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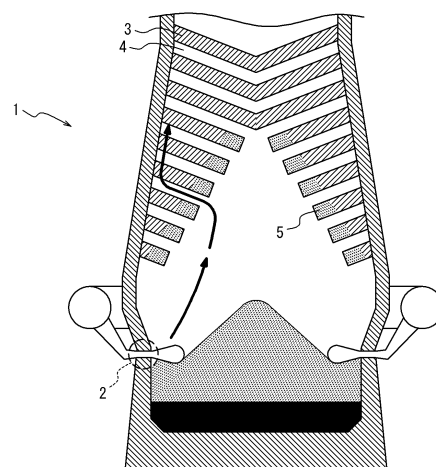
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(54) **METHOD FOR CHARGING RAW MATERIAL INTO BLAST FURNACE**

(57) To provide a method of charging raw material into a blast furnace capable of achieving a raw material particle size distribution in a furnace top bunker suitable for both forward tilt charging and reverse tilt charging, thereby increasing the gas flow rate near the center part of the blast furnace regardless of the tilting mode to further improve gas permeability and reduction efficiency. A structure that has a predetermined shape is placed in a raw material storage part of a furnace top bunker, and a raw material impact position on the structure in a storing process is determined according to a tilting mode in a charging process.

FIG. 1



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Description

TECHNICAL FIELD

[0001] This disclosure relates to a method of charging raw material into a blast furnace.

BACKGROUND

[0002] A blast furnace, as illustrated in FIG. 1, usually operates to obtain pig iron by charging sintered ores, pellets, lumps of ore, and other ore material, and coke alternately in layers from the top to form ore layers and coke layers and by flowing a hot-reducing gas upward from ends of tuyeres. Hereafter, ore material and coke are referred to collectively as raw material. In the figure, reference numeral 1 is a blast furnace, reference numeral 2 is a tuyere, reference numeral 3 is an ore layer, reference numeral 4 is a coke layer, and reference numeral 5 is a fusion layer.

[0003] In such a blast furnace operation, the flow of gas in the blast furnace affects the reduction efficiency of ore material and the amount of heat dissipated out of the blast furnace. In general, it is desirable to flow more gas near the center part of the blast furnace in order to improve the reduction efficiency of ore material and reduce the amount of heat dissipated out of the blast furnace.

[0004] The two main reasons for this are given below.

(1) As the gas flow rate near the furnace wall of the blast furnace increases, the amount of heat dissipated out of the blast furnace increases and energy efficiency decreases.

(2) In the bottom part of the blast furnace, the ore material charged into the blast furnace is heated and reduced by the reducing gas to form a fusion zone. The fusion zone is a region in which fusion layers, which have a bedrock-like structure in which particles of ore material are fused to each other, and coke slits, in which coke is present by itself, are present in alternating layers. Because the fusion layers have a bedrock-like structure in which the particles of the ore material are fused to each other as described above, the void ratio within the layers is extremely low. On the other hand, the void ratio of the coke slits is higher than that of the fusion layers. Therefore, in the fusion zone, gas flowing in a vertical direction from the bottom selectively flows through the coke slits. As the amount of gas flowing near the center part of the blast furnace increases, the height of the region of the fusion zone extends. As a result, the number of coke slits in the fusion zone increases and gas permeability improves.

[0005] To increase the gas flow rate near the center of the blast furnace, it is advantageous to place large particle size raw material near the center part and small particle size raw material near the furnace wall in the radial direction of the blast furnace.

ticle size raw material near the furnace wall in the radial direction of the blast furnace.

[0006] This is because, when comparing a packed layer of particles of large particle size with a packed layer of particles of small particle size, the packed particles of the former have a smaller total specific surface area, i.e., the friction between the particles and the gas flowing through the packed layer is reduced and the gas flow rate increases.

[0007] Therefore, various technologies have been proposed to increase the gas flow rate near the center part of the blast furnace by controlling the particle size distribution and even the thickness of the ore layers and coke layers formed in the blast furnace.

[0008] For example, JP 4591520 B (PTL 1) proposes: "A method of charging raw material into a blast furnace which uses a bell-less charging device equipped with a rotating chute and in which bunkers are arranged in parallel at the top of the furnace, comprising:

when charging raw material into the furnace through a furnace top bunker which temporarily stores the raw material to be charged into the blast furnace and discharges the raw material into the rotating chute installed below the furnace top bunker, providing a freely tilting movable plate into the furnace top bunker, and making the raw material, which is charged into the furnace top bunker, impinge on the movable plate;

in the case that the tip of the rotating chute is tilted from the periphery of the blast furnace to the center, operating the movable plate so that the drop direction of the raw material is in the direction of the discharge outlet of the furnace top bunker and making the drop position of the raw material charged into the furnace top bunker be directly above the discharge outlet of the raw material so that, due to deposition properties, fine particles of the raw material in the furnace top bunker collect near the discharge outlet and coarse particles collect at a position away from the discharge outlet;

in the case that the tip of the rotating chute is tilted from the center of the blast furnace toward the periphery, operating the movable plate so that the drop direction of the raw material is in the direction opposite the discharge outlet of the furnace top bunker and making the drop position of the raw material charged into the furnace top bunker be at a sidewall away from the discharge outlet so that coarse particles of raw material collect near the discharge outlet and fine particles of raw material collect far from the discharge outlet; and depositing coarse particles into the center part of the blast furnace."

CITATION LIST

Patent Literature

[0009] PTL 1: JP 4591520 B

SUMMARY

(Technical Problem)

[0010] In a bell-less blast furnace as illustrated in FIG. 2, furnace top bunkers, which temporarily store raw material to be charged into the blast furnace, are located at a top part of the blast furnace. A flow regulating gate is then opened to charge the raw material, which is discharged from the furnace top bunker, into the blast furnace through a collecting hopper and rotating chute. At this time, the radial tip position of the rotating chute may be changed (hereinafter referred to as tilting) to adjust the drop position of the raw material in the radial direction of the blast furnace.

[0011] In the figure, reference numeral 6 are furnace top bunkers, reference numeral 7 are flow regulating gates, reference numeral 8 is a collecting hopper, and reference numeral 9 is a rotating chute.

[0012] In detail, the rotating chute, when charging raw material into the blast furnace, rotates at a constant speed in the circumferential direction of the blast furnace with the axial center of the blast furnace as its axis of rotation, while tilting at regular intervals. The tilting mode is divided into two main types: forward tilt charging, in which the rotating chute is tilted from near the blast furnace wall to the center part of the blast furnace, and reverse tilt charging in which the rotating chute is tilted from the center part of the blast furnace to near the wall of the blast furnace.

[0013] Of these two types, reverse tilt charging has the effect of preventing raw material from flowing into the center part of the blast furnace after the raw material is charged and deposited into the blast furnace. Therefore, reverse tilt charging, in comparison with forward tilt charging, more easily stabilizes the raw material deposition shape and is more advantageous for controlling the raw material particle size distribution in the blast furnace.

[0014] As mentioned above, from the viewpoint of increasing gas flow rate near the center part of the blast furnace, it is advantageous to place large particle size raw material near the center part of the blast furnace in the radial direction and small particle size raw material near the furnace wall of the blast furnace. As used herein, coke, ore (including lumped ore), and auxiliary raw materials such as limestone, which are charged from the top part of the blast furnace, are collectively referred to as raw material. For all of the raw material, it is most preferable to place the larger particles in the center part of the blast furnace, but it is also advantageous to place the larger particles in the center part for any one or more

of coke, ore, and mixtures of coke and ore. The furnace top bunkers typically store the raw material for each batch. Therefore, when performing reverse tilt charging, the raw material particle size distribution in the furnace top bunker is preferably such that much of the large particle size raw material is discharged at the initial stage of raw material discharge from the furnace top bunker.

[0015] In this regard, the technology of PTL 1 intentionally segregates the raw material stored in a furnace top bunker by using a freely tilting movable plate (hereinafter referred to as a segregation control plate) installed in the furnace top bunker. This is an attempt to achieve a favorable raw material particle size distribution in the furnace top bunker of the furnace, depending on the tilting mode.

[0016] However, the technology in PTL1 does not sufficiently achieve a raw material particle size distribution in the furnace top bunker suitable for reverse tilt charging. In detail, certain amounts of large particle size raw material were mixed in the raw material discharged from the furnace top bunker at the mid to end stages of raw material discharge, resulting in a certain amount of large particle size raw material being mixed near the furnace wall of the blast furnace.

[0017] In view of the above-mentioned current situation, it would be helpful to provide a method of charging raw material into a blast furnace capable of achieving a raw material particle size distribution in a furnace top bunker suitable for both forward tilt charging and reverse tilt charging, thereby increasing the gas flow rate near the center part of the blast furnace regardless of the tilting mode to further improve gas permeability and reduction efficiency.

(Solution to Problem)

[0018] We conducted many intensive investigations to address the issues mentioned above.

[0019] First, we investigated the reasons why a sufficient raw material particle size distribution in the furnace top bunker suitable for reverse tilt charging may not be achieved in the technology of PTL 1.

[0020] In general, from the viewpoint of downsizing the collecting hopper that receives raw material discharged from the furnace top bunker and the viewpoint of strengthening particle segregation in the bunker, the raw material discharge outlet of the furnace top bunker is located eccentrically in the horizontal plane (projected surface to the vertical direction) from the center of the raw material storage part to the axial center of the blast furnace, as illustrated in FIG. 3. FIG. 3 is a schematic diagram illustrating the arrangement of each part of the furnace top bunker when viewed from above in the vertical direction. In the figure, reference numeral 6-1 is a raw material storage part and reference numeral 6-2 is a raw material discharge outlet.

[0021] The direction of eccentricity is defined as a direction from the center of the raw material storage part

to the center of the raw material discharge outlet in a horizontal plane. When viewed from above in the vertical direction, a direction rotated 90° clockwise from the direction of eccentricity is called a first direction, a direction rotated 180° is called a direction opposite eccentricity, and a direction rotated 270° is called a second direction. The raw material discharge outlet of the furnace top bunker is located eccentrically from the center of the raw material storage part to the axial center of the blast furnace in the horizontal plane (projected surface to the vertical direction). Therefore, with the furnace top bunker placed at the top part of the blast furnace, the direction of eccentricity is usually the same direction as the direction from the center of the raw material storage part to the axial center of the blast furnace (hereinafter also referred to as the blast furnace axial center direction).

[0022] When performing reverse tilt charging with the technology of PTL 1, the segregation control plate is operated so that the drop direction of raw material is near the side opposite the raw material discharge outlet of the furnace top bunker in a horizontal plane, that is, near the wall in the direction opposite eccentricity (hereinafter referred to as the wall opposite eccentricity) as illustrated in FIG. 4. Therefore, the shape of the stacked layers of raw material in the furnace top bunker is such that a raw material deposition surface inclines vertically downward toward the direction of eccentricity (from the wall opposite eccentricity to the wall in the direction of eccentricity (hereinafter referred to as the wall of eccentricity)). In the figure, 6-3 is a segregation control plate.

[0023] In this case, the particle size distribution of raw material in the furnace top bunker and the raw material discharge sequence when discharging raw material from the furnace top bunker (the discharge time for each raw material storage position in the furnace top bunker) were calculated with a numerical simulation called the discrete element method, and as illustrated in FIG. 5, more than half of the large particle size raw material collects near the raw material discharge outlet, i.e., in the area where the raw material is discharged at the initial stage of raw material discharge. However, it was found that most of the remaining large particle size raw material was positioned near the walls in the first direction and the second direction (hereinafter referred to as the first wall and the second wall), which are perpendicular to the direction of eccentricity of the furnace top bunker, i.e., in the area where the raw material is discharged at the mid to end stages of raw material discharge. In other words, it was found that this causes a certain amount of large particle size raw material to be mixed also near the furnace wall of the blast furnace when performing reverse tilt charging.

[0024] In light of this issue, we further examined the matter, and found that it is advantageous to:

- distribute the drop position of raw material, which is charged into the furnace top bunker, not only near the wall opposite eccentricity but also near the first wall and the second wall, and

- thereby incline the shape of the stacked layers of raw material in the furnace top bunker vertically downward toward the raw material discharge outlet, not only from the wall opposite eccentricity, but also from the first wall and the second wall, in other words, make the shape of the stacked layers of raw material substantially bowl-shaped as illustrated in FIG. 6.

[0025] We have found that this enables the large particle size raw material to more densely collect near the raw material discharge outlet.

[0026] We believe that the reason for the above is as follows.

[0027] Large particle size raw material, compared to small particle size raw material, tends to roll more easily on the deposition surface. Therefore, by distributing the drop position of the raw material, which is charged into the furnace top bunker, not only near the wall opposite eccentricity but also near the first wall and the second wall, stacked layers of raw material that incline vertically downward from the first wall and the second wall toward the raw material discharge outlet are formed. The large particle size raw material, which is gradually charged, rolls on this deposition surface, whereas the small particle size raw material is deposited at a drop position, thereby enabling the large particle size raw material to more densely collect near the raw material discharge outlet.

[0028] Based on the above findings, we examined methods to distribute the drop position of the raw material, which is charged into the furnace top bunker, not only near the wall opposite eccentricity but also near the first wall and the second wall, and found that it is advantageous to:

- place a structure with a raw material impingement surface inside the raw material storage part of the furnace top bunker, and
- incline the shape of the raw material impingement surface downward from the top part of the structure to edge parts of the raw material impingement surface in each of the direction opposite eccentricity, and in the first direction and the second direction which are perpendicular to the direction opposite eccentricity and the vertical direction.

[0029] We also investigated the issue further, and as illustrated in FIG. 8, found that:

- by inclining the shape of the raw material impingement surface downward from the top part of the structure to the edge parts of the raw material impingement surface in the direction opposite eccentricity, and in addition the first direction and the second direction, which are perpendicular to the direction opposite eccentricity and the vertical direction, and further to the direction of eccentricity, and
- by determining the raw material impingement position on the structure (positioned inside the raw ma-

terial storage part of the furnace top bunker) according to the tilting mode employed when charging raw material into the blast furnace, it is possible to achieve a raw material particle size distribution in the furnace top bunker suitable for each case of forward tilt charging and reverse tilt charging. In the figure, reference numeral 6-4 is a structure and reference numeral 6-5 is a raw material impingement surface.

[0030] The present disclosure is based on these discoveries and further investigations.

[0031] Specifically, the primary features of the present disclosure are as follows.

[1] A method of charging raw material into a blast furnace,

the blast furnace having furnace top bunkers at a top part of the furnace,
at least one of the furnace top bunkers comprising:

a raw material storage part;
a raw material charging inlet configured to charge raw material into the raw material storage part from above the raw material storage part;
a structure disposed inside the raw material storage part and having a raw material impingement surface on which the raw material charged from the raw material charging inlet impinges; and
a raw material discharge outlet configured to discharge, below the raw material storage part, the raw material in the raw material storage part,

wherein the raw material discharge outlet is positioned eccentrically from a center of the raw material storage part in a horizontal plane, and the raw material impingement surface of the structure inclines downward from a top part of the structure to edge parts of the raw material impingement surface in at least each of a direction of eccentricity, a direction opposite eccentricity, and a first direction and a second direction which are perpendicular to the direction of eccentricity and a vertical direction, and the method of charging raw material into a blast furnace further comprising:

a storing process comprising charging the raw material from the raw material charging inlet of the at least one furnace top bunker into the raw material storage part, and, after causing the raw material to impinge on the structure, storing the raw material in the raw

material storage part; and
a charging process comprising discharging, from the raw material discharge outlet, the raw material stored in the raw material storage part and charging the discharged raw material into the blast furnace through a rotating chute of the blast furnace,

wherein a raw material impingement position on the structure in the storing process is determined according to a tilting mode in the charging process,
where the direction of eccentricity is a direction in which the raw material discharge outlet is eccentric from the center of the raw material storage part in the horizontal plane, and the direction opposite eccentricity is a direction opposite to the direction of eccentricity in the same horizontal plane.

[2] The method of charging raw material into a blast furnace according to aspect [1], wherein inclination angles α and α' of a line segment connecting the top part of the structure and the edge parts of the raw material impingement surface in the direction of eccentricity and direction opposite eccentricity are each 25° to 45° from a horizontal direction.

[3] The method of charging raw material into a blast furnace according to aspect [1] or [2], wherein inclination angles β and γ of a line segment connecting the top part of the structure and the edge parts of the raw material impingement surface in the first direction and the second direction are each 25° to 45° from a horizontal direction.

[4] The method of charging raw material into a blast furnace according to any of aspects [1] to [3], wherein the top part of the structure is positioned in the horizontal plane at a dimensionless distance (r/R) of 0 to 0.6 from the center of the raw material storage part, where the dimensionless distance (r/R) is a value obtainable by dividing a distance (r) from the center of the raw material storage part in the horizontal plane by an inner radius (R) of the raw material storage part.

(Advantageous Effect)

[0032] According to the present disclosure, it is possible to achieve a raw material particle size distribution in the furnace top bunker suitable for each case of forward tilt charging and reverse tilt charging.

[0033] As a result, the gas flow rate near the center part of the blast furnace can be increased during blast furnace operation regardless of the tilting mode to further improve gas permeability and reduction efficiency.

[0034] In addition, our method is superior in terms of ease of operation and maintenance because it does not require strict control or complex structures for that pur-

pose.

BRIEF DESCRIPTION OF THE DRAWINGS

[0035] In the accompanying drawings:

FIG. 1 is a schematic diagram illustrating gas flow in a blast furnace;

FIG. 2 is a schematic diagram illustrating the charging of raw material into a blast furnace;

FIG. 3 is a schematic diagram illustrating the arrangement of each part of a furnace top bunker when viewed from above in the vertical direction;

FIGS. 4A and 4B are schematic diagrams illustrating raw material accumulation in a furnace top bunker when material is charged into the furnace top bunker equipped with segregation control plates (assuming reverse tilt charging); FIG. 4A is a schematic view when viewed from the direction of eccentricity, and FIG. 4B is a perspective view;

FIG. 5 illustrates numerical simulation results of the raw material particle size distribution in a furnace top bunker when charging raw material into a furnace top bunker equipped with segregation control plates (assuming reverse tilt charging) and the raw material discharge sequence when discharging raw material from the furnace top bunker (the discharge time for each raw material storage position in the furnace top bunker);

FIGS. 6A and 6B are schematic diagrams illustrating raw material accumulation in a furnace top bunker which is suitable when performing reverse tilt charging; FIG. 6A is a schematic view when viewed from the direction of eccentricity, and FIG. 6B is a perspective view;

FIGS. 7A and 7B are schematic diagrams illustrating raw material accumulation in a furnace top bunker which is suitable for forward tilt charging; FIG. 7A is a schematic view when viewed from the direction of eccentricity, and FIG. 7B is a perspective view;

FIG. 8 is a schematic diagram illustrating an example of the procedure for storing raw material in a furnace top bunker in accordance with the method of charging raw material into a blast furnace according to one of the disclosed embodiments;

FIG. 9 is a schematic diagram illustrating an example of the shape (circumferential shape) from the top part of the structure to the edge parts of the raw material impingement surface;

FIG. 10 is a schematic diagram illustrating examples of the structure installed inside a furnace top bunker; FIG. 11 is a schematic diagram illustrating a suitable area where the top part of a structure may be positioned;

FIG. 12 illustrates, for Conditions 1 and 2, numerical simulation results of the raw material particle size distribution in a furnace top bunker when charging raw material into the furnace top bunker, assuming

reverse tilt charging is performed, and the raw material discharge sequence when discharging raw material from the furnace top bunker (the discharge time for each raw material storage position in the furnace top bunker);

FIG. 13 is a schematic diagram illustrating the apparatus used in model experiments;

FIG. 14 is a schematic diagram illustrating raw material particle size distributions obtained by model experiments (forward tilt charging);

FIG. 15 is a schematic diagram illustrating raw material particle size distributions obtained by model experiments (reverse tilt charging); and

FIG. 16 is a schematic diagram illustrating a procedure for adjusting a raw material impingement position on a structure.

DETAILED DESCRIPTION

[0036] Our method will be described below by way of embodiments.

[0037] The method of charging raw material into a blast furnace according to one of the disclosed embodiments is carried out in a blast furnace equipped with one or more furnace top bunkers arranged at the top part of the furnace, and comprises:

a storing process comprising charging the raw material from a raw material charging inlet of a furnace top bunker, and, after causing the raw material to impinge on a structure of a predetermined shape, storing the raw material in a raw material storage part of the furnace top bunker; and

a charging process comprising discharging the raw material stored in the raw material storage part of the furnace top bunker and charging the discharged raw material into the blast furnace through a rotating chute of the blast furnace.

[0038] As illustrated in FIG. 2, the furnace top bunkers are located at the top part of the blast furnace and temporarily stores raw material to be charged into the blast furnace. The number of furnace top bunkers located at the top part of the blast furnace is not particularly limited and can be appropriately set according to the number of raw material types and the capacity required for the furnace top bunkers, but the number is usually 2 to 4.

[0039] The following is a description of the furnace top bunker used in the method of charging raw material into a blast furnace according to one of the disclosed embodiments, as well as the storing process and charging process of the method of charging raw material into a blast furnace according to one of the disclosed embodiments.

[Furnace Top Bunker]

[0040] As illustrated in FIG. 8, in the method of charging raw material into a blast furnace according to one of the

disclosed embodiments, for at least one of the furnace top bunkers, a furnace top bunker comprising:

- a raw material storage part,
- a raw material charging inlet (not illustrated) configured to charge raw material into the raw material storage part from above the raw material storage part,
- a structure disposed inside the raw material storage part and having a raw material impingement surface on which the raw material charged from the raw material charging inlet impinges, and
- a raw material discharge outlet configured to discharge, below the raw material storage part, the raw material in the raw material storage part is used.

[0041] Preferably, the above furnace top bunker is used for all of the furnace top bunkers located at the top part of the blast furnace.

[0042] As used herein, the terms above, below, top part and bottom part shall mean above, below, top part and bottom part in the vertical direction, unless otherwise noted.

[0043] The raw material charging inlet is located at the top part of the raw material storage part. The position of the raw material charging inlet in the horizontal plane is not particularly limited but is generally positioned from the center position of the raw material storage part to the axial center of the blast furnace (in the same direction as the raw material discharge outlet).

[0044] The raw material charged from the raw material charging inlet is caused to impinge on the raw material impingement surface of the structure located inside the raw material storage part, then drops into the raw material storage part and is temporarily stored in the raw material storage part. The raw material temporarily stored in the raw material storage part is usually one batch. The raw material storage part has a body part, which can be cylindrical, conical cylindrical, or a combination of these shapes, and a reduced diameter part that decreases in diameter toward the bottom.

[0045] The maximum diameter (outer diameter) of the furnace top bunkers is usually 4000 mm to 5000 mm, and the height of the furnace top bunkers is 9000 mm to 13000 mm.

[0046] Then, in accordance with the operation of the blast furnace, a flow regulating gate is opened and the raw material is gradually discharged from the raw material discharge outlet at the bottom edge of the reduced diameter part of the raw material storage part by the weight of the raw material, and the raw material is charged into the blast furnace through the collecting hopper and rotating chute.

[0047] As illustrated in FIG. 3, the raw material discharge outlet is eccentric from the center of the raw material storage part in the horizontal plane, and usually the distance, denoted as A, between the centers of the raw material storage part and the raw material discharge out-

let in the horizontal direction (amount of eccentricity) is 0.60 to 0.70 times the inner radius, R, of the raw material storage part. The inner radius, B, of the raw material discharge outlet is usually 0.10 to 0.30 times the inner radius R of the raw material storage part. The center position and inner diameter of the raw material storage part are based on the installation height of the top part of the structure, which is described below. The center position and inner diameter of the raw material discharge outlet are based on the height where it connects with the bottom edge of the raw material storage part. The same also applies hereafter.

[0048] In FIG. 3, the horizontal cross-section of the raw material storage part is described by way of example as a circular shape. However, in the case of other shapes, the center of the raw material storage part is the center of gravity of the horizontal cross-section that has the largest area. In this case, the direction of eccentricity is the direction from the center of the raw material storage part to the center of the raw material discharge outlet, which connects the center of the raw material discharge outlet and the center of the raw material storage part in the relevant horizontal cross-section (the horizontal cross-section that has the largest area), where R is 1/2 the length of the raw material storage part in the direction of eccentricity in the relevant horizontal cross-section.

[0049] In the method of charging raw material into a blast furnace according to one of the disclosed embodiments, the shape of the raw material impingement surface of the above structure is extremely important.

[0050] Specifically, as illustrated in FIG. 8, it is important that the shape of the raw material impingement surface incline downward from the top part of the structure (raw material impingement surface) to the edge parts of the raw material impingement surface, at least in each of the direction of eccentricity, the direction opposite eccentricity, and the first direction and the second direction which are perpendicular to the direction of eccentricity and the vertical direction.

[0051] That is, when performing reverse tilt charging as described above, the drop position of the raw material charged into the furnace top bunker is distributed not only near the wall opposite eccentricity, but also near the first wall and the second wall as illustrated in FIG. 6. This makes it important that the shape of the stacked layers of raw material in the furnace top bunker incline vertically downward toward the raw material discharge outlet, not only from the wall opposite eccentricity but also from the first wall and the second wall, in other words, that the shape of the stacked layers of raw material be substantially bowl-shaped. This enables the large particle size raw material to more densely collect near the raw material discharge outlet. Therefore, it is important that the shape of the raw material impingement surface of the above structure (circumferential shape of the vertical cross-section) incline downward from the top part of the structure to the edge parts of the raw material impingement surface not only in the direction opposite eccentricity but also in

each of the first direction and the second direction.

[0052] When performing forward tilt charging, as illustrated in FIG. 7, the drop position of raw material charged into the furnace top bunker is distributed not only near the wall of eccentricity (i.e., near the raw material discharge outlet) but also near the first wall and the second wall. Therefore, it is important that the shape of the stacked layers of raw material in the furnace top bunker are made to incline vertically downward toward the wall opposite eccentricity, not only from the wall of eccentricity but also from the first wall and the second wall. This enables the large particle size raw material to collect at a position away from the raw material raw discharge outlet. That is, large particle size raw material is discharged at the end stage of discharge from the furnace top bunker. Therefore, it is important that the shape of the raw material impingement surface of the above structure (circumferential shape of the vertical cross section) incline downward from the top part of the structure to the edge part of the raw material impingement surface, even in the direction of eccentricity.

[0053] The shape of the raw material impingement surface inclining downward from the top part of the structure to the edge parts of the raw material impingement surface in the direction of eccentricity and direction opposite eccentricity means that when the vertical cross-section of the structure at a position which passes through the top part of the structure is viewed from the first direction, the shape inclines downward from the top part of the structure to the edge parts of the raw material impingement surface as illustrated in FIG. 8. Similarly, the shape of the raw material impingement surface inclining downward from the top part of the structure to the edge parts of the raw material impingement surface in the first direction and the second direction means that when the vertical cross-section of the structure at a position which passes through the top part of the structure is viewed from the direction of eccentricity, the shape inclines downward from the top part of the structure to the edge parts of the raw material impingement surface in the first direction and the second direction as illustrated in FIG. 8. It also means that the shape inclines downward from the highest point on the raw material impingement surface to the edge parts in the cross-section of the structure along the first direction and the second direction.

[0054] The raw material impingement surface is the top surface of the structure (the area of the structure when viewed from above). Therefore, the top part of the structure is the highest point on the raw material impingement surface in the vertical direction. In the case there are multiple highest points on the raw material impingement surface, the point that is at the furthest distance from the raw material discharge outlet in the direction of eccentricity among the highest points is considered to be the top part. Components and other members used to secure the structure are excluded from the raw material impingement surface. The raw material impingement surface may comprise one continuous surface or multiple surfac-

es.

[0055] Inclination angles α and α' of line segments connecting the top part of the structure and the edge parts of the raw material impingement surface in the direction of eccentricity and the direction opposite eccentricity are each preferably 25° or more from a horizontal direction, α and α' are each preferably 45° or less. α and α' are each more preferably 40° or more. α and α' are each more preferably 43° or less.

[0056] Furthermore, inclination angles β and γ of line segments connecting the top part of the structure and the edge parts of the raw material impingement surface in the first direction and the second direction are each preferably 25° or more from the horizontal direction. β and γ are each preferably 45° or less. β and γ are each more preferably 40° or more. β and γ are each more preferably 43° or less.

[0057] Similarly, the shape from the top part of the structure to the edge parts of the raw material impingement surface in a direction from the first direction, through the direction opposite eccentricity to the second direction (a direction between 90° and 270° clockwise from the direction of eccentricity) also preferably inclines downward from the top part of the structure to the edge parts of the raw material impingement surface. Suitable inclination angles from the horizontal direction of the straight lines connecting the top part of the structure and the edge parts of the raw material impingement surface in these directions are also similar to the inclination angles α , α' , β and γ above.

[0058] The shape (circumferential shape) of the structure from the top part of the structure to the edge parts of the raw material impingement surface in each vertical section of the structure does not have to be a constant slope regardless of the direction but can be a shape whose slope varies in various ways, such as an arc shape or a shape whose slope varies in steps, as illustrated in FIG. 9.

[0059] In addition, the shape from the top part of the structure to the edge parts of the raw material impingement surface in a direction from the first direction, through the direction of eccentricity to the second direction (a direction between 0° and 90° and between 270° and 360° clockwise from the direction of eccentricity but excluding the first direction and the second direction) is not particularly limited.

[0060] For example, similarly to the direction opposite eccentricity and the first direction and the second direction, the shape may incline downward from the top part of the structure to the edge parts of the raw material impingement surface. In this case, as illustrated in FIG. 10, the shape of the structure may be, for example, a cone, an oblique cone, an elliptical cone, a cone joined on top of a conical base (Shape 1), a half-split cone and a half-split elliptical cone joined at their cut surfaces (Shape 2), a dome whose raw material impingement surface is a sphere, a polyhedron such as a square pyramid, hexagonal pyramid, octagonal pyramid, and shapes such as

these cut in a vertical direction at arbitrary positions. The interior of the structure may be hollow, and no members may be placed on surfaces other than the raw material impingement surface, such as the bottom and sides. The shapes described above also include those whose shape has been changed by providing a member to the bottom or other surface, as long as the area of the raw material impingement surface does not change.

[0061] In addition, the length, a , of the above structure (the distance between the edge parts of the raw material impingement surface in the horizontal direction when the structure is viewed from the first direction) is preferably 0.4 to 0.8 times the inner radius R of the raw material storage part (see FIG. 8, the same applies to the width and height of the structure described below). The width, b , of the above structure (the distance between the edge parts of the raw material impingement surface in the horizontal direction when the structure is viewed from the direction of eccentricity) is preferably 0.4 to 0.8 times the inner radius R of the raw material storage part. The height, h , of the above structure (the distance from the bottom edge of the raw material impingement surface to the top part) is preferably 0.47 to 1.0 times the length a of the structure.

[0062] The shape of the structure may be symmetrical or asymmetrical in the first direction and the second direction.

[0063] Furthermore, regarding the installation position of the above structure in the horizontal direction, the top part of the structure is preferably positioned at a dimensionless distance (r/R) of 0 to 0.6 from the center of the raw material storage part, as illustrated in FIG. 11.

[0064] The dimensionless distance (r/R) is a value obtainable by dividing the distance (r) from the center of the raw material storage part in the horizontal plane (projected surface to the vertical direction) by the inner radius (R) of the raw material storage part.

[0065] In addition, although there is no particular limitation on the installation position of the above structure in the vertical direction, the dimensionless height (h'/H) at the top part of the structure is preferably in the range of 0.75 to 0.85.

[0066] The dimensionless height (h'/H) is a value obtainable by dividing the distance (height), h' , from the bottom edge of the furnace top bunker (the height position of the raw material discharge outlet) to the top part of the structure in the vertical direction by the height, H , of the furnace top bunker.

[0067] The above structure is preferably arranged so that the shape is symmetrical with respect to a vertical line passing through the center of the raw material storage part when viewed from the direction of eccentricity. However, the shape does not have to be symmetrical as long as it inclines downward from the top part of the structure to the edge parts in the first direction and the second direction.

[0068] In addition, the materials of the above structures are not particularly limited, and in general steel or other

materials can be used. The installation method of the structure is not particularly limited. For example, a beam member can be fixed to the inner wall of the furnace top bunker by metal fittings or welding, and the above structure can be fixed to this beam member by metal fittings or welding. Furthermore, the above structure may have a position adjustment mechanism for changing its position and an installation angle adjustment mechanism for changing its installation angle.

[Storing process]

[0069] The storing process of the method of charging raw material into a blast furnace according to one of the disclosed embodiments comprises: charging raw material from the charging inlet of the furnace top bunker to the raw material storage part; and, after causing the raw material to impinge on the structure, storing the raw material in the raw material storage part.

[0070] In this process, it is important to determine (set) the raw material impingement position on the structure according to the tilting mode to be employed in the charging process described below.

[0071] As mentioned above, the preferred raw material particle size distribution in the furnace top bunker varies depending on the tilting mode. For example, in the case of reverse tilt charging, as illustrated in FIG. 6, it is important to incline the shape of the stacked layers of raw material in the furnace top bunker vertically downward from not only the wall opposite eccentricity, but also from the first wall and the second wall to the raw material discharge outlet, in other words, to make the shape of the stacked layers of raw material substantially bowl-shaped (to collect large particle size raw material near the raw material discharge outlet). Therefore, in the case of reverse tilt charging, the raw material impingement position on the structure should be further in the direction opposite eccentricity than the top part of the structure.

[0072] On the other hand, in the case of forward tilt charging, as illustrated in FIG. 7, it is important that the shape of the stacked layers of raw material in the furnace top bunker incline vertically downward not only from the wall of eccentricity but also from the first wall and the second wall toward the wall opposite eccentricity. Therefore, in the case of forward tilt charging, the raw material impingement position on the structure should be further in the direction of eccentricity than the top part of the structure.

[0073] Here, whether the raw material impingement position on the structure is in the direction opposite eccentricity or in the direction of eccentricity is determined based on a representative position in the direction opposite eccentricity of the raw material impingement range on the structure.

[0074] In detail, the impingement position (range) of each particle of raw material on the structure (raw material impingement surface) when viewed from above in the vertical direction is plotted with the top part of the

structure as the origin, the horizontal axis (x-axis) as the distance from the top part of the structure in the direction opposite eccentricity, and the vertical axis (y-axis) as the distance from the top part of the structure in the first direction (the distances in the direction opposite eccentricity and the first direction are positive values, and the distances in the direction of eccentricity and the second direction are negative values). The position of the center of gravity in the direction opposite eccentricity, i.e., the average value in the direction opposite eccentricity (x-coordinate) in the plot of the impingement position of each particle, is the representative position in the direction opposite eccentricity of the raw material impingement range on the structure (hereinafter referred to simply as the representative position in the direction opposite eccentricity). Similarly, the position of the center of gravity in the first direction, i.e., the average value in the first direction (y-coordinate) in the plot of the impingement position of each particle, is the representative position in the first direction of the raw material impingement range on the structure (hereinafter referred to simply as the representative position in the first direction).

[0075] For example, if the impingement representative position in the direction opposite eccentricity is a positive value (greater than 0), the raw material impingement position on the structure is further in the direction opposite eccentricity than the top part of the structure, and if the impingement representative position in the direction opposite eccentricity is a negative value (less than 0), the raw material impingement position on the structure is further in the direction of eccentricity than the top part of the structure.

[0076] In the case of reverse tilt loading, the representative position of impingement in the direction opposite eccentricity is preferably in the range of $a_1/4$ to $a_1/2$. Here, a_1 is the distance between the top part of the structure and the edge part of the raw material impingement surface in the direction opposite eccentricity (the distance between the top part of the structure and the edge part of the raw material impingement surface in the direction opposite eccentricity when the structure is viewed from the first direction, see FIG. 8).

[0077] In the case of forward tilt charging, the representative position of impingement in the direction opposite eccentricity is preferably in the range of $-a_2/2$ to $-a_2/4$. Here, a_2 is the distance between the top part of the structure and the edge part of the raw material impingement surface in the direction of eccentricity (the distance between the top part of the structure and the edge part of the raw material impingement surface in the direction of eccentricity when the structure is viewed from the first direction, see FIG. 8).

[0078] The impingement range of the raw material in the first direction on the structure is not particularly limited, but the representative position in the first direction of the raw material impingement range on the structure (hereinafter also referred to as the representative position of impingement in the first direction) is preferably in

the range of $-b/10$ to $b/10$. Particularly preferably, the representative position of impingement in the first direction is 0.

[0079] The raw material impingement position on the structure is adjusted so that 80 % or more, preferably 90 % or more, of the raw material particles (number of particles) falling from the raw material charging inlet impinge on the structure (raw material impingement surface) (i.e., the raw material impingement ratio on the structure (= [number of raw material particles impinging on the structure (raw material impingement surface)] / [number of raw material particles charged in the furnace top bunker] $\times$ 100) is 80 % or more, preferably 90 % or more. The raw material impingement ratio on the structure may be 100 %.

[0080] The raw material impingement position and raw material impingement angle on the structure can be adjusted by, for example, providing a movable control plate 17 in a raw material flow passage from the receiving hopper to the raw material charging inlet of the furnace top bunker as illustrated in FIG. 16 and changing its position and angle. FIG. 16 illustrates a case in which the raw material impingement surface of the movable control plate 17 is fixed at a right angle to the horizontal plane and the movable control plate 17 is moved in the direction opposite eccentricity and the direction of eccentricity of the furnace top bunker 6, but the embodiment is not so limited. For example, it is possible to further adjust the angle of the raw material impingement surface of the movable control plate 17, allowing the position and angle of the raw material impingement surface to be changed, so that the impingement position and impingement angle of the raw material on the structure can be adjusted more finely.

[Charging process]

[0081] The above storing process comprises: discharging, from the raw material discharge outlet, the raw material stored in the raw material storage part of the furnace top bunker; and charging the discharged raw material into the blast furnace through the rotating chute of the blast furnace, either by reverse tilt charging or forward tilt charging.

[0082] That is, when performing reverse tilt charging, the raw material is discharged from the furnace top bunker, which has a raw material particle size distribution suitable for reverse tilt charging, and the discharged raw material is charged into the blast furnace.

[0083] However, when performing forward tilt charging, the raw material is discharged from the furnace top bunker, which has a raw material particle size distribution suitable for forward tilt charging, and the discharged raw material is charged into the blast furnace.

[0084] As a result, the gas flow rate near the center part of the blast furnace increases for both forward tilt charging and reverse tilt charging, improving gas permeability and reduction efficiency.

[0085] The conditions are not particularly limited to those above and may be in accordance with conventional methods.

EXAMPLES

[0086] The furnace top bunkers were modeled in accordance with Condition 1 and Condition 2 below, and the raw material particle size distribution in each furnace top bunker when charging raw material into the furnace top bunker and the raw material discharge sequence when discharging raw material from the furnace top bunker (the discharge time for each raw material storage position in the furnace top bunker) were calculated using the discrete element method.

- Condition 1 (example)

[Shape of the structure installed in the furnace top bunker]

Inclination angles: $\alpha = 42^\circ$, $\alpha' = 42^\circ$, $\beta = 42^\circ$, $\gamma = 42^\circ$.

Width: $a = R \times 0.5$, Length: $b = R \times 0.5$, Height: $h = a \times 0.5$

[Installation position of the structure in the furnace top bunker]

Position of the top part of the structure: $r/R = 0.53$ in the direction of eccentricity from the center position of the raw material storage part

Installation height of the top part of the structure: $h'/H = 0.82$

[Raw material impingement position on the structure in the furnace top bunker]

- In the case of forward tilt charging

Side in the direction of eccentricity
(Representative position of impingement in the direction opposite eccentricity: $-a_2/4$, representative position of impingement in the first direction: 0,
(Raw material impingement ratio: 100 %)

- In the case of reverse tilt loading

Side in the direction opposite eccentricity
(Representative position of impingement in the direction opposite eccentricity: $a_1/2$, representative position of impingement in the first direction: 0,
(Raw material impingement ratio: 100 %)

- Condition 2 (comparative example)

[Shape of the structure installed in the furnace top bunker]

Plate (Segregation Control Plate as referred to in PTL 1)

Inclination angles:

- In the case of forward tilt charging $\alpha = 80^\circ$, $\beta = 0^\circ$, and $\gamma = 0^\circ$.
- In the case of reverse tilt loading $\alpha = 155^\circ$ ($\alpha' = 25^\circ$), $\beta = 0^\circ$, and $\gamma = 0^\circ$.

Width: $R \times 0.31$, Length: $R \times 1.0$, Thickness: 160 mm

[Installation position of the structure in the furnace top bunker]

Center position of segregation control plate: $r/R = 0.37$ in the direction of eccentricity from the center position of the raw material storage part

Installation height at the center position of the segregation control plate: $h'/H = 0.42$

[Raw material impingement position on the structure in the furnace top bunker]

Approximate center position of segregation control plate, raw material impingement ratio: 100 %

(Same for forward tilt charging and reverse tilt charging)

[0087] The structures in Conditions 1 and 2 were arranged so that they are symmetrical with respect to a vertical line passing through the center of the raw material storage part when viewed from the direction of eccentricity.

[0088] Furthermore, the shapes of the raw material storage part, raw material charging inlet, and raw material discharge outlet of the furnace top bunker were modeled using the same conditions as Conditions 1 and 2 ($R = 2350$ mm, $H = 12000$ mm, the distance between the centers of the raw material storage part and the raw material discharge outlet (amount of eccentricity): $A = R \times 0.64$, the inner radius of the raw material discharge outlet: $B = R \times 0.35$) to match the actual equipment.

[0089] The raw material charging conditions were also the same for Conditions 1 and 2. Specifically, the raw material here refers to ore, and the amount of raw material charged is equivalent to one batch. Based on the particle size distribution in the actual raw material, the particle size was represented by three types of particles: large particles, medium particles, and small particles, and the particle size ratio of large particles, medium particles, and small particles was set to 3.8:2.0:1.0 to match the actual raw material. It was further assumed that the large,

medium, and small particles each contained the same mass. At this time, the same bunker of coke was used for Conditions 1 and 2, and the charging conditions were the same.

[0090] FIG. 12 illustrates representative results of the evaluation when reverse tilt charging was performed.

[0091] As illustrated in FIG. 12, Condition 1 (example) achieved a raw material particle size distribution in the furnace top bunker suitable for reverse tilt charging. In detail, in the case of reverse tilt charging, large particles collect near the raw material discharge outlet and many large particles can be discharged at the initial stage of discharge from the furnace top bunker. It was also possible to achieve a raw material particle size distribution in the furnace top bunker suitable for forward tilt charging. In detail, in the case of forward tilt charging, large particles collect at a position away from the raw material discharge outlet and many large particles can be discharged at the end stage of discharge from the furnace top bunker.

[0092] On the other hand, Condition 2 (comparative example) could not sufficiently collect large particles near the raw material discharge outlet in the case of reverse tilt charging and could not achieve a raw material particle size distribution in the furnace top bunker suitable for reverse tilt charging.

[0093] Based on the conditions of Condition 1 (example), the results were almost the same as those of Condition 1 (example) even when the shape of the structure was varied in various ways in the ranges of $\alpha = 25^\circ$ to 45° , $\beta = 25^\circ$ to 45° , and $\gamma = 25^\circ$ to 45° . Even when the position of the top part of the structure was changed in various ways in the range of $r/R = 0$ to 0.6 , the results were almost the same as in Condition 1 (example). Furthermore, even when other shapes such as the oblique cone and elliptical cone mentioned above were used as the shape of the structure, the results were almost the same as in Condition 1 (example).

[0094] Model experiments were also conducted to confirm the accuracy of the particle size distribution in the furnace top bunker based on the above numerical simulation.

[0095] In detail, the actual 1/17.8 size furnace top bunker models corresponding to Condition 1 (example) and Condition 2 (comparative example), as illustrated in FIG. 13, were each fabricated. In the figure, reference numeral 10 is a charging belt conveyor, reference numeral 11 are furnace top bunker models, reference numeral 12 is a collecting hopper model, reference numeral 13 are sampling boxes, reference numeral 14 is a roller conveyor, reference numeral 15 is a belt conveyor for the sampling boxes, and reference numeral 16 is a segregation control plate model or structure model.

[0096] The raw material (in this case ore) was then charged from the charging belt conveyor into the furnace top bunker model of the furnace. The charging position of the raw material (the impingement position of raw material impinging on the segregation control plate model and the structure model) was adjusted by changing the

position of the charging belt conveyor. After charging, the valve of the discharge outlet connected to the bottom edge of the furnace top bunker model was opened and the raw material was discharged from the discharge outlet. The discharged raw material was then collected in multiple sampling boxes. At this time, the sampling boxes were gradually moved in a horizontal direction by a belt conveyor for the sampling boxes, and the discharged material was sorted chronologically at regular intervals from the start of discharge to the end of discharge. The dimensionless particle size of the raw material for each dimensionless discharge time was then calculated by sieving the raw material collected in each sampling box, calculating the average particle size of the raw material collected in each sampling box, and dividing the result by the average particle size of all the raw material before being charged the raw material into the furnace top bunker model. The results are illustrated in FIGS. 14 and 15.

[0097] FIGS. 14 and 15 illustrate that the model experiment also produced data that corroborate the above numerical simulation results.

[0098] That is, under Condition 1 (example), in the case of forward tilt charging, many large particles could be discharged at the end stage of discharge from the furnace top bunker. In the case of reverse tilt charging, many large particles could be discharged at the initial stage of discharge from the furnace top bunker.

[0099] On the other hand, under Condition 2 (comparative example), when compared with Condition 1 (example), many large particles could not be discharged at the initial stage of discharge from the furnace top bunker with reverse tilt charging.

REFERENCE SIGNS LIST

[0100]

- 1: Blast furnace
- 2: Tuyeres
- 3: Ore layer
- 4: Coke layer
- 5: Fusion layer
- 6: Furnace top bunker
- 6-1: Raw material storage part
- 6-2: Raw material discharge outlet
- 6-3: Segregation control plate
- 6-4: Structure
- 6-5: Raw material impingement surface
- 6-6: Dispersion adjustment plate
- 7: Flow regulating gate
- 8: Collecting hopper
- 9: Rotating chute
- 10: Charging belt conveyor
- 11: Furnace top bunker model
- 12: Collecting hopper model
- 13: Sampling box
- 14: Roller conveyor
- 15: Belt conveyor for sampling box

16: Segregation control plate model or structure model

17: Movable control plate

Claims

1. A method of charging raw material into a blast furnace,

the blast furnace having furnace top bunkers at a top part of the furnace,
at least one of the furnace top bunkers comprising:

a raw material storage part;
a raw material charging inlet configured to charge raw material into the raw material storage part from above the raw material storage part;
a structure disposed inside the raw material storage part and having a raw material impingement surface on which the raw material charged from the raw material charging inlet impinges; and
a raw material discharge outlet configured to discharge, below the raw material storage part, the raw material in the raw material storage part,

wherein the raw material discharge outlet is positioned eccentrically from a center of the raw material storage part in a horizontal plane, and the raw material impingement surface of the structure tilts downward from a top part of the structure to edge parts of the raw material impingement surface in at least each of a direction of eccentricity, a direction opposite eccentricity, and a first direction and a second direction which are perpendicular to the direction of eccentricity and a vertical direction, and
the method of charging raw material into a blast furnace further comprising:

a storing process comprising charging the raw material from the raw material charging inlet of the at least one furnace top bunker into the raw material storage part, and, after causing the raw material to impinge on the structure, storing the raw material in the raw material storage part; and
a charging process comprising discharging, from the raw material discharge outlet, the raw material stored in the raw material storage part and charging the discharged raw material into the blast furnace through a rotating chute of the blast furnace,

wherein a raw material impingement position on the structure in the storing process is determined according to a tilting mode in the charging process,

where the direction of eccentricity is a direction in which the raw material discharge outlet is eccentric from the center of the raw material storage part in the horizontal plane, and the direction opposite eccentricity is a direction opposite to the direction of eccentricity in the same horizontal plane.

2. The method of charging raw material into a blast furnace according to claim 1, wherein inclination angles α and α' of a line segment connecting the top part of the structure and the edge parts of the raw material impingement surface in the direction of eccentricity and direction opposite eccentricity are each 25° to 45° from a horizontal direction.
3. The method of charging raw material into a blast furnace according to claim 1 or 2, wherein inclination angles β and γ of a line segment connecting the top part of the structure and the edge parts of the raw material impingement surface in the first direction and the second direction are each 25° to 45° from a horizontal direction.
4. The method of charging raw material into a blast furnace according to any of claims 1 to 3, wherein the top part of the structure is positioned in the horizontal plane at a dimensionless distance (r/R) of 0 to 0.6 from the center of the raw material storage part, where the dimensionless distance (r/R) is a value obtainable by dividing a distance (r) from the center of the raw material storage part in the horizontal plane by an inner radius (R) of the raw material storage part.

FIG. 1

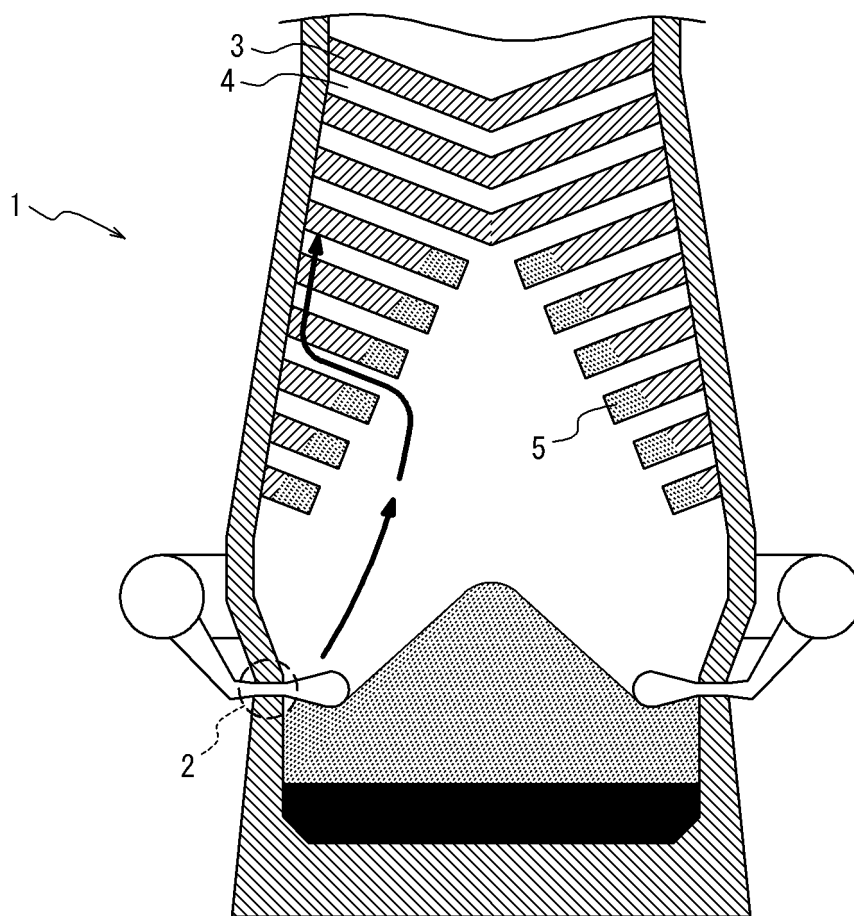


FIG. 2

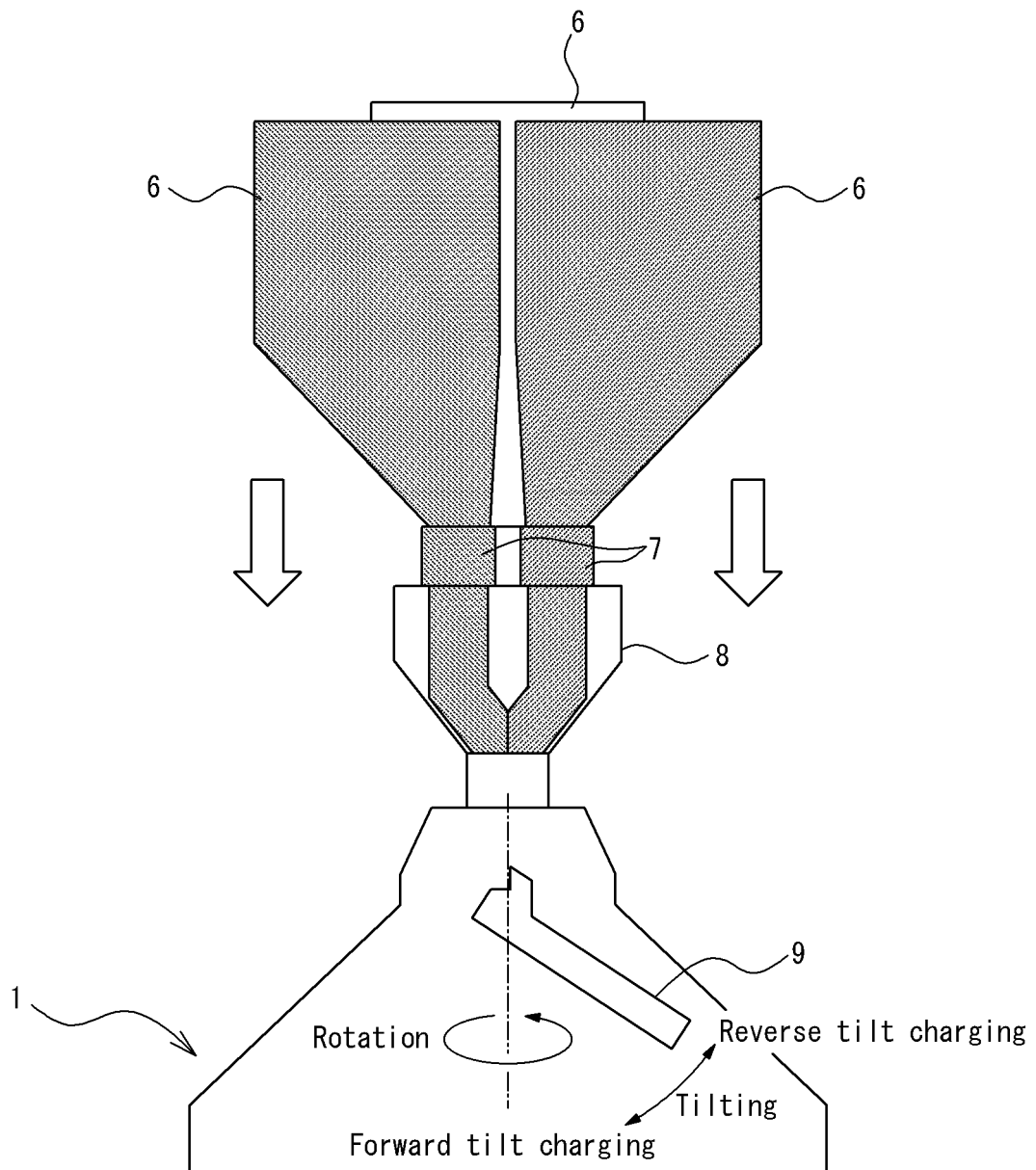


FIG. 3

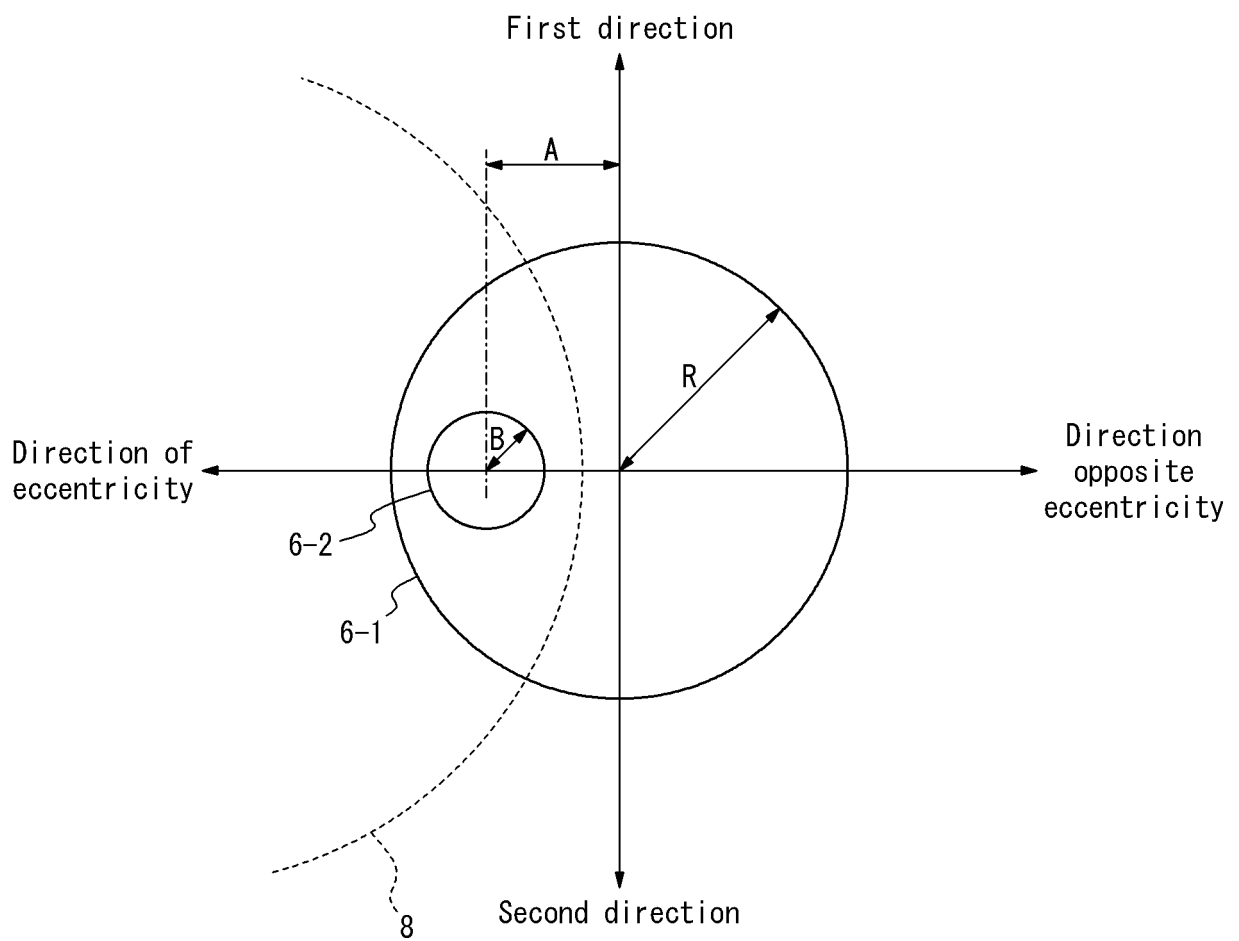


FIG. 4A

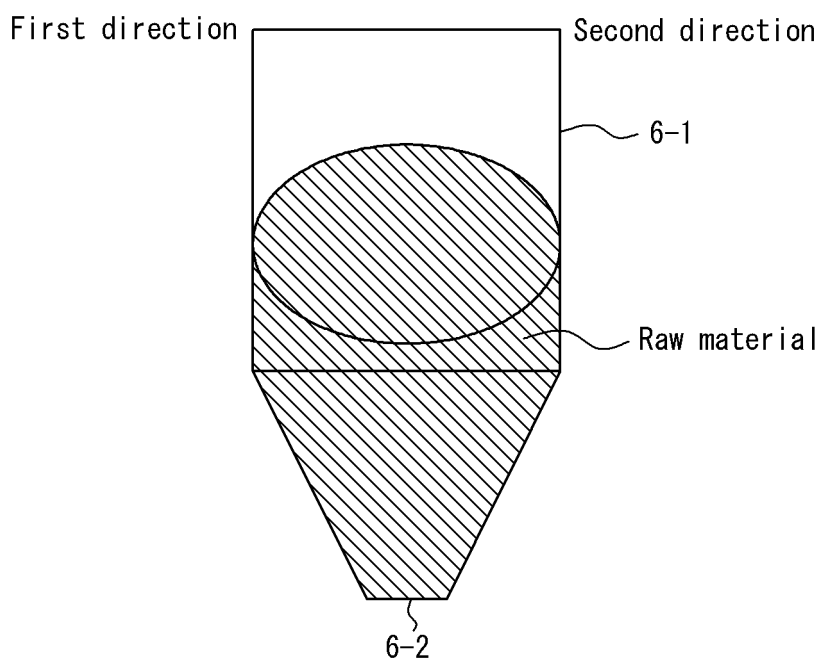


FIG. 4B

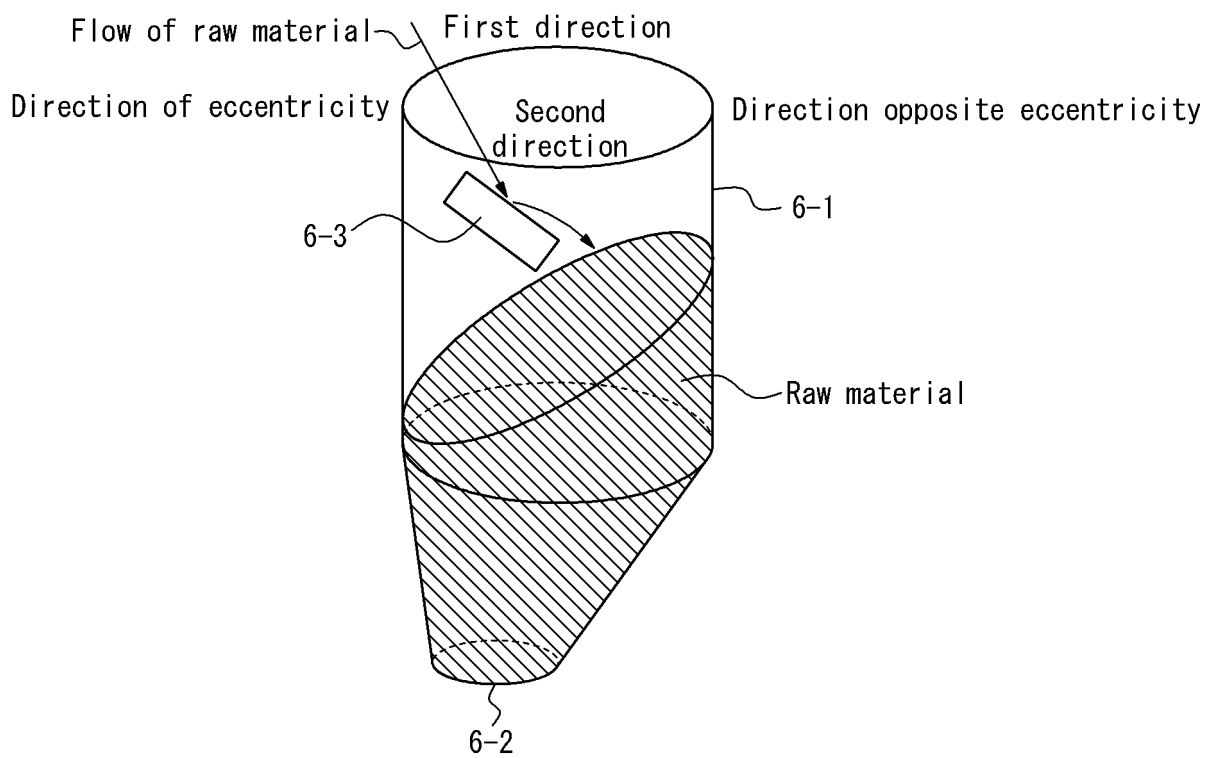


FIG. 6A

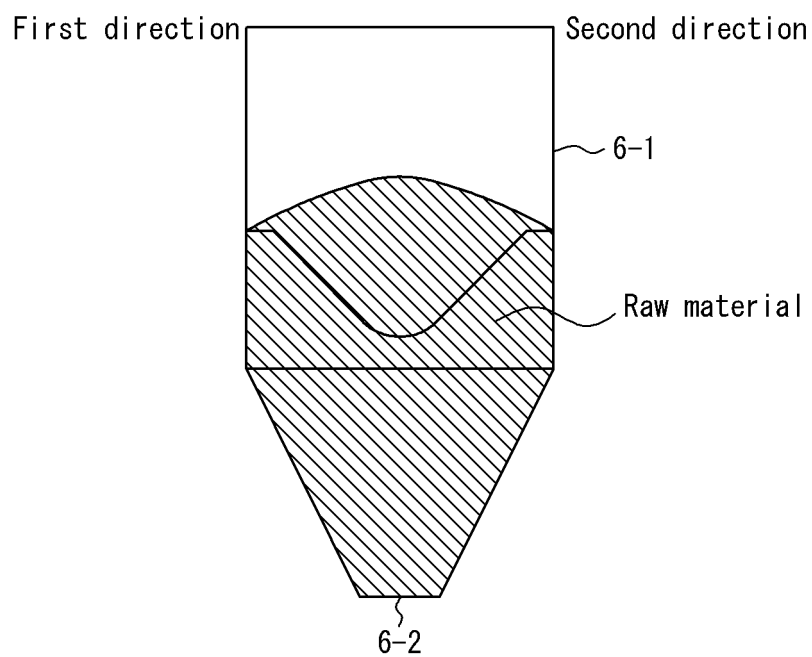


FIG. 6B

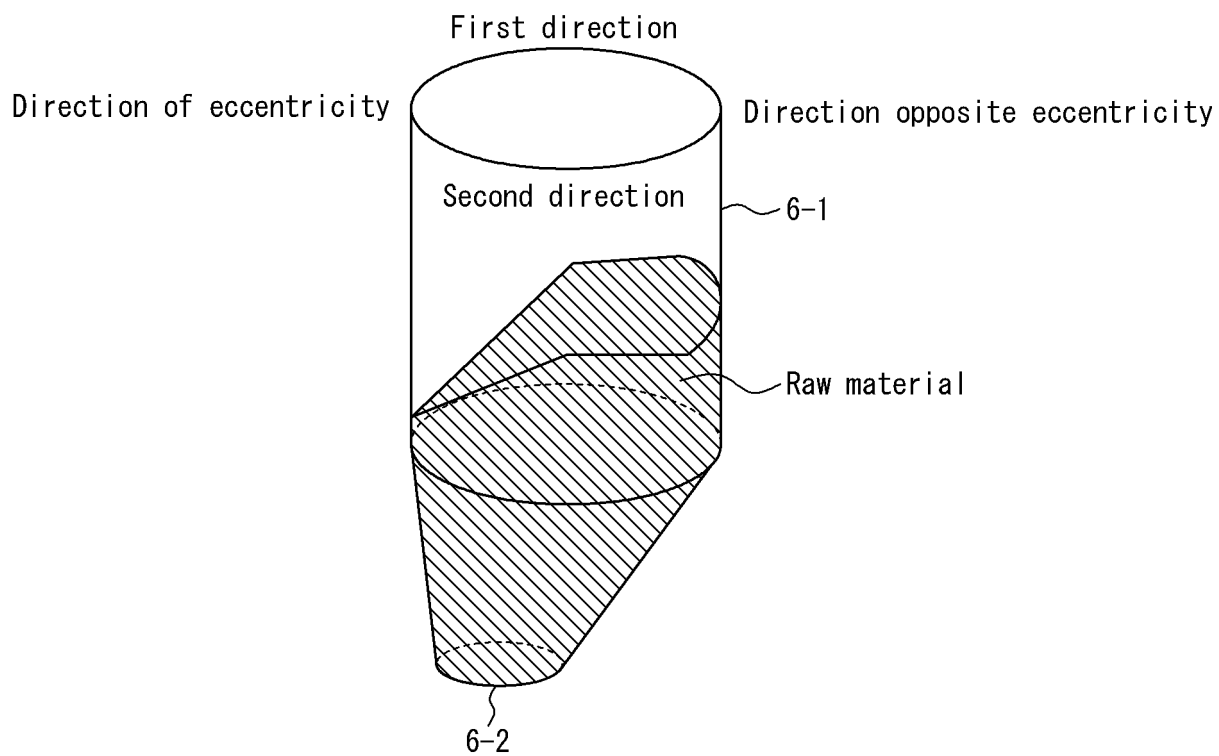


FIG. 7A

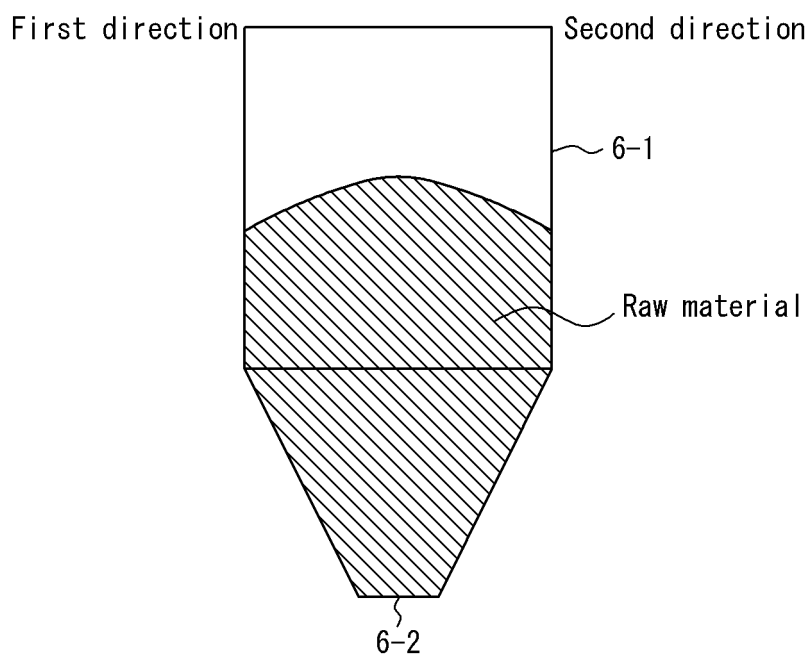


FIG. 7B

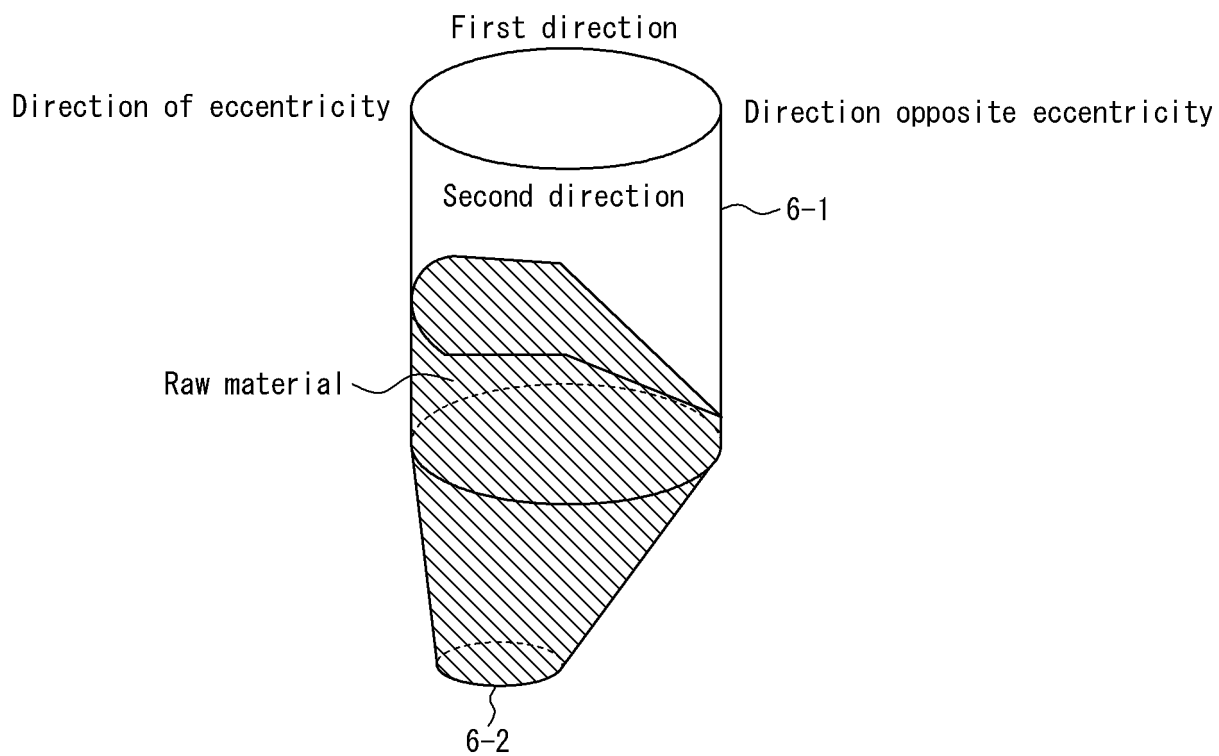
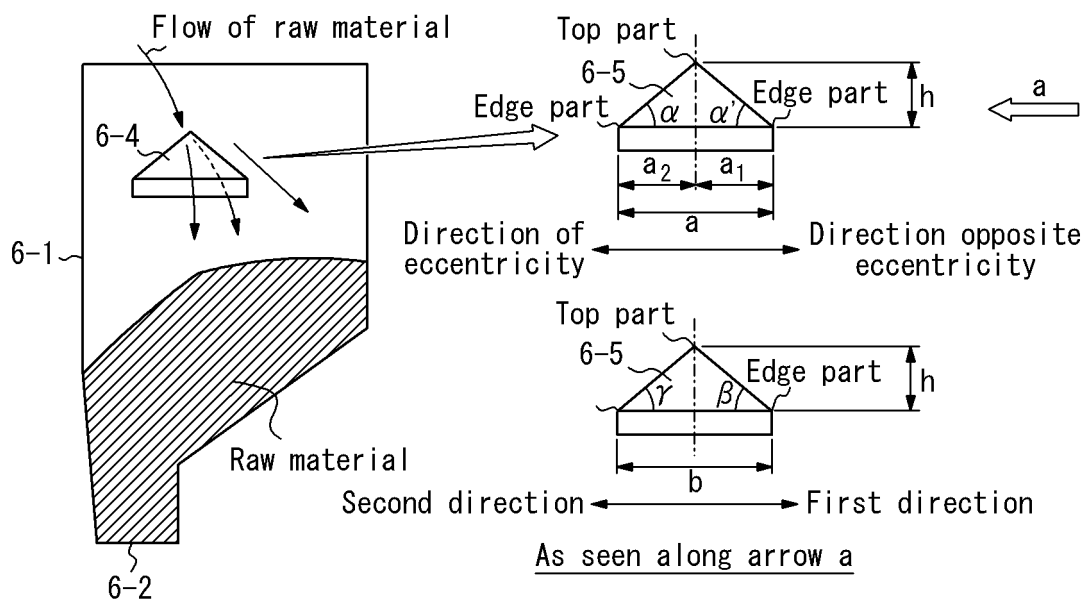


FIG. 8

Reverse tilt charging



Forward tilt charging

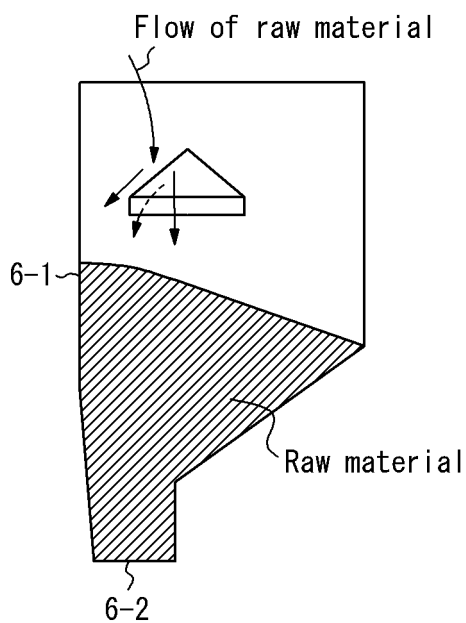


FIG. 9

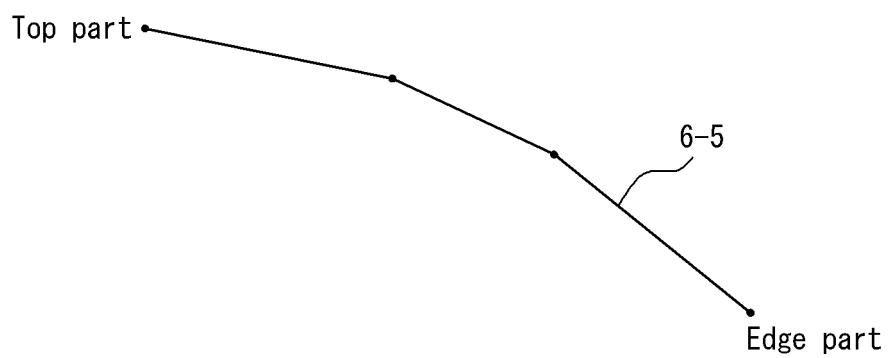
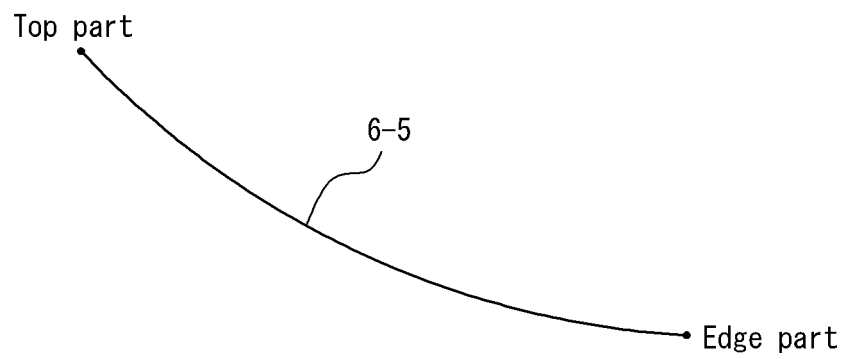
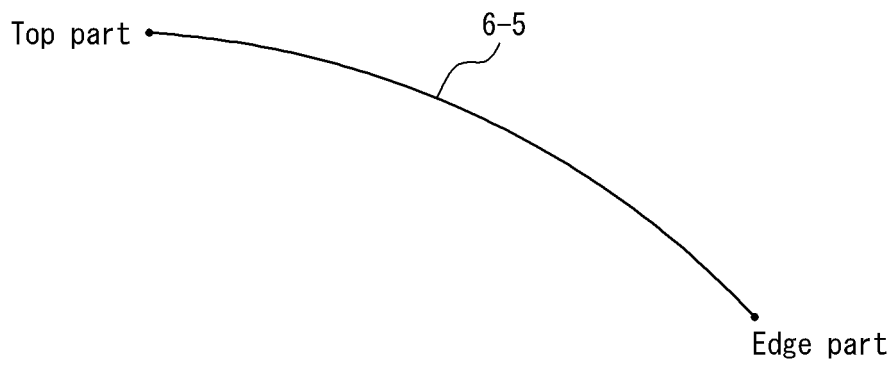
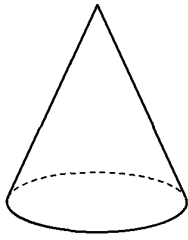
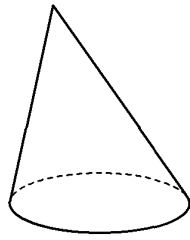


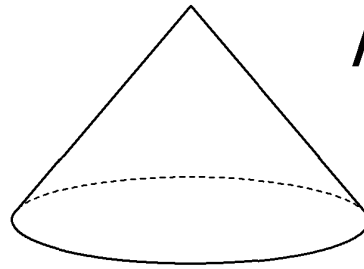
FIG. 10



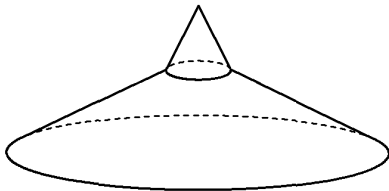
Cone



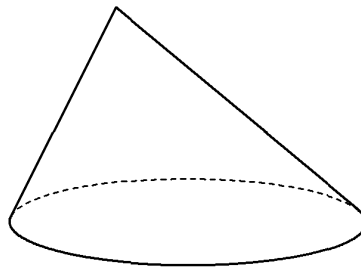
Oblique cone



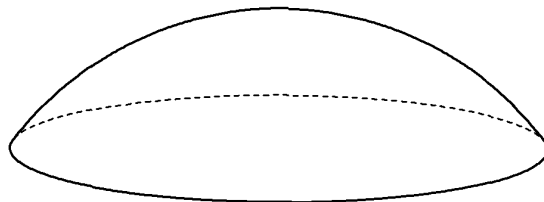
Elliptical cone



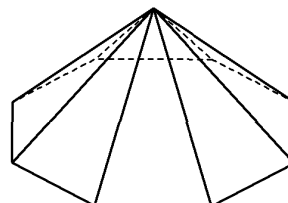
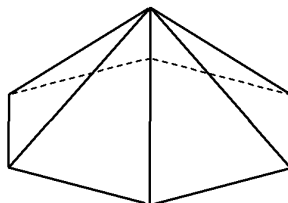
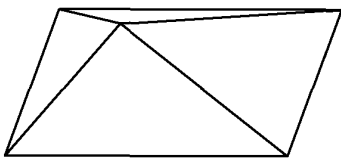
Shape 1



Shape 2



Dome



Polyhedron

FIG. 11

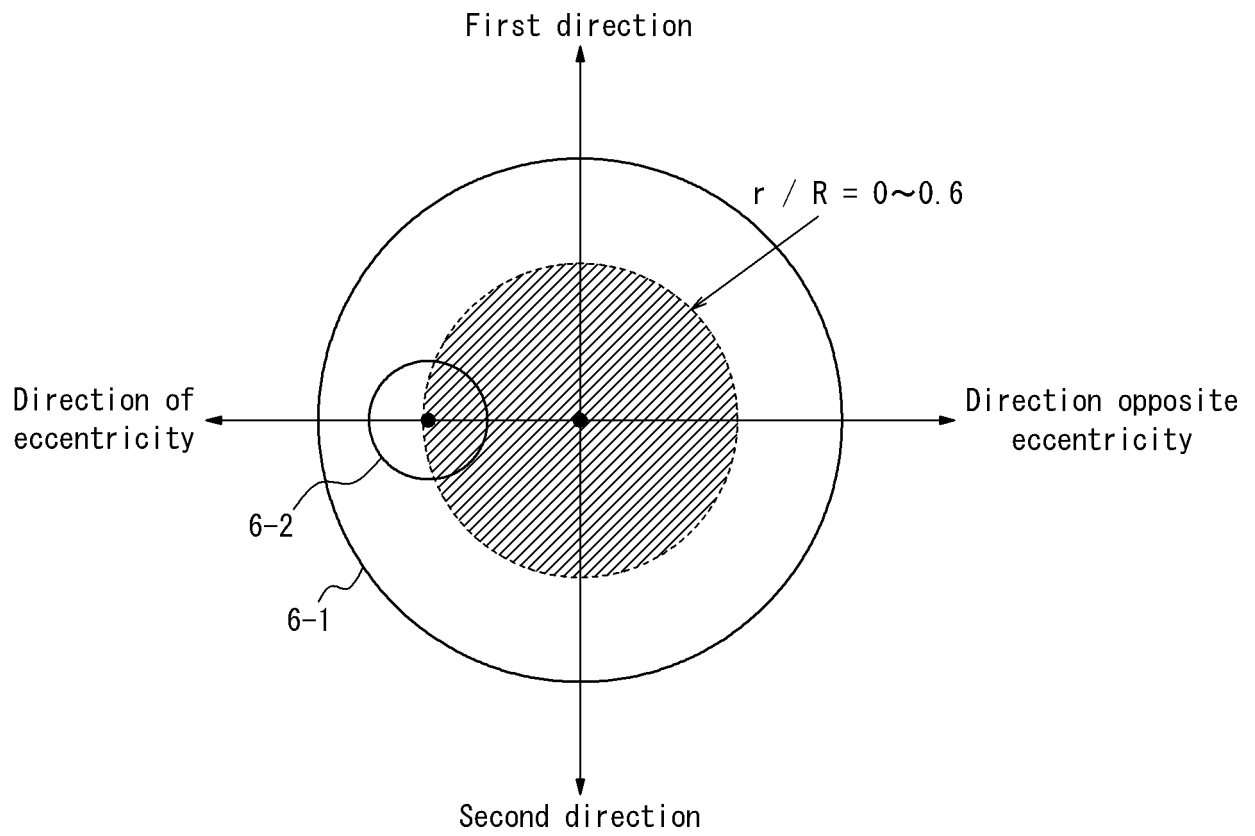


FIG. 12

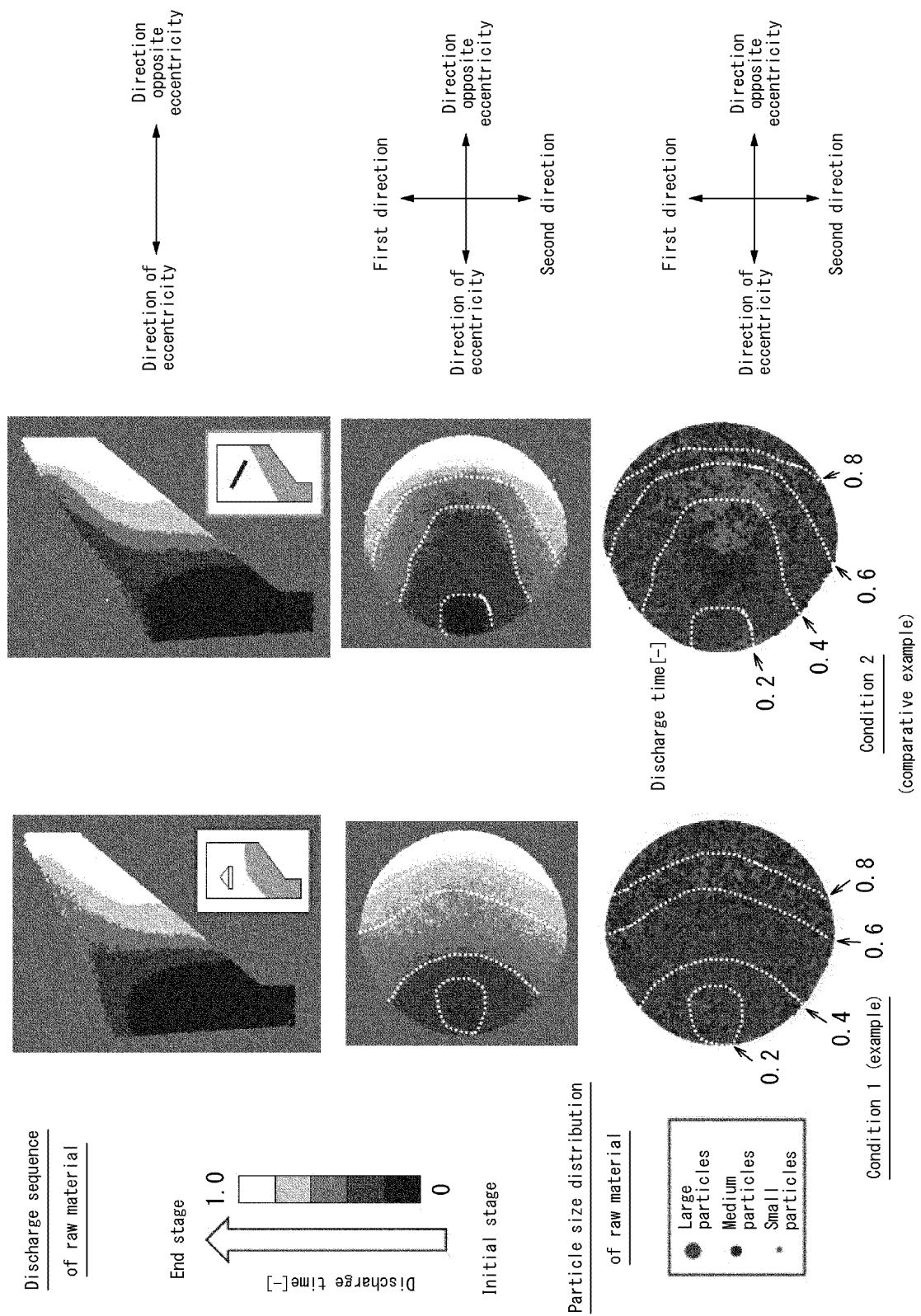


FIG. 13

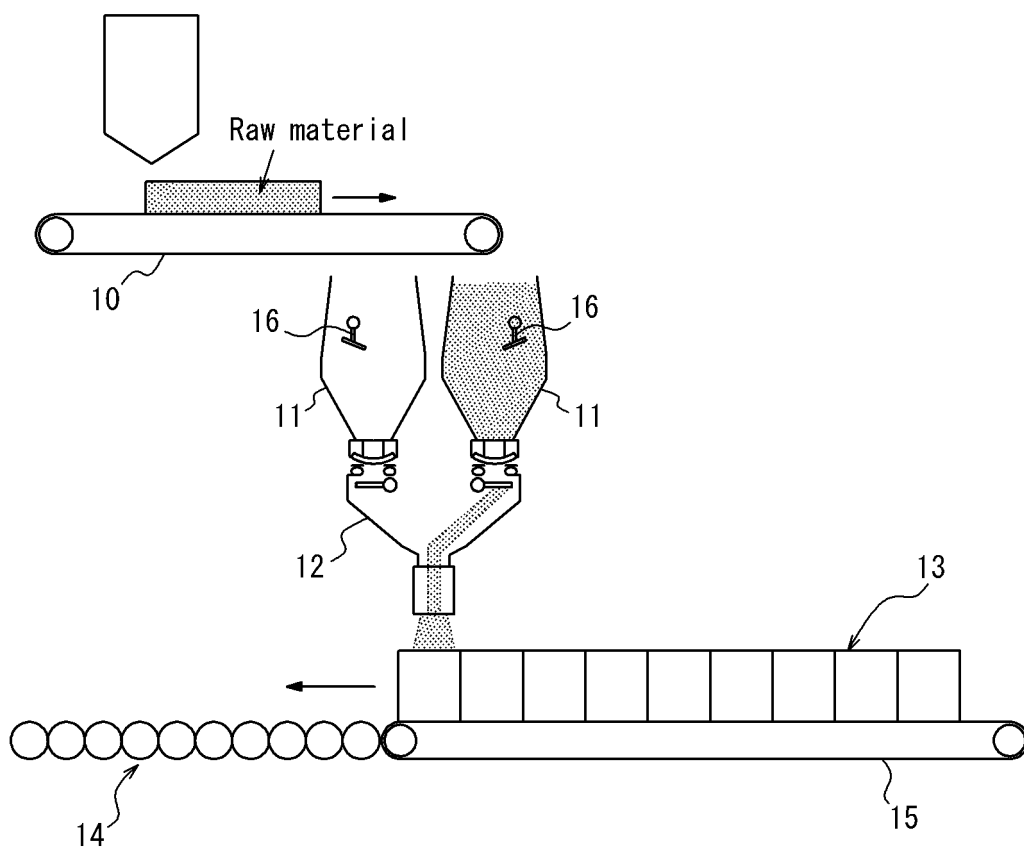


FIG. 14

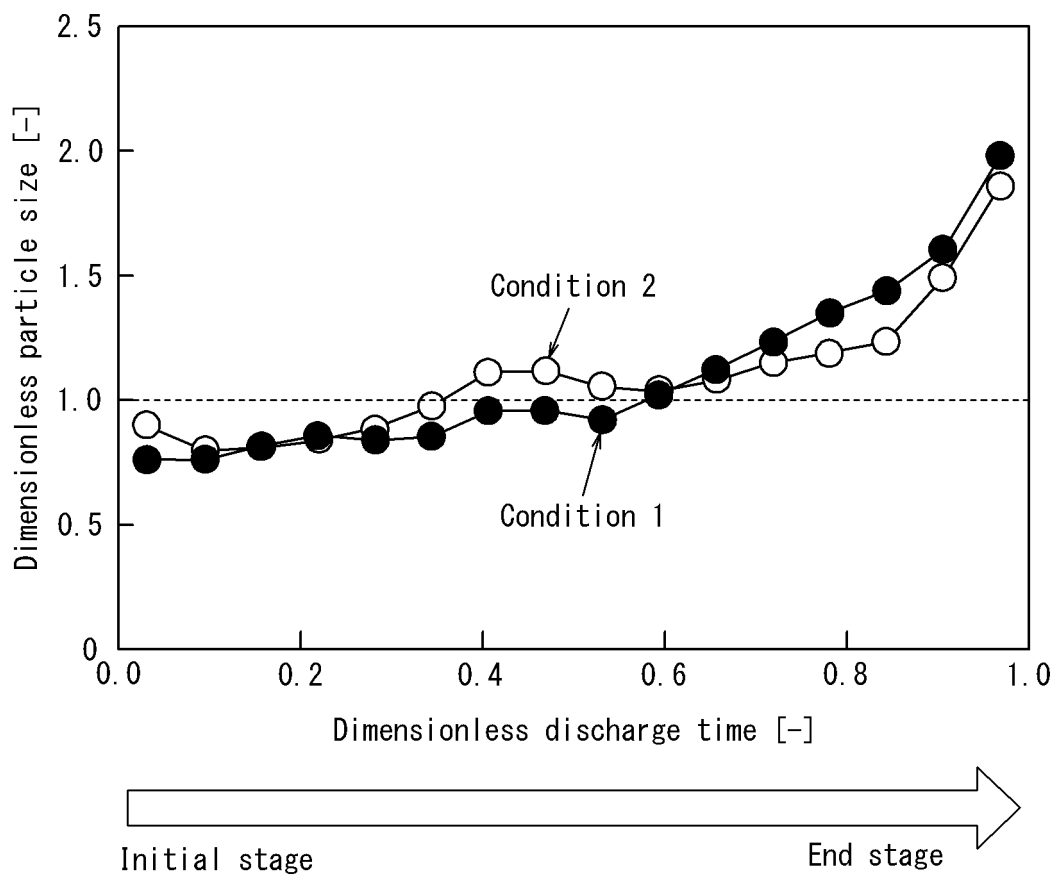


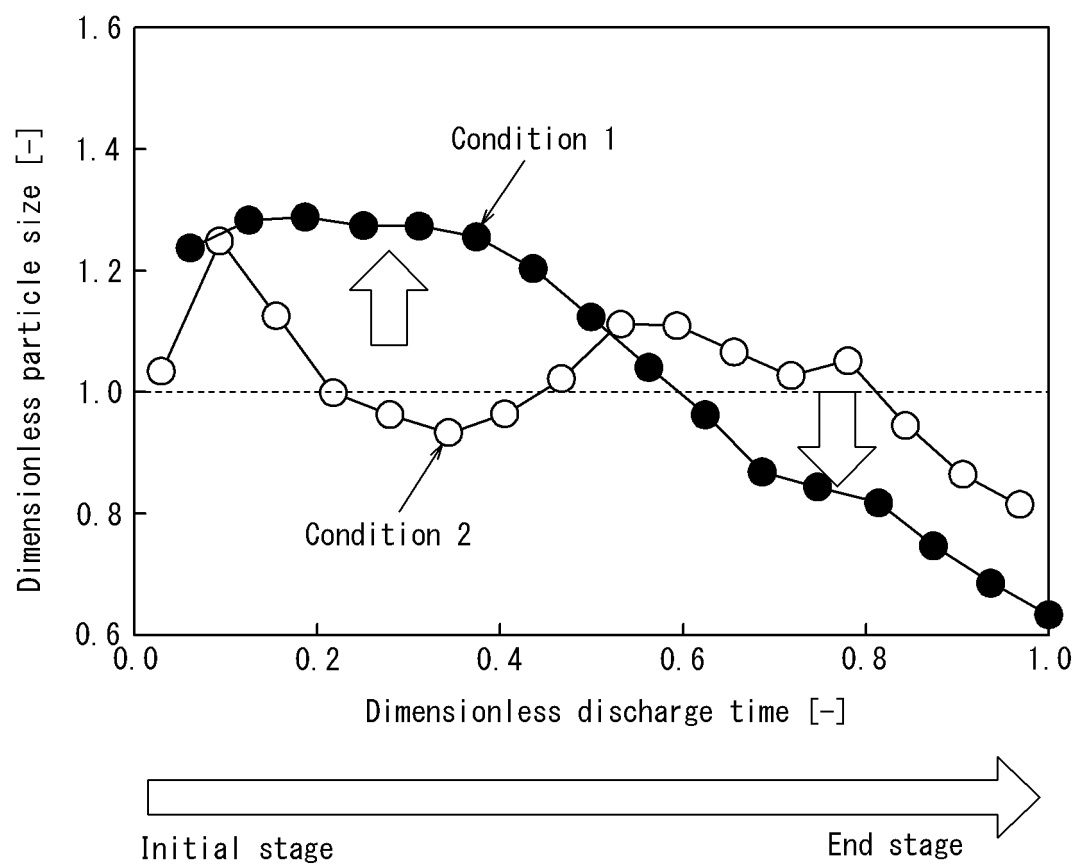
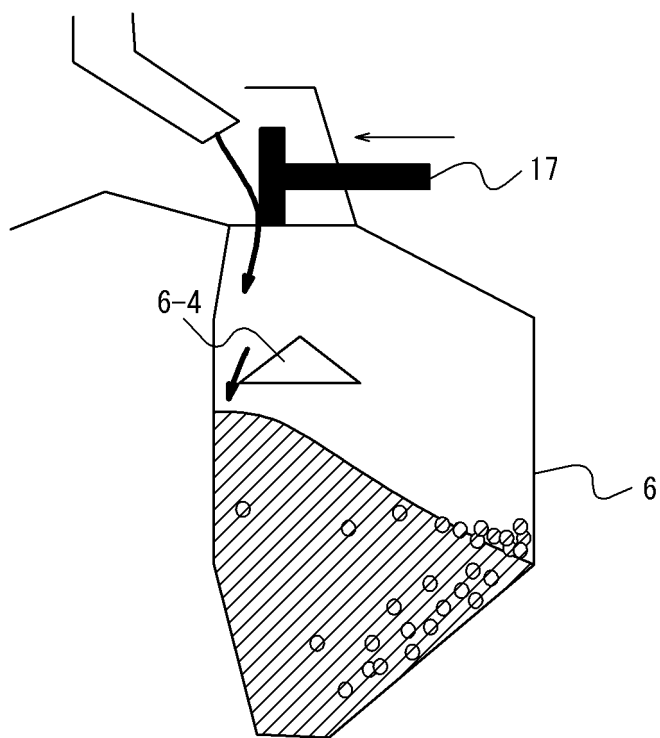
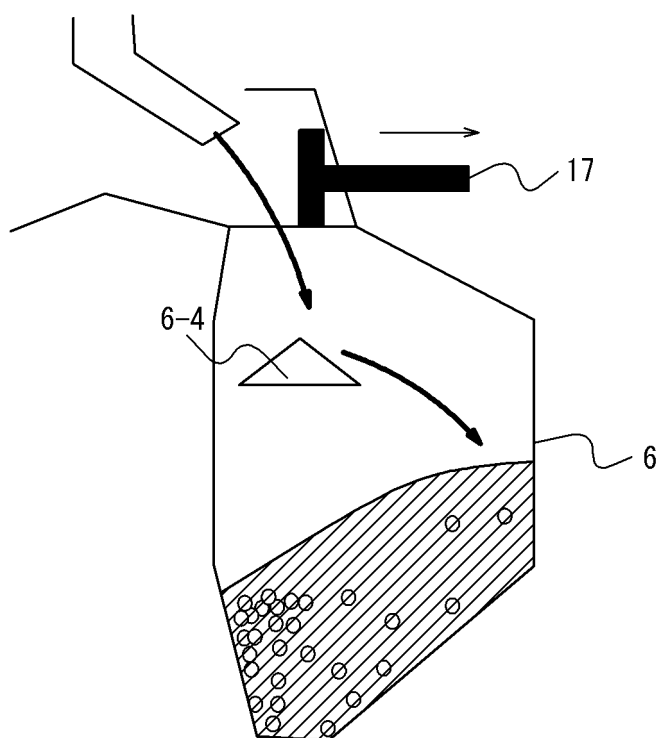
FIG. 15

FIG. 16



Forward tilt charging



Reverse tilt charging

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/002471

A. CLASSIFICATION OF SUBJECT MATTER <i>C21B 5/00</i> (2006.01)i; <i>C21B 7/18</i> (2006.01)i; <i>F27B 1/20</i> (2006.01)i; <i>F27D 3/10</i> (2006.01)i FI: C21B5/00 311; F27B1/20; F27D3/10; C21B7/18 303 According to International Patent Classification (IPC) or to both national classification and IPC															
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C21B5/00; C21B7/18; F27B1/20; F27D3/10 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 1971-2022 Registered utility model specifications of Japan 1996-2022 Published registered utility model applications of Japan 1994-2022 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)															
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>Y</td> <td>JP 2000-178624 A (KAWASAKI STEEL CORP) 27 June 2000 (2000-06-27) paragraphs [0003]-[0020], fig. 1-3</td> <td>1-4</td> </tr> <tr> <td>Y</td> <td>JP 62-218507 A (SUMITOMO METAL IND LTD) 25 September 1987 (1987-09-25) p. 3, upper right column, lines 9-13, p. 3, lower right column, lines 5-16, fig. 1</td> <td>1, 4</td> </tr> <tr> <td>Y</td> <td>JP 2017-039969 A (JFE STEEL CORP) 23 February 2017 (2017-02-23) paragraphs [0004]-[0017], [0034], fig. 1, 6</td> <td>1-4</td> </tr> <tr> <td>Y</td> <td>JP 2016-053201 A (JFE STEEL CORP) 14 April 2016 (2016-04-14) paragraph [0020], fig. 2</td> <td>1, 4</td> </tr> </tbody> </table> ☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex. * Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed “T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art “&” document member of the same patent family	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	Y	JP 2000-178624 A (KAWASAKI STEEL CORP) 27 June 2000 (2000-06-27) paragraphs [0003]-[0020], fig. 1-3	1-4	Y	JP 62-218507 A (SUMITOMO METAL IND LTD) 25 September 1987 (1987-09-25) p. 3, upper right column, lines 9-13, p. 3, lower right column, lines 5-16, fig. 1	1, 4	Y	JP 2017-039969 A (JFE STEEL CORP) 23 February 2017 (2017-02-23) paragraphs [0004]-[0017], [0034], fig. 1, 6	1-4	Y	JP 2016-053201 A (JFE STEEL CORP) 14 April 2016 (2016-04-14) paragraph [0020], fig. 2	1, 4
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Y	JP 2000-178624 A (KAWASAKI STEEL CORP) 27 June 2000 (2000-06-27) paragraphs [0003]-[0020], fig. 1-3	1-4													
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Y	JP 2017-039969 A (JFE STEEL CORP) 23 February 2017 (2017-02-23) paragraphs [0004]-[0017], [0034], fig. 1, 6	1-4													
Y	JP 2016-053201 A (JFE STEEL CORP) 14 April 2016 (2016-04-14) paragraph [0020], fig. 2	1, 4													
Date of the actual completion of the international search 15 March 2022	Date of mailing of the international search report 29 March 2022														
Name and mailing address of the ISA/JP Japan Patent Office (ISA/JP) 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915 Japan	Authorized officer Telephone No.														

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2022/002471

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2000-178624 A	27 June 2000	(Family: none)	
JP 62-218507 A	25 September 1987	(Family: none)	
JP 2017-039969 A	23 February 2017	(Family: none)	
JP 2016-053201 A	14 April 2016	(Family: none)	

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REFERENCES CITED IN THE DESCRIPTION

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- JP 4591520 B [0008] [0009]