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(54) **UP-DRAWING CONTINUOUS CASTING APPARATUS AND UP-DRAWING CONTINUOUS CASTING METHOD**

(57) 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 near a molten-metal surface of the molten metal held in the holding furnace, the shape defining member being configured to define a cross-sectional shape of a cast-metal article to be cast as the molten metal passes through the shape defining member, a

first nozzle that blows a cooling gas on the cast-metal article, the cast-metal article being formed as the molten metal that has passed through the shape defining member solidifies, and a second nozzle that blows a gas toward the cast-metal article in an obliquely upward direction from below a place on the cast-metal article on which the cooling gas is blown from the first nozzle.

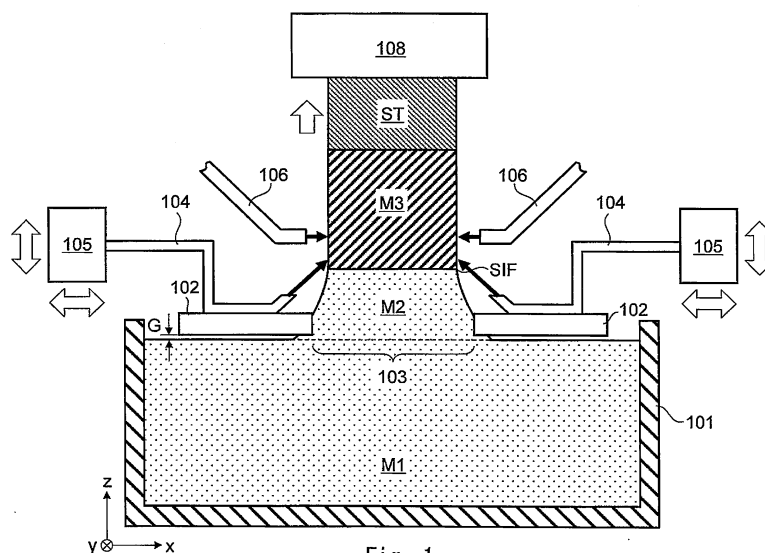


Fig. 1

Description

Technical Field

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

Background Art

[0002] As a revolutionary continuous casting method that does not require any mold, Patent Literature 1 proposes a pulling-up-type free casting method. As shown in Patent Literature 1, 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.

[0003] In the ordinary continuous casting method, the shape of the cast-metal article in the longitudinal direction as well as the shape thereof in cross section is defined by the mold. In the continuous casting method, in particular, since the solidified metal (i.e., cast-metal article) needs to pass through the inside of the mold, the cast-metal article has such a shape that it extends in a straight-line shape in the longitudinal direction.

[0004] In contrast to this, the shape defining member used in the free casting method defines only the cross-sectional shape of the cast-metal article, while it does not define the shape in the longitudinal direction. Further, since the shape defining member can be moved in the direction parallel to the molten-metal surface (i.e., in the horizontal direction), cast-metal articles having various shapes in the longitudinal direction can be produced. For example, Patent Literature 1 discloses a hollow cast-metal article (i.e., a pipe) having a zigzag shape or a helical shape in the longitudinal direction rather than the straight-line shape.

Citation List

Patent Literature

[0005] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2012-61518

Summary of Invention

Technical Problem

[0006] The present inventors have found the following problem.

[0007] In the free casting method disclosed in Patent

Literature 1, the molten metal drawn up through the shape defining member is cooled by a cooling gas. Specifically, a cooling gas is blown on the cast metal immediately after it is solidified and the molten metal is thereby indirectly cooled. It should be noted that by increasing the flow rate of the cooling gas, the casting speed can be increased and the productivity can be thereby improved. However, there has been a problem that when the flow rate of the cooling gas is increased, an undulation occurs in the molten metal drawn up from the shape defining member due to the cooling gas and hence the size accuracy and the surface quality of the cast-metal article deteriorate.

[0008] The present invention has been made in view of the above-described problem, and an object thereof is to provide a pulling-up-type continuous casting apparatus capable of producing cast-metal articles having excellent size accuracy and surface quality, and having excellent productivity.

Solution to Problem

[0009] 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 near a molten-metal surface of the molten metal held in the holding furnace, the shape defining member being configured to define a cross-sectional shape of a cast-metal article to be cast as the molten metal passes through the shape defining member;
- a first nozzle that blows a cooling gas on the cast-metal article, the cast-metal article being formed as the molten metal that has passed through the shape defining member solidifies; and
- a second nozzle that blows a gas toward the cast-metal article in an obliquely upward direction from below a place on the cast-metal article on which the cooling gas is blown from the first nozzle.

[0010] The above-described configuration makes it possible to provide a pulling-up-type continuous casting apparatus capable of producing cast-metal articles having excellent size accuracy and surface quality, and having excellent productivity.

[0011] The second nozzle is preferably fixed on the shape defining member or formed inside the shape defining member. This configuration can reduce the necessary space.

[0012] Further, the pulling-up-type continuous casting apparatus preferably further includes a projection disposed on the shape defining member, the projection being disposed at an end on a side of the shape defining member where the molten metal passes through, the projection extending in a pulling-up direction. Further, a tip of the second nozzle is preferably formed on a top surface of the projection.

[0013] An angle between a surface of the cast-metal article and a flux of the gas blown from the second nozzle is preferably equal to or less than 25 degrees. This configuration can effectively block the cooling gas.

[0014] Further, the gas blown from the second nozzle is preferably the same gas as the cooling gas blown from the first nozzle. This can simplify the equipment.

[0015] A pulling-up-type continuous casting apparatus according to another aspect of the present invention includes:

a holding furnace that holds molten metal;
 a shape defining member disposed near a molten-metal surface of the molten metal held in the holding furnace, the shape defining member being configured to define a cross-sectional shape of a cast-metal article to be cast as the molten metal passes through the shape defining member;
 a nozzle that blows a cooling gas on the cast-metal article, the cast-metal article being formed as the molten metal that has passed through the shape defining member solidifies; and
 a projection disposed on the shape defining member, the projection being disposed at an end on a side of the shape defining member where the molten metal passes through, the projection extending in a pulling-up direction.

[0016] The above-described configuration makes it possible to provide a pulling-up-type continuous casting apparatus capable of producing cast-metal articles having excellent size accuracy and surface quality, and having excellent productivity.

[0017] A pulling-up-type continuous casting method according to an aspect of the present invention includes:

a step of pulling up molten metal held in a holding furnace while making the molten metal pass through a shape defining member, the shape defining member being configured to define a cross-sectional shape of a cast-metal article to be cast; and
 a step of blowing a cooling gas on the cast-metal article, the cast-metal article being formed from the molten metal that has passed through the shape defining member, in which
 in the step of blowing the cooling gas, a gas is blown toward the cast-metal article in an obliquely upward direction from below a place on the cast-metal article on which the cooling gas is blown.

[0018] The above-described configuration makes it possible to provide a pulling-up-type continuous casting method capable of producing cast-metal articles having excellent size accuracy and surface quality, and having excellent productivity. The pulling-up-type continuous casting method preferably further includes a step of adjusting a flow rate of the gas according to a flow rate of the cooling gas.

[0019] The nozzle for blowing the gas toward the cast-metal article in the obliquely upward direction is preferably fixed on the shape defining member or formed inside the shape defining member. This configuration can reduce the necessary space.

[0020] Further, a projection is preferably provided on the shape defining member, the projection being disposed at an end on a side of the shape defining member where the molten metal passes through, the projection extending in a pulling-up direction. Further, a tip of the nozzle is preferably formed on a top surface of the projection.

[0021] An angle between a surface of the cast-metal article and a flux of the gas blown toward the cast-metal article in the obliquely upward direction is preferably equal to or less than 25 degrees. This configuration can effectively block the cooling gas.

[0022] Further, the gas blown toward the cast-metal article in the obliquely upward direction is preferably the same gas as the cooling gas. This can simplify the equipment.

[0023] A pulling-up-type continuous casting method according to another aspect of the present invention includes:

a step of pulling up molten metal held in a holding furnace while making the molten metal pass through a shape defining member, the shape defining member being configured to define a cross-sectional shape of a cast-metal article to be cast; and
 a step of blowing a cooling gas on the cast-metal article, the cast-metal article being formed from the molten metal that has passed through the shape defining member, in which
 a projection is provided on the shape defining member, the projection being disposed at an end on a side of the shape defining member where the molten metal passes through, the projection extending in a pulling-up direction.

[0024] The above-described configuration makes it possible to provide a pulling-up-type continuous casting method capable of producing cast-metal articles having excellent size accuracy and surface quality, and having excellent productivity.

Advantageous Effects of Invention

[0025] According to the present invention, it is possible to provide a pulling-up-type continuous casting apparatus capable of producing cast-metal articles having excellent size accuracy and surface quality, and having excellent productivity.

Brief Description of Drawings

[0026]

Fig. 1 is a schematic cross section of a free casting apparatus according to a first exemplary embodiment;

Fig. 2 is a plan view of a shape defining member 102 according to the first exemplary embodiment;

Fig. 3 is a side view showing a positional relation between a gas blowing-up nozzle 104 and a cooling gas nozzle 106 provided in the free casting apparatus according to a first exemplary embodiment;

Fig. 4 is a diagram for explaining an effect of an angle θ between the flux of a blocking gas and the surface of cast metal M3;

Fig. 5 is a graph for explaining an effect of an angle θ between the flux of a blocking gas and the surface of cast metal M3;

Fig. 6 is a plan view of a shape defining member 102 according to a modified example of the first exemplary embodiment;

Fig. 7 is a side view of the shape defining member 102 according to the modified example of the first exemplary embodiment;

Fig. 8 is a schematic cross section of a free casting apparatus according to a second exemplary embodiment;

Fig. 9 is a schematic cross section of a free casting apparatus according to a third exemplary embodiment;

Fig. 10 is a schematic cross section of a free casting apparatus according to a modified example of the third exemplary embodiment; and

Fig. 11 is a schematic cross section of a free casting apparatus according to a fourth exemplary embodiment.

Description of Embodiments

[0027] 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]

[0028] 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 schematic cross section of a free casting apparatus according to the first exemplary embodiment. As shown in Fig. 1, the free casting apparatus according to the first exemplary embodiment includes a molten-metal holding furnace 101, a shape defining member 102, a gas blowing-up nozzle(s) 104, an actuator(s) 105, a cooling gas nozzle(s) 106, and a pulling-up machine 108. 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.

[0029] 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. 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 can be raised by increasing the setting temperature of the holding furnace and the position of the solidification interface can be lowered by lowering the setting temperature of the holding furnace. Needless to say, the molten metal M1 may be a metal or an alloy other than aluminum.

[0030] The shape defining member 102 is made of ceramic or stainless steel, for example, and disposed near the molten-metal surface. In the example shown in Fig. 1, the shape defining member 102 is disposed so that a gap G between its principal surface on the underside (molten metal side) and the molten-metal surface is about 0.5 mm. By providing the gap G, it is possible to prevent the shape defining member 102 from lowering the temperature of the molten metal.

[0031] Meanwhile, the shape defining member 102 is in contact with held molten metal M2, which is pulled up from the molten-metal surface, on the periphery of its opening (molten-metal passage section 103) through which molten metal passes. Therefore, the shape defining member 102 can define the cross-sectional shape of cast metal M3 to be cast while preventing 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. The cast metal M3 shown in Fig. 1 is a solid cast-metal article having a plate-like shape in a horizontal cross section (hereinafter referred to as "lateral cross section").

[0032] Alternatively, the shape defining member 102 may be disposed so that its underside principal surface is entirely in contact with the molten-metal surface. In that case, the underside principal surface may be coated with a mold wash having a heat-insulating property so that the decrease in the temperature of the molten metal due to the shape defining member 102 is reduced. Examples of the mold wash include a vermiculite mold wash. The vermiculite mold wash is a mold wash that is obtained by suspending refractory fine particles made of silicon oxide (SiO_2), iron oxide (Fe_2O_3), aluminum oxide (Al_2O_3), or the like in water.

[0033] Fig. 2 is a plane view of the shape defining member 102 according to the first exemplary embodiment. 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. As shown in Fig. 2, the shape

defining member 102 has, for example, a rectangular shape as viewed from the top, and has a rectangular opening (molten-metal passage section 103) having a thickness t_1 and a width w_1 at the center thereof. The molten metal passes through the rectangular opening (molten-metal passage section 103). Further, the xyz-coordinate system shown in Fig. 2 corresponds to that shown in Fig. 1.

[0034] As shown in Fig. 1, the molten metal M1 follows the cast metal M3 and is pulled up by the cast metal M3 by its surface film and/or the surface tension. Further, the molten metal M1 passes through the molten-metal passage section 103 of the shape defining member 102. That is, as the molten metal M1 passes through the molten-metal passage section 103 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 cast metal M3 and is pulled up from the molten-metal surface by the surface film of the molten metal 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.

[0035] As shown in Fig. 1, the gas blowing-up nozzle(s) (second nozzle(s)) 104 is disposed and fixed on the shape defining member 102. It should be noted that the gas blowing-up nozzle 104 blows a gas (hereinafter called "blocking gas") toward the cast metal M3 in an obliquely upward direction in order to prevent a cooling gas blown from the cooling gas nozzle 106 onto the cast metal M3 from causing an undulation on the surface of the held molten metal M2. Further, the gas blowing-up nozzle 104 supports the shape defining member 102. Details of the gas blowing-up nozzle 104 are described later. Note that a gas similar to the cooling gas can be used as the blocking gas. Further, when the blocking gas is the same gas as the cooling gas, the blocking gas can also be supplied from the cooling gas supply unit (not shown). That is, the equipment can be simplified and hence the use of the same gas is preferred. Note that the gas blowing-up nozzle 104 does not necessarily have to be fixed on the shape defining member 102.

[0036] The gas blowing-up nozzle 104 is connected to the actuator 105. The gas blowing-up nozzle 104 and the shape defining member 102 can be moved in the up/down direction (vertical direction) and the horizontal direction by the actuator 105. This configuration makes it possible, for example, to move the shape defining member 102 downward as the molten-metal surface is lowered due to the advance of the casting process. Further, since the shape defining member 102 can be moved in the horizontal direction, the shape in the longitudinal direction of the cast metal M3 can be arbitrarily changed.

[0037] The cooling gas nozzle 106 is cooling means for blowing a cooling gas (such as air, nitrogen, and argon) supplied from the cooling gas supply unit (not shown) on the cast metal M3 and thereby cooling the

cast metal M3. The position of the solidification interface can be lowered by increasing the flow rate of the cooling gas and the position of the solidification interface can be raised by reducing the flow rate of the cooling gas. Note that although it is not shown in the figure, the cooling gas nozzle (cooling unit) 106 can also be moved in the horizontal direction and the vertical direction in accordance with the movement of the gas blowing-up nozzle 104 and the shape defining member 102.

[0038] By cooling the cast metal M3 by the cooling gas while pulling up the cast metal M3 by using the pulling-up machine 108 connected to the starter ST, the held molten metal M2 located in the vicinity of the solidification interface SIF is successively solidified, and the cast metal M3 is thereby formed. The position of the solidification interface can be raised by increasing the pulling-up speed of the pulling-up machine 108 and the position of the solidification interface can be lowered by reducing the pulling-up speed.

[0039] Next, a positional relation between the gas blowing-up nozzle 104 and the cooling gas nozzle 106 provided in the free casting apparatus according to the first exemplary embodiment is explained with reference to Fig. 3. Fig. 3 is a side view showing a positional relation between the gas blowing-up nozzle 104 and the cooling gas nozzle 106 provided in the free casting apparatus according to the first exemplary embodiment.

[0040] As shown in Fig. 3, the flux of the cooling gas for cooling the cast metal M3 is blown from the cooling gas nozzle 106 in a direction roughly perpendicularly to the surface of the cast metal M3. This is because the closer the blowing direction is to the direction perpendicular to the surface, the more the cooling efficiency improves. Further, the closer the tip of the cooling gas nozzle 106 is to the cast metal M3, the more the casting speed can be increased. The larger the flow rate of the cooling gas, the more the casting speed can be increased. Further, the closer the place on which the cooling gas is blown is to the solidification interface, the more the casting speed can be increased. The cooling gas that has collided onto the surface of the cast metal M3 branches off into an upward direction and a downward direction along the surface of the cast metal M3. Then, if there is nothing that blocks the downward-branched cooling gas, the downward-branched cooling gas causes an undulation on the surface of the held molten metal M2. When the flow rate of the cooling gas is increased, this undulation becomes larger, thus deteriorating the size accuracy and the surface quality of the cast-metal article.

[0041] Therefore, in the free casting apparatus according to the first exemplary embodiment, the gas blowing-up nozzle 104 blows a blocking gas in an obliquely upward direction from a place located on the shape defining member 102 as shown in Fig. 3. Note that as is obvious from Fig. 3, it is necessary that the place on the surface of the cast metal M3 on which the blocking gas is blown is located between the place on the surface of the cast metal M3 on which the cooling gas is blown and the so-

lidification interface SIF. By using the blocking gas, it is possible to block the cooling gas that has branched in the downward direction along the surface of the cast metal M3. As a result, it is possible to prevent (or reduce) the occurrence of an undulation on the surface of the held molten metal M2 and improve the size accuracy and the surface quality of the cast-metal article. Further, it is possible to increase the casting speed and improve the productivity compared to the related art by increasing the flow rate of the cooling gas. Further, the blocking gas can improve the cooling effect of the cast metal M3. Note that the flow rate of the blocking gas is preferably adjusted according to the flow rate of the cooling gas.

[0042] Next, the effect of the angle θ between the flux of the blocking gas and the surface of the cast metal M3 is explained with reference to Figs. 4 and 5. Fig. 4 is a schematic diagram for explaining the effect of the angle θ between the flux of the blocking gas and the surface of the cast metal M3. Letting "Q0", "Q1" and "Q2" stand for the total flow rate of the blocking gas blown from the gas blowing-up nozzle 104, the flow rate of the blocking gas that has branched downward, and the flow rate of the blocking gas that has branched upward, respectively, as shown in Fig. 4, a relation "Q0 = Q1 + Q2" holds. Note that the blocking gas is blown so that the angle of the blocking gas with respect to the surface of the cast metal M3 is the angle θ .

[0043] Fig. 5 is a graph for explaining the effect of the angle θ between the flux of the blocking gas and the surface of the cast metal M3. As shown in Fig. 5, as the angle θ between the flux of the blocking gas and the surface of the cast metal M3 changes, the ratio (%) of the flow rate Q1 of the downward-branched blocking gas to the total flow rate Q0 changes. This ratio (%) can be calculated by an expression " $\frac{1}{2} \times (1 - \cos \theta) \times 100$ ". Fig. 5 shows a plot in accordance with this expression. The horizontal axis in Fig. 5 indicates angles θ (degrees) and the vertical axis indicates ratios Q1/Q0 (%) of the flow rate Q1 of the downward-branched blocking gas to the total flow rate Q0. When the ratio Q1/Q0 (%) increases, the blocking gas itself causes an undulation on the surface of the held molten metal M2. The ratio Q1/Q0 (%) is preferably equal to or less than 5% and hence the angle θ is preferably equal to or less than 25 degrees.

[0044] Next, a free casting method according to the first exemplary embodiment is explained with reference to Fig. 1.

[0045] Firstly, a starter ST is lowered and made to pass through the molten-metal passage section 103 of the shape defining member 102, and the tip of the starter ST is submerged into the molten metal M1.

[0046] 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 from the molten-metal surface by the surface film and/or the surface tension. That is, the held molten metal M2 is formed. As shown in Fig. 1, the held molten metal M2 is

formed in the molten-metal passage section 103 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.

[0047] Next, since the starter ST is cooled by the cooling gas blown from the cooling gas nozzle 106, the held molten metal M2 successively solidifies from its upper side toward its lower side. As a result, the cast metal M3 grows. In this manner, it is possible to continuously cast the cast metal M3.

[0048] As described above, the free casting apparatus according to the first exemplary embodiment is equipped with the gas blowing-up nozzle 104 that blows a blocking gas in an obliquely upward direction from a place located on the shape defining member 102. By using this blocking gas, it is possible to block the cooling gas that has branched in the downward direction along the surface of the cast metal M3. As a result, it is possible to prevent (or reduce) the occurrence of an undulation on the surface of the held molten metal M2 and improve the size accuracy and the surface quality of the cast-metal article.

(Modified example of first exemplary embodiment)

[0049] Next, a free casting apparatus according to a modified example of the first exemplary embodiment is explained with reference to Figs. 6 and 7. Fig. 6 is a plan view of a shape defining member 102 according to the modified example of the first exemplary embodiment. Fig. 7 is a side view of the shape defining member 102 according to the modified example of the first exemplary embodiment. Note that the xyz-coordinate systems shown in Figs. 6 and 7 correspond to that shown in Fig. 1.

[0050] The shape defining member 102 according to the first exemplary embodiment shown in Fig. 2 is composed of one plate. Therefore, the thickness t1 and the width w1 of the molten-metal passage section 103 are fixed. In contrast to this, the shape defining member 102 according to the modified example of the first exemplary embodiment includes four rectangular shape defining plates 102a, 102b, 102c and 102d as shown in Fig. 6. That is, the shape defining member 102 according to the modified example of the first exemplary embodiment is divided into a plurality of sections. With this configuration, it is possible to change the thickness t1 and the width w1 of the molten-metal passage section 103. Further, the four rectangular shape defining plates 102a, 102b, 102c and 102d can be moved in unison in the z-axis direction.

[0051] As shown in Fig. 6, the shape defining plates 102a and 102b are arranged to be opposed to each other in the x-axis direction. Further, as shown in Fig. 7, the shape defining plates 102a and 102b are disposed at the same height in the z-axis direction. The gap between the shape defining plates 102a and 102b defines the width w1 of the molten-metal passage section 103. Further, since each of the shape defining plates 102a and 102b can be independently moved in the x-axis direction, the width w1 can be changed. Note that, as shown in Figs.

6 and 7, a laser displacement gauge S1 and a laser reflector plate S2 may be provided on the shape defining plates 102a and 102b, respectively, in order to measure the width w_1 of the molten-metal passage section 103.

[0052] Further, as shown in Fig. 6, the shape defining plates 102c and 102d are arranged to be opposed to each other in the y-axis direction. Further, the shape defining plates 102c and 102c are disposed at the same height in the z-axis direction. The gap between the shape defining plates 102c and 102d defines the thickness t_1 of the molten-metal passage section 103. Further, since each of the shape defining plates 102c and 102d can be independently moved in the y-axis direction, the thickness t_1 can be changed. The shape defining plates 102a and 102b are disposed in such a manner that they are in contact with the top sides of the shape defining plates 102c and 102d.

[0053] Next, a driving mechanism for the shape defining plate 102a is explained with reference to Figs. 6 and 7. As shown in Figs. 6 and 7, the driving mechanism for the shape defining plate 102a includes slide tables T1 and T2, linear guides G11, G12, G21 and G22, actuators A1 and A2, and rods R1 and R2. Note that although each of the shape defining plates 102b, 102c and 102d also includes its driving mechanism as in the case of the shape defining plate 102a, the illustration of them is omitted in Figs. 6 and 7.

[0054] As shown in Figs. 6 and 7, the shape defining plate 102a is placed and fixed on the slide table T1, which can be slid in the x-axis direction. The slide table T1 is slidably placed on a pair of linear guides G11 and G12 extending in parallel with the x-axis direction. Further, the slide table T1 is connected to the rod R1 extending from the actuator A1 in the x-axis direction. With the above-described configuration, the shape defining plate 102a can be slid in the x-axis direction.

[0055] Further, as shown in Figs. 6 and 7, the linear guides G11 and G12 and the actuator A1 are placed and fixed on the slide table T2, which can be slid in the z-axis direction. The slide table T2 is slidably placed on a pair of linear guides G21 and G22 extending in parallel with the z-axis direction. Further, the slide table T2 is connected to the rod R2 extending from the actuator A2 in the z-axis direction. The linear guides G21 and G22 and the actuator A2 are fixed on a horizontal floor surface or a horizontal pedestal (not shown). With the above-described configuration, the shape defining plate 102a can be slid in the z-axis direction. Note that examples of the actuators A1 and A2 include a hydraulic cylinder, an air cylinder, and a motor.

[Second exemplary embodiment]

[0056] Next, a free casting apparatus according to a second exemplary embodiment is explained with reference to Fig. 8. Fig. 8 is a schematic cross section of a free casting apparatus according to the second exemplary embodiment. Note that the xyz-coordinate system

shown in Fig. 8 also corresponds to that shown in Fig. 1. In the free casting apparatus according to the first exemplary embodiment, the gas blowing-up nozzle 104 is formed on the shape defining member 102. In contrast to this, in the free casting apparatus according to the second exemplary embodiment, a gas blowing-up nozzle(s) 204 is formed inside a shape defining member 202. In other words, a passage(s) for a blocking gas is formed inside the shape defining member 202. In the free casting apparatus according to the second exemplary embodiment, by forming the passage(s) for the blocking gas inside the shape defining member 202, the space necessary for the free casting apparatus is reduced in the second exemplary embodiment even further than it is in the first exemplary embodiment.

[0057] In the free casting apparatus according to the second exemplary embodiment, the gas blowing-up nozzle 204 that blows a blocking gas in an obliquely upward direction is disposed inside the shape defining member 202. Meanwhile, similarly to the first exemplary embodiment, it is necessary that the place on the surface of the cast metal M3 on which the blocking gas is blown is located between the place on the surface of the cast metal M3 on which the cooling gas is blown and the solidification interface SIF. Note that the effect of the angle θ between the flux of the blocking gas and the surface of the cast metal M3 is similar to that in the first exemplary embodiment. Therefore, the angle θ is preferably equal to or less than 25 degrees.

[0058] The cooling gas that has branched in the downward direction along the surface of the cast metal M3 can be blocked by the blocking gas blown up in an obliquely upward direction from the gas blowing-up nozzle 204 formed inside the shape defining member 202. As a result, it is possible to prevent (or reduce) the occurrence of an undulation on the surface of the held molten metal M2 and improve the size accuracy and the surface quality of the cast-metal article. In addition, it is possible to increase the casting speed and improve the productivity compared to the related art by increasing the flow rate of the cooling gas. Further, the blocking gas can improve the cooling effect of the cast metal M3.

[Third exemplary embodiment]

[0059] Next, a free casting apparatus according to a third exemplary embodiment is explained with reference to Fig. 9. Fig. 9 is a schematic cross section of a free casting apparatus according to the third exemplary embodiment. Note that the xyz-coordinate system shown in Fig. 9 also corresponds to that shown in Fig. 1. In the free casting apparatus according to the first exemplary embodiment, the gas blowing-up nozzle 104 is formed on the shape defining member 102. In contrast to this, in the free casting apparatus according to the third exemplary embodiment, a blocking wall(s) (projection(s)) 302a for blocking the cooling gas that has branched in the downward direction along the surface of the cast metal

M3 is formed. The blocking wall 302a is formed on a shape defining member near the end on the side of the shape defining member 302 where the molten-metal passage section 103 passes through.

[0060] It should be noted that the height of the blocking wall 302a and distance between the molten-metal passage section 103 and the blocking wall 302a are determined according to the shape in the longitudinal direction of the cast metal M3. Specifically, the higher the blocking wall 302a is, the more the effect of blocking the downward-branched cooling gas improves. Further, the shorter the distance between the molten-metal passage section 103 and the blocking wall 302a is, the more the effect of blocking the downward-branched cooling gas improves. However, the flexibility in the shape in the longitudinal direction of the cast metal M3 decreases, thus leading to the cast metal M3 extending on a straight line.

[0061] Note that there is no particular restriction on the width W of the blocking wall 302a.

[0062] Here, Fig. 10 is a schematic cross section of a free casting apparatus according to a modified example of the third exemplary embodiment. For example, as shown in Fig. 10, the blocking wall 302a may reach the outer edge (the end on the outer side) of the shape defining member 302.

[0063] In the free casting apparatus according to the third exemplary embodiment, the cooling gas that has branched in the downward direction along the surface of the cast metal M3 can be blocked by the blocking wall 302a. As a result, it is possible to prevent (or reduce) the occurrence of an undulation on the surface of the held molten metal M2 and improve the size accuracy and the surface quality of the cast-metal article. Further, it is possible to increase the casting speed and improve the productivity compared to the related art by increasing the flow rate of the cooling gas.

[Fourth exemplary embodiment]

[0064] Next, a free casting apparatus according to a fourth exemplary embodiment is explained with reference to Fig. 11. Fig. 11 is a schematic cross section of a free casting apparatus according to the fourth exemplary embodiment. Note that the xyz-coordinate system shown in Fig. 11 also corresponds to that shown in Fig. 1. In the free casting apparatus according to the second exemplary embodiment, the gas blowing-up nozzle 204 is formed inside the shape defining member 202. Further, in the free casting apparatus according to the third exemplary embodiment, the blocking wall 302a is formed on the shape defining member 302. In contrast to this, in the free casting apparatus according to the fourth exemplary embodiment, a gas blowing-up nozzle(s) 404 is formed inside a shape defining member 402 and a blocking wall(s) 402a. In other words, a passage(s) for a blocking gas is formed inside the shape defining member 402 and the blocking wall(s) 402a. Further, tip(s) (blowing hole(s)) of the gas blowing-up nozzle(s) 404 is formed

on the top surface of the blocking wall(s) 402a.

[0065] In the free casting apparatus according to the fourth exemplary embodiment, the gas blowing-up nozzle 404 that blows up a blocking gas in an obliquely upward direction is disposed inside the shape defining member 402 and the blocking wall 402a. Meanwhile, similarly to the first and second exemplary embodiments, it is necessary that the place on the surface of the cast metal M3 on which the blocking gas is blown is located between the place on the surface of the cast metal M3 on which the cooling gas is blown and the solidification interface SIF. Note that the effect of the angle θ between the flux of the blocking gas and the surface of the cast metal M3 is similar to that in the first exemplary embodiment. Therefore, the angle θ is preferably equal to or less than 25 degrees.

[0066] The cooling gas that has branched in the downward direction along the surface of the cast metal M3 can be blocked by both the blocking wall 402a and the blocking gas blown up in an obliquely upward direction from the inside of that blocking wall 402a. As a result, it is possible to prevent (or reduce) the occurrence of an undulation on the surface of the held molten metal M2 and improve the size accuracy and the surface quality of the cast-metal article. In addition, it is possible to increase the casting speed and improve the productivity compared to the related art by increasing the flow rate of the cooling gas. Further, the blocking gas can improve the cooling effect of the cast metal M3.

[0067] 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.

Reference Signs List

[0068]

101 MOLTEN METAL HOLDING FURNACE
102,202,302,402 SHAPE DEFINING MEMBER
102a-102d SHAPE DEFINING PLATE
103 MOLTEN-METAL PASSAGE SECTION
104,204,404 GAS BLOWING-UP NOZZLE
105 ACTUATOR
106 COOLING GAS NOZZLE
108 PULLING-UP MACHINE
302a, 402a BLOCKING WALL (PROJECTION)
A1, A2 ACTUATOR
G11, G12, G21, G22 LINEAR GUIDE
M1 MOLTEN METAL
M2 HELD MOLTEN METAL
M3 CAST METAL
R1, R2 ROD
S 1 LASER DISPLACEMENT GAUGE
S2 LASER REFLECTOR PLATE
SIF SOLIDIFICATION INTERFACE
ST STARTER
T1, T2 SLIDE TABLE

Claims

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

a holding furnace that holds molten metal;
 a shape defining member disposed near a molten-metal surface of the molten metal held in the holding furnace, the shape defining member being configured to define a cross-sectional shape of a cast-metal article to be cast as the molten metal passes through the shape defining member;
 a first nozzle that blows a cooling gas on the cast-metal article, the cast-metal article being formed as the molten metal that has passed through the shape defining member solidifies; and
 a second nozzle that blows a gas toward the cast-metal article in an obliquely upward direction from below a place on the cast-metal article on which the cooling gas is blown from the first nozzle.

2. The pulling-up-type continuous casting apparatus according to Claim 1, wherein the second nozzle is fixed on the shape defining member.

3. The pulling-up-type continuous casting apparatus according to Claim 1, wherein the second nozzle is formed inside the shape defining member.

4. The pulling-up-type continuous casting apparatus according to Claim 3, further comprising a projection disposed on the shape defining member, the projection being disposed at an end on a side of the shape defining member where the molten metal passes through, the projection extending in a pulling-up direction, wherein
 a tip of the second nozzle is formed on a top surface of the projection.

5. The pulling-up-type continuous casting apparatus according to any one of Claims 1 to 4, wherein an angle between a surface of the cast-metal article and a flux of the gas blown from the second nozzle is equal to or less than 25 degrees.

6. The pulling-up-type continuous casting apparatus according to any one of Claims 1 to 5, wherein the gas blown from the second nozzle is the same gas as the cooling gas blown from the first nozzle.

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

a holding furnace that holds molten metal;
 a shape defining member disposed near a mol-

ten-metal surface of the molten metal held in the holding furnace, the shape defining member being configured to define a cross-sectional shape of a cast-metal article to be cast as the molten metal passes through the shape defining member;

a nozzle that blows a cooling gas on the cast-metal article, the cast-metal article being formed as the molten metal that has passed through the shape defining member solidifies; and
 a projection disposed on the shape defining member, the projection being disposed at an end on a side of the shape defining member where the molten metal passes through, the projection extending in a pulling-up direction.

8. A pulling-up-type continuous casting method comprising:

a step of pulling up molten metal held in a holding furnace while making the molten metal pass through a shape defining member, the shape defining member being configured to define a cross-sectional shape of a cast-metal article to be cast; and

a step of blowing a cooling gas on the cast-metal article, the cast-metal article being formed from the molten metal that has passed through the shape defining member, wherein
 in the step of blowing the cooling gas, a gas is blown toward the cast-metal article in an obliquely upward direction from below a place on the cast-metal article on which the cooling gas is blown.

9. The pulling-up-type continuous casting method according to Claim 8, further comprising a step of adjusting a flow rate of the gas according to a flow rate of the cooling gas.

10. The pulling-up-type continuous casting method according to Claim 8 or 9, wherein the nozzle for blowing the gas toward the cast-metal article in the obliquely upward direction is fixed on the shape defining member.

11. The pulling-up-type continuous casting method according to Claim 8 or 9, wherein the nozzle for blowing the gas toward the cast-metal article in the obliquely upward direction is formed inside the shape defining member.

12. The pulling-up-type continuous casting method according to Claim 11, wherein
 a projection is provided on the shape defining member, the projection being disposed at an end on a side of the shape defining member where the molten metal passes through, the projection extending in a

pulling-up direction, and
a tip of the nozzle is formed on a top surface of the
projection.

13. The pulling-up-type continuous casting method according to any one of Claims 8 to 12, wherein an angle between a surface of the cast-metal article and a flux of the gas blown toward the cast-metal article in the obliquely upward direction is equal to or less than 25 degrees. 5 10
14. The pulling-up-type continuous casting method according to any one of Claims 8 to 13, wherein the gas blown toward the cast-metal article in the obliquely upward direction is the same gas as the cooling gas. 15
15. A pulling-up-type continuous casting method comprising: 20
- a step of pulling up molten metal held in a holding furnace while making the molten metal pass through a shape defining member, the shape defining member being configured to define a cross-sectional shape of a cast-metal article to be cast; and 25
- a step of blowing a cooling gas on the cast-metal article, the cast-metal article being formed from the molten metal that has passed through the shape defining member, wherein 30
- a projection is provided on the shape defining member, the projection being disposed at an end on a side of the shape defining member where the molten metal passes through, the projection extending in a pulling-up direction. 35

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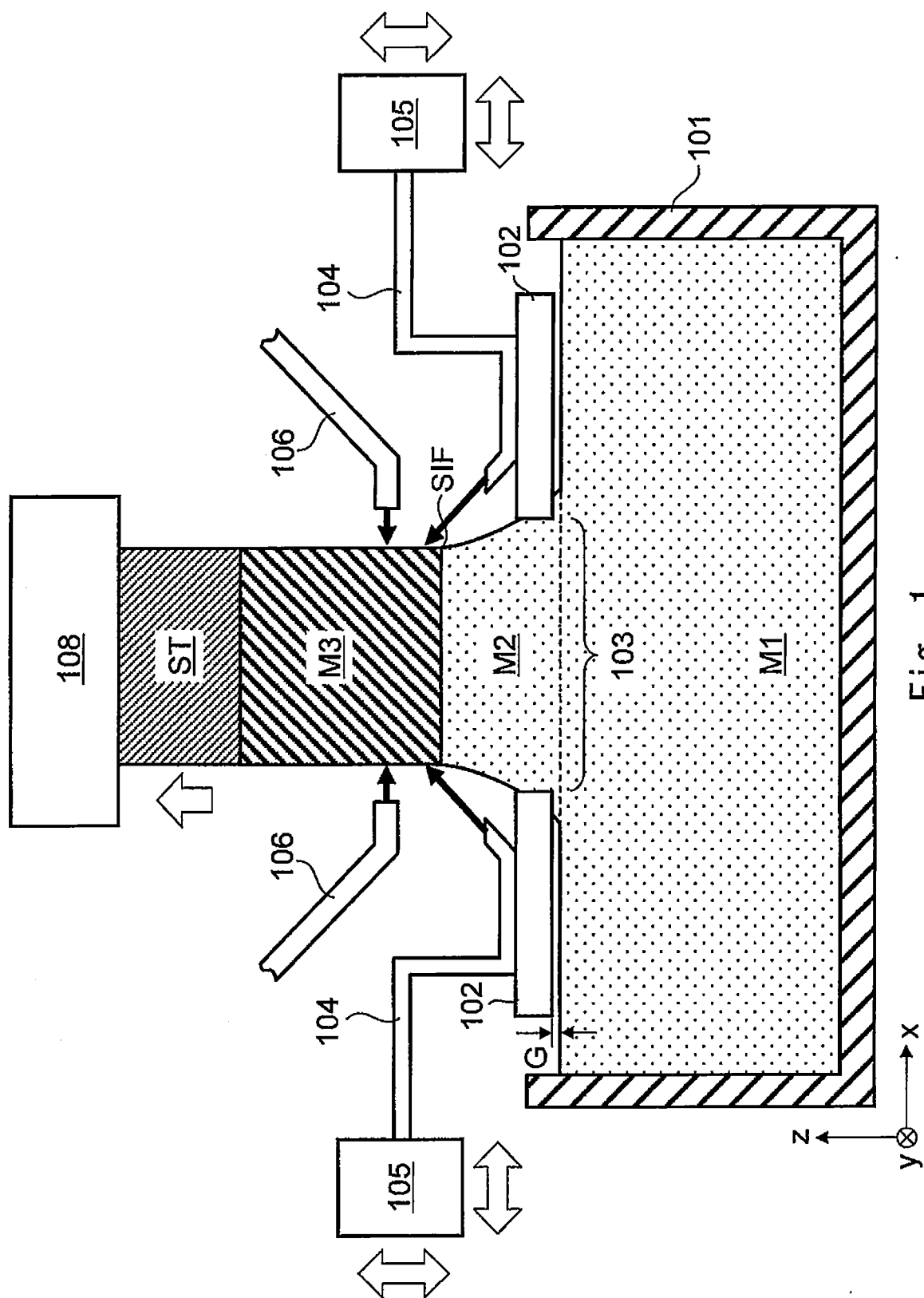


Fig. 1

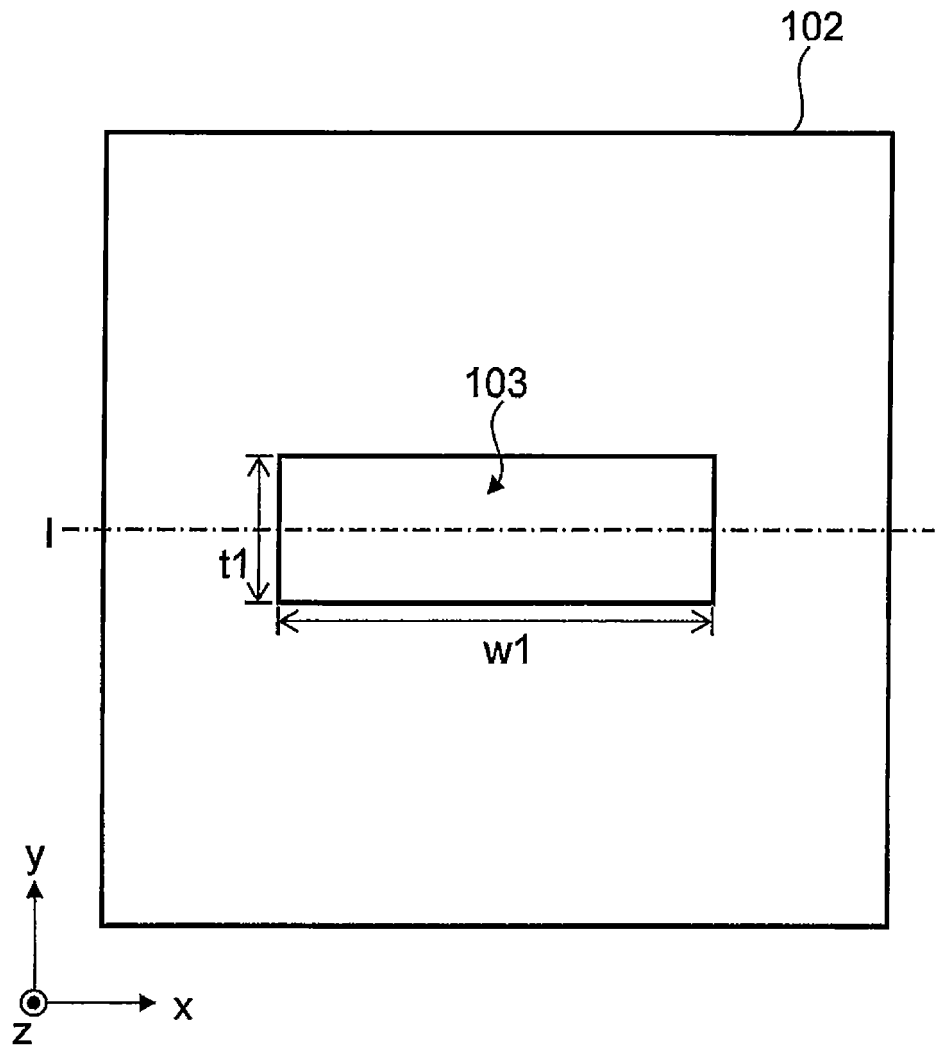


Fig. 2

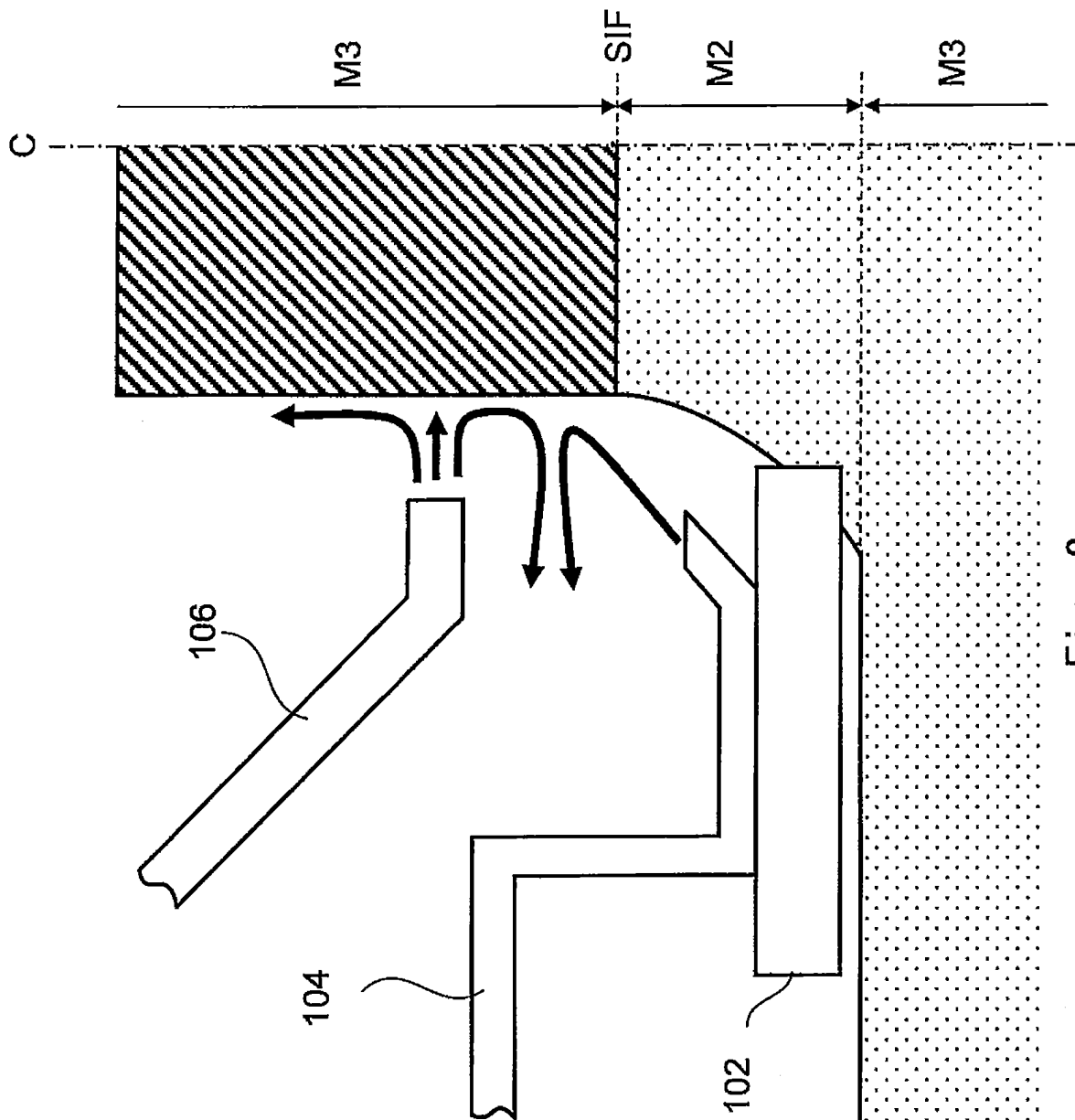


Fig. 3

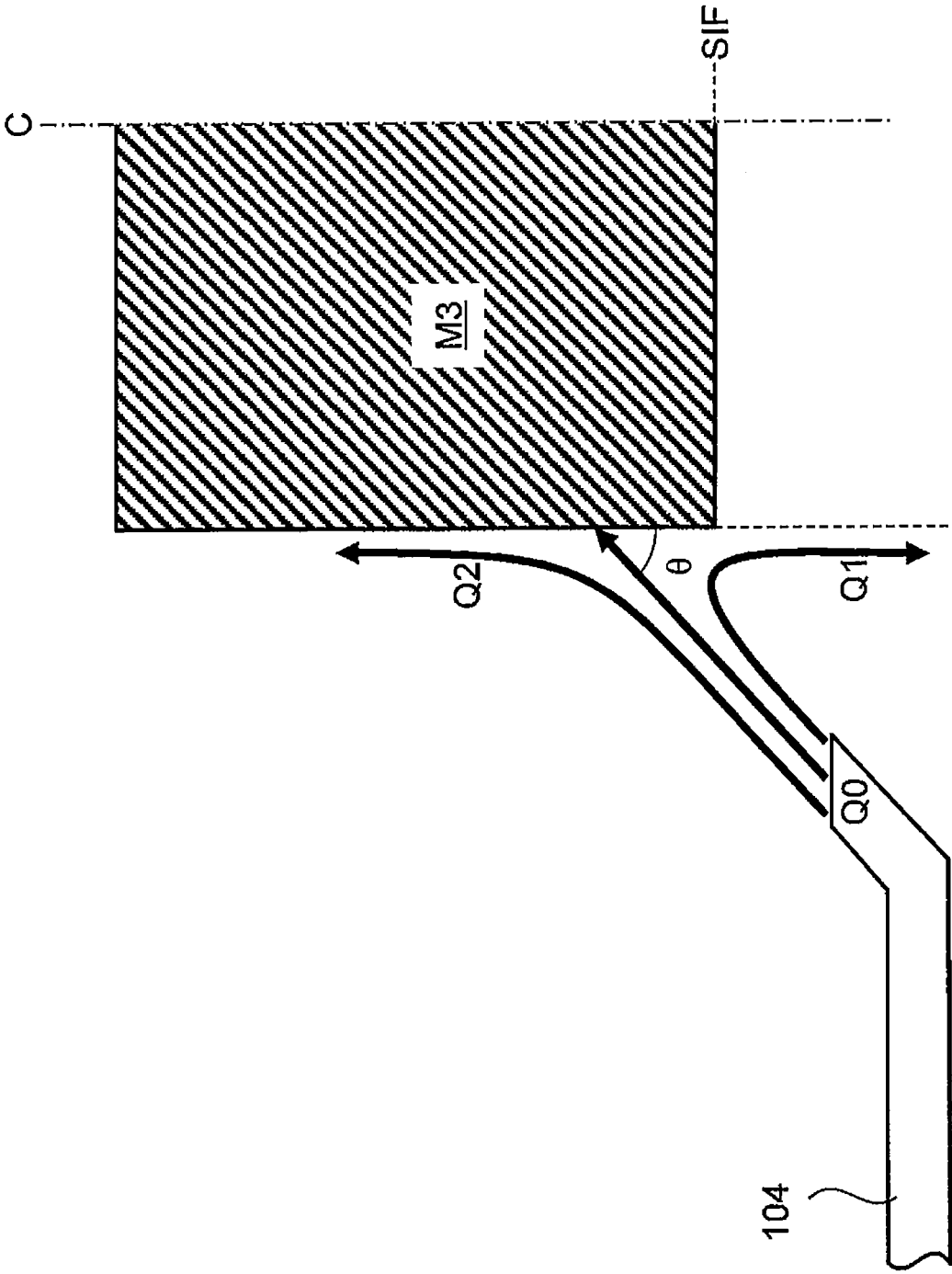
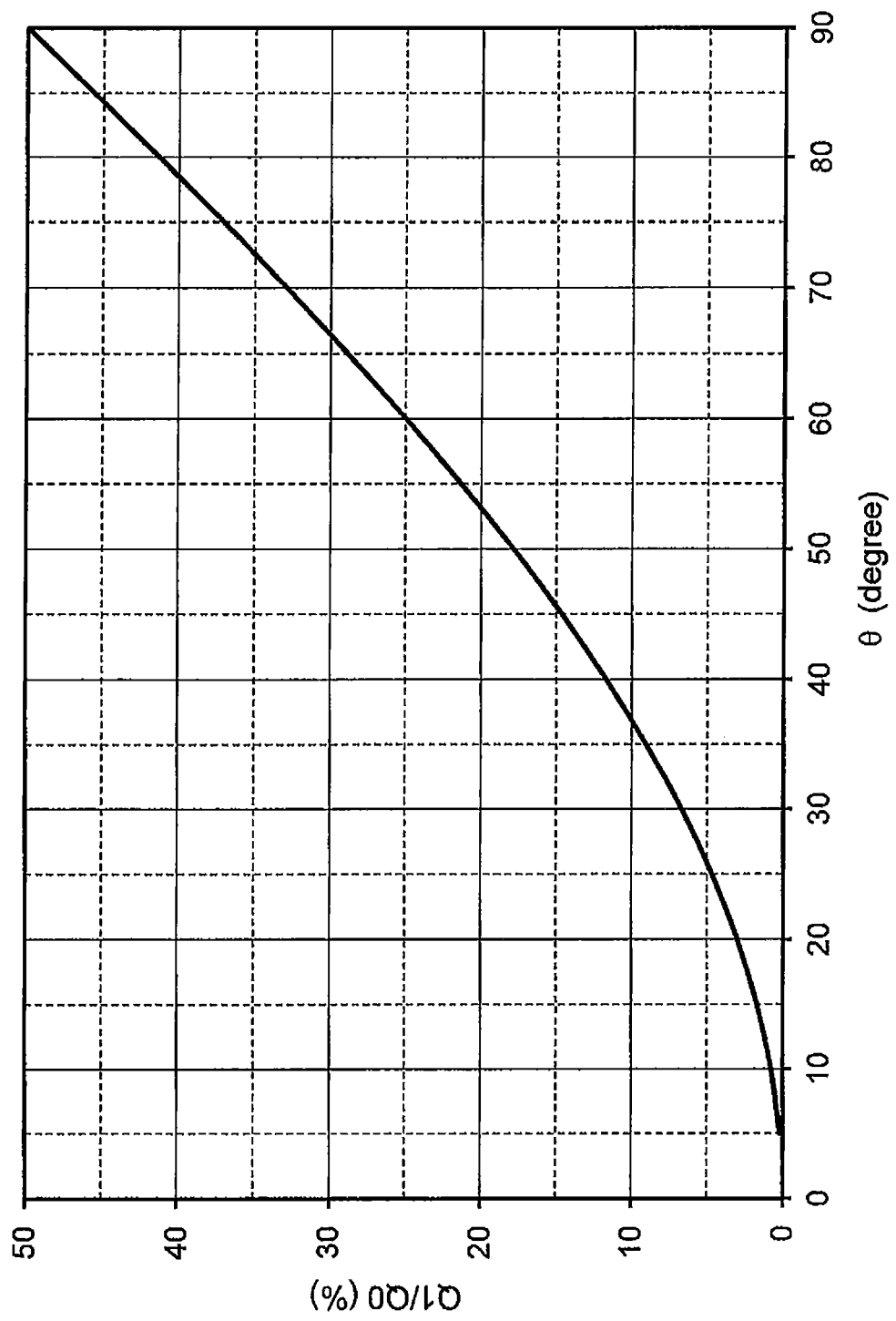


Fig. 4

Fig. 5



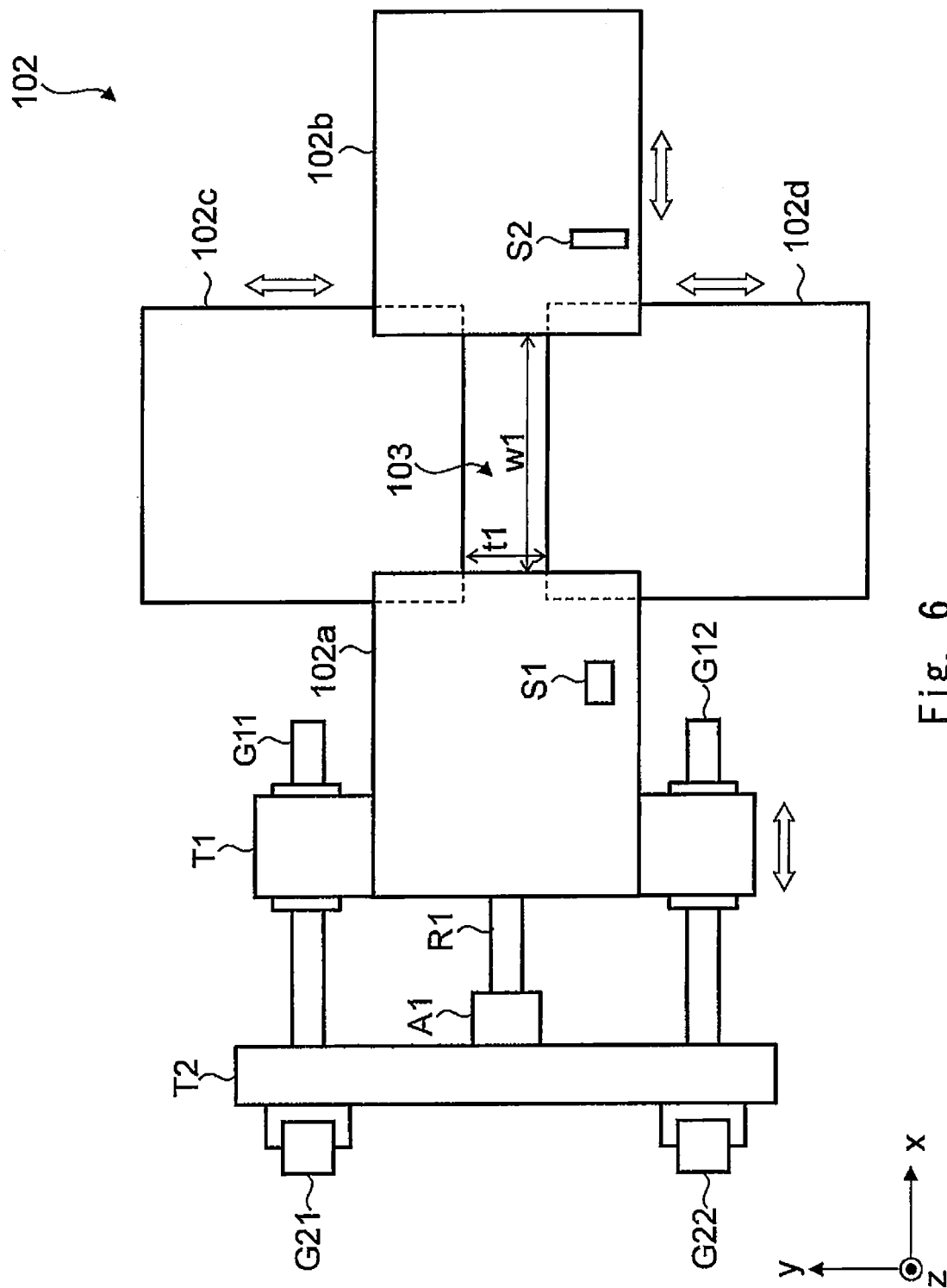


Fig. 6

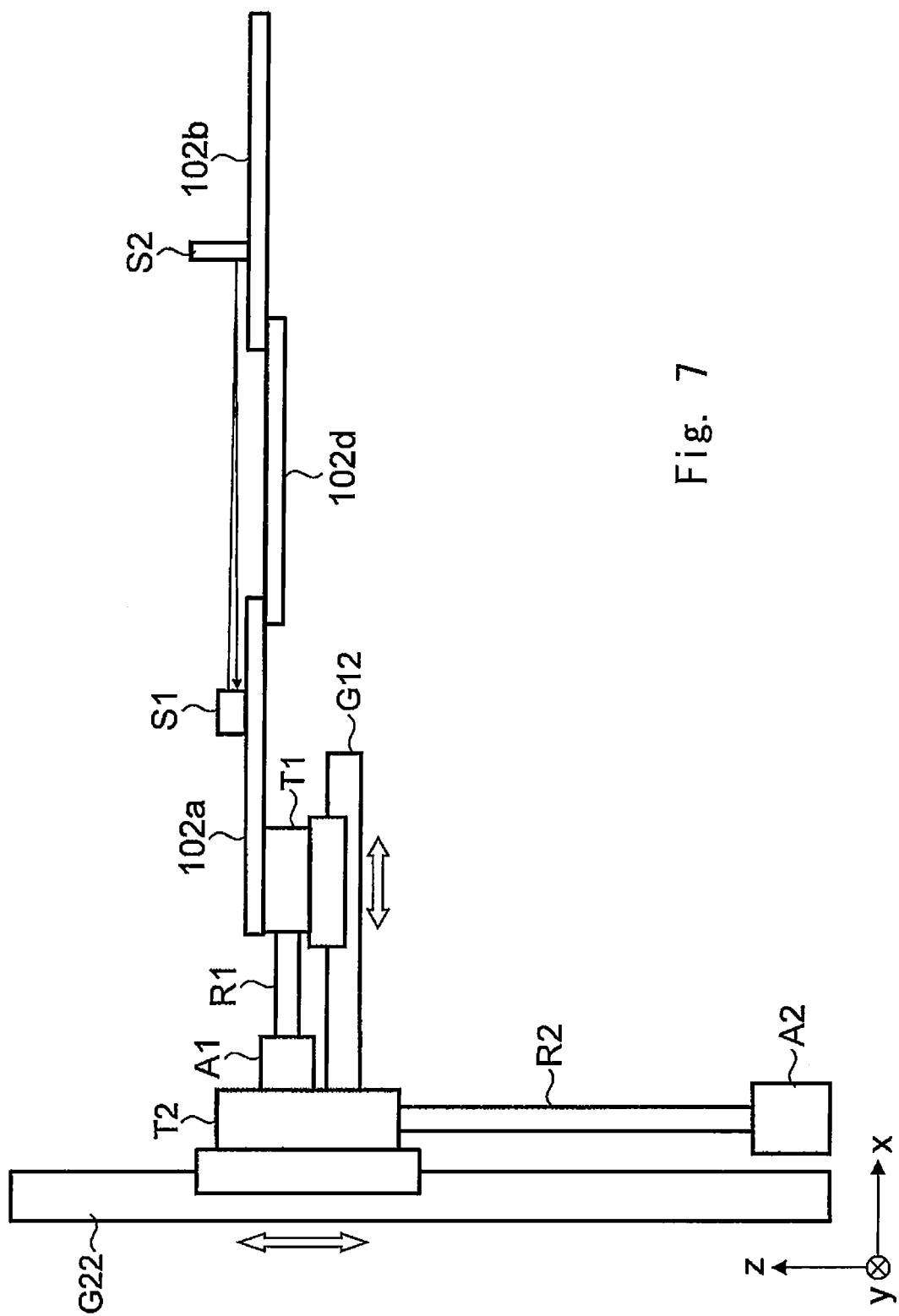


Fig. 7

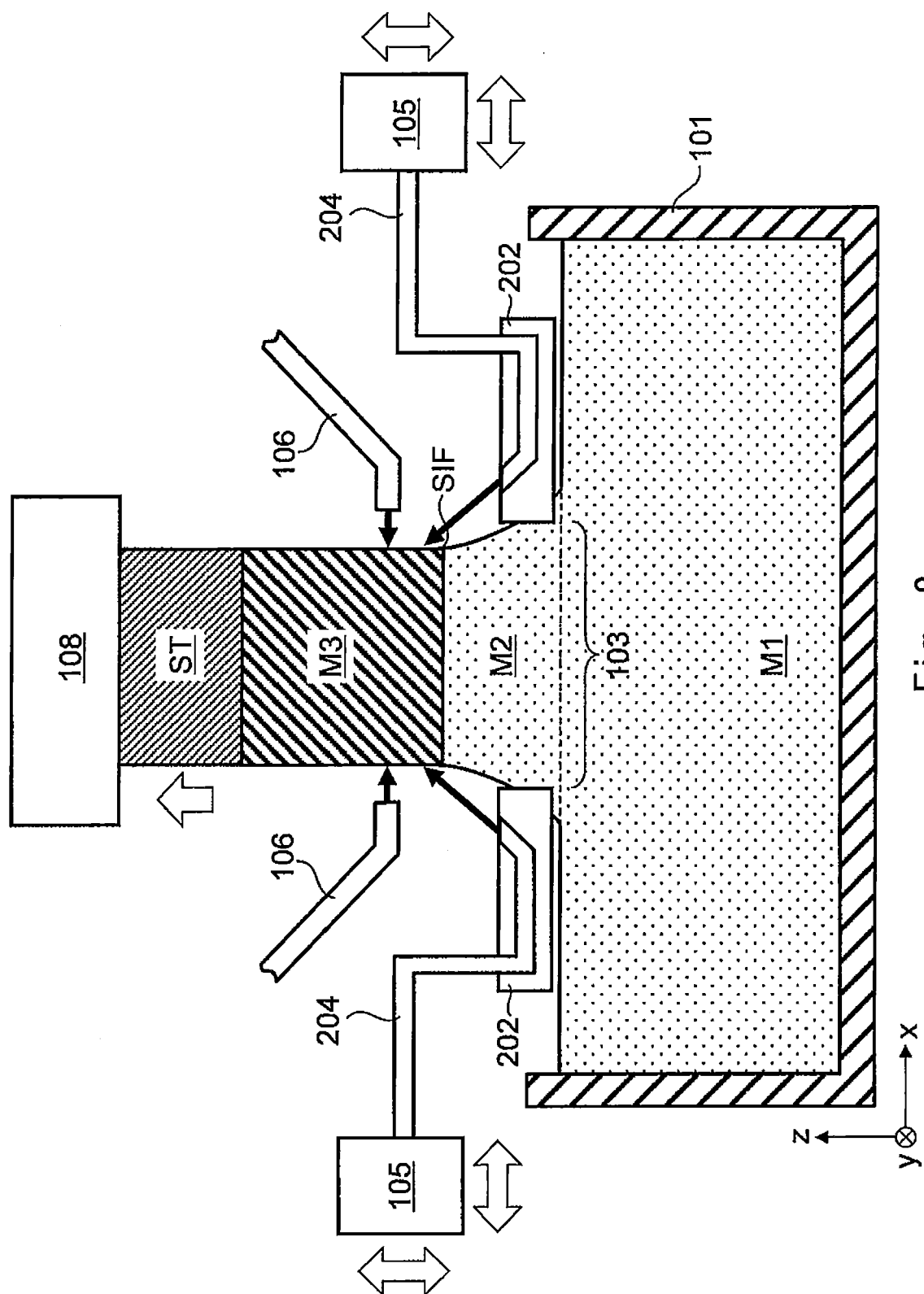
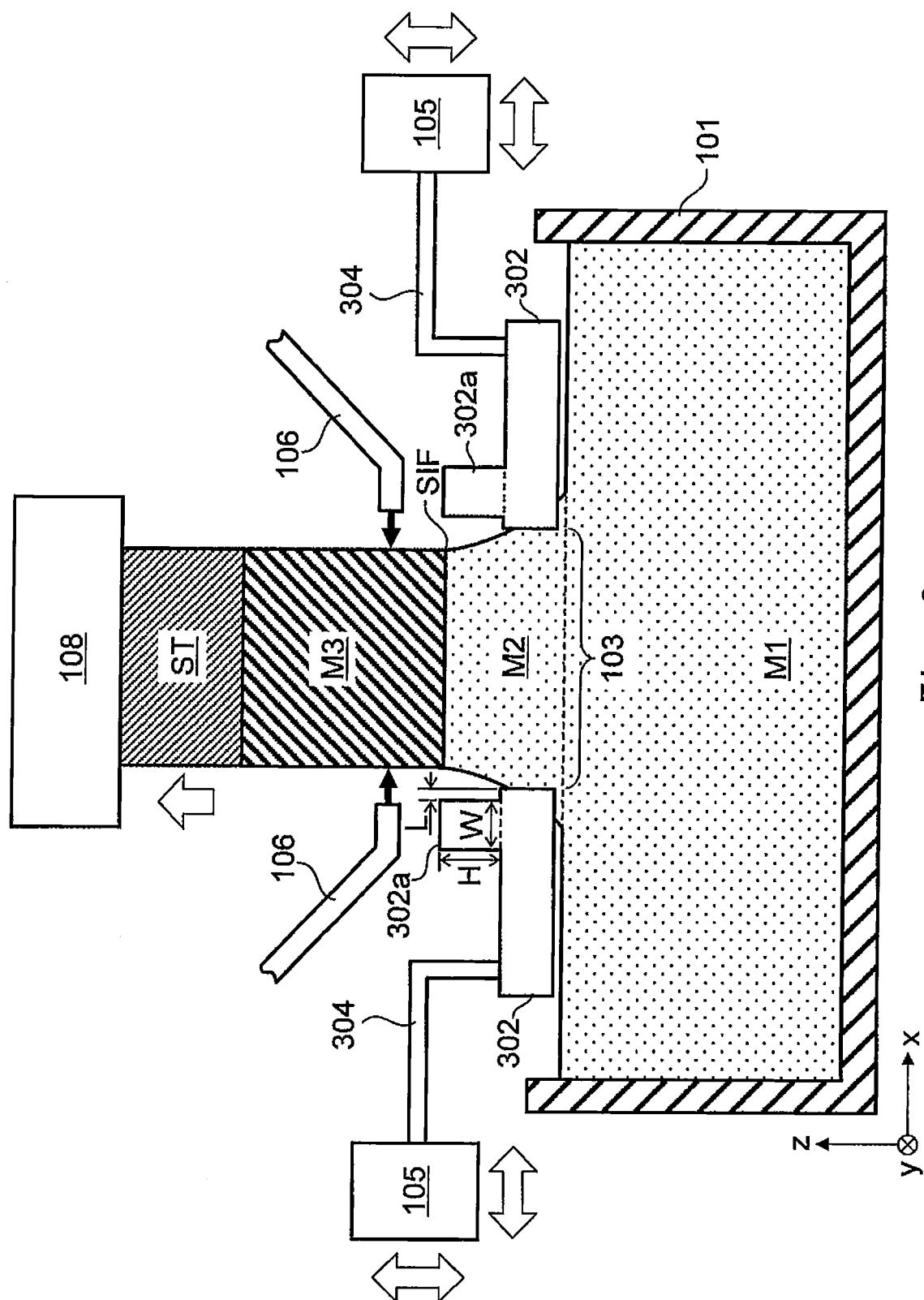
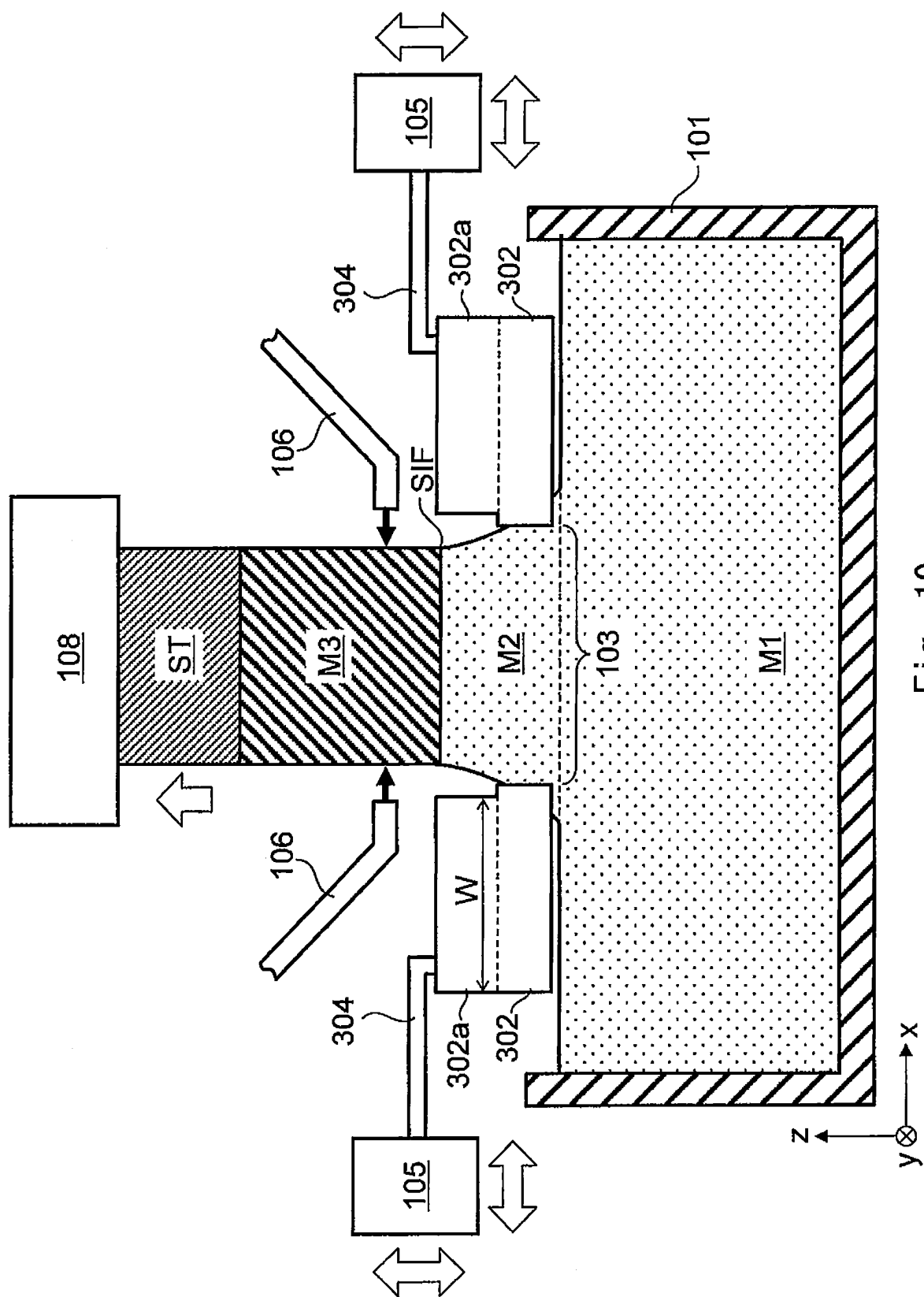
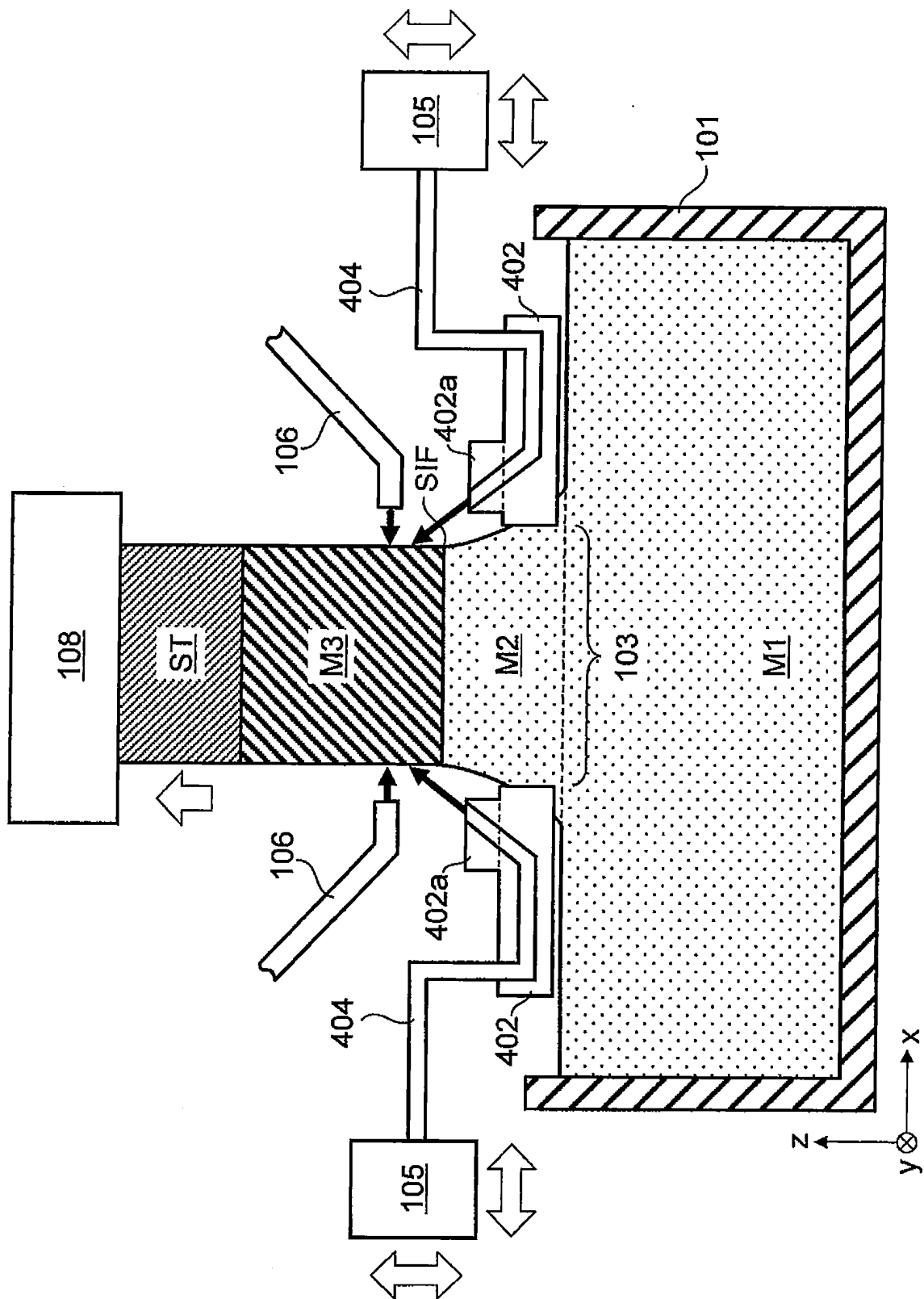


Fig. 8





Fi. 10



Fi 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/002453

A. CLASSIFICATION OF SUBJECT MATTER

B22D11/01 (2006.01) i, B22D11/04 (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)

B22D11/01, B22D11/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2012-61518 A (Toyota Central Research and Development Laboratories, Inc.), 29 March 2012 (29.03.2012), entire text & WO 2012/035752 A1	1-15
A	JP 2-205232 A (Director General of National Research Institute for Science and Technology Agency), 15 August 1990 (15.08.1990), entire text (Family: none)	1-15

☒ 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
24 April, 2013 (24.04.13)Date of mailing of the international search report
14 May, 2013 (14.05.13)Name and mailing address of the ISA/
Japanese Patent Office

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/002453

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 63-199049 A (Sumitomo Electric Industries, Ltd.), 17 August 1988 (17.08.1988), entire text (Family: none)	1-15

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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