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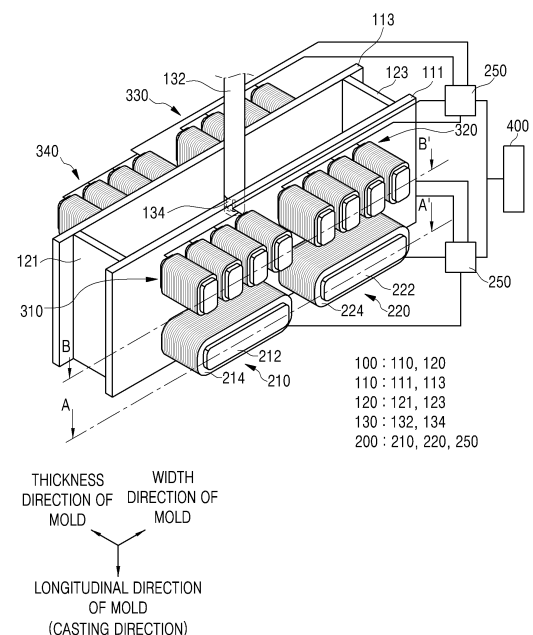
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(54) **CASTING EQUIPMENT AND CASTING METHOD**

(57) The present disclosure relates to a casting equipment and a casting method. The casting method includes injecting a molten material into a mold by using a nozzle, forming a static magnetic field applied region and a non-static magnetic field applied region in a width direction of the mold and controlling a flow of the molten material in a longitudinal direction of the mold, and drawing a cast slab. Through this, as the flow of the molten material accommodated in a container is locally controlled, cleanliness of the molten material may be secured, and a quality of a product may be improved.

Fig. 1



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Description**TECHNICAL FIELD**

5 **[0001]** The present disclosure relates to a casting equipment and a casting method, and more particularly, to a casting equipment and a casting method, which are capable of controlling a flow of a molten material to secure a cleanliness of the molten material, thereby improving a quality of a product.

BACKGROUND ART

10 **[0002]** In general, a continuous casting process may produce various shaped cast slabs such as a slab, a bloom, a billet, and a beam blank by injecting molten steel into a mold having a predetermined inner shape and continuously drawing a semi-solidified cast slab downward from the mold. The cast slab produced as described above has a surface quality and an inner quality, which are affected by various factors. Particularly, the surface quality of the cast slab is highly affected by a flow of the molten steel in the mold.

15 **[0003]** When a molten material is injected into a mold by using a submerged entry nozzle in the continuous casting process, the molten material discharged from a discharge hole of the submerged entry nozzle forms a jet stream to flow in a width direction of the mold. The molten material flowing in the width direction of the mold collides an inner surface of the mold, e.g., an inner surface of a short side plate, so that a portion of the molten material forms an upflow, and a portion thereof forms a downflow. The upflow moves to a central portion of the mold around a molten surface of the molten material, e.g., a portion at which the submerged entry nozzle is installed. The molten material moving toward the central portion of the mold collides with the molten material moving in an opposite direction and the submerged entry nozzle to form a vortex at the molten surface around the submerged entry nozzle, thereby causing instability of the flow of the molten surface. Here, the instability of the flow of the molten surface becomes worse as a flow velocity of the upflow increases and causes a different kind of material such as mold slag or mold flux disposed at an upper portion of the molten surface of the molten material to be mixed into the molten material.

20 **[0004]** Also, the downflow flows downward along an edge of the mold to form a secondary upflow moving upward at the central portion of the mold. Here, as the inclusions contained in the molten steel moves along a casting direction with the downflow and floats with the secondary upflow, the inclusions may flow into the mold slag or the mold flux and be removed together. However, when the movement distance of the inclusion is changed according to a flow velocity of the downflow, and the downflow has a fast flow velocity, the inclusion is permeated to a solidified cell and causes a surface defect of the produced cast slab.

25 **[0005]** To resolve the above-described limitation, a method of controlling the flow of the molten steel in the mold by installing a magnetic field generator in the mold is used. By using this method, the mold flux is restricted from flowing into the molten steel by controlling the upflow around the molten surface of the molten steel, and the movement distance of the inclusion is controlled by controlling the downflow below the submerged entry nozzle to restrict the surface defect of the cast slab from being generated. However, in the process of controlling the downflow, formation of the secondary upflow generated by the downflow is also restricted. Accordingly, the inclusion moving in the casting direction with the downflow is remained in the molten steel instead of floating properly to cause degradation in quality of the cast slab.

40 (Related art document 1) KR10-1176816 B

(Related art document 2) JP4411945 B

DISCLOSURE OF THE INVENTION**TECHNICAL PROBLEM**

45 **[0006]** The present disclosure provides a casting equipment capable of controlling a flow of a molten material and a casting method.

50 **[0007]** The present disclosure also provides a casting equipment capable of smoothly removing an inclusion contained in a molten material and restricting a different kind of material from being mixed into the molten material to improve a quality of a product and a casting method.

TECHNICAL SOLUTION

55 **[0008]** In accordance with an exemplary embodiment, a casting equipment for casting a cast slab includes: a mold configured to provide an inner space for accommodating a molten material; a nozzle disposed above the mold to supply the molten material into the mold; a static magnetic field generation unit disposed on an outside in a width direction of

the mold so that magnetic fields at both edges in the width direction of the mold are controlled in different directions; and a control unit configured to control an operation of the static magnetic field generation unit.

[0009] The mold may include one pair of long side plates spaced apart from each other and one pair of short side plates configured to connect both sides of each of the one pair of long side plates, and the static magnetic field generation unit may include: a plurality of static magnetic field generators disposed in a width direction of the long side plate below the nozzle so as to be spaced apart from a central portion in the width direction of the mold; and a first current supplier configured to supply a direct current to the plurality of static magnetic field generators so as to form a magnetic field passing in a thickness direction of the mold at both sides of the nozzle in the width direction of the mold.

[0010] Each of the plurality of static magnetic field generators may include: a core extending along a portion of the width direction of the long side plate and spaced apart from another core; and a coil wound around an outside of the core.

[0011] The plurality of static magnetic field generators may include: a first static magnetic field generator; a second static magnetic field generator disposed at one side of the first static magnetic field generator while being spaced apart therefrom so that the nozzle is disposed therebetween; a third static magnetic field generator disposed to face the second static magnetic field generator; and a fourth static magnetic field generator disposed at one side of the third static magnetic field generator while being spaced apart therefrom so that the nozzle is disposed therebetween and disposed to face the first static magnetic field generator, and the first current supplier may supply a direct current to the first static magnetic field generator, the second static magnetic field generator, the third static magnetic field generator, and the fourth static magnetic field generator so as to form opposite polarities in directions facing each other in the thickness direction of the mold and opposite polarities in the width direction of the mold.

[0012] The first static magnetic field generator and the second static magnetic field generator may be spaced by a first distance from each other, and the third static magnetic field generator and the fourth static magnetic field generator may be spaced by a second distance from each other. Here, the first distance may be the same as the second distance.

[0013] When the cast slab has an entire width of 100, each of the first distance and the second distance may be in a range from 4 to 36.

[0014] At least one of the first static magnetic field generator, the second static magnetic field generator, the third static magnetic field generator, and the fourth static magnetic field generator may be movable along the width direction of the mold.

[0015] The casting equipment may further include: a first connection core configured to connect the first static magnetic field generator and the second static magnetic field generator; and a second connection core configured to connect the third static magnetic field generator and the fourth static magnetic field generator.

[0016] The static magnetic field generation unit may form a magnetic field that rotates in a circumferential direction of the mold.

[0017] The casting equipment may further include a dynamic magnetic field generation unit disposed above the static magnetic field generation unit to form a dynamic magnetic field for controlling a flow of the molten material, and the control unit may control an operation of the dynamic magnetic field generation unit so as to adjust at least one of an intensity and a direction of the dynamic magnetic field.

[0018] The dynamic magnetic field generation unit may include a plurality of dynamic magnetic field generators configured to form a dynamic magnetic field at both sides of the nozzle in the width direction of the mold.

[0019] The dynamic magnetic field generation unit may be disposed in parallel to the static magnetic field generation unit and control the flow of the molten material in a direction different from the static magnetic field generation unit.

[0020] In accordance with another exemplary embodiment, a casting method includes: injecting a molten material into a mold by using a nozzle; forming a static magnetic field applied region and a non-static magnetic field applied region in a width direction of the mold and controlling a flow of the molten material in a longitudinal direction of the mold;

and drawing a cast slab.

[0021] The casting method may further include, before the injecting of the molten material, arranging the nozzle at a central portion in the width direction of the mold, and the controlling of the flow of the molten material may include forming the non-static magnetic field applied region at a central portion in the width direction of the mold and forming the static magnetic field applied region at both sides of the non-static magnetic field applied region.

[0022] The controlling of the flow of the molten material may include forming the static magnetic field applied region and the non-static magnetic field applied region below the nozzle.

[0023] The controlling of the flow of the molten material may include forming a magnetic field along a thickness direction of the mold, and the forming of the static magnetic field applied region may include forming a static magnetic field so that magnetic fields at both sides of the nozzle have opposite directions.

[0024] The controlling of the flow of the molten material may include forming the non-static magnetic field applied region at a portion of the central portion in the width direction of the mold, at which the nozzle is disposed.

[0025] The controlling of the flow of the molten material may include controlling a range of the static magnetic field

applied region so that the non-static magnetic field applied region has a magnetic field of 0 Gauss to 100 Gauss.

[0026] The controlling of the flow of the molten material may include adjusting a distance between the static magnetic field applied regions according to a width of the cast slab.

[0027] The controlling of the flow of the molten material may include forming the static magnetic field applied region at both edges in the width direction of the mold to reduce a flow velocity of a downflow of the molten material and forming the non-static magnetic field applied region between the static magnetic field applied regions to form an upflow of the molten material.

[0028] The controlling of the flow of the molten material may further include forming a dynamic magnetic field applied region and a non-dynamic magnetic field applied region to control the flow of the molten material in the width direction of the mold.

[0029] The controlling of the flow of the molten material in the width direction of the mold may include forming a dynamic magnetic field applied region and a non-dynamic magnetic field applied region between a molten surface of the molten material and a lower end of the nozzle.

[0030] The forming of the dynamic magnetic field applied region may include forming a dynamic magnetic field in the width direction of the mold at both sides of the nozzle in the width direction of the mold.

[0031] The forming of the dynamic magnetic field applied region may include adjusting at least one of an intensity and a direction of the dynamic magnetic field.

ADVANTAGEOUS EFFECTS

[0032] In accordance with the exemplary embodiment, the flow of the molten material in the container may be locally controlled. That is, the flow of the molten material in the longitudinal direction of the mold may be selectively controlled by selectively applying the static magnetic field in the width direction of the mold. Thus, the inclusion contained in the molten material may have the reduced downward movement distance along the molten material and simultaneously easily float upward to restrict the quality degradation of the product caused by the inclusion. Also, as the dynamic magnetic field is formed in the width direction of the mold, the flow of the molten material around the molten surface of the molten material may be controlled to restrict the different kind of material such as the mold flux or the mold slag from being mixed with the molten material. Through this, the cleanliness of the molten material may be secured, and the quality of the product manufactured by using the molten material may be improved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033]

FIG 1 is a perspective view illustrating a casting equipment in accordance with an exemplary embodiment.

FIG 2 is a cross-sectional view illustrating the casting equipment taken along line A-A' of FIG 1.

FIG 3 is a view for explaining a principle of controlling a flow of a molten material by using a static magnetic field generator.

FIG 4 is a cross-sectional view illustrating a casting equipment in accordance with a modified example.

FIG 5 is a view illustrating a state of controlling a flow of a molten material by a casting method in accordance with an exemplary embodiment.

FIG. 6 is a view illustrating a flow analysis result of a secondary upflow in a mold according to whether a non-static magnetic field applied region is formed in a width direction of the mold.

FIG. 7 is a cross-sectional view illustrating the casting equipment taken along line B-B' of FIG 1.

FIG. 8 is a view illustrating an example of controlling a flow of a molten material by using a dynamic magnetic field generator.

MODE FOR CARRYING OUT THE INVENTION

[0034] Hereinafter, specific embodiments will be described in more detail with reference to the accompanying drawings. The present invention may, however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the present invention to those skilled in the art. In every possible case, like reference numerals are used for referring to the same or similar elements in the description and drawings. In the figures, the dimensions of layers and regions are exaggerated for clarity of illustration. Like reference numerals in the drawings denote like elements, and thus their description will be omitted.

[0035] FIG. 1 is a perspective view illustrating a casting equipment in accordance with an exemplary embodiment, and FIG. 2 is a cross-sectional view taken along line A-A' of FIG. 1.

[0036] Referring to FIGS. 1 and 2, the casting equipment in accordance with an exemplary embodiment may include: a mold 100 providing a space for accommodating a molten material therein; a nozzle 130 having at least a portion inserted into the mold 100 to supply the molten material to the mold 100; a static magnetic field generation unit 200 provided on an outside in a width direction of the mold 100 to control a direction of a magnetic field in different directions at both edges in the width direction of the mold 100; and a control unit 400 capable of controlling an operation of the static magnetic field generation unit 200.

[0037] The mold 100 may include a plurality of plates 110 and 120 for providing a space for accommodating a molten material, e.g., molten steel, therein. Here, the plurality of plates 110 and 120 may include long side plates 110 and short side plates 120.

[0038] The long side plates 110, e.g., a first long side plate 111 and a second long side plate 113, may be spaced apart from each other to face each other, and the short side plates 120, e.g., a first short side plate 121 and a second short side plate 123, may contact both sides of each of the first long side plate 111 and the second long side plate 113 to form a space for accommodating a molten material therein. Here, upper and lower portions of the mold 100 may be opened, and the long side plates 110 and the short side plates 120 may closely contact each other to prevent the molten material from being leaked through a contact portion thereof.

[0039] Here, a length in a horizontal direction of each of the long side plates 110 is referred to as a width of the long side plate 110, and a direction of the width is referred to as a width direction of the long side plate 110. Here, the width direction of the long side plate 110 may represent a width direction of the mold 100. Here, a length in a vertical direction of the long side plate 110 is referred to as a length of the long side plate 110, and a direction of the length is referred to as a longitudinal direction of the long side plate 110. Here, the longitudinal direction of the long side plate 110 may represent a longitudinal direction of the mold 100 or a drawing direction of a cast slab. Also, a length in a horizontal direction of each of the short side plates 120 is referred to as a width of the short side plate 120, and a direction of the width is referred to as a width direction of the short side plate 120. Here, the width direction of the short side plate 120 may represent a width direction of the mold 100.

[0040] As a flow path (not shown) through which a cooling medium moves is formed in each of the long side plate 110 and the short side plate 120, the molten material injection to the mold may be cooled by the cooling medium moving along the flow path. Thus, the molten material may be solidified from a portion contacting an inner surface of the mold 100 to be cast into a solidified cell or a cast slab, and drawn to a lower portion of the mold 100.

[0041] The nozzle 130 may be disposed at an upper portion of the mold 100 to inject the molten material into the mold 100. The nozzle 130 may have at least a portion, e.g., a lower portion, inserted into the mold 100 to inject the molten material accommodated in a tundish (not shown) disposed above the mold 100 into the mold 100. The nozzle 130 may include a nozzle body 132 having an inner empty part through which the molten material moves and a discharge hole 134 through which the molten material moves from the inner hole part to the outside, i.e., the mold 100. Here, the nozzle body 132 may have an opened upper portion and a closed lower end, and the inner empty part (not shown) may be defined in the nozzle body 132 to form a path through which the molten material moves. Also, at least two discharge holes 134, e.g., two or four discharge holes, may be defined in a lower side surface of the nozzle body 132 to discharge the molten material into the mold 100. Here, the discharge hole 134 may be formed in the lower side surface of the nozzle body 132, which faces the short side plate 120, to discharge the molten material in the width direction of the mold 100.

[0042] The static magnetic field generation unit 200 may be disposed at an outside in the width direction of the mold 100 and apply a magnetic field, e.g., a static magnetic field, to the molten material. Here, the static magnetic field generation unit 200 may be disposed below a lower end of the nozzle 130 to control a flow of a downflow of the molten material discharged from the discharge hole 134. Also, the static magnetic field generation unit 200 may be formed at each of both edges in the width direction of the mold 100, in which the downflow is formed, to form a static magnetic field applied region. The static magnetic field generation unit 200 may apply a static magnetic field in the width direction of the mold 100 to reduce a flow velocity of the downflow of the molten material, which is formed at the edge in the width direction of the mold 100. Here, the static magnetic field may be formed by using a direct current power in a magnetic field generator and reduce a flow velocity of fluid by restricting an overall movement or flow of fluid in a magnetic field region. When the static magnetic field is applied by the static magnetic field generation unit 200, a movement of the downflow may be restricted by the static magnetic field to reduce the flow velocity of the downflow. Thus, as a movement distance of an inclusion in a downward direction is reduced, a penetration depth of the inclusion in the molten material may decrease.

[0043] Even in the related art, a method of controlling the downflow by installing the static magnetic field generation unit in the mold is used. In this case, since the static magnetic field generation unit is installed in the mold to apply the static magnetic field along the entire width direction of the mold, the flow velocity of the downflow may be reduced. However, as the flow of the molten material is restricted by the magnetic field formed along the entire width direction of the mold, a secondary upflow may be also reduced to allow the inclusion contained in the molten material to float upward.

[0044] Thus, in accordance with an exemplary embodiment, as a static magnetic field applied region and a non-static

magnetic field applied region are selectively formed along the width direction of the mold 100 by using the static magnetic field generation unit 200, the flow velocity of the downflow may be reduced by using the static magnetic field in the static magnetic field applied region, and the secondary upflow may be formed by minimizing an effect of the static magnetic field in the non-static magnetic field applied region.

[0045] The static magnetic field generation unit 200 may form the static magnetic fields at both sides in the width direction of the mold 100 in different directions, e.g., opposite directions, in a thickness direction of the mold 100. Thus, the static magnetic field generation unit 200 may form the static magnetic field applied region at both the edge in the width direction of the mold 100 and form a region in which an intensity of the magnetic field formed in the static magnetic field applied region is offset, i.e., the non-static magnetic field applied region, at a central portion in the width direction of the mold 100. Thus, since an inclusion having a reduced penetration depth in the static magnetic field applied region may easily float upward by the secondary upflow formed in the non-static magnetic field applied region, a defect of a surface of the cast slab caused by the including may be restricted.

[0046] The static magnetic field generation unit 200 may reduce the flow velocity of the downflow formed in the longitudinal direction of the mold at both the edges in the width direction of the mold 100, in which the static magnetic field applied region is formed, and increase the flow velocity of the secondary upflow formed in the longitudinal direction of the mold or allow the secondary upflow to be smoothly formed at the central portion in the width direction of the mold 100, in which the non-static magnetic field applied region is formed.

[0047] Here, the static magnetic field applied region, as a region in which the static magnetic field or the magnetic field is formed by the static magnetic field generation unit 200, may represent a region in which the static magnetic field or the magnetic field having an intensity capable of causing the flow of the molten material is applied. Also, the non-static magnetic field applied region may represent a region in which the static magnetic field or the magnetic field having an intensity that is not affected to the flow of the molten material is applied or a region in which the static magnetic field or the magnetic field is not applied at all. For example, the non-static magnetic field applied region may represent a region in which the static magnetic field or the magnetic field having an intensity of 0 Gauss to 100 Gauss is applied.

[0048] Referring to FIG. 2, the static magnetic field generation unit 200 may include a plurality of static magnetic field generators 210, 220, 230, and 240 disposed in the width direction of the long side plate 110 below the lower end of the nozzle 130 and a first direct current supplier 250 for supplying a direct current to the plurality of static magnetic field generators 210, 220, 230, and 240.

[0049] The plurality of static magnetic field generators 210, 220, 230, and 240 may include a first static magnetic field generator 210, a second static magnetic field generator 220 spaced apart from the first static magnetic field generator 210 so that the nozzle 130 is disposed between the first static magnetic field generator 210 and the second static magnetic field generator 220, a third static magnetic field generator 230 disposed to face the second static magnetic field generator 220, and a fourth static magnetic field generator 240 spaced apart from the third static magnetic field generator 230 so that the nozzle 130 is disposed between the third static magnetic field generator 230 and the fourth static magnetic field generator 240 and disposed to face the first static magnetic field generator 210. The first static magnetic field generator 210 and the second static magnetic field generator 220 may be spaced apart from each other on an outer surface of the first long side plate 111, and the third static magnetic field generator 230 and the fourth static magnetic field generator 240 may be spaced apart from each other on an outer surface of the second long side plate 113. Here, a spaced distance D between the first static magnetic field generator 210 and the second static magnetic field generator 220, e.g., a first distance, may be the same as a spaced distance D between the third static magnetic field generator 230 and the fourth static magnetic field generator 240, e.g., a second distance. This allows the non-static magnetic field applied region to be formed at the central portion in the width direction of the mold 100. Each of the first distance and the second distance may be varied based on a width of the cast slab to be cast. When an entire width of the cast slab is 100, each of the first distance and the second distance may be adjusted in a range from 4 to 36. Alternatively, when the entire width of the cast slab is 100, each of the first distance and the second distance may be adjusted in a range from 10 to 25 or in a range from 15 to 20. Here, when each of the first distance and the second distance is much less than the suggested range, a space for forming the secondary upflow may be sufficiently secured. Since the secondary upflow is almost not formed or formed in a relatively small region although the secondary upflow is formed, the inclusion contained in the molten material may not be sufficiently removed. On the other hand, when each of the first distance and the second distance is much greater than the suggested range, the downflow having a reduced flow velocity may not sufficiently move from both the edges in the width direction of the mold 100 to the central portion of the mold 100, and accordingly the flow velocity of the secondary upflow may be also reduced, so that the inclusion is difficult to float upward.

[0050] Thus, as each of the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240 is movable in the width of the mold 100, each of the first distance and the second distance may be appropriately adjusted based on the width of the cast slab to effectively removing the inclusion contained in the molten material. Here, the first distance and the second distance may be affected by a casting speed. For example, when the width of the cast slab is 1100 mm or less,

and the casting speed is in a range from 0.7 m/min to 2.8 m/min, each of the first distance and the second distance may be adjusted in a range from 50 mm to 250 mm. Also, when the width of the cast slab is in a range from 1100 mm to 1500 mm, and the casting speed is in a range from 0.7 m/min to 2.8 m/min, each of the first distance and the second distance may be adjusted in a range from 100 mm to 350 mm, and when the width of the cast slab is in a range from 1500 mm to 1900 mm, and the casting speed is in a range from 0.7 m/min to 2.8 m/min, each of the first distance and the second distance may be adjusted in a range from 100 mm to 500 mm

[0051] Firstly, the first static magnetic field generator 210 may be biased to one side of the first long side plate 111, and the second static magnetic field generator 220 may be spaced apart from the first static magnetic field generator 210 and biased to the other side of the first long side plate 111. Here, the first static magnetic field generator 210 may include a first core 212 and a first coil 214 wound around an outside of the first core 212. The second static magnetic field generator 220 may include a second core 222 and a second coil 224 wound around an outside of the second core 222. Here, one side of the mold 100 or one side of the long side plate 110 may represent a direction in which the first short plate 121 is disposed, and the other side of the mold 100 or the other side of the long side plate 110 may represent a direction in which the second short plate 123 is disposed.

[0052] The first core 212 and the second core 222 may be disposed on an outside of the mold 100 and spaced apart from each other in the width direction of the mold 100. Each of the first core 212 and the second core 222 may have a plate shape extending in one direction. For example, each of the first core 212 and the second core 222 may have a plate shape in which a length in the width direction of the mold 100 is greater than that in the thickness direction of the mold 100. The first core 212 and the second core 222 may be arranged in a row on an outer surface of the first long side plate 111 to each extend along a portion of the width direction of the first long side plate 111. Here, the first core 212 and the second core 222 may be spaced apart from the central portion in the width direction of the mold 100 in which the nozzle 130 is disposed so that the nozzle 130 is disposed therebetween.

[0053] Also, the first coil 214 may be wound around the outside of the first core 212 in a direction in which the first core 212 extends, e.g., the width direction of the mold 100. Also, the second coil 224 may be wound around the outside of the second core 222 in a direction in which the second core 222 extends, e.g., a horizontal direction in the width direction of the mold 100.

[0054] Also, the third static magnetic field generator 230 may be biased to the other side of the second long side plate 113, and the fourth static magnetic field generator 240 may be spaced apart from the third static magnetic field generator 230 and biased to the one side of the second long side plate 113. Here, the third static magnetic field generator 230 may be disposed at a position facing the second static magnetic field generator 220, e.g., disposed to face the second static magnetic field generator 220, and the fourth static magnetic field generator 240 may be disposed to face the first static magnetic field generator 210. The third static magnetic field generator 230 may include a third core 232 and a third coil 234 wound around an outside of the third core 232. The fourth static magnetic field generator 240 may include a fourth core 242 and a fourth coil 244 wound around an outside of the fourth core 242. The third core 232 and the fourth core 242 may be disposed on an outside of the mold 100 and spaced apart from each other in the width direction of the mold 100. The third core 232 and the fourth core 242 may be arranged in a row on an outer surface of the second long side plate 113 to each extend along a portion of a width direction of the second long side plate 113. Here, the third core 232 and the fourth core 242 may be spaced apart from the central portion in the width direction of the mold 100 in which the nozzle 130 is disposed so that the nozzle 130 is disposed therebetween.

[0055] Also, the third coil 234 may be wound around the outside of the third core 232 in the width direction of the mold 100 that is a direction in which the third core 232 extends. Also, the fourth coil 244 may be wound around the outside of the fourth core 222 in the width direction of the mold 100 that is a direction in which the fourth core 242 extends.

[0056] The first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240 may be electrically connected with the first direct current supplier 250. The first direct current supplier 250 may supply a direct current to the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240. The first direct current supplier 250 may supply the direct current simultaneously or selectively to the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240 through control of the control unit 400. The first direct current supplier 250 may supply the direct current to each of the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240 so that a magnetic field direction is formed in the thickness direction of the mold 100. Here, the first direct current supplier 250 may supply the direct current so that the magnetic field directions are formed in opposite directions at the central portion in the width direction of the mold 100, e.g., at both the sides of the nozzle 130. That is, the first direct current supplier 250 may supply the direct current to the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240 so that the magnetic field direction is formed from the first static magnetic field generator 210 to the fourth static magnetic field generator 240 at the one side of the mold 100, and the magnetic field

direction is formed from the third static magnetic field generator 230 to the second static magnetic field generator 220 at the other side of the mold 100. Here, the control unit 400 may control the first direct current supplier 250 to adjust a current amount supplied to each of the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240 in order to adjust an intensity or a strength of the magnetic field.

[0057] Here, the magnetic field direction formed at one side of the nozzle 130 in the width direction of the mold 100, e.g., the one side of the mold 100, is referred to as a first direction, and the magnetic field direction formed at the other side of the nozzle 130 in the width direction of the mold 100, e.g., the other side of the mold 100, is referred to as a second direction. For example, the magnetic field direction formed between the first static magnetic field generator 210 and the fourth static magnetic field generator 240 is referred to as the first direction, and the magnetic field direction formed between the second static magnetic field generator 220 and the third static magnetic field generator 230 is referred to as the second direction. Here, the first direction and the second direction may be opposite to each other. Also, in each of the first core 212, the second core 222, the third core 232, and the fourth core 242, a direction facing the mold 100 is referred to as one side, and a direction facing the outside of the mold 100 is referred to as the other side. Thus, the first current supplier 250 may supply the direct current so that one side of the first core 212 and one side of the fourth core 242, which face each other, have opposite polarities. Also, the first current supplier 250 may supply the direct current so that one side of the second core 222 and one side of the third core 232, which face each other, have opposite polarities. Here, the first current supplier 250 may supply the direct current so that one side of the first core 212 and one side of the second core 222 have opposite polarities, and one side of the third core 232 and one side of the fourth core 242 have opposite polarities.

[0058] For example, the first current supplier 250 may supply the direct current so that each of one side of the first core 212 and one side of the third core 232 has an N pole, and each of one side of the second core 222 and one side of the fourth core 242 has a S pole. In this case, when the first current supplier 250 supplies the direct current to each of the static magnetic field generators 210, 220, 230, and 240, a static magnetic field may be formed in each of the static magnetic field generators 210, 220, 230, and 240. The static magnetic field having a magnetic field direction heading from the S pole to the N pole may be formed in each of the static magnetic field generators 210, 220, 230, and 240. Here, the static magnetic field generated in the first static magnetic field generator 210 may have a magnetic field direction heading from the other side of the first core 212 and one side of the first core 212, and the static magnetic field generated in the fourth static magnetic field generator 240 may have a magnetic field direction heading from one side of the fourth core 242 and the other side of the fourth core 242. The magnetic field having a direction from the first static magnetic field generator 210 to the fourth static magnetic field generator 240, e.g., the first direction, may be formed at one side of the mold 100. Also, the static magnetic field generated in the third static magnetic field generator 230 may have a magnetic field direction heading from the other side of the third core 232 and one side of the third core 232, and the static magnetic field generated in the second static magnetic field generator 220 may have a magnetic field direction heading from one side of the second core 222 and the other side of the second core 222. The magnetic field having a direction from the third static magnetic field generator 230 to the second static magnetic field generator 220, e.g., the second direction, may be formed at one side of the mold 100. Here, although, herein, the first direction heads from the first static magnetic field generator 210 to the fourth static magnetic field generator 240, and the second direction heads from the third static magnetic field generator 230 to the second static magnetic field generator 220, the first direction and the second direction may be changed according to a state of supplying the direct current from the first current supplier 250 to each of the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240. However, even in the case, the first direction and the second direction may be opposite to each other.

[0059] FIG. 3 is a view for explaining a principle of controlling the flow of the molten material by using the static magnetic field generator.

[0060] Firstly, the molten material may be injected into the mold 100 by using the nozzle 130. Before the molten material is injected into the mold 100, the nozzle 130 may be positioned at the central portion in the width direction of the mold 100. Then, the cast slab may be drawn while forming the static magnetic field applied region and the non-static magnetic field applied region in the width direction of the mold 100 and controlling the flow of the molten material in the width direction of the mold 100. Here, the process of forming the static magnetic field applied region and the non-static magnetic field applied region in the width direction of the mold 100 may be performed before the molten material is injected into the mold 100, after the molten material is injected into the mold 100, or simultaneously when molten material is injected into the mold 100.

[0061] The flow of the molten material may be controlled as stated below.

[0062] Referring to FIG 3, when the direct current is supplied to each of the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240 through the first current supplier 250, each of the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field

generator 240 may form the magnetic field. Here, the first static magnetic field generator 210 and the third static magnetic field generator 230, which are misaligned with respect to the nozzle 130, may have the same polarity, and second static magnetic field generator 220 and the fourth static magnetic field generator 240, which are misaligned with respect to the nozzle 130, may also have the same polarity. For example, one side of the first core 212 and one side of the third core 232 may form the same polarity, e.g., the N pole, and one side of the second core 222 and one side of the fourth core 242 may form the same polarity, e.g., the S pole. Also, the static magnetic field formed in each of the static magnetic field generators 210, 220, 230, and 240 has a magnetic field direction heading from the S pole to the N pole according to the cores 212, 222, 232, and 242 thereof. Here, the magnetic field formed around each of the cores 212, 222, 232, and 242 may have the magnetic field direction heading from the S pole to the N pole, and the magnetic field may be formed in the thickness direction of the mold 100 by the magnetic field direction of the magnetic field formed around each of the cores 212, 222, 232, and 242. Also, the magnetic field may have a magnetic field intensity that gradually decreases in a direction away from each of the cores 212, 222, 232, and 242. Thus, the magnetic field may be offset between the first static magnetic field generator 210 and the fourth static magnetic field generator 240, which face each other, to form a region in which the magnetic field is not applied or the magnetic field intensity is extremely weak. This is because the one side of the first core 212 and the one side of the fourth core 242 have opposite polarities. Also, the region in which the magnetic field is not applied or the magnetic field intensity is extremely weak may be also formed between the second static magnetic field generator 220 and the third static magnetic field generator 230, which face each other. This is because the one side of the second core 222 and the one side of the third core 232 have opposite polarities. Also, the region in which the magnetic field is not applied or the magnetic field intensity is extremely weak may be also formed between the first static magnetic field generator 210 and the second static magnetic field generator 220 and between the third static magnetic field generator 230 and the fourth static magnetic field generator 240. Thus, the region in which the magnetic field is not applied or the magnetic field intensity is extremely weak, i.e., the non-static magnetic field applied region, may be formed between the static magnetic fields generated from the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240, e.g., the central portion in the thickness direction of the mold 100 and the central portion in the width direction of the mold 100. Here, a feature in which the magnetic field is not applied or the magnetic field intensity is extremely weak may represent a case of the magnetic field intensity in a range from 0 Gauss to 100 Gauss.

[0063] As described above, as the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240 are installed on the outside of the mold 100, the static magnetic field applied region may be formed in the region in which each of the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240 is disposed, and the non-static magnetic field applied region may be selectively formed between the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240. Thus, the flow velocity of the downflow of the molten material may be reduced by using the magnetic field in the static magnetic field applied region, and the secondary upflow may be smoothly formed by minimizing effects of the magnetic field in the non-static magnetic field applied region. Here, a width of the non-static magnetic field applied region may be adjusted according to a width of the cast slab to be cast. As described above, the secondary upflow may be smoothly formed by adjusting the width of the non-static magnetic field applied region according to the width of the cast slab.

[0064] As the example in which the first core 212 and the second core 222, and the third core 232 and the fourth core 242 are spaced apart from each other in the width direction of the mold 100 herein, the example of forming the non-static magnetic field applied region and the static magnetic field applied region in the width direction of the mold 100 is described. However, the non-static magnetic field applied region and the static magnetic field may be formed in the thickness direction of the mold 100.

[0065] FIG. 4 is a cross-sectional view illustrating a casting equipment in accordance with a modified example. The casting equipment in accordance with a modified example may have almost the structure as the above-described casting equipment in accordance with an exemplary embodiment except that a first static magnetic field generator 210 and a second static magnetic field generator 220 is connected by a first connection core 272, and a third static magnetic field generator 230 and a fourth static magnetic field generator 240 is connected by a second connection core 274.

[0066] The first connection core 272 may connect a first core 212 of the first static magnetic field generator 210 and a second core 222 of the second static magnetic field generator 220 in a width direction of a mold 100. Here, the first connection core 272 may connect the other side of the first core 212 and the other side of the second core 222 and be spaced apart from an outer surface of a first long side plate 111 of the mold 100. The second connection core 274 may connect a third core 232 of the third static magnetic field generator 230 and a fourth core 242 of the fourth static magnetic field generator 240 in the width direction of the mold 100. Here, the second connection core 274 may connect the other side of the third core 232 and the other side of the fourth core 242 and be spaced apart from an outer surface of a second long side plate 113 of the mold 100.

[0067] As described above, when the first core 212 and the second core 222 are connected by the first connection core 272, the third core 232 and the fourth core 242 are connected by the second connection core 274, and a direct current is supplied to the third static magnetic field generator 230 and the fourth static magnetic field generator 240, a static magnetic field may be formed in each of the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240. In this case, the static magnetic field may be formed in the width direction of the mold 100 at an outside of the mold 100, and the static magnetic field may be formed along a thickness direction of the mold 100. For example, a S pole may be formed at one side of each of the first core 212 and the third core 232, and a N pole may be formed at one side of each of the second core 222 and the fourth core 242. In this case, the static magnetic field formed in each of the static magnetic field generators 210, 220, 230, and 240 has a magnetic field direction heading from the S pole to the N pole according to each of the cores 212, 222, 232, and 242 thereof. Here, the magnetic field formed around each of the cores 212, 222, 232, and 242 may have the magnetic field direction heading from the S pole to the N pole, and the magnetic field may be formed in the thickness direction of the mold 100 by the magnetic field direction of the magnetic field formed around each of the cores 212, 222, 232, and 242. The magnetic field having a magnetic field direction heading from the fourth static magnetic field generator 240 to the first static magnetic field generator 210 and the magnetic field having a magnetic field direction heading from the second static magnetic field generator 220 to the third static magnetic field generator 230 may be formed in the thickness direction of the mold 100. Also, the magnetic field may have a magnetic field intensity that gradually decreases in a direction away from each of the cores 212, 222, 232, and 242. Thus, the magnetic field may be offset between the first static magnetic field generator 210 and the fourth static magnetic field generator 240, which face each other, to form a region in which the magnetic field is not applied or the magnetic field intensity is extremely weak. This is because the one side of the first core 212 and the one side of the fourth core 242 have opposite polarities.

[0068] Also, the region in which the magnetic field is not applied or extremely weak may be also formed between the second static magnetic field generator 220 and the third static magnetic field generator 230, which face each other. This is because the one side of the second core 222 and the one side of the third core 232 have opposite polarities. Also, the region in which the magnetic field is not applied or the magnetic field intensity is extremely weak may be also formed between the first static magnetic field generator 210 and the second static magnetic field generator 220 and between the third static magnetic field generator 230 and the fourth static magnetic field generator 240. Thus, the region in which the magnetic field is not applied or the magnetic field intensity is extremely weak, i.e., the non-static magnetic field applied region, may be formed between the static magnetic fields generated from the first static magnetic field generator 210, the second static magnetic field generator 220, the third static magnetic field generator 230, and the fourth static magnetic field generator 240, e.g., the central portion in the thickness direction of the mold 100 and the central portion in the width direction of the mold 100.

[0069] In addition, the static magnetic field having the magnetic field direction heading from the first static magnetic field generator 210 to the second static magnetic field generator 220 may be formed on the first connection core 272 connecting the first core 212 and the second core 222, and the static magnetic field having the magnetic field direction heading from the third static magnetic field generator 230 to the fourth static magnetic field generator 240 may be formed on the second connection core 274. Here, the magnetic fields formed on the first connection core 272 and the second connection core 274 may have opposite magnetic field directions.

[0070] Thus, the magnetic field direction may rotate along the width direction and the thickness direction of the mold 100. Thus, a region in which the magnetic field is not applied or the magnetic field intensity is extremely weak in the width direction of the mold 100 may be formed between the static magnetic fields formed at both sides in the width direction of the mold 100. Also, a region in which the magnetic field is not applied or the magnetic field intensity is extremely weak in the thickness direction of the mold 100 may be formed between the static magnetic fields formed at both sides in the thickness direction of the mold 100. Thus, the region in which the magnetic field is not applied or the magnetic field intensity is extremely weak, i.e., the non-static magnetic field applied region, may be formed at a position at which a region contacting the magnetic field formed in the thickness direction of the mold 100 and a region contacting the magnetic field formed in the width direction of the mold 100 cross each other, e.g., a central portion of the mold 100.

[0071] FIG. 5 is a view illustrating a state of controlling a flow of a molten material by a casting method in accordance with an exemplary embodiment.

[0072] Here, (a) of FIG 5 is a view illustrating a flow state of the molten material in a mold 100 before a flow of each of a downflow and a secondary upflow is controlled by using a static magnetic field generation unit 200, (b) of FIG. 5 is a view illustrating a flow state of the molten material when a static magnetic field is applied along an entire width direction of the mold 100, and (c) of FIG. 5 is a view illustrating a flow state of the molten material when a static magnetic field applied region and a non-static magnetic field applied region are formed along the width direction of the mold 100 by using the static magnetic field generation unit 200.

[0073] A discharge flow of a molten material M discharged through a discharge hole 134 of a nozzle 130 may collide both inner surfaces of the mold 100 in the width direction of the mold 100 and then form an upflow and a downflow. In FIG. 5, a reference symbol MF may represents a mold flux, and a reference symbol MS may represent a mold slag

obtained as the mold flux is melted.

[0074] Referring to (a) of FIG. 5, it may be known that when a flow of the molten material is not controlled by using the static magnetic field generation unit 200, a movement distance, i.e., a penetration depth, of an inclusion is deep because the downflow has a relatively fast flow velocity. In this case, since the flow of the molten material is not controlled by using the static magnetic field generation unit 200, the secondary upflow may be smoothly formed. However, since the inclusion contained in the molten material moves far along a longitudinal direction of the mold 100, i.e., a drawing direction of a cast slab, by the downflow, the inclusion may not sufficiently float by the secondary upflow, and thus a large amount of inclusions are still remained.

[0075] Referring to (b) of FIG. 5, it may be known that when the magnetic field is applied along the entire width direction of the mold 100, a flow velocity of the downflow is reduced by the magnetic field, and a downward movement distance of the inclusion becomes short. Also, since the secondary upflow is not properly formed as the formation of the secondary upflow is restricted by the magnetic field, the including moving by the downflow in the longitudinal direction of the mold 100, i.e., the drawing direction of the cast slab, may not float upward and stay in the molten material.

[0076] However, referring to (c) of FIG. 5, it may be known that when the flow of the molten material is controlled by using the static magnetic field generation unit 200, the flow velocity of the downflow is reduced at both sides in the width direction of the mold 100, and the downward movement distance of the inclusion becomes short. Also, as the non-static magnetic field applied region is formed at the central portion in the width direction of the mold 100 that is the non-static magnetic field applied region, the secondary upflow may be sufficiently formed, and the inclusion contained in the molten material may smoothly float upward and be removed.

[0077] FIG. 6 is a view illustrating a flow analysis result of the secondary upflow in the mold according to whether the non-static magnetic field applied region is formed in the width direction of the mold. Here, (a) of FIG. 6 is a view illustrating a flow state of the molten material when the static magnetic field is applied to the entire width direction of the mold, and (b) of FIG. 6 is a view illustrating a flow state of the molten material when the non-static magnetic field applied region is formed at the central portion in the width direction of the mold.

[0078] Referring to (a) of FIG. 6, it may be known that when the static magnetic field is applied to the entire width direction of the mold, the secondary upflow is almost not formed. However, referring to (b) of FIG. 6, it may be known that when the non-static magnetic field applied region is formed at the central portion in the width direction of the mold, the secondary upflow is smoothly formed at the central portion in the width direction of the mold, to which the static magnetic field is not applied.

[0079] As described above, as the static magnetic field applied region and the non-static magnetic field applied region are selectively formed along the width direction of the mold, the flow of the molten material in the mold may be locally controlled to secure a clearness of the molten material. Also, the cast slab that is cast by using the above-described molten material may have an improved quality.

[0080] The casting equipment in accordance with an exemplary embodiment may include a dynamic magnetic field generation unit 300 disposed above the static magnetic field generation unit 200 at the outside of the mold 100 in order to control the flow of the molten material above the static magnetic field generation unit 200. Here, the control unit 400 may control an operation of the dynamic magnetic field generation unit 300 to adjust at least one of an intensity and a direction of a dynamic magnetic field.

[0081] A portion of the molten material discharged from the nozzle 130 may form an upflow that collides with the short side plate 120 and then moves upward. Also, the upflow horizontally moves toward the central portion in the width direction of the mold as a movement direction of the upflow is changed around a molten surface of the molten material. A flow of the molten material moving toward the central portion in the width direction of the mold, e.g., a horizontal directional flow, may collide with a flow of the molten material moving from an opposite direction thereof to form a vortex around the nozzle 130. Here, when the horizontal directional flow has an extremely fast flow velocity, a different kind of material such as the mold flux or the mold slag disposed on the molten material may be mixed with the molten material. However, when the horizontal directional flow has an extremely slow flow velocity, the molten material in the mold 100 may have an ununiform temperature. Thus, as the horizontal directional flow of the molten material around the molten surface of the molten material is controlled by using the dynamic magnetic field generation unit 300, the different kind of material such as the mold flux or the mold slag may be restricted from being mixed into the molten material, and the temperature of the molten material in the mold 100 may be uniformly controlled. The flow velocity of the horizontal directional flow of the molten material may be affected by the flow velocity of the molten material discharged through the discharge hole 134 of the nozzle 130, i.e., the flow velocity of the discharge flow. Thus, as the flow velocity of the discharge flow is controlled by using the dynamic magnetic field generation unit 300, the flow velocity of the horizontal directional flow of the molten material formed around the molten surface of the molten material may be controlled.

[0082] FIG. 7 is a cross-sectional view illustrating the casting equipment taken along line B-B' of FIG. 1.

[0083] The dynamic magnetic field generation unit 300 may be disposed above the static magnetic field generation unit 200, e.g., disposed between the molten surface of the molten material and the lower end of the nozzle 130, to control the flow of the molten material in a direction different from the static magnetic field generation unit 200. Referring to FIG.

7, the dynamic magnetic field generation unit 300 may include a plurality of dynamic magnetic field generators 310, 320, 330, and 340 spaced apart from each other in the width direction of the long side plate and a second current supplier 350 selectively supplying an alternating current to the plurality of dynamic magnetic field generators. The plurality of dynamic magnetic field generators 310, 320, 330, and 340 may include: a first dynamic magnetic field generator 310 disposed in parallel to the first static magnetic field generator 210 above the first static magnetic field generator 210; a second dynamic magnetic field generator 320 spaced apart from the first dynamic magnetic field generator 310 so that the nozzle 130 is disposed therebetween and disposed in parallel to the second static magnetic field generator 220 above the second static magnetic field generator 220; a third dynamic magnetic field generator 330 facing the second dynamic magnetic field generator 310 and disposed in parallel to the third static magnetic field generator 230 above the third static magnetic field generator 230; and a fourth dynamic magnetic field generator 340 spaced apart from the third dynamic magnetic field generator 330 so that the nozzle 130 is disposed therebetween and disposed in parallel to the fourth static magnetic field generator 240 above the fourth static magnetic field generator 240. That is, the first dynamic magnetic field generator 310 and the second dynamic magnetic field generator 320 may be disposed at the outside of the first long side plate 111 to form a dynamic magnetic field applied region and a non-dynamic magnetic field applied region in the width direction of the mold 100. Also, the third dynamic magnetic field generator 330 and the fourth dynamic magnetic field generator 340 may be disposed at the outside of the second long side plate 113 to form a dynamic magnetic field applied region and a non-dynamic magnetic field applied region in the width direction of the mold 100. Each of the first dynamic magnetic field generator 310, the second dynamic magnetic field generator 320, the third dynamic magnetic field generator 330, and the fourth dynamic magnetic field generator 340 may include a plurality of cores and a coil wound around an outside of the core. Each of the dynamic magnetic field generators 310, 320, 330, and 340 may include three, four, five, or more cores. Hereinafter, an example in which each of the dynamic magnetic field generators 310, 320, 330, and 340 includes four cores will be described.

[0084] For example, the first dynamic magnetic field generator 310 may include a first core 312a, a second core 312b, a third core 312c, and a fourth core 312d, which are arranged in parallel in the width direction of the mold 100, and a first coil 314a, a second coil 314b, a third coil 314c, and a fourth coil 314d, which are respectively wound around the cores 312a, 312b, 312c, and 312d. Also, the second current supplier 350 may be electrically connected with the first coil 314a, the second coil 314b, the third coil 314c, and the fourth coil 314d and selectively supply an alternating current to each of the coils 314a, 314b, 314c, and 314d. In this case, the second current supplier 350 may apply a cosine type current to each of the coils 314a, 314b, 314c, and 314d so that each of the coils 314a, 314b, 314c, and 314d has the S pole and the N pole at a phase difference of 0°, 90°, 180°, and 270° as shown in table 1 below.

[Table 1]

	First coil	Second coil	Third coil	Fourth coil
0°	s	-	N	-
90°	-	s	-	N
180°	N	-	s	-
270°	-	N	-	s

[0085] Referring to table 1, when an alternating current power having a phase of 0° is supplied to the first coil 314a and the third coil 314c, the first coil 314a may have the S pole, and the third coil 314c may have the N pole. Also, when an alternating current power having a phase of 90° is supplied to the second coil 314b and the fourth coil 314d, the second coil 314b may have the S pole, and the fourth coil 314d may have the N pole. When an alternating current power having a phase of 180° is supplied to the first coil 314a and the third coil 314c, the first coil 314a may have the N pole, and the third coil 314c may have the S pole. Also, when an alternating current power having a phase of 270° is supplied to the second coil 314b and the fourth coil 314d, the second coil 314b may have the N pole, and the fourth coil 314d may have the S pole. When the alternating current power is supplied to each of the coils as described above, the polarity of each of the coils is periodically changed according to the phase of the supplied alternating current. Thus, a magnetic field, i.e., a dynamic magnetic field, moving in a direction in which the coils are arranged, i.e., the width direction of the mold 100, may be formed in the first dynamic magnetic field generator 310.

[0086] The dynamic magnetic field may be formed in each of the second dynamic magnetic field generator 320, the third dynamic magnetic field generator 330, and the fourth dynamic magnetic field generator 340 in the same methods as the first dynamic magnetic field generator 310. Thus, the dynamic magnetic field applied region and the non-dynamic magnetic field applied region may be formed along the width direction of the mold 100. In FIG. 7, reference symbols 322a to 322d and 324a to 324d represent the core and coil of the second dynamic magnetic field generator 320, reference symbols 332a to 332d and 334a to 334d represent the core and coil of the third dynamic magnetic field generator 330,

and reference symbols 342a to 342d and 344a to 344d represent the core and coil of the fourth dynamic magnetic field generator 340.

[0087] The second current supplier 350 may supply an alternating current to the first dynamic magnetic field generator 310, the second dynamic magnetic field generator 320, the third dynamic magnetic field generator 330, and the fourth dynamic magnetic field generator 340 so that the magnetic field direction is formed in the width direction of the mold 100. Here, the second current supplier 350 may control the horizontal directional flow formed by the upflow by controlling the flow of the discharge flow in the mold 100. To this end, the second current supplier 350 may supply the alternating current to the first dynamic magnetic field generator 310, the second dynamic magnetic field generator 320, the third dynamic magnetic field generator 330, and the fourth dynamic magnetic field generator 340 so that the magnetic field direction is formed in the horizontal direction similar to the movement direction of the discharge flow, i.e., the width direction of the mold 100. In this case, the second current supplier 350 may supply the alternating current so that at least a portion of the dynamic magnetic field generators 310, 320, 330, and 340 form the dynamic magnetic fields in different directions. For example, the second current supplier 350 may supply the alternating current in order to form the dynamic magnetic field on the first dynamic magnetic field generator 310 and the second dynamic magnetic field generator 320, which are disposed on the outside of the first long side plate 111, in the same direction, e.g., in the third direction, and form the dynamic magnetic field on the third dynamic magnetic field generator 330 and the fourth dynamic magnetic field generator 340, which are disposed on the outside of the second long side plate 113, in the same direction, e.g., in the fourth direction. Here, the third direction and the fourth direction may be opposite to each other. Alternatively, the second current supplier 350 may supply the alternating current in order to form the dynamic magnetic field on the first dynamic magnetic field generator 310 and the fourth dynamic magnetic field generator 340, which face each other, in the same direction, e.g., in the third direction, and form the dynamic magnetic field on the second dynamic magnetic field generator 320 and the third dynamic magnetic field generator 330, which face each other, in the same direction, e.g., in the fourth direction. Here, the magnetic field direction formed by each of the first dynamic magnetic field generator 310, the second dynamic magnetic field generator 320, the third dynamic magnetic field generator 330, and the fourth dynamic magnetic field generator 340 may be changed according to the flow velocity of the discharge flow discharged from the discharge hole 134 of the nozzle 130.

[0088] FIG. 8 is a view illustrating an example of controlling the flow of the molten material by using the dynamic magnetic field generator. As illustrated in (a) of FIG. 8, when the discharge flow has an extremely fast flow velocity, a flow velocity of a horizontal directional flow around the molten surface of the molten material becomes fast. In this case, the second current supplier 350 may supply the alternating current to the first dynamic magnetic field generator 310, the second dynamic magnetic field generator 320, the third dynamic magnetic field generator 330, and the fourth dynamic magnetic field generator 340 so that the dynamic magnetic field is formed in a direction opposite to the movement direction of the discharge flow. Here, the second current supplier 350 may supply the alternating current to the first dynamic magnetic field generator 310, the second dynamic magnetic field generator 320, the third dynamic magnetic field generator 330, and the fourth dynamic magnetic field generator 340 so that the dynamic magnetic field direction is formed from the edge to the central portion of the mold 100. Thus, as the flow velocity of the discharge flow formed by being discharged from the discharge hole 134 of the nozzle 130 is reduced, the molten surface of the molten material may be stably controlled.

[0089] On the other hand, as illustrated in (b) of FIG. 8, when the discharge flow has an extremely slow flow velocity, the flow velocity of the horizontal directional flow around the molten surface of the molten material becomes slow. In this case, the second current supplier 350 may supply the alternating current to the first dynamic magnetic field generator 310, the second dynamic magnetic field generator 320, the third dynamic magnetic field generator 330, and the fourth dynamic magnetic field generator 340 so that the dynamic magnetic field is formed in the same direction as the movement direction of the discharge flow. Here, the second current supplier 350 may supply the alternating current to the first dynamic magnetic field generator 310, the second dynamic magnetic field generator 320, the third dynamic magnetic field generator 330, and the fourth dynamic magnetic field generator 340 so that the dynamic magnetic field direction is formed from the central portion to the edge of the mold 100. Accordingly, the flow velocity of the discharge flow formed by being discharged from the discharge hole 134 of the nozzle 130 may be accelerated to smoothly form the flow such as the downflow, the upflow, and the secondary upflow. Thus, the temperature of the molten material in the mold 100 may be uniformly controlled.

[0090] Also, the second current supplier 350 may supply the alternating current to the first dynamic magnetic field generator 310, the second dynamic magnetic field generator 320, the third dynamic magnetic field generator 330, and the fourth dynamic magnetic field generator 340 in order to form the dynamic magnetic field rotating in a circumferential direction of the mold 100. In case of forming the dynamic magnetic field in the circumferential direction of the mold 100, when the temperature of the molten material around the molten surface of the molten material is ununiform or decreases, the temperature of the molten material around the molten surface may be uniformly controlled by stirring the molten material. Although the method of controlling the horizontal directional flow and the discharge flow of the molten material by controlling the magnetic field direction, i.e., the dynamic magnetic field direction, is described herein, the flow of the

molten material may be controlled by changing at least one of the magnetic field direction and the magnetic field intensity as necessary. Here, the magnetic field intensity may be changed by adjusting the current amount of the alternating current supplied to each of the dynamic magnetic field generators 310, 320, 330, and 340.

[0091] As the horizontal directional flow and the discharge flow of the molten material in the mold is controlled by using the dynamic magnetic field generation unit 300 based on the above-described method, the molten surface of the molten material may be stabilized, and the different kind of material such as the mold slag or the mold flux disposed on the molten surface of the molten material may be restricted or prevented from being mixed into the molten material.

[0092] Although the exemplary embodiments of the present invention have been described, it is understood that the present invention should not be limited to these exemplary embodiments but various changes and modifications can be made by one ordinary skilled in the art within the spirit and scope of the present invention as hereinafter claimed. Hence, the real protective scope of the present invention shall be determined by the technical scope of the accompanying claims.

INDUSTRIAL APPLICABILITY

[0093] In accordance with an exemplary embodiment, as the flow of the molten material is selectively controlled in the longitudinal direction of the mold by selectively applying the static magnetic field in the width direction of the mold, the different kind of material such as the mold flux or the mold slag may be restricted from being mixed with the molten material to manufacture a high quality product. Through this, as the cleanliness of the molten material is secured, a product manufactured by using the molten material may have an improved quality.

Claims

1. A casting equipment for casting a cast slab, comprising:

a mold configured to provide an inner space for accommodating a molten material;
a nozzle disposed above the mold to supply the molten material into the mold;
a static magnetic field generation unit disposed on an outside in a width direction of the mold so that magnetic fields at both edges in the width direction of the mold are controlled in different directions; and
a control unit configured to control an operation of the static magnetic field generation unit.

2. The casting equipment of claim 1, wherein the mold comprises one pair of long side plates spaced apart from each other and one pair of short side plates configured to connect both sides of each of the one pair of long side plates, and the static magnetic field generation unit comprises:

a plurality of static magnetic field generators disposed in a width direction of the long side plate below the nozzle so as to be spaced apart from a central portion in the width direction of the mold; and
a first current supplier configured to supply a direct current to the plurality of static magnetic field generators so as to form a magnetic field passing in a thickness direction of the mold at both sides of the nozzle in the width direction of the mold.

3. The casting equipment of claim 2, wherein each of the plurality of static magnetic field generators comprises:

a core extending along a portion of the width direction of the long side plate and spaced apart from another core; and
a coil wound around an outside of the core.

4. The casting equipment of claim 3, wherein the plurality of static magnetic field generators comprise:

a first static magnetic field generator;
a second static magnetic field generator disposed at one side of the first static magnetic field generator while being spaced apart therefrom so that the nozzle is disposed therebetween;
a third static magnetic field generator disposed to face the second static magnetic field generator; and
a fourth static magnetic field generator disposed at one side of the third static magnetic field generator while being spaced apart therefrom so that the nozzle is disposed therebetween and disposed to face the first static magnetic field generator, and
the first current supplier supplies a direct current to the first static magnetic field generator, the second static magnetic field generator, the third static magnetic field generator, and the fourth static magnetic field generator

so as to form opposite polarities in directions facing each other in the thickness direction of the mold and opposite polarities in the width direction of the mold.

5 5. The casting equipment of claim 4, wherein the first static magnetic field generator and the second static magnetic field generator are spaced by a first distance from each other, and the third static magnetic field generator and the fourth static magnetic field generator are spaced by a second distance from each other, wherein the first distance is the same as the second distance.

10 6. The casting equipment of claim 5, wherein when the cast slab has an entire width of 100, each of the first distance and the second distance is in a range from 4 to 36.

15 7. The casting equipment of claim 6, wherein at least one of the first static magnetic field generator, the second static magnetic field generator, the third static magnetic field generator, and the fourth static magnetic field generator is movable along the width direction of the mold.

8. The casting equipment of claim 7, further comprising:

a first connection core configured to connect the first static magnetic field generator and the second static magnetic field generator; and

20 a second connection core configured to connect the third static magnetic field generator and the fourth static magnetic field generator.

25 9. The casting equipment of claim 8, wherein the static magnetic field generation unit forms a magnetic field that rotates in a circumferential direction of the mold.

30 10. The casting equipment of any one of claims 1 to 9, further comprising a dynamic magnetic field generation unit disposed above the static magnetic field generation unit to form a dynamic magnetic field for controlling a flow of the molten material, wherein the control unit controls an operation of the dynamic magnetic field generation unit so as to adjust at least one of an intensity and a direction of the dynamic magnetic field.

35 11. The casting equipment of claim 10, wherein the dynamic magnetic field generation unit comprises a plurality of dynamic magnetic field generators configured to form a dynamic magnetic field at both sides of the nozzle in the width direction of the mold.

40 12. The casting equipment of claim 11, wherein the dynamic magnetic field generation unit is disposed in parallel to the static magnetic field generation unit and controls the flow of the molten material in a direction different from the static magnetic field generation unit.

45 13. A casting method comprising:

injecting a molten material into a mold by using a nozzle;

forming a static magnetic field applied region and a non-static magnetic field applied region in a width direction of the mold and controlling a flow of the molten material in a longitudinal direction of the mold; and

drawing a cast slab.

50 14. The casting method of claim 13, further comprising, before the injecting of the molten material, arranging the nozzle at a central portion in the width direction of the mold, wherein the controlling of the flow of the molten material comprises forming the non-static magnetic field applied region at a central portion in the width direction of the mold and forming the static magnetic field applied region at both sides of the non-static magnetic field applied region.

55 15. The casting method of claim 14, wherein the controlling of the flow of the molten material comprises forming the static magnetic field applied region and the non-static magnetic field applied region below the nozzle.

16. The casting method of claim 15, wherein the controlling of the flow of the molten material comprises forming a magnetic field along a thickness direction of the mold, and the forming of the static magnetic field applied region comprises forming a static magnetic field so that magnetic

fields at both sides of the nozzle have opposite directions.

5 17. The casting method of claim 16, wherein the controlling of the flow of the molten material comprises forming the non-static magnetic field applied region at a portion of the central portion in the width direction of the mold, at which the nozzle is disposed.

10 18. The casting method of claim 17, wherein the controlling of the flow of the molten material comprises controlling a range of the static magnetic field applied region so that the non-static magnetic field applied region has a magnetic field of 0 Gauss to 100 Gauss.

19. The casting method of claim 18, wherein the controlling of the flow of the molten material comprises adjusting a distance between the static magnetic field applied regions according to a width of the cast slab.

15 20. The casting method of claim 19, wherein the controlling of the flow of the molten material comprises forming the static magnetic field applied region at both edges in the width direction of the mold to reduce a flow velocity of a downflow of the molten material and forming the non-static magnetic field applied region between the static magnetic field applied regions to form an upflow of the molten material.

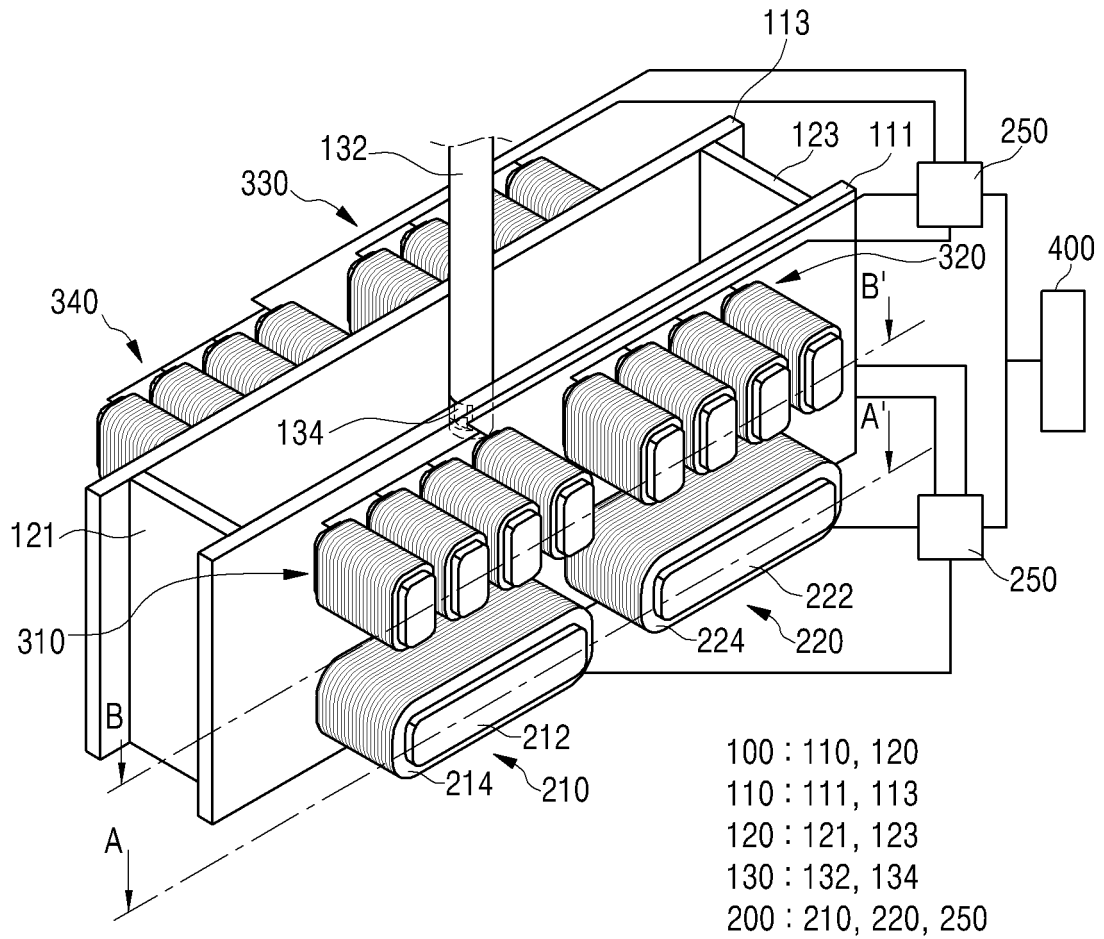
20 21. The casting method of claim 20, wherein the controlling of the flow of the molten material further comprises forming a dynamic magnetic field applied region and a non-dynamic magnetic field applied region to control the flow of the molten material in the width direction of the mold.

25 22. The casting method of claim 21, wherein the controlling of the flow of the molten material in the width direction of the mold comprises forming a dynamic magnetic field applied region and a non-dynamic magnetic field applied region between a molten surface of the molten material and a lower end of the nozzle.

23. The casting method of claim 22, wherein the forming of the dynamic magnetic field applied region comprises forming a dynamic magnetic field in the width direction of the mold at both sides of the nozzle in the width direction of the mold.

30 24. The casting method of claim 23, wherein the forming of the dynamic magnetic field applied region comprises adjusting at least one of an intensity and a direction of the dynamic magnetic field.

Fig. 1

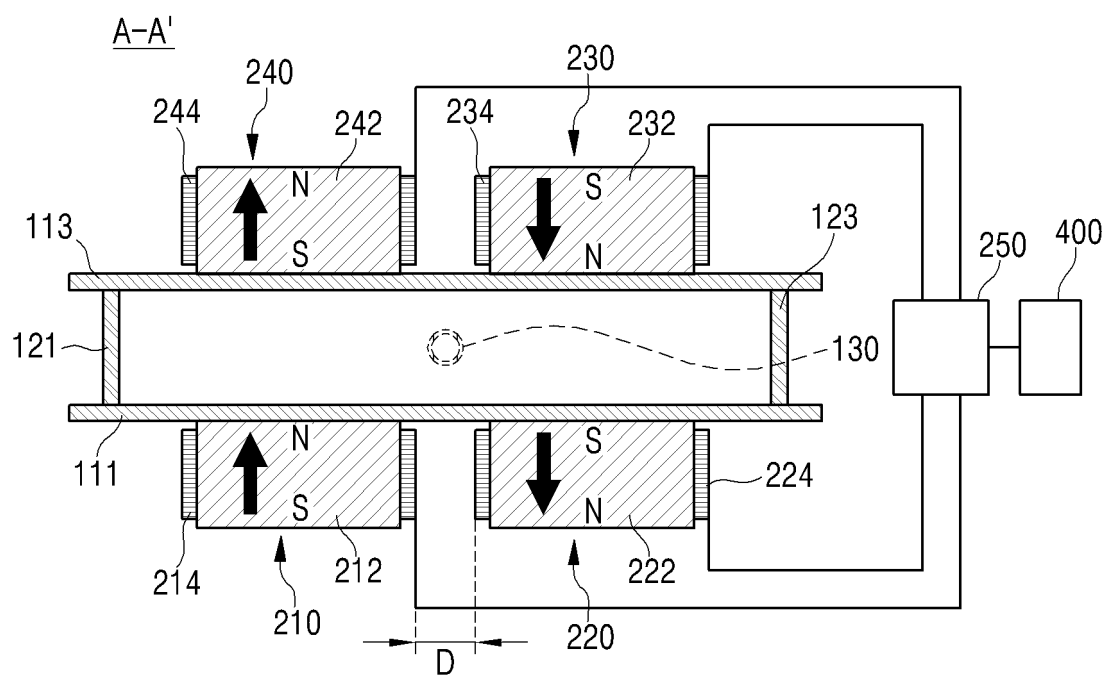


THICKNESS
DIRECTION OF
MOLD

WIDTH
DIRECTION OF
MOLD

LONGITUDINAL DIRECTION
OF MOLD
(CASTING DIRECTION)

Fig.2



- 100 : 110, 120
- 110 : 111, 113
- 120 : 121, 123
- 130 : 132, 134
- 200 : 210, 220, 230, 240, 250
- 210 : 212, 214
- 220 : 222, 224
- 230 : 232, 234
- 240 : 242, 244

Fig.3

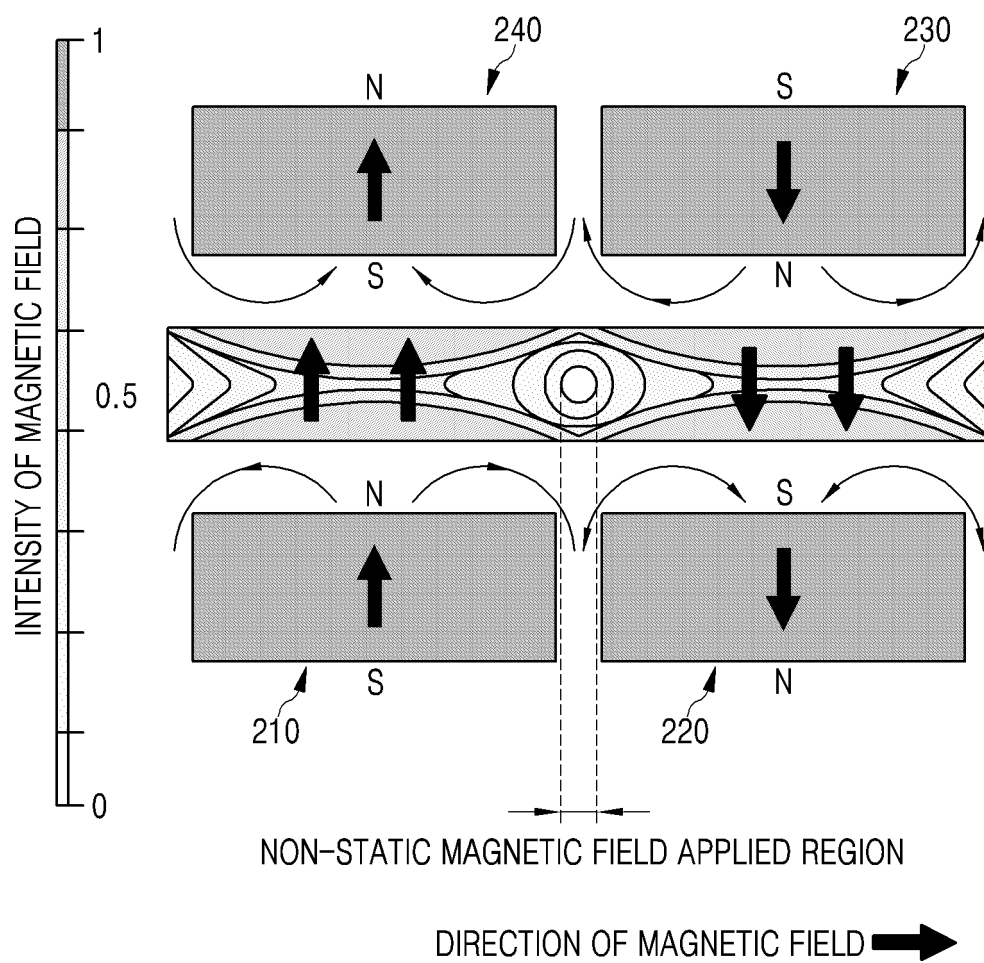
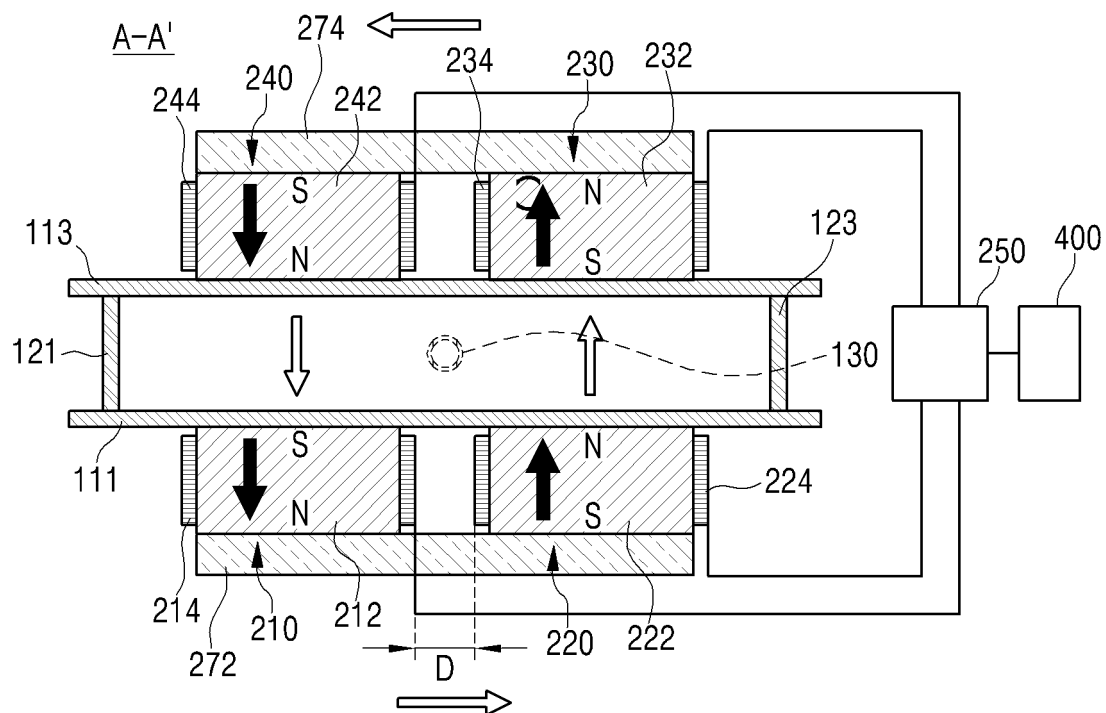


Fig.4



- 100 : 110, 120
- 110 : 111, 113
- 120 : 121, 123
- 130 : 132, 134
- 200 : 210, 220, 230, 240, 250
- 210 : 212, 214
- 220 : 222, 224
- 230 : 232, 234
- 240 : 242, 244

Fig.5

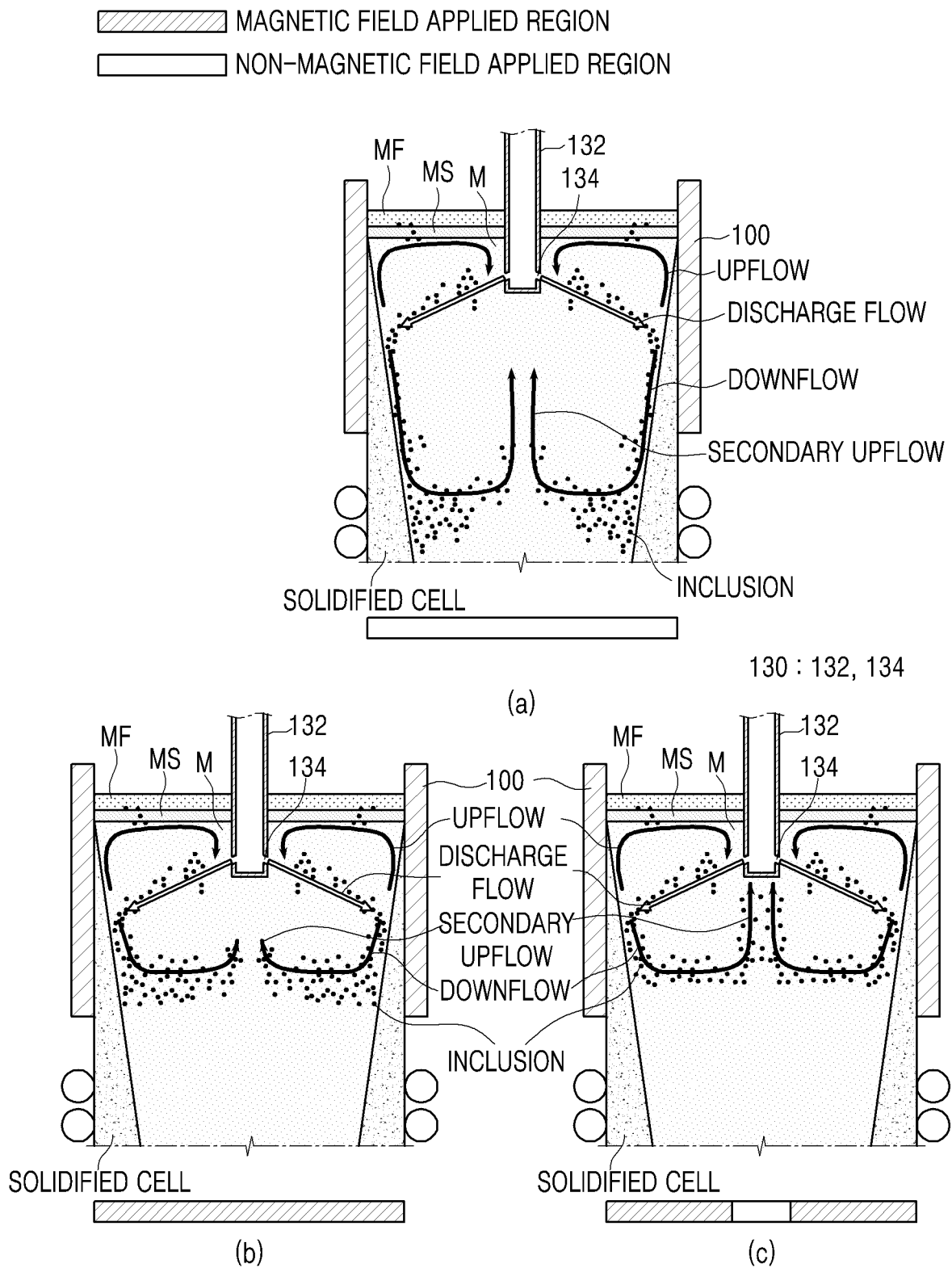


Fig.6

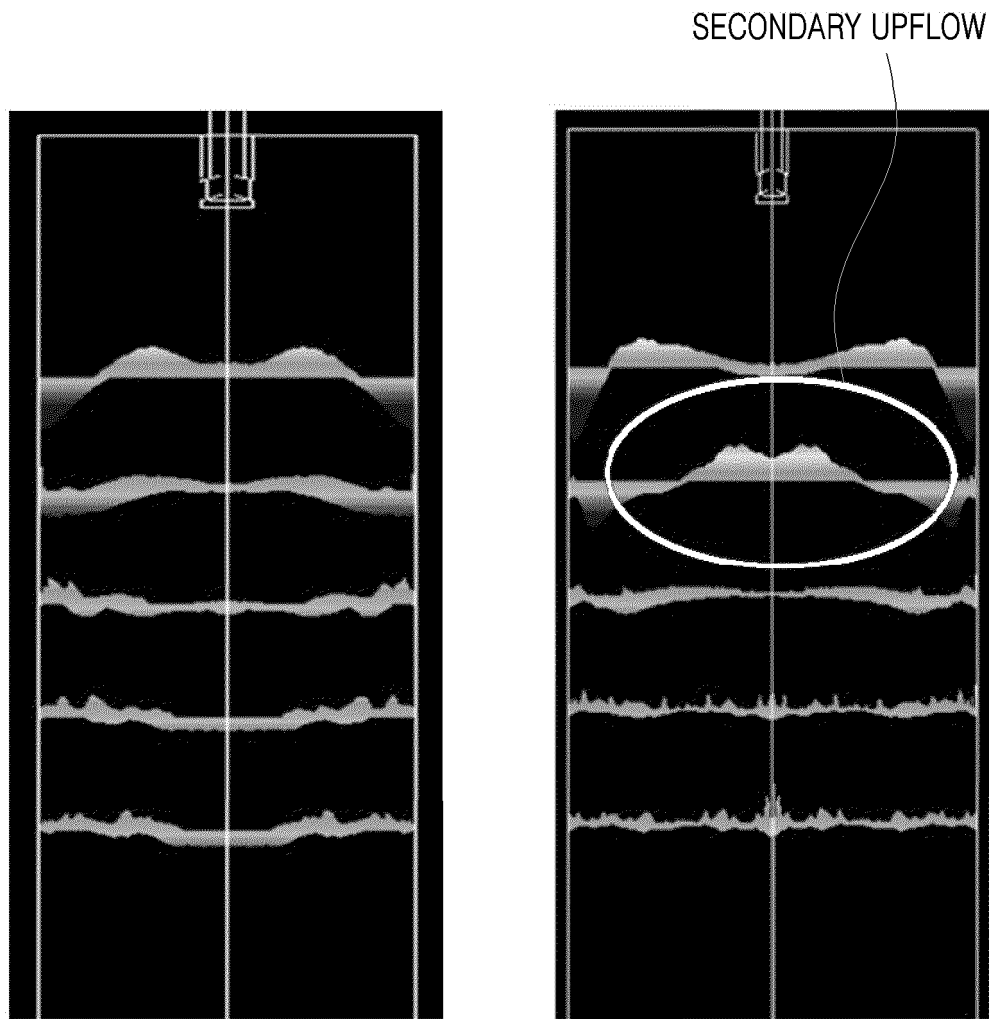
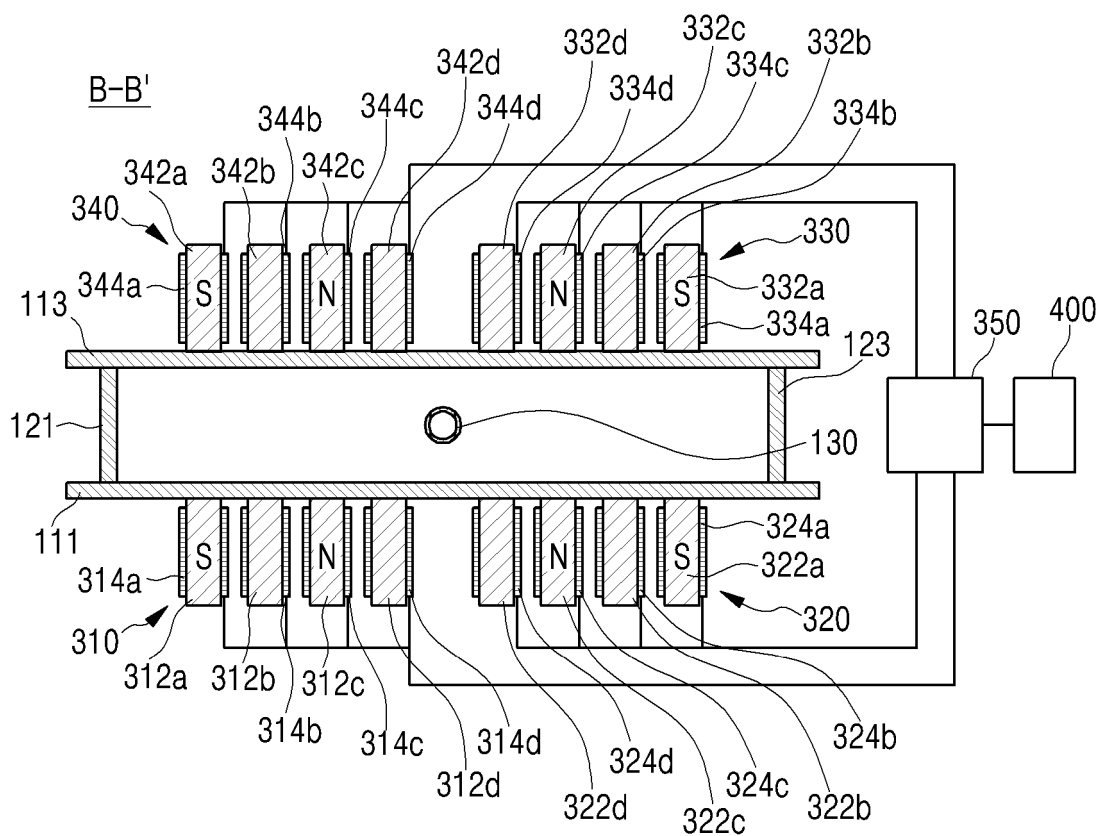
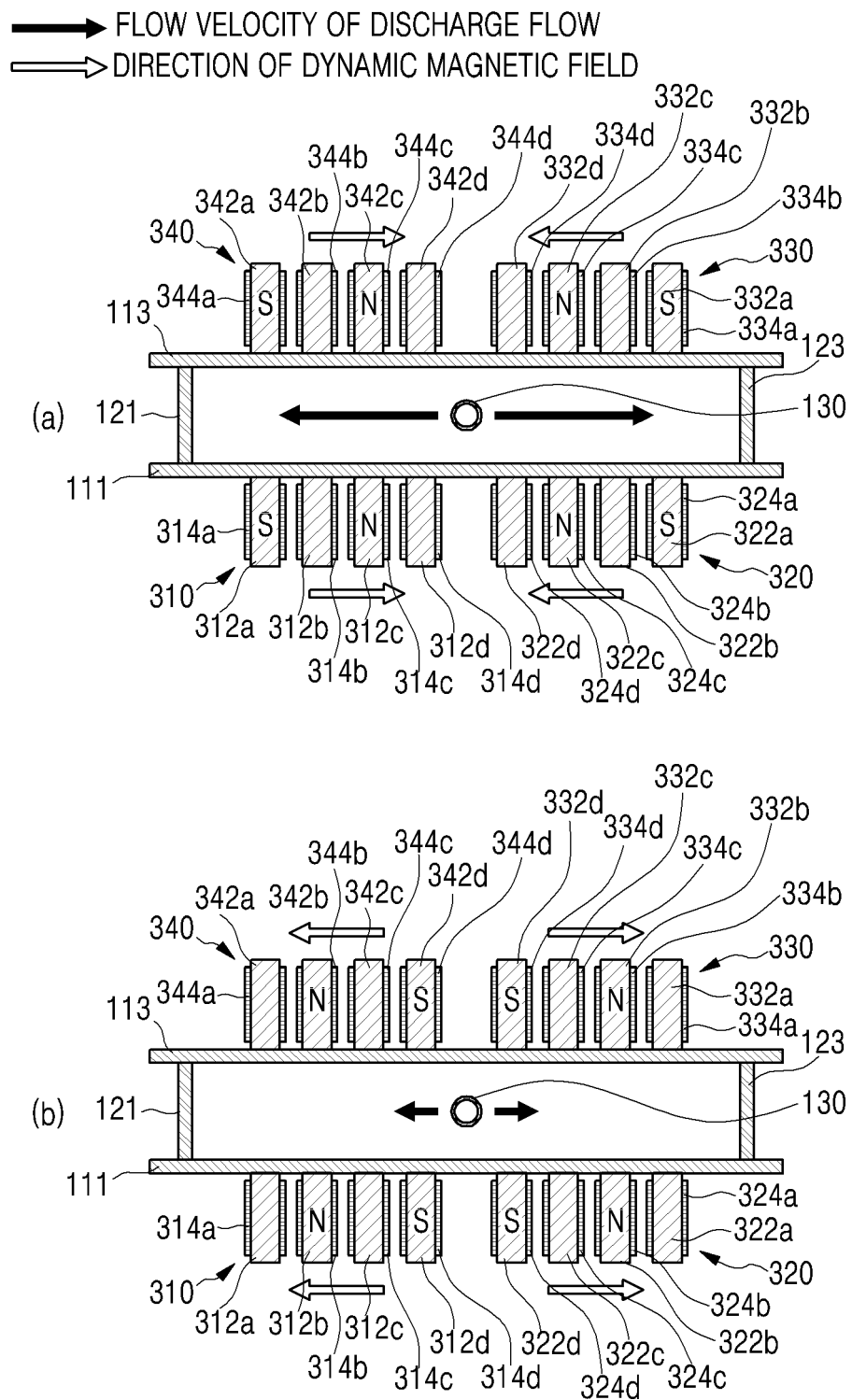


Fig.7



100 : 110, 120	110 : 111, 113
120 : 121, 123	300 : 310a, 310b, 310c, 310d
310a : 312a, 314a	310b : 312b, 314b
310c : 312c, 314c	310d : 312d, 314d
320a : 322a, 324a	320b : 322b, 324b
320c : 322c, 324c	320d : 322d, 324d
330a : 332a, 334a	330b : 332b, 334b
330c : 332c, 334c	330d : 332d, 334d
340a : 342a, 344a	340b : 342b, 344b
340c : 342c, 344c	340d : 342d, 344d

Fig.8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2020/008597

A. CLASSIFICATION OF SUBJECT MATTER B22D 11/115(2006.01)i; B22D 11/16(2006.01)i According to International Patent Classification (IPC) or to both national classification and IPC																		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) B22D 11/115; B22D 11/00; B22D 11/04; B22D 11/11; B22D 11/18; B22D 27/02; B22D 11/16 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean utility models and applications for utility models: IPC as above Japanese utility models and applications for utility models: IPC as above Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS (KIPO internal) & keywords: 자기장(magnetic field), 방향(direction), 노즐(nozzle), 몰드(mold), 유동(flow), 제어(control), 폭(width)																		
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>X</td> <td>JP 2018-144107 A (NIPPON STEEL & SUMITOMO METAL) 20 September 2018. See paragraphs [0028]-[0036] and figures 1-2 and 4.</td> <td>1-6,13-19</td> </tr> <tr> <td>Y</td> <td></td> <td>7-12,20-24</td> </tr> <tr> <td>Y</td> <td>KR 10-1143827 B1 (ROTELEC) 09 May 2012. See paragraphs [0043]-[0048] and claim 1.</td> <td>7-9</td> </tr> <tr> <td>Y</td> <td>KR 10-2002-0005949 A (KAWASAKI STEEL CORPORATION) 18 January 2002. See page 4 and figure 5.</td> <td>8-9</td> </tr> <tr> <td>Y</td> <td>JP 2008-055431 A (JFE STEEL K.K.) 13 March 2008. See paragraphs [0022]-[0026] and [0039]-[0041] and figures 4-7.</td> <td>10-12,20-24</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	JP 2018-144107 A (NIPPON STEEL & SUMITOMO METAL) 20 September 2018. See paragraphs [0028]-[0036] and figures 1-2 and 4.	1-6,13-19	Y		7-12,20-24	Y	KR 10-1143827 B1 (ROTELEC) 09 May 2012. See paragraphs [0043]-[0048] and claim 1.	7-9	Y	KR 10-2002-0005949 A (KAWASAKI STEEL CORPORATION) 18 January 2002. See page 4 and figure 5.	8-9	Y	JP 2008-055431 A (JFE STEEL K.K.) 13 March 2008. See paragraphs [0022]-[0026] and [0039]-[0041] and figures 4-7.	10-12,20-24
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.																		
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Date of the actual completion of the international search 07 October 2020	Date of mailing of the international search report 07 October 2020																	
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208 Facsimile No. +82-42-481-8578	Authorized officer Telephone No.																	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2020/008597

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
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