width was large, and the coke deposition angle in a near-furnace-wall portion was 26.1°, which was small; whereas, in Invention Examples 1 to 15, the coke deposition angle in a near-furnace-wall portion was greater than or equal to 26.5°. As a result, the area of the region where [Ore/Coke] was lowered was reduced in the near-furnace-wall portion, and, hence, a gas utilization ratio of the entire furnace interior was improved. Accordingly, in Invention Examples 1 to 15, the reducing agent ratio and the coke ratio were lower than in Comparative Example 1.

[0049] Regarding Invention Examples 4 to 15, in which the rotational speed of the distribution chute was greater than or equal to 12.0 rpm, when the inclination angle of the distribution chute was greater than or equal to 1.36α, the coke deposition angle in a near-furnace-wall portion was large, and the reducing agent ratio and the coke ratio were low, compared with the instances in which the inclination angle of the distribution chute was less than 1.36α, provided that the rotational speeds were the same. These results confirmed that when an angle of rotation of the distribution chute is greater than or equal to 1.36α, the reducing agent ratio and the coke ratio in a blast furnace operation can be further reduced.

[0050] Furthermore, regarding Invention Examples 13 to 15, in which the rotational speed of the distribution chute was greater than or equal to 14.0 rpm, when the inclination angle of the distribution chute was greater than or equal to 1.41α, the coke deposition angle in a near-furnace-wall portion was large, and the reducing agent ratio and the coke ratio were low, compared with the instances in which the inclination angle of the distribution chute was less than 1.41α. These results confirmed that when the angle of rotation of the distribution chute is greater than or equal to 1.41α, the reducing agent ratio and the coke ratio in a blast furnace operation can be further reduced.

Reference Signs List

[0051]

10 Model apparatus
12 Furnace top bunker
14 Hopper
16 Collecting hopper
18 Distribution chute
20 Chute
21 Arrow
22 Diversion plate
24 Sample box
26 Storage section
30 Model apparatus
32 Model furnace
40 Horizontal plane
42 Center position

Claims

1. A method for charging raw materials into a bell-less blast furnace, the method comprising charging an iron source material and a carbonaceous material into a furnace interior of the blast furnace by rotating a distribution chute, wherein

the distribution chute includes a diversion plate at an end of the distribution chute, the diversion plate being inclined downward relative to a conveying direction of the distribution chute, and
a rotational speed of the distribution chute is greater than 10.0 rpm.

2. The method for charging raw materials into a bell-less blast furnace according to Claim 1, wherein the rotational speed of the distribution chute is greater than or equal to 12.0 rpm.

3. The method for charging raw materials into a bell-less blast furnace according to Claim 2, wherein an inclination angle of the distribution chute is greater than or equal to 1.36α, where α is an angle defined by a distance d, a throat radius Ro, and expression (1), shown below, and the distance d is a distance from a center of rotation of the distribution chute to a raw material deposition level of the furnace interior, the raw material deposition level being a level at a start of raw material charging.

$$\tan\alpha = Ro/d \quad \ldots(1)$$

4. The method for charging raw materials into a bell-less blast furnace according to Claim 1, wherein the rotational speed of the distribution chute is greater than or equal to 14.0 rpm.

5. The method for charging raw materials into a bell-less blast furnace according to Claim 4, wherein an inclination angle of the distribution chute is greater than or equal to 1.41α, where α is an angle defined by a distance d, a throat radius Ro, and expression (1), shown below, and the distance d is a distance from a center of rotation of the distribution chute to a raw material deposition level of the furnace interior, the raw material deposition level being a level at a start of raw material charging.

$$\tan\alpha = Ro/d \quad \ldots(1)$$

6. A blast furnace operation method comprising charging an iron source material and a carbonaceous material into a furnace interior of the blast furnace by using the method for charging raw materials into a bell-less blast furnace according to any one of Claims 1 to 5.

FIG. 1

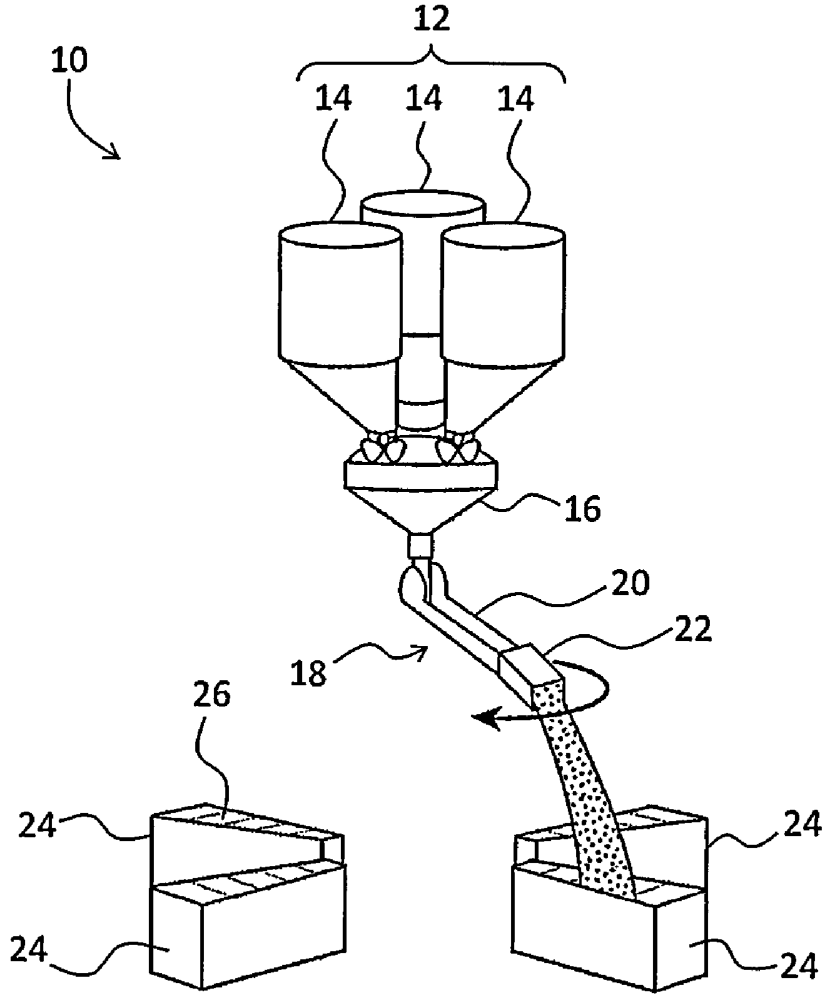


FIG. 2

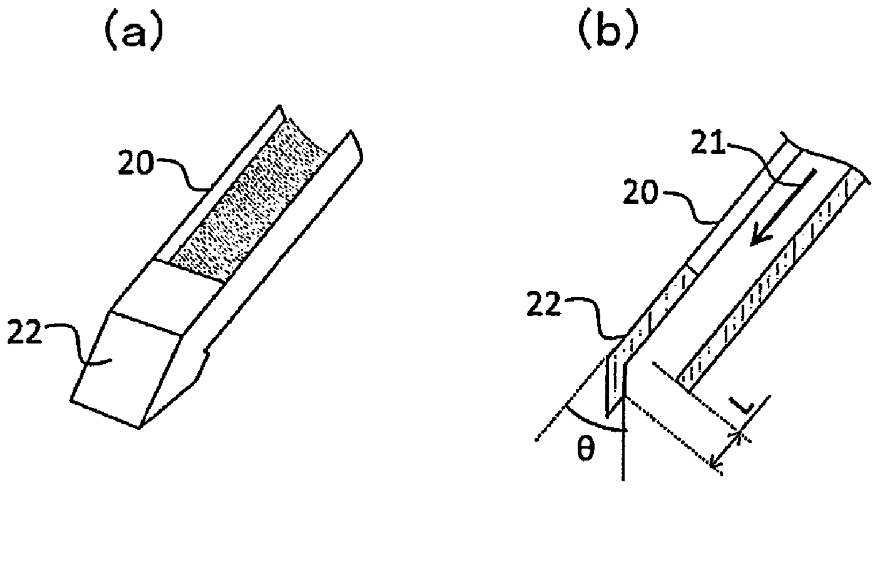


FIG. 3

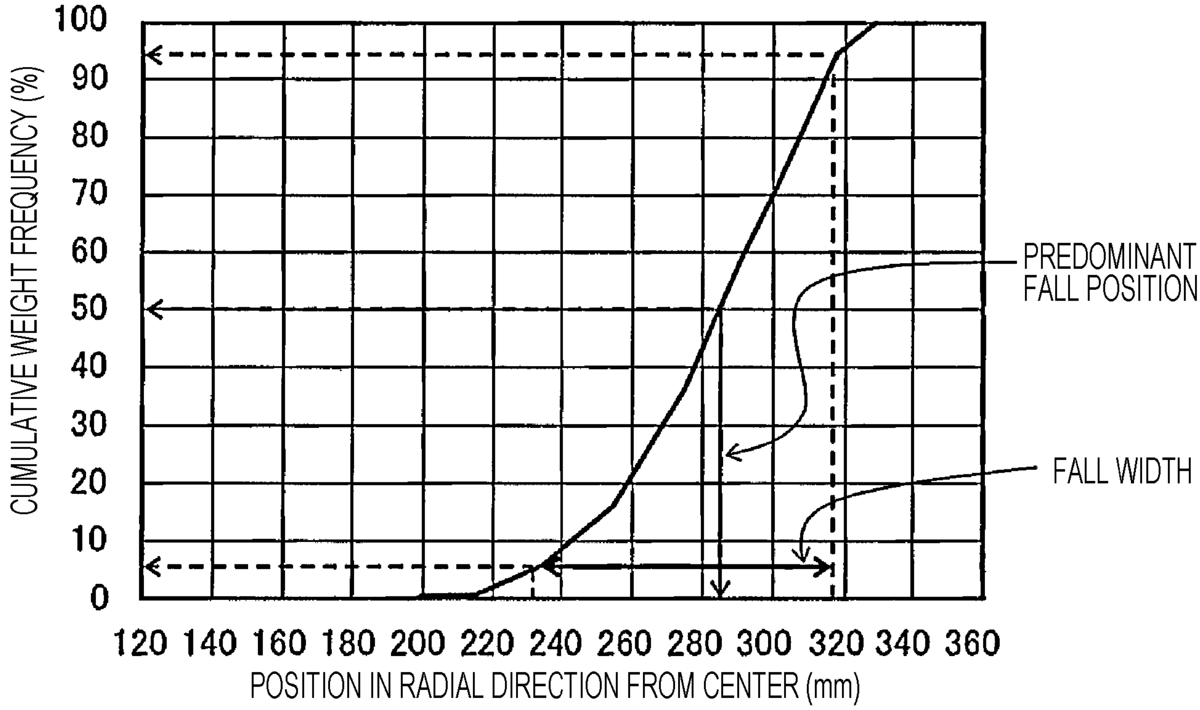

100
90
80
70
60
50
40
30
20
10
0
CUMULATIVE WEIGHT FREQUENCY (%)
120 140 160 180 200 220 240 260 280 300 320 340 360
POSITION IN RADIAL DIRECTION FROM CENTER (mm)
PREDOMINANT FALL POSITION
FALL WIDTH

FIG. 4

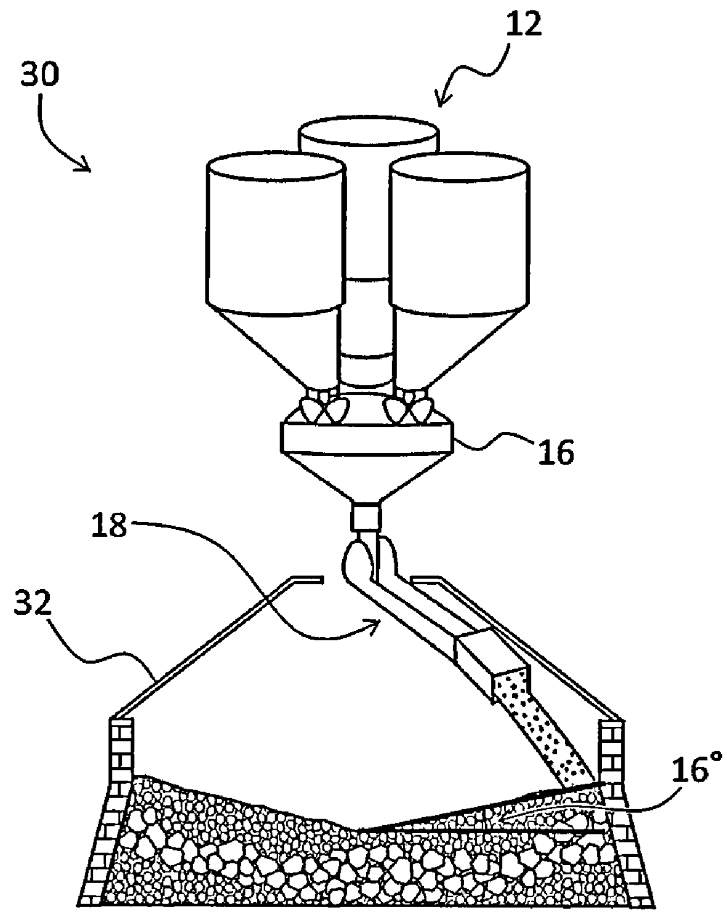
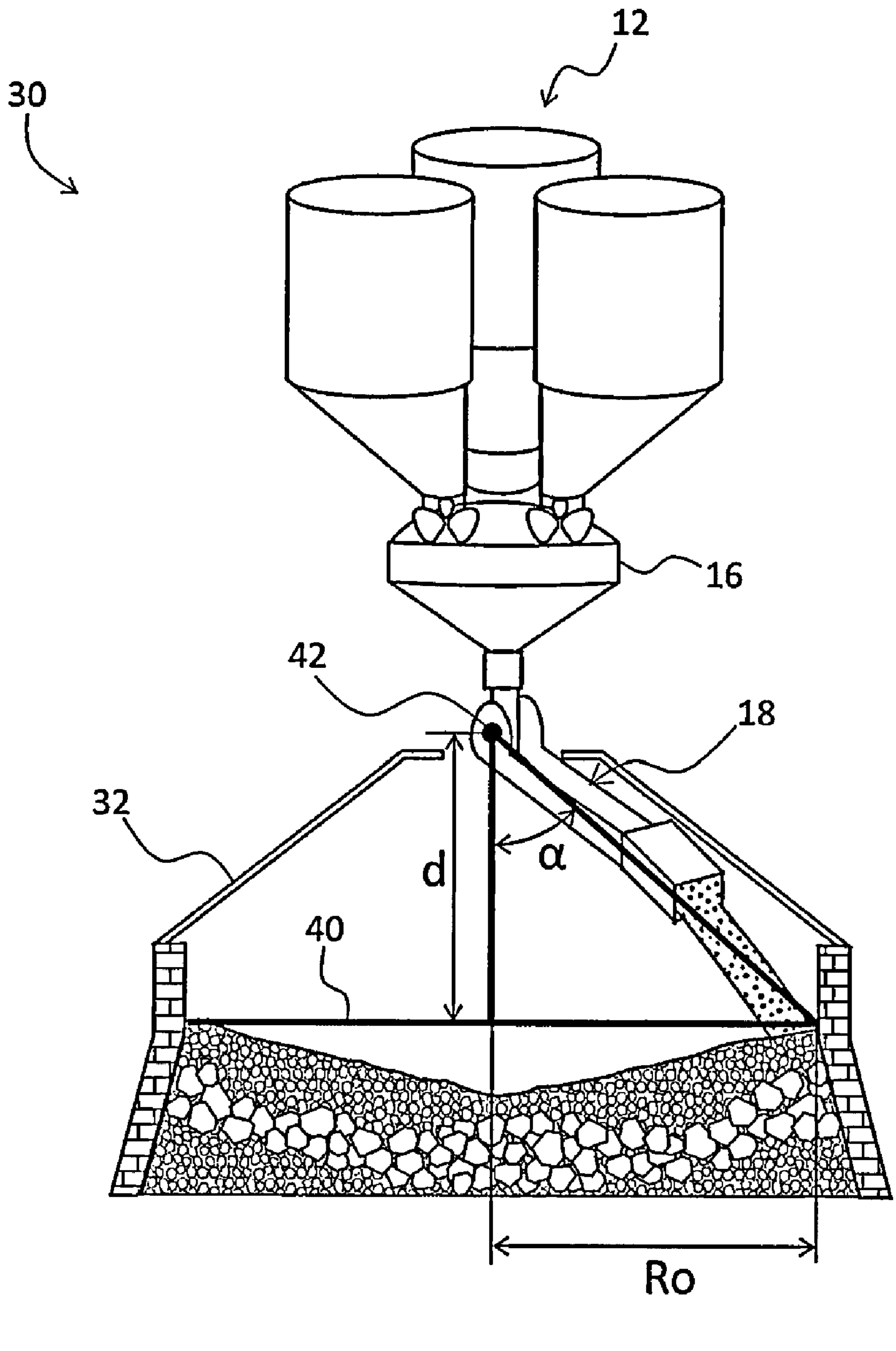

30
12
16
18
32
16°

FIG. 5



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2020/003337

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. C21B5/00(2006.01)i, C21B7/20(2006.01)i, F27B1/20(2006.01)i, F27D3/10(2006.01)i
FI: C21B5/00311, C21B7/20303, C21B7/20302, F27B1/20, F27D3/10
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)
Int.Cl. C21B3/00-5/06, C21B11/00-15/04, C21B7/00-9/16, F27B1/00-3/28, F27D3/00-5/00

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2011-140705 A (NIPPON STEEL CORPORATION) 21.07.2011 (2011-07-21), claims, paragraph [0068], fig. 1, 4	1, 2, 4, 6 3, 5
Y A	JP 2011-63836 A (JFE STEEL CORPORATION) 31.03.2011 (2011-03-31), claims, paragraphs [0016]-[0030], fig. 1-6	1, 2, 4, 6 3, 5
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 156587/1978 (Laid-open No. 075645/1980) (SUMITOMO METAL INDUSTRIES, LTD.) 24.05.1980 (1980-05-24), claims, page 3, line 11 to page 5, line 1, fig. 3, 4	1, 2, 4, 6 3, 5
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 016036/1973 (Laid-open No. 11730/1974) (ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD.) 07.10.1974 (1974-10-07), claims, page 2, line 4 to page 4, line 14, page 5, line 14 to page 6, line 16	1, 2, 4, 6 3, 5

☒ 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	Date of mailing of the international search report
12.03.2020	24.03.2020

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/003337

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 58-123808 A (SUMITOMO METAL INDUSTRIES, LTD.) 23.07.1983 (1983-07-23), claims, page 3, lower left column, line 20 to lower right column, line 15, fig. 1, 2	1, 2, 4, 6 3, 5
Y A	JP 2015-117388 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 25.06.2015 (2015-06-25), claims, paragraph [0057], fig. 1, 19	1, 2, 4, 6 3, 5

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/003337

JP 2011-140705 A	21.07.2011	(Family: none)
JP 2011-63836 A	31.03.2011	(Family: none)
JP 55-075645 U1	24.05.1980	(Family: none)
JP 49-11730 U1	07.10.1974	(Family: none)
JP 58-123808 A	23.07.1983	(Family: none)
JP 2015-117388 A	25.06.2015	(Family: none)

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- JP 2018193579 A **[0010]**
- JP 2003328018 A **[0010]**