(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 106 246 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
21.12.2016 Bulletin 2016/51

(51) Int Cl.:
B22D 11/01 *(2006.01)* ***B22D 11/16*** *(2006.01)*

(21) Application number: **16172806.8**

(22) Date of filing: **03.06.2016**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **15.06.2015 JP 2015120515**

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(54) PULLING-UP-TYPE CONTINUOUS CASTING APPARATUS AND PULLING-UP-TYPE CONTINUOUS CASTING METHOD

(57) A pulling-up-type continuous casting apparatus according to an aspect of the present invention includes a molten-metal holding furnace that holds molten metal, a shape defining member configured to define a cross-sectional shape of a hollowed cast-metal article to be casted as held molten metal drawn from the molten-metal surface passes through the shape defining member, a cooling unit that cools the held molten metal by blowing a cooling gas on an inner peripheral surface of the hollowed cast-metal article near an solidification interface, the drawn molten metal continuously extending to the cast-metal article through the solidification interface, and a blower unit that blows air to a negative pressure area formed in a space between a flow path through which the cooling gas blown from the cooling unit flows and a top surface of the shape defining member.

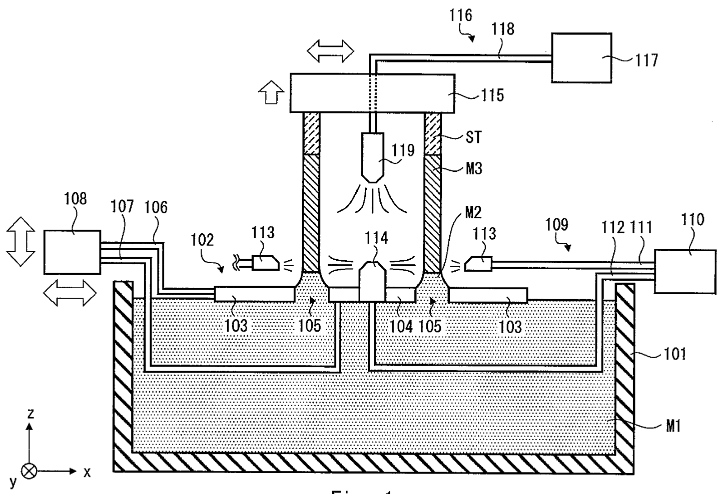

Fig. 1

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a pulling-up-type continuous casting apparatus and a pulling-up-type continuous casting method.

2. Description of Related Art

[0002] Japanese Unexamined Patent Application Publication No. H9-248657 proposes a pulling-up-type continuous casting method that does not requires any mold. As shown in Japanese Unexamined Patent Application Publication No. H9-248657, after a starter is submerged under the surface of a melted metal (molten metal) (i.e., molten-metal surface), the starter is pulled up, so that some of the molten metal follows the starter and is drawn up by the starter by the surface film of the molten metal and/or the surface tension. Note that it is possible to continuously cast a cast-metal article having a desired cross-sectional shape by drawing the molten metal and cooling the drawn molten metal through a shape defining member disposed in the vicinity of the molten-metal surface.

SUMMARY OF THE INVENTION

[0003] The present inventors have found the following problem.

[0004] There are cases in the continuous casting method disclosed in Patent Literature 1 in which a hollowed cast-metal article (hollow cast-metal article) is cast. In such cases, the solidification of molten metal drawn from the molten-metal surface can be accelerated by blowing a cooling gas on the outer peripheral surface and the inner peripheral surface of the hollow cast-metal article near the solidification interface and thereby indirectly cooling the molten metal drawn from the molten-metal surface. However, there has been a problem that when the cooling gas is blown on the inner peripheral surface of the hollow cast-metal article near the solidification interface, a negative pressure area is formed in a space between the flow path through which the blown cooling gas flows and the top surface of a shape defining member due to the effect of the airflow of the cooling gas, and the molten metal drawn from the molten-metal surface is pulled by its negative pressure and flows into the inside of the hollow cast-metal article.

[0005] The present invention has been made in view of the above-described circumstance and an object thereof is to provide a pulling-up-type continuous casting apparatus and a pulling-up-type continuous casting method capable of preventing the molten metal drawn from the molten-metal surface from flowing into the inside of the hollow cast-metal article.

[0006] A pulling-up-type continuous casting apparatus according to an aspect of the present invention includes: a holding furnace that holds molten metal; a shape defining member disposed above a molten-metal surface of the molten metal, the shape defining member being configured to define a cross-sectional shape of a hollow cast-metal article to be casted as the molten metal drawn from the molten-metal surface passes through the shape defining member; and a cooling unit that cools the molten metal drawn from the molten-metal surface by blowing a cooling gas on an inner peripheral surface of the hollow cast-metal article near an solidification interface, the drawn molten metal continuously extending to the hollow cast-metal article through the solidification interface, in which the pulling-up-type continuous casting apparatus further includes a blower unit that blows air to a negative pressure area formed in a space between a flow path through which the cooling gas blown from the cooling unit flows and a top surface of the shape defining member. In this way, since the negative pressure state of the negative pressure area is alleviated, it is possible to prevent the molten metal drawn from the molten-metal surface from flowing into the inside of the hollow cast-metal article.

[0007] An air blowing hole of the blower unit is preferably disposed above the cooling unit inside the hollow cast-metal article and blows air toward the negative pressure area located below the air blowing hole. In this way, there is no need to dispose a nozzle inside the holding furnace, thus making the setting of the blower unit easier.

[0008] The air blowing hole of the blower unit is preferably disposed in a component adjacent to the negative pressure area and opened toward the negative pressure area. In this way, air can be sent to the negative pressure area more accurately, thus alleviating the negative pressure state of the negative pressure area more reliably.

[0009] The pulling-up-type continuous casting apparatus preferably further includes a pressure sensor that measures a pressure of the negative pressure area and the blower unit preferably blows air at a flow rate according to a measurement result of the pressure sensor. In this way, it is possible to send air at a flow rate suitable for alleviating the negative pressure state of the negative pressure area, thus alleviating the negative pressure state of the negative pressure area more accurately.

[0010] A pulling-up-type continuous casting method according to an aspect of the present invention is a pulling-up-type continuous casting method for casting a hollow cast-metal article by drawing molten metal held in a holding furnace from a molten-metal surface of the molten metal and making the drawn molten metal pass through a shape defining member, the shape defining member being configured to define a cross-sectional shape of the hollow cast-metal article, the pulling-up-type continuous casting method including: a step of cooling the molten metal drawn from the molten-metal surface by blowing a cooling gas on an inner peripheral surface of the hollow cast-metal article near an solidification interface, the drawn molten metal continuously extending to the hollow cast-metal article through the solidification interface; and a step of blowing air to a negative pressure area formed in a space between a flow path through which the blown cooling gas flows and a top surface of the shape defining member. In this way, since the negative pressure state of the negative pressure area is alleviated, it is possible to prevent the molten metal drawn from the molten-metal surface from flowing into the inside of the hollow cast-metal article.

[0011] According to the present invention, it is possible to provide a pulling-up-type continuous casting apparatus and a pulling-up-type continuous casting method capable of preventing the molten metal drawn from the molten-metal surface from flowing into the inside of the hollow cast-metal article.

[0012] The above and other objects, features and advantages of the present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not to be considered as limiting the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Fig. 1 is a cross section schematically showing a free casting apparatus according to a first exemplary embodiment;
Fig. 2 is a plan view of the shape defining member shown in Fig. 1;
Fig. 3 is a diagram for explaining a problem in a free casting apparatus according to a comparative example;
Fig. 4 is a diagram for explaining the problem in the free casting apparatus according to the comparative example;
Fig. 5 is an enlarged cross section showing a part of the free casting apparatus shown in Fig. 1;
Fig. 6 is a flowchart showing a free casting method according to the first exemplary embodiment;
Fig. 7 is a graph showing a relation between a flow rate of a cooling gas and a pressure difference between the pressure of a negative pressure area and the atmospheric pressure;
Fig. 8 is a cross section schematically showing a free casting apparatus according to a second exemplary embodiment;
Fig. 9 is an enlarged cross section showing a part of a free casting apparatus according to a third exemplary embodiment;
Fig. 10 is a plan view showing the shape defining member and its periphery shown in Fig. 9;
Fig. 11 is an enlarged cross section showing a part of a modified example of the free casting apparatus shown in Fig. 9; and
Fig. 12 is a plan view showing the shape defining member and its periphery shown in Fig. 11.

DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0014] Specific exemplary embodiments to which the present invention is applied are explained hereinafter in detail with reference to the drawings. However, the present invention is not limited to exemplary embodiments shown below. Further, the following descriptions and the drawings are simplified as appropriate for clarifying the explanation.

<First exemplary embodiment>

[0015] Firstly, a free casting apparatus (pulling-up-type continuous casting apparatus) according to a first exemplary embodiment is explained with reference to Fig. 1. Fig. 1 is a cross section schematically showing a free casting apparatus according to a first exemplary embodiment. As shown in Fig. 1, the free casting apparatus according to the first exemplary embodiment includes a molten-metal holding furnace (holding furnace) 101, a shape defining member 102, support rods 106 and 107, an actuator 108, a cooling unit 109, a blower unit 116, and a pulling-up machine 115. Note that for explaining the positional relation among components, a right-hand xyz-coordinate system is shown in Fig. 1 for the sake of convenience. In Fig. 1, the xy-plane forms a horizontal plane and the z-axis direction is the vertical direction. More specifically, the positive direction on the z-axis is the vertically upward direction.

[0016] The molten-metal holding furnace 101 contains molten metal M1 such as aluminum or its alloy, and maintains the molten metal M1 at a predetermined temperature at which the molten metal M1 has fluidity. In the example shown in Fig. 1, since the molten-metal holding furnace 101 is not replenished with molten metal during the casting process, the surface of molten metal M1 (i.e., molten-metal surface) is lowered as the casting process advances. Alternatively, the molten-metal holding furnace 101 may be replenished with molten metal as required during the casting process so that the molten-metal surface is kept at a fixed level. Note that the position of the solidification interface SIF can be raised by increasing the setting temperature of the molten-metal holding furnace 101 and the solidification interface SIF can be lowered by lowering the setting temperature of the molten-metal holding furnace 101. Needless to say, the molten metal M1 may be a metal other than aluminum and an alloy thereof.

[0017] The shape defining member 102 is made of, for example, ceramic or stainless and disposed above the molten-metal surface. The shape defining member 102 is composed of an outer-shape defining member 103 and an inner-shape defining member 104. The outer-shape defining member 103 defines the outer cross-sectional shape of cast metal M3 to be cast and the inner-shape defining member 104 defines the inner cross-sectional shape of the cast metal M3 to be cast. The cast metal M3 shown in Fig. 1 is a hollow cast-metal article (i.e., pipe) having a tubular shape in a horizontal cross section (hereinafter referred to as "lateral cross section").

[0018] In the example shown in Fig. 1, the outer-shape defining member 103 and the inner-shape defining member 104 are disposed so that their bottom-side main surfaces (bottom surfaces) are in contact with the molten-metal surface. This configuration prevents oxide films formed on the surface of the molten metal M1 and foreign substances floating on the surface of the molten metal M1 from entering the cast metal M3. Alternatively, the outer-shape defining member 103 and the inner-shape defining member 104 may be disposed so that their bottom surfaces are not in contact with the molten-metal surface. Specifically, the outer-shape defining member 103 and the inner-shape defining member 104 may be disposed so that their bottom surfaces are a predetermined distance (e.g., about 0.5 mm) away from the molten-metal surface. This configuration reduces the thermal deformation and the erosion of the outer-shape defining member 103 and the inner-shape defining member 104, thus improving their durability.

[0019] Fig. 2 is a plan view of the shape defining member 102 shown in Fig. 1. Note that the cross section of the shape defining member 102 shown in Fig. 1 corresponds to a cross section taken along the line I-I in Fig. 2. In the example shown in Fig. 2, the outer-shape defining member 103 has, for example, a rectangular shape in the plan view, and has a circular opening at the center. The inner-shape defining member 104 has a circular shape in the plan view, and is disposed at the center of the opening of the outer-shape defining member 103. The gap between the outer-shape defining member 103 and the inner-shape defining member 103 serves as a molten-metal passage section 105 through which molten metal passes. Note that the xyz-coordinate system shown in Fig. 2 corresponds to that shown in Fig. 1.

[0020] Note that a nozzle head 114 of the cooling unit 109 is also shown in Fig. 2. The nozzle head 114 is disposed at the center of the inner-shape defining member 104. In the nozzle head 114, a plurality of cooling-gas blowing holes 114a that are opened toward the molten-metal passage section 105 in the plan view are provided.

[0021] The pulling-up machine 115 grasps a starter (drawing member) ST. Then, the pulling-up machine 115 submerges the starter ST into the molten metal M1 and pulls up the submerged starter ST from the molten metal M1.

[0022] As shown in Fig. 1, after the molten metal M1 adheres to the submerged starter ST, the molten metal M1 follows the starter ST and is pulled up by the starter ST while maintaining its outer shape by its surface film and/or the surface tension. Further, the molten metal M1 passes through the molten-metal passage section 105 of the shape defining member 102. As the molten metal M1 passes through the molten-metal passage section 105 of the shape defining member 102, an external force(s) is applied from the shape defining member 102 to the molten metal M1 and the cross-sectional shape of the cast metal M3 is thereby defined. Note that the molten metal that follows the starter ST (or the cast metal M3 that is formed as the molten metal M1 that follows and is pulled up by the starter ST solidifies) and is pulled up from the molten-metal surface by the surface film of the molten metal M1 and/or the surface tension is called "held molten metal M2". Further, the boundary between the cast metal M3 and the held molten metal M2 is the solidification interface SIF.

[0023] The support rods 106 and 107 support the outer-shape defining member 103 and the inner-shape defining member 104, respectively. Both of the support rods 106 and 107 are connected to the actuator 108.

[0024] The actuator 108 can move the outer-shape defining member 103 and the inner-shape defining member 104 in the up/down direction (z-axis direction) through the support rods 106 and 107, respectively. In this manner, it is possible to move the shape defining member 102 downward as the molten-metal surface is lowered due to the advance of the casting process.

[0025] The cooling unit 109 is a unit that blows a cooling gas (such as air, nitrogen, and argon) on the starter ST and/or the cast metal M3, and thereby indirectly cools the held molten metal M2. The position of the solidification interface SIF can be lowered by increasing the flow rate of the cooling gas and the position of the solidification interface SIF can be raised by reducing the flow rate of the cooling gas. Note that the cooling unit 109 can also be moved in the up/down direction (vertical direction; z-axis direction) and the horizontal direction (x-axis direction and/or y-axis direction). Therefore, for example, it is possible to move the cooling unit 109 downward in conformity with the downward movement of the shape defining member 102 as the molten-metal surface is lowered due to the advance of the casting process. Alternatively, the cooling unit 109 can be moved in a horizontal direction in conformity with the horizontal movement of the pulling-up machine 115 and/or the shape defining member 102.

[0026] More specifically, the cooling unit 109 includes a cooling gas supply section 110, nozzles 111 and 112, and nozzle heads 113 and 114. The cooling unit 109 blows out a cooling gas, which is supplied from the cooling gas supply section 110, from the nozzle heads 113 and 114 through the nozzles 111 and 112, respectively.

[0027] The nozzle head 113 is disposed outside the cast metal M3 so as to surround the outer peripheral surface of the cast metal M3. A plurality of cooling-gas blowing holes formed in the nozzle head 113 are opened toward the outer peripheral surface of the cast metal M3 near the solidification interface SIF. The nozzle head 113 blows the cooling gas blown out from the plurality of cooling-gas blowing holes onto the outer peripheral surface of the cast metal M3 near the solidification interface SIF.

[0028] The nozzle head 114 is disposed inside the cast metal M3 (at the center of the inner-shape defining member 104 in this example). A plurality of cooling-gas blowing holes 114a formed in the nozzle head 114 are opened toward the inner peripheral surface of the cast metal M3 near the solidification interface SIF. The nozzle head 114 blows the cooling gas blown out from the plurality of cooling-gas blowing holes 114a onto the inner peripheral surface of the cast metal M3 near the solidification interface SIF.

[0029] By cooling the starter ST and/or the cast metal M3 by the cooling gas while pulling up the cast metal M3 by using the pulling-up machine 115 connected to the starter ST, the held molten metal M2 located in the vicinity of the solidification interface SIF is successively solidified from its upper side (the positive side in the z-axis direction) toward its lower side (the negative side in the z-axis direction) and the cast metal M3 is formed. The position of the solidification interface SIF can be raised by increasing the pulling-up speed of the pulling-up machine 115 and the position of the solidification interface SIF can be lowered by reducing the pulling-up speed.

[0030] Further, the held molten metal M2 can be drawn in an oblique direction by pulling up the starter ST and/or the cast metal M3 while moving the pulling-up machine 115 in a horizontal direction (x-axis direction and/or y-axis direction). By doing so, the shape in the longitudinal direction of the cast metal M3 can be arbitrarily changed. Note that the shape in the longitudinal direction of the cast metal M3 may be arbitrarily changed by moving the shape defining member 102 in a horizontal direction instead of moving the pulling-up machine 115 in a horizontal direction.

[0031] The blower unit 116 is a unit that blows air to a negative pressure area X which is formed as the cooling gas is blown on the inner peripheral surface of the cast metal M3 near the solidification interface SIF. Details of the negative pressure area X are described later.

[0032] More specifically, the blower unit 116 includes a wind supply section 117, a nozzle 118, and a nozzle head 119. The blower unit 116 blows wind (air, the same type of gas as the cooling gas, or the like), which is supplied from the wind supply section 117, from the nozzle head 119 through the nozzle 118.

[0033] The nozzle head 119 is disposed so that it is suspended inside the hollowed cast metal M3 (i.e., inside the pipe) from the vicinity of the pulling-up machine 115 through the nozzle 118. A plurality of air blowing holes 119a formed in the nozzle head 119 are located above the nozzle head 114 of the cooling unit 109 and opened toward the negative pressure area X located below the air blowing holes 119a. Therefore, the plurality of air blowing holes blow air to the negative pressure area X. In the case of the above-described arrangement of the blower unit 116, there is no need to dispose a nozzle 118 inside the molten-metal holding furnace 101, thus making the setting of the blower unit 116 easier.

[0034] A problem caused by the formation of a negative pressure area X and an effect obtained by using the blower unit 116 are explained hereinafter with reference to Figs. 3 to 5.

[0035] Figs. 3 and 4 are diagrams for explaining a problem in a free casting apparatus according to a comparative example. The blower unit 116 is not provided in the free casting apparatus shown in Figs. 3 and 4. Fig. 5 is an enlarged cross section showing a part of the free casting apparatus shown in Fig. 1.

[0036] As shown in Fig. 3, the space between the flow path (indicated by black arrows in the figure) through which a cooling gas blown out from the plurality of cooling-gas blowing holes 114a formed in the nozzle head 114 flows and the top surface of the inner-shape defining member 104 is brought into a negative pressure state in which the space has a pressure value lower than the atmospheric pressure due to the effect of the airflow of the cooling gas. The space having this negative pressure state is referred to as a "negative pressure area X".

[0037] As shown in Fig. 4, when the blower unit 116 is not provided, there are cases in which the held molten metal M2 adjacent to the negative pressure area X is pulled by its negative pressure and flows into the inside of the hollowed cast metal M3. To avoid this, it is necessary to reduce the flow rate of the cooling gas to prevent or suppress the formation of the negative pressure area X. However, if the flow rate of the cooling gas is reduced, a longer time is required to solidify the held molten metal M2 and hence the productivity of the cast metal M3 deteriorates.

[0038] In contrast to this, in the case where the blower unit 116 is provided, air is blown from the blower unit 116 to the negative pressure area X and hence the negative pressure state of the negative pressure area X is alleviated as shown in Fig. 5. That is, the pressure difference between the negative pressure area X and the atmospheric pressure is reduced. Therefore, it is possible to prevent the held molten metal M2 from flowing into the inside of the hollowed cast metal M3 without reducing the flow rate of the cooling gas.

[0039] Next, a free casting method according to the first exemplary embodiment is explained with reference to Figs. 1 and 6. Fig. 6 is a flowchart showing a free casting method according to the first exemplary embodiment.

[0040] Firstly, the starter ST is lowered by the pulling-up machine 115 and made to pass through the molten-metal passage section 105 located between the outer-shape defining member 103 and the inner-shape defining member 104, and the tip (the bottom) of the starter ST is submerged into the molten metal M1 (step S101).

[0041] Next, the starter ST starts to be pulled up at a predetermined speed. Note that even when the starter ST is pulled away from the molten-metal surface, the molten metal M1 follows the starter ST and is pulled up (drawn) from the molten-metal surface by the surface film and/or the surface tension. Further, the pulled-up molten metal M1 forms held molten metal M2. As shown in Fig. 1, the held molten metal M2 is formed in the molten-metal passage section 105 of the shape defining member 102. That is, the held molten metal M2 is shaped into a given shape by the shape defining member 102 (step S102).

[0042] Next, the starter ST and/or the cast metal M3 are cooled by a cooling gas blown from the cooling unit 109 (step S103). As a result, the held molten metal M2 is indirectly cooled and successively solidifies from its upper side toward its lower side and hence the cast metal M3 grows (step S104). In this manner, it is possible to continuously cast the cast metal M3.

[0043] It should be noted that a negative pressure area X is formed in the space between the flow path through which the cooling gas blown out from the plurality of cooling-gas blowing holes 114a formed in the nozzle head 114 flows and the top surface of the inner-shape defining member 104 due to the effect of the airflow of the cooling gas. Therefore, air is blown from the blower unit 116 to the negative pressure area X (step S103). As a result, the negative pressure state of the negative pressure area X is alleviated. That is, the pressure difference between the negative pressure area X and the atmospheric pressure is reduced. In this way, it is possible to prevent the held molten metal M2 from flowing into the inside of the hollowed cast metal M3.

[0044] Fig. 7 is a graph showing a relation between the flow rate of the cooling gas and the pressure difference between the pressure of the negative pressure area X and the atmospheric pressure. As shown in Fig. 7, when the flow rate of the cooling gas is zero, no negative pressure area X is formed (the pressure difference is zero). Further, the negative pressure of the negative pressure area X increases (the pressure difference between the pressure of the negative pressure area X and the atmospheric pressure increases) as the flow rate of the cooling gas increases. Further, in the case where the flow rate of the cooling gas is fixed, the flow speed of the cooling gas increases as the size of the cooling-gas blowing holes 114a decreases. Therefore, the negative pressure of the negative pressure area X increases as the size of the cooling-gas blowing holes 114a decreases. Note that the blower unit 116 may, for example, estimate the pressure of the negative pressure area X based on the information shown in Fig. 7 and adjust the volume of air based on the estimated pressure of the negative pressure area X.

[0045] As described above, the free casting apparatus according to this exemplary embodiment includes the blower unit 116 that blows air to the negative pressure area X which is formed due to the effect of the cooling gas blown on the inner peripheral surface of the hollowed cast metal M3. As a result, the free casting apparatus according to this exemplary embodiment can alleviate the negative pressure state of the negative pressure area X and thereby prevent the held molten metal M2 from flowing into the inside of the hollowed cast metal M3.

<Second exemplary embodiment>

[0046] Fig. 8 is a cross section schematically showing a free casting apparatus according to a second exemplary embodiment. Compared to the free casting apparatus shown in Fig. 1, the free casting apparatus shown in Fig. 8 further includes a feedback function by which the blower unit 116 blows air in a volume according to the pressure of the negative pressure area X. Note that the xyz-coordinate system shown in Fig. 8 corresponds to that shown in Fig. 1.

[0047] Specifically, the free casting apparatus shown in Fig. 8 further includes a pressure sensor 120 disposed inside the negative pressure area X. The pressure sensor 120 measures the pressure of the negative pressure area X. Then, the blower unit 116 blows air to the negative pressure area X in a volume according to the measurement result of the pressure sensor 120. For example, when the pressure difference between the pressure of the negative pressure area X and the atmospheric pressure is small, the blower unit 116 decreases the volume of air. Further, when the pressure difference between the pressure of the negative pressure area X and the atmospheric pressure is large, the blower unit 116 increases the volume of air.

[0048] In this way, the free casting apparatus according to this exemplary embodiment can send air to the negative pressure area X at a flow rate suitable for alleviating the negative pressure state of the negative pressure area X, thus making it possible to alleviate the negative pressure state of the negative pressure area X more accurately.

<Third exemplary embodiment>

[0049] Fig. 9 is an enlarged cross section showing a part of a free casting apparatus according to a third exemplary embodiment. Fig. 10 is a plan view showing the shape defining member 102 and its periphery shown in Fig. 9. Note that the xyz-coordinate systems shown in Figs. 9 and 10 correspond to that shown in Fig. 1.

[0050] Compared to the free casting apparatus shown in Fig. 1, the position of the nozzle head (and its air blowing holes) provided in the blower unit 116 of the free casting apparatus shown in Fig. 9 differs from that of the free casting apparatus shown in Fig. 1.

[0051] The free casting apparatus shown in Fig. 9 includes, as the blower unit 116, a wind supply section 117, a nozzle 121, and a plurality of nozzle heads 122. A part of the nozzle 121 is disposed in the molten metal M1. The nozzle 121 disposed in the molten metal M1 extends from the bottom surface of the inner-shape defining member 104 to the top surface of the inner-shape defining member 104 through the inside thereof, and connects to the plurality of nozzle heads 122. As shown in Fig. 10, the plurality of nozzle heads 122 are disposed on the top surface of the inner-shape defining member 104, which is one of the components adjacent to the negative pressure area X, so as to surround the nozzle head 114 of the cooling unit 109. Further, a plurality of air blowing holes 122a formed in the respective nozzle heads 122 are opened toward the negative pressure area X.

[0052] The rest of the configuration of the free casting apparatus shown in Fig. 9 is similar to that of the free casting apparatus shown in Fig. 1 and therefore its explanation is omitted.

[0053] By the above-described feature, the free casting apparatus according to this exemplary embodiment can send wind to the negative pressure area X more accurately and thereby alleviate the negative pressure state of the negative pressure area X more reliably.

(Modified example of free casting apparatus shown in Fig. 9)

[0054] Fig. 11 is an enlarged cross section showing a part of a modified example of the free casting apparatus shown in Fig. 9. Fig. 12 is a plan view showing the shape defining member 102 and its periphery shown in Fig. 11. Note that the xyz-coordinate systems shown in Figs. 11 I and 12 correspond to that shown in Fig. 1.

[0055] Compared to the free casting apparatus shown in Fig. 9, the position of the nozzle head (and its air blowing holes) provided in the blower unit 116 of the free casting apparatus shown in Fig. 11 differs from that of the free casting apparatus shown in Fig. 9.

[0056] The free casting apparatus shown in Fig. 11 includes, as the blower unit 116, a wind supply section 117, a nozzle 123, and a nozzle head 124. A part of the nozzle 123 is disposed in the molten metal M1. The nozzle 123 disposed in the molten metal M1 extends from the bottom surface of the inner-shape defining member 104 to the top surface of the inner-shape defining member 104 through the inside thereof, and connects to the nozzle head 124. Note that the nozzle head 124 of the blower unit 116 uses a cylindrical member that is also used to form the nozzle head 114 of the cooling unit 109. As shown in Figs. 11 and 12, a plurality of air blowing holes 124a are formed on the side of the cylindrical member, which is used to form the nozzle heads 114 and 124 and is one of the components adjacent to the negative pressure area X, and opened toward the negative pressure area X.

[0057] The rest of the configuration of the free casting apparatus shown in Fig. 11 is similar to that of the free casting apparatus shown in Fig. 9 and therefore its explanation is omitted.

[0058] By the above-described feature, the free casting apparatus according to this exemplary embodiment can send wind to the negative pressure area X more accurately and thereby alleviate the negative pressure state of the negative pressure area X more reliably.

[0059] As described above, each of the free casting apparatuses according to the first to third exemplary embodiments includes the blower unit 116 that blows air to the negative pressure area X which is formed due to the effect of the cooling gas blown on the inner peripheral surface of the hollowed cast metal M3. As a result, the free casting apparatuses according to the first to third exemplary embodiments can alleviate the negative pressure state of the negative pressure area X and thereby prevent the held molten metal M2 from flowing into the inside of the hollowed cast metal M3.

[0060] Although the above-described exemplary embodiments are explained by using examples where a cylindrical cast-metal article is cast, the present invention is not limited to such examples. The present invention can also be applied to cases where other types of hollowed cast-metal articles such as a square tubular-shaped cast-metal article are cast.

[0061] Note that the present invention is not limited to the above-described exemplary embodiments, and various modifications can be made without departing the spirit and scope of the present invention.

[0062] From the invention thus described, it will be obvious that the embodiments of the invention may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended for inclusion within the scope of the following claims. A pulling-up-type continuous casting apparatus according to an aspect of the present invention includes a molten-metal holding furnace that holds molten metal, a shape defining member configured to define a cross-sectional shape of a hollowed cast-metal article to be casted as held molten metal drawn from the molten-metal surface passes through the shape defining member, a cooling unit that cools the held molten metal by blowing a cooling gas on an inner peripheral surface of the hollowed cast-metal article near an solidification interface, the drawn molten metal continuously extending to the cast-metal article through the solidification interface, and a blower unit that blows air to a negative pressure area formed in a space between a flow path through which the cooling gas blown from the cooling unit flows and a top surface of the shape defining member.

Claims

1. A pulling-up-type continuous casting apparatus comprising:

   a holding furnace (101) that holds molten metal (M1);
   a shape defining member (102) disposed above a molten-metal surface of the molten metal (M1), the shape defining member (102) being configured to define a cross-sectional shape of a hollow cast-metal article (M3) to be casted as the molten metal (M2) drawn from the molten-metal surface passes through the shape defining member (102); and
   a cooling unit (109) that cools the molten metal (M2) drawn from the molten-metal surface by blowing a cooling gas on an inner peripheral surface of the hollow cast-metal article (M3) near an solidification interface, the drawn molten met-

al (M2) continuously extending to the hollow cast-metal article (M3) through the solidification interface, wherein

the pulling-up-type continuous casting apparatus further comprises a blower unit (116) that blows air to a negative pressure area formed in a space between a flow path through which the cooling gas blown from the cooling unit (109) flows and a top surface of the shape defining member (102).

2. The pulling-up-type continuous casting apparatus according to Claim 1, wherein an air blowing hole (119a) of the blower unit (116) is disposed above the cooling unit (109) inside the hollow cast-metal article (M3) and blows air toward the negative pressure area located below the air blowing hole (119a).

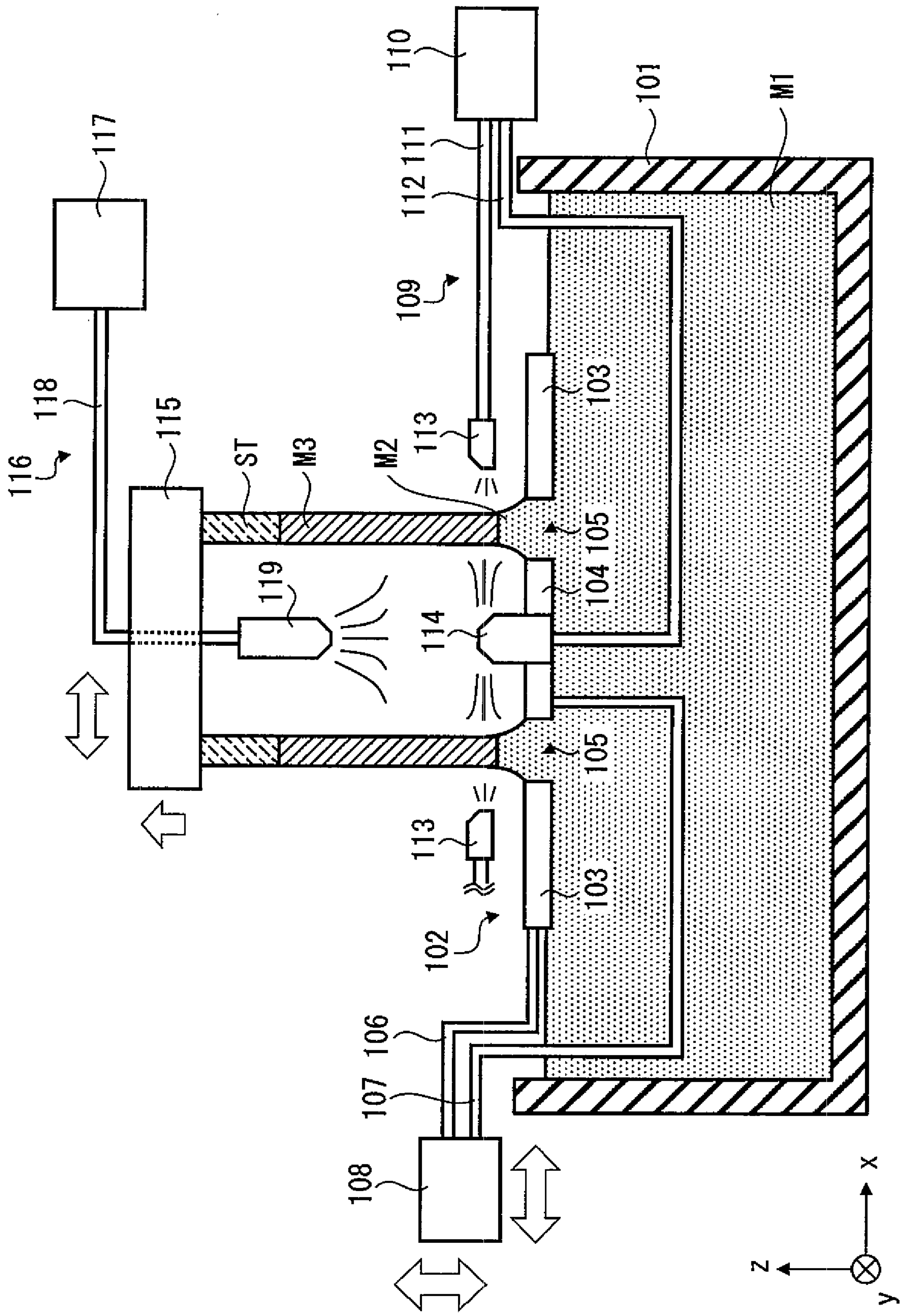
3. The pulling-up-type continuous casting apparatus according to Claim 1 or 2, wherein the air blowing hole (119a) of the blower unit (116) is disposed in a component adjacent to the negative pressure area and opened toward the negative pressure area.

4. The pulling-up-type continuous casting apparatus according to any one of Claims 1 to 3, further comprising a pressure sensor (120) that measures a pressure of the negative pressure area, wherein
the blower unit (116) blows air at a flow rate according to a measurement result of the pressure sensor (120).

5. A pulling-up-type continuous casting method for casting a hollow cast-metal article (M3) by drawing molten metal (M1) held in a holding furnace (101) from a molten-metal surface of the molten metal (M1) and making the drawn molten metal (M2) pass through a shape defining member (102), the shape defining member (102) being configured to define a cross-sectional shape of the hollow cast-metal article (M3), the pulling-up-type continuous casting method comprising:

a step of cooling the molten metal (M2) drawn from the molten-metal surface by blowing a cooling gas on an inner peripheral surface of the hollow cast-metal article (M3) near an solidification interface, the drawn molten metal (M2) continuously extending to the hollow cast-metal article (M3) through the solidification interface; and

a step of blowing air to a negative pressure area formed in a space between a flow path through which the blown cooling gas flows and a top surface of the shape defining member (102).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101
M1
111
112
109
117
118
116
115
ST
M3
M2
113
103
104
105
119
114
102
106
107
108
x
z
y

Fig. 1

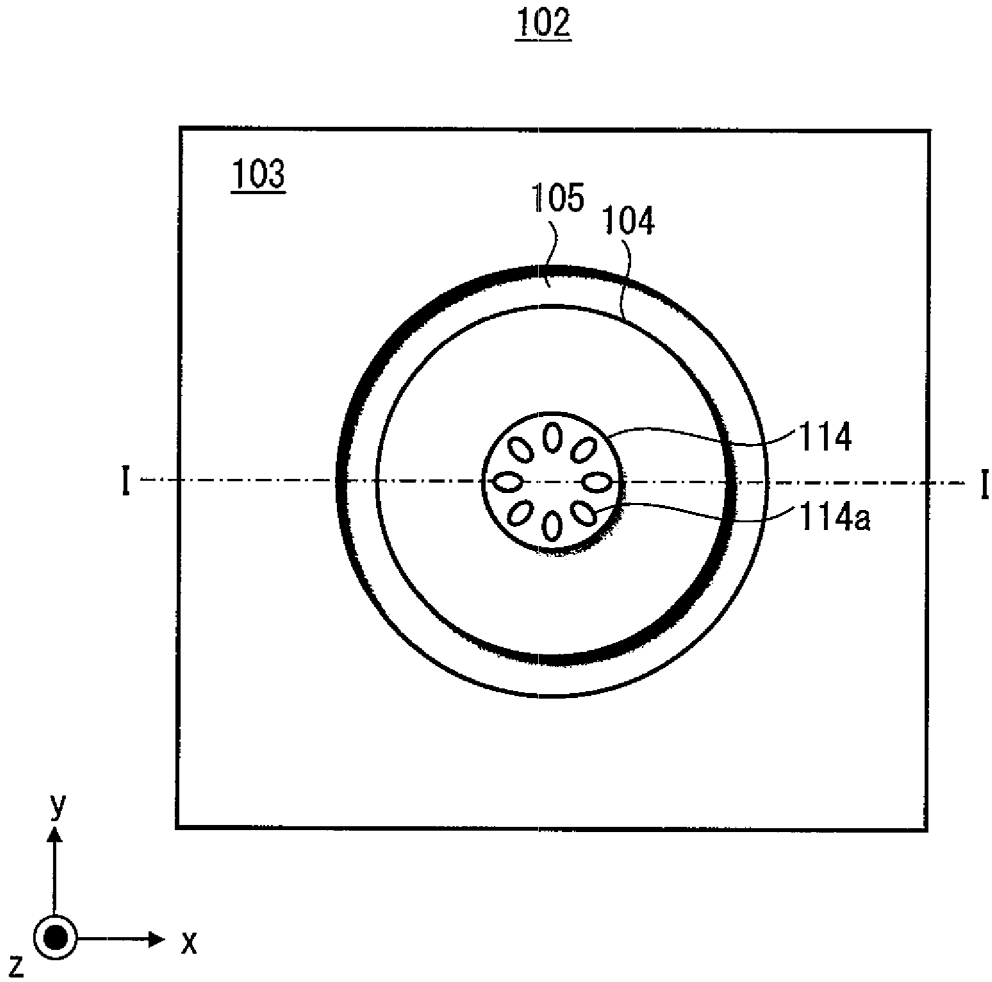
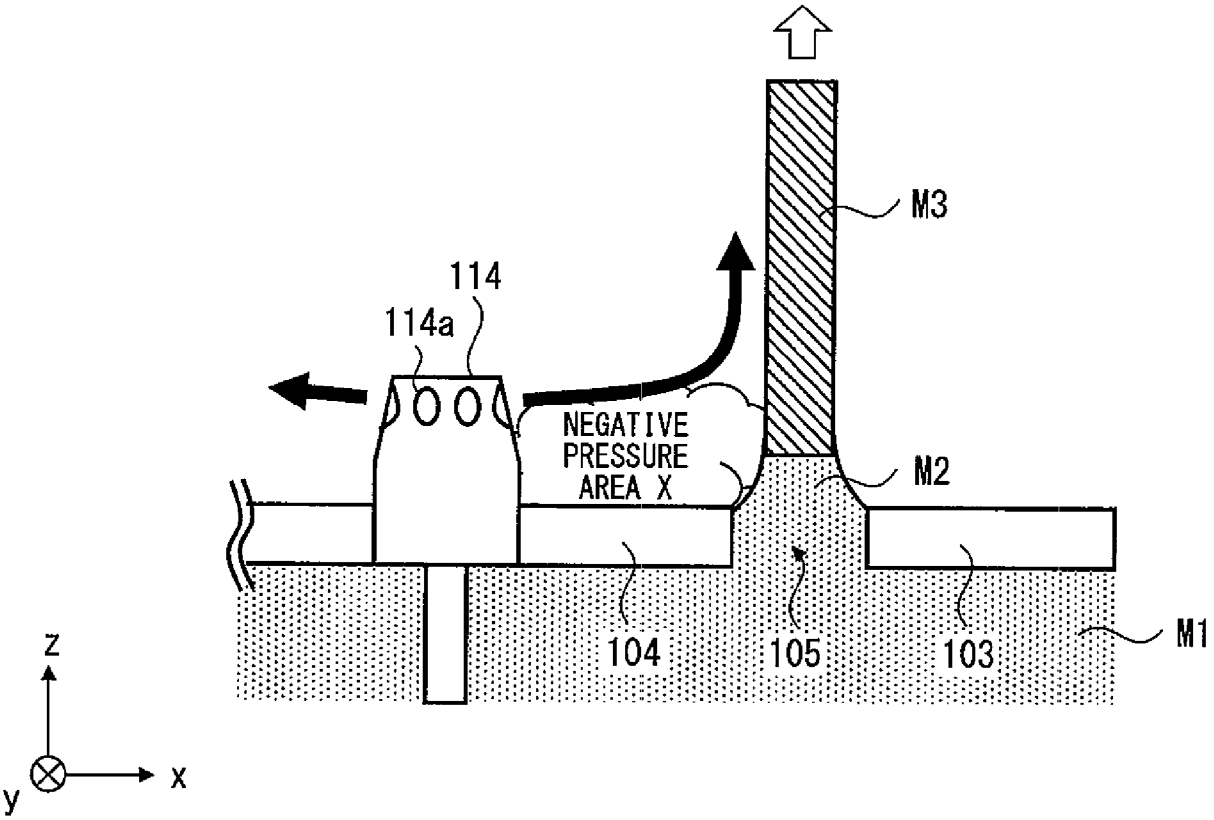


Fig. 2



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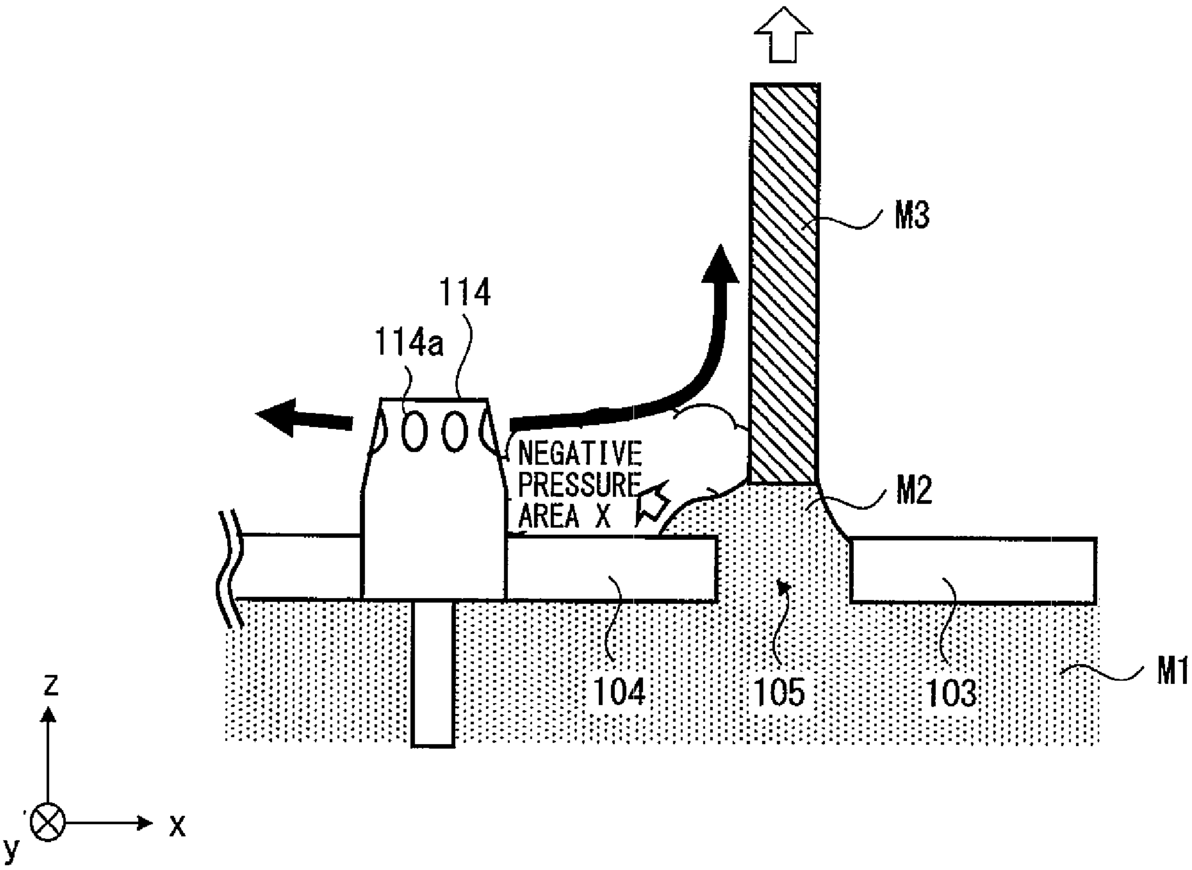

Fig. 4

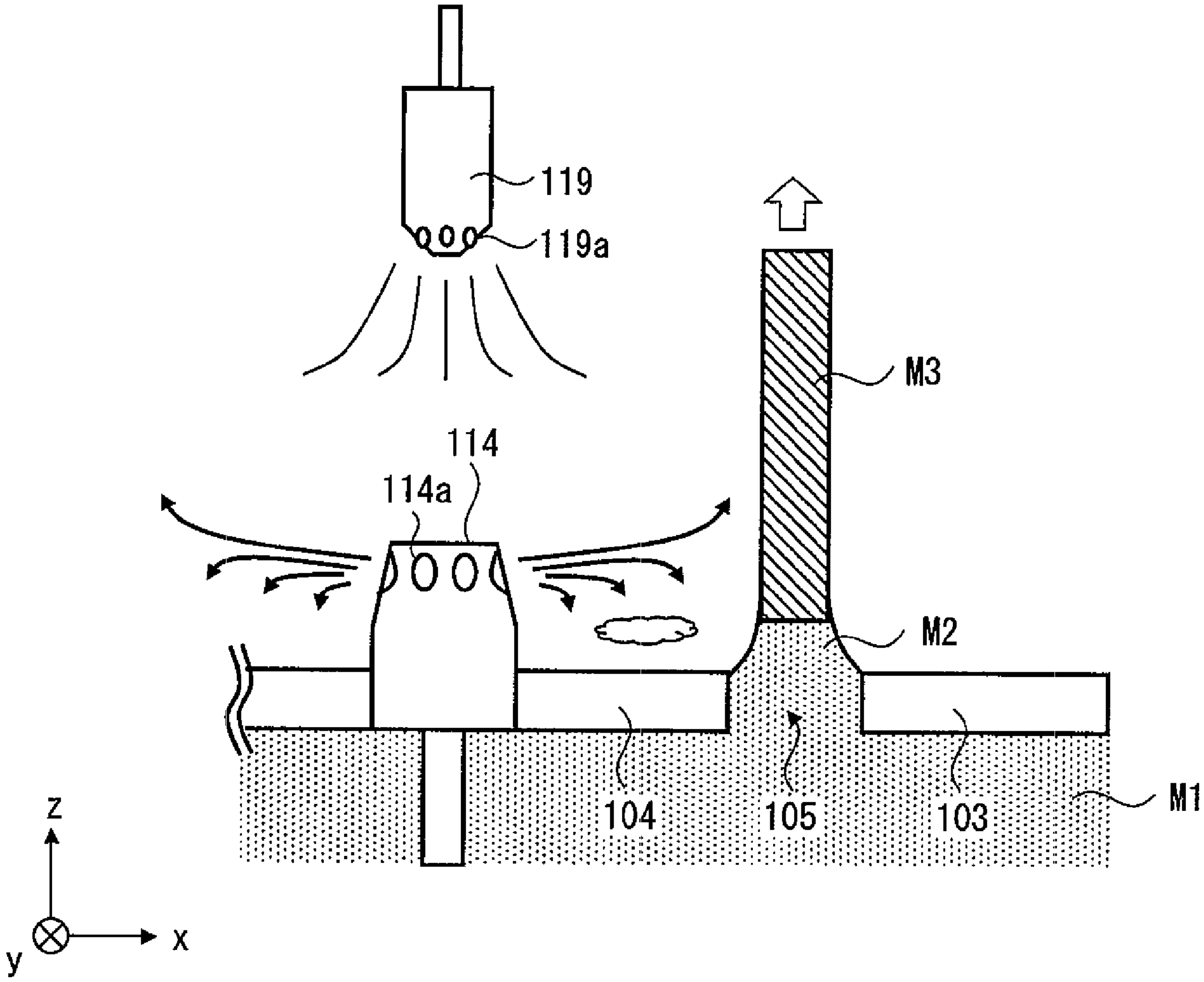

Fig. 5

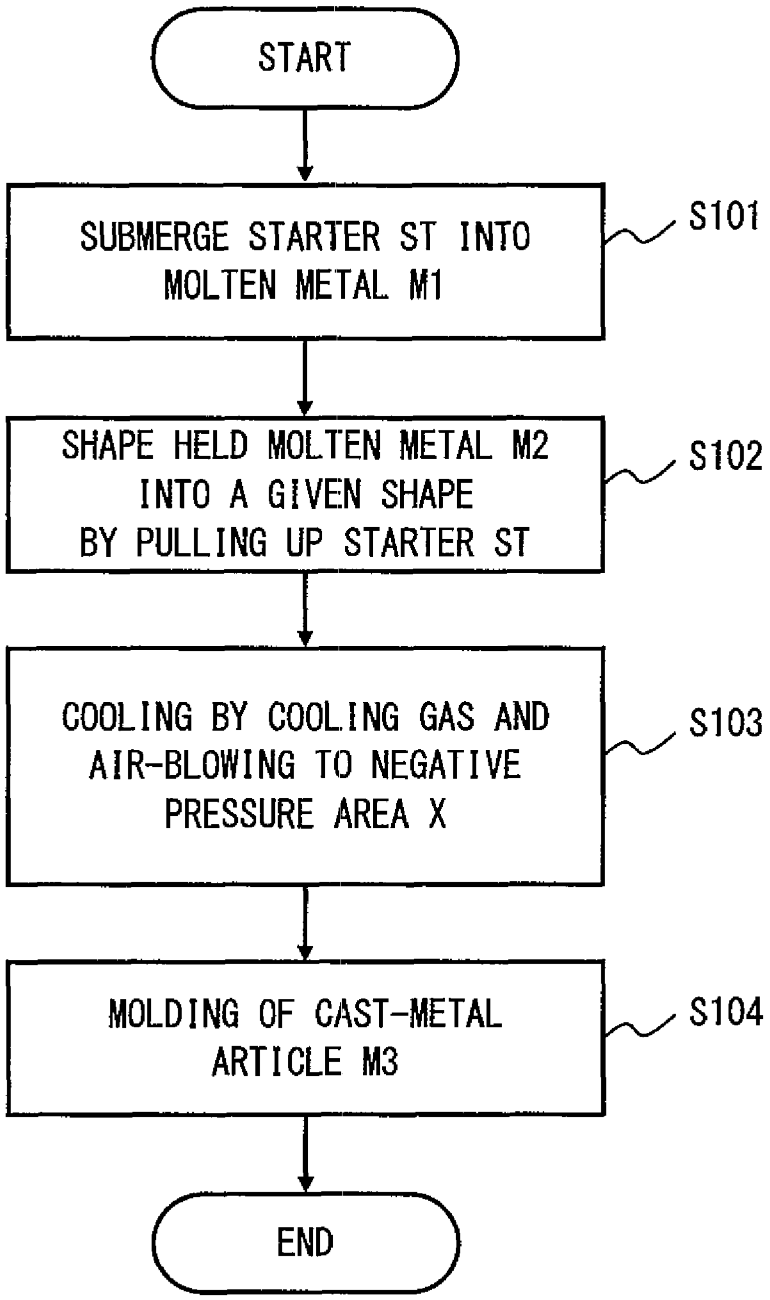
START
SUBMERGE STARTER ST INTO MOLTEN METAL M1
S101
SHAPE HELD MOLTEN METAL M2 INTO A GIVEN SHAPE BY PULLING UP STARTER ST
S102
COOLING BY COOLING GAS AND AIR-BLOWING TO NEGATIVE PRESSURE AREA X
S103
MOLDING OF CAST-METAL ARTICLE M3
S104
END

Fig. 6

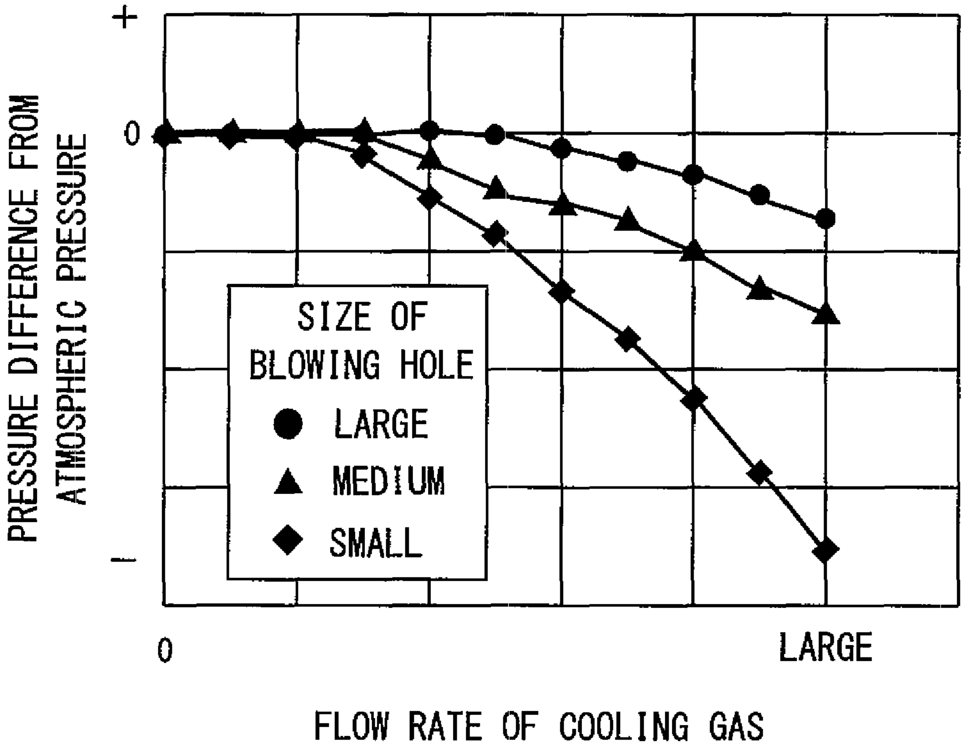
+
0
−
PRESSURE DIFFERENCE FROM
ATMOSPHERIC PRESSURE
SIZE OF
BLOWING HOLE
LARGE
MEDIUM
SMALL
0
LARGE
FLOW RATE OF COOLING GAS

Fig. 7

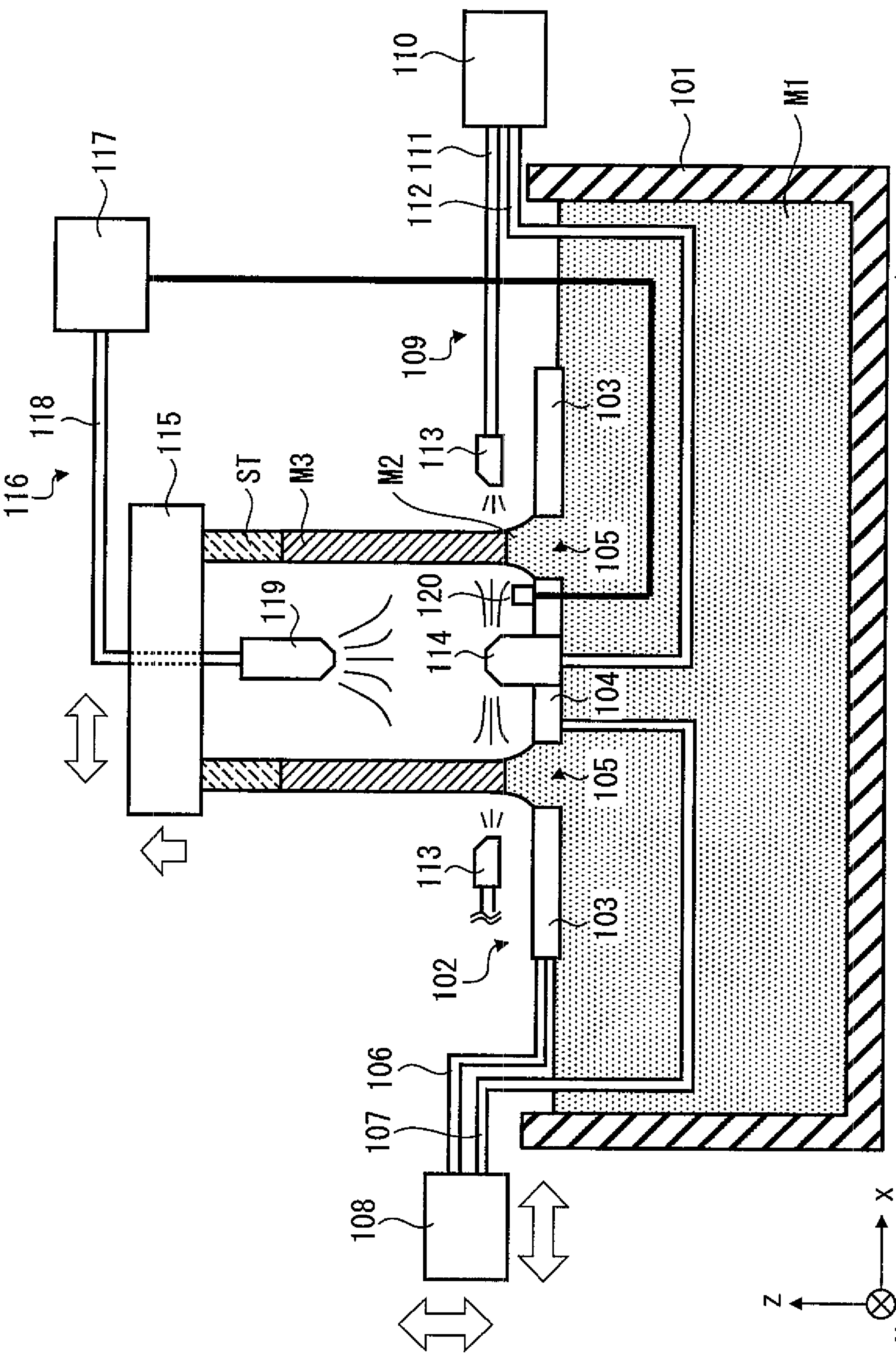
110
101
M1
117
112
111
109
118
116
115
ST
M3
M2
113
103
105
119
120
114
104
105
113
103
102
106
107
108
x
z
y

Fig. 8

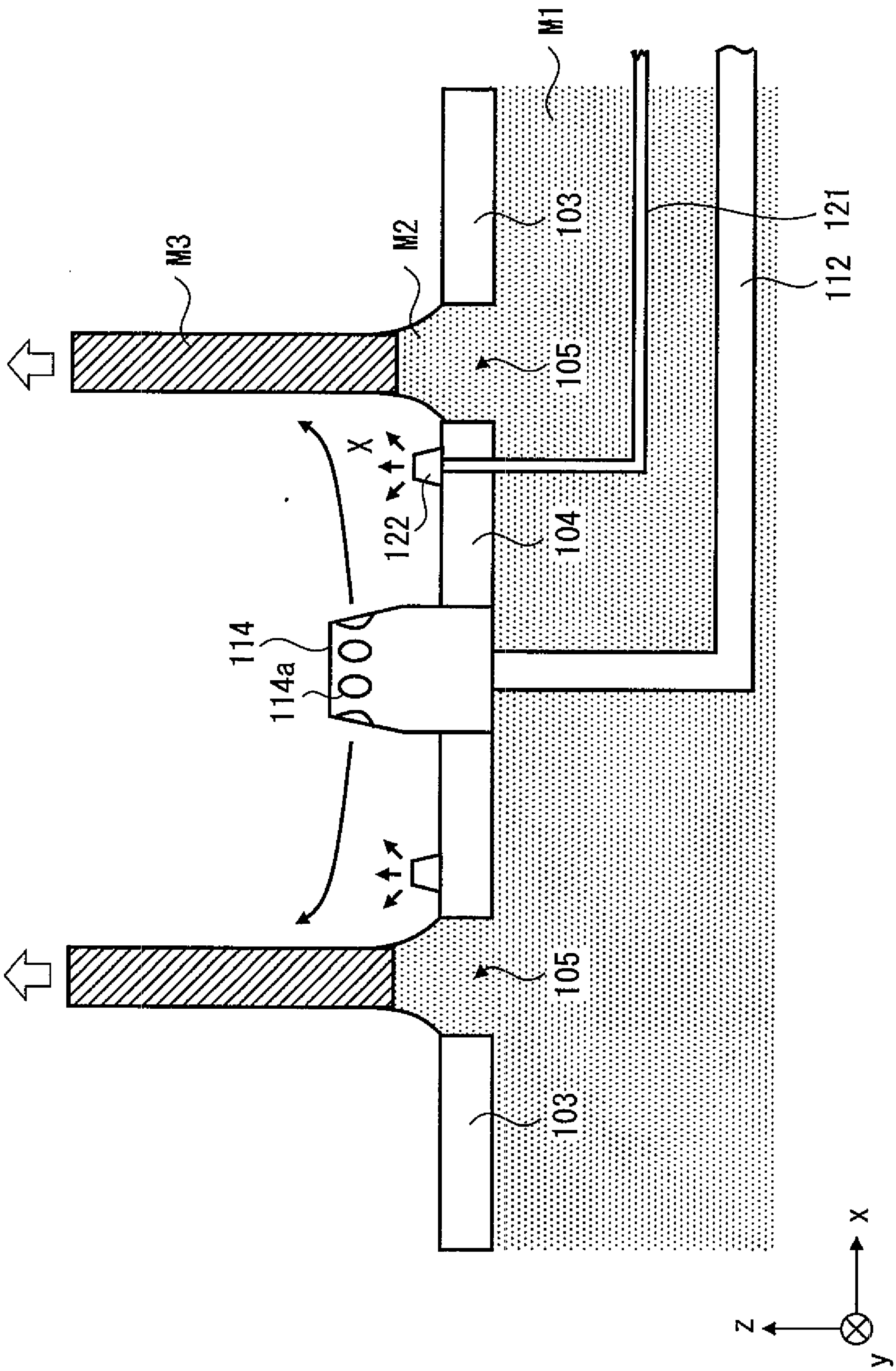

Fig. 9

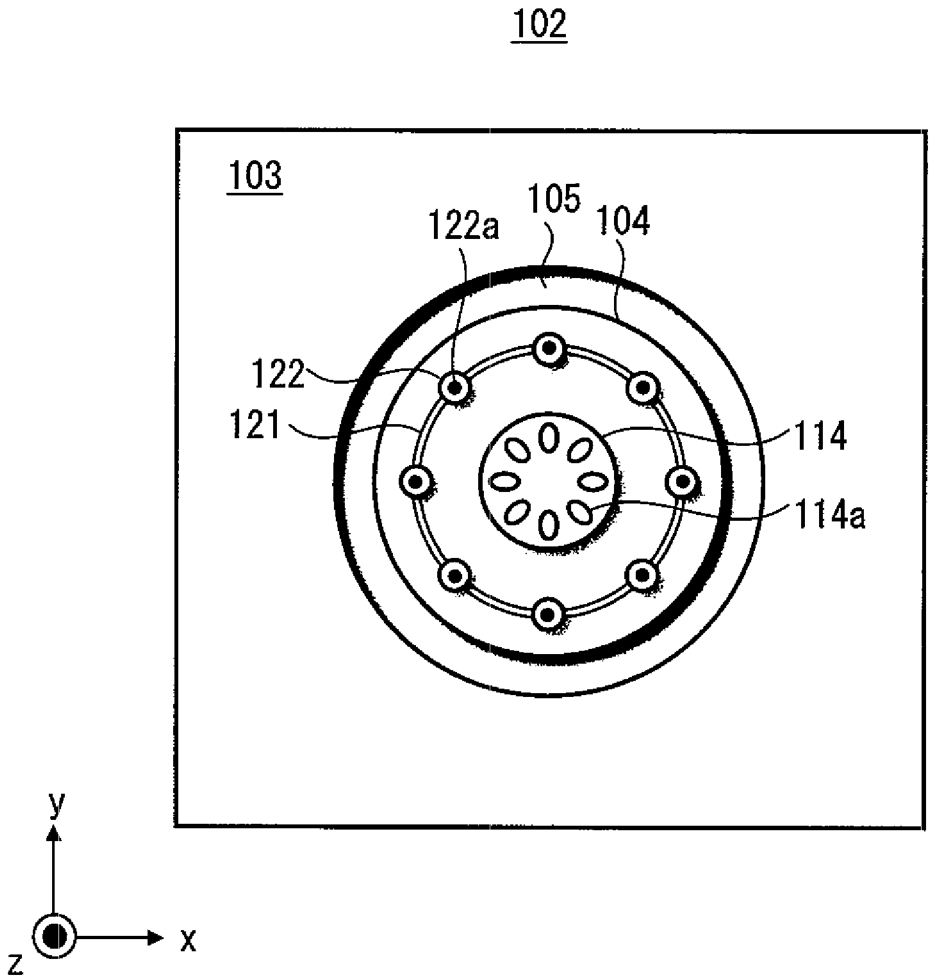

Fig. 10

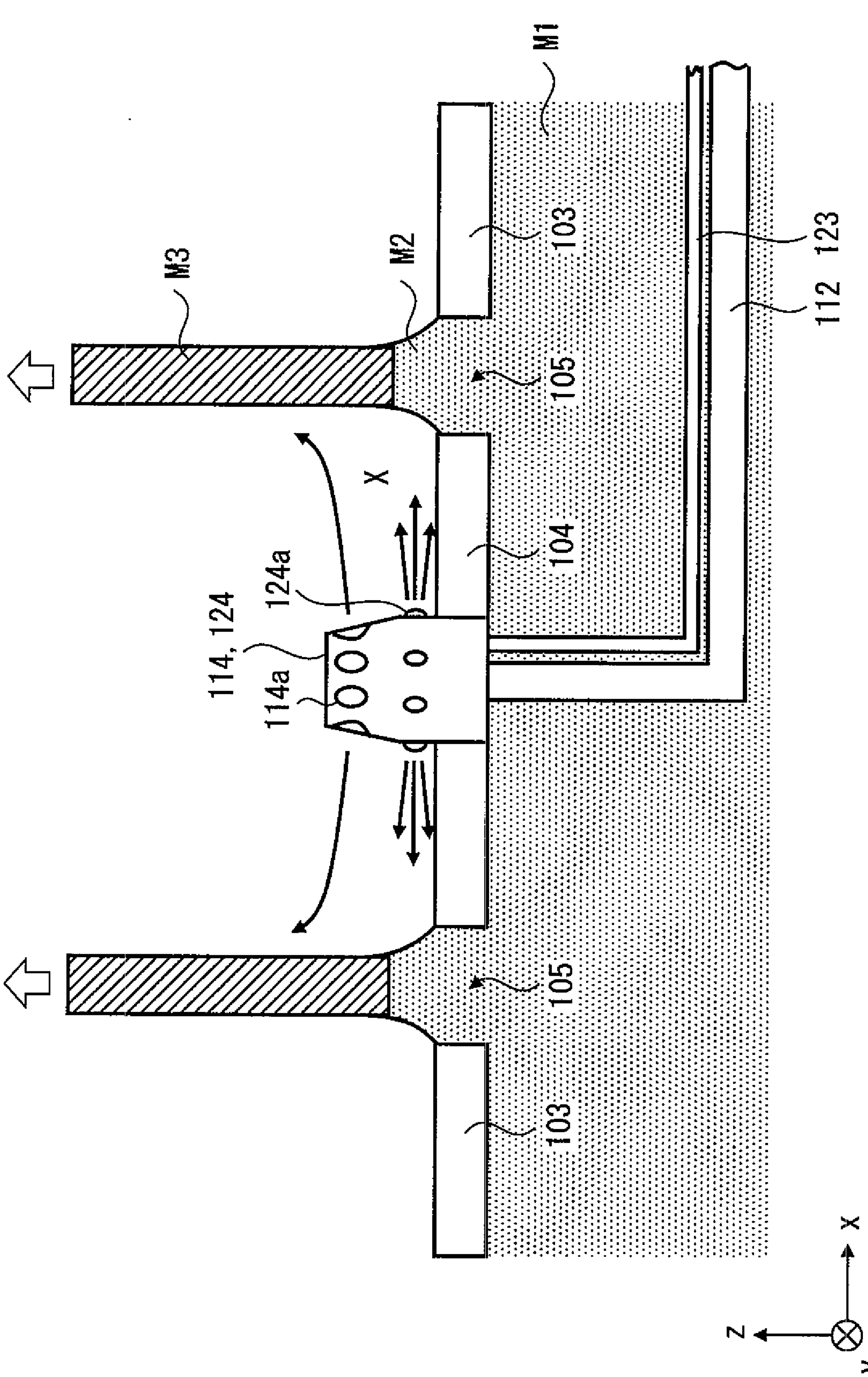

Fig. 11

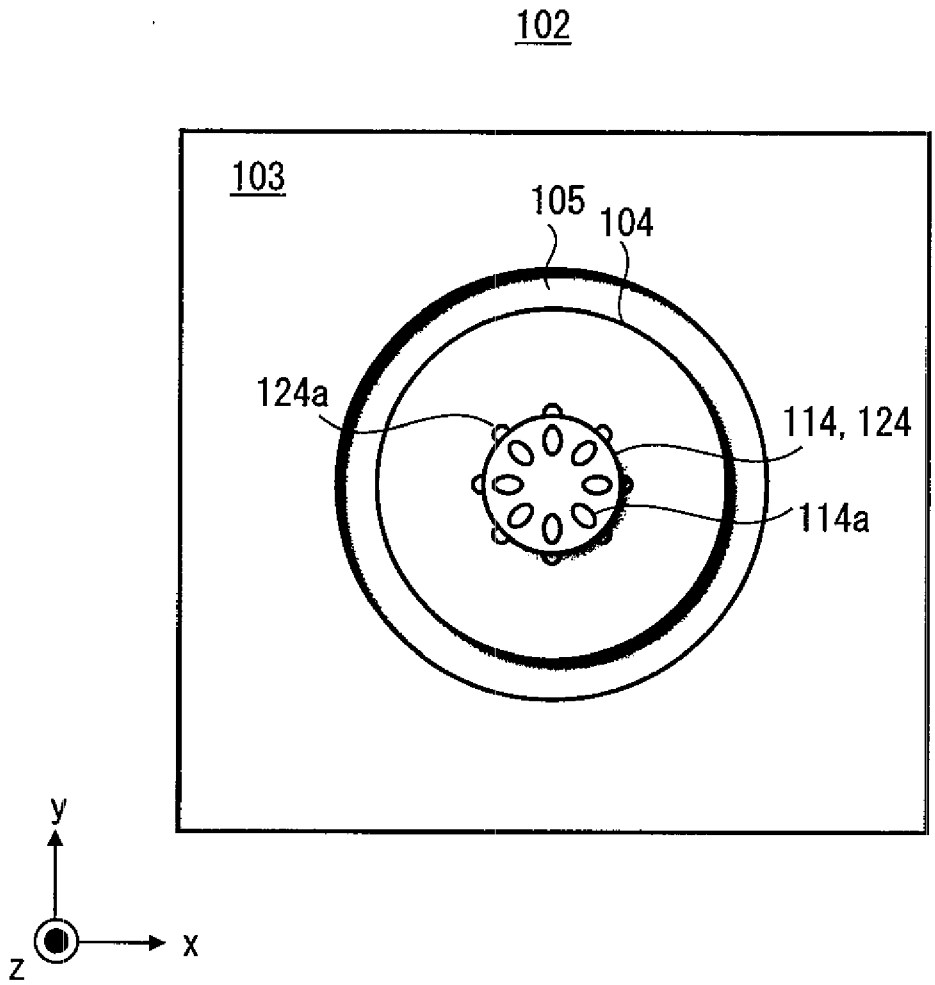

Fig. 12

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EUROPEAN SEARCH REPORT

Application Number
EP 16 17 2806

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A	WO 2014/118611 A1 (TOYOTA MOTOR CO LTD [JP]; NAKAJIMA TETSUYA [JP]; FURUKAWA YUICHI [JP];) 7 August 2014 (2014-08-07) * the whole document *	1-5	
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The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	14 September 2016	Nikolaou, Ioannis

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X : particularly relevant if taken alone
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