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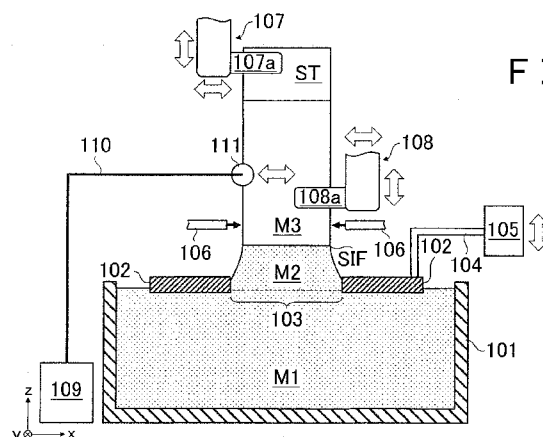


FIG. 1

(57) **Abstract:** An up-drawing continuous casting method according to one aspect of the invention is an up-drawing continuous casting method for forming a casting while drawing up molten metal held in a holding furnace, and includes: a step of drawing up the molten metal by a first draw-up machine via a starter gripped by the first draw-up machine; a step of gripping, by a second draw-up machine, the casting drawn up by the first draw-up machine; a step of fusion cutting the casting between the first draw-up machine and the second draw-up machine; and a step of drawing up the molten metal by the second draw-up machine via the casting gripped by the second draw-up machine.

UP-DRAWING CONTINUOUS CASTING METHOD AND UP-DRAWING CONTINUOUS CASTING APPARATUS

BACKGROUND OF THE INVENTION

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1. Field of the Invention

[0001] The present invention relates to an up-drawing continuous casting method and an up-drawing continuous casting apparatus.

10 2. Description of Related Art

[0002] Japanese Patent Application Publication No. 2012-61518 (JP 2012-61518 A) describes a free casting method as an epoch-making up-drawing continuous casting method that does not require a mold. As described in JP 2012-61518 A, when a starter is immersed into a surface of molten metal (that is, a molten metal surface) and then the
15 starter is drawn up, the molten metal follows the starter due to a surface film and a surface tension of the molten metal and the molten metal is also led out. Here, a casting having a desired sectional shape can be continuously casted by leading out the molten metal via a shape determining member placed near the molten metal surface, and then cooling the molten metal thus led out.

20 **[0003]** With a normal continuous casting method, the sectional shape and the shape in a longitudinal direction are both determined by a mold. Particularly, in the continuous casting method, solidified metal (i.e., a casting) should pass through a mold, so that a casting casted hereby has a shape that extends linearly in the longitudinal direction. In the meantime, the shape determining member in the free casting method determines
25 only the sectional shape of the casting and does not determine a longitudinal shape thereof. On that account, castings having various longitudinal shapes can be obtained by drawing up the starter while moving the starter (or the shape determining member) horizontally. For example, JP 2012-61518 A describes a hollow casting (that is, pipe) formed not in a linear shape in its longitudinal direction, but in a zigzag shape or a helical shape in the

longitudinal direction.

[0004] The inventor(s) found the following problem in terms of the up-drawing continuous casting method described in JP 2012-61518 A. In the up-drawing continuous casting method described in JP 2012-61518 A, the casting cannot be cut while the casting is casted, so it is necessary to change a starter per product. That is, the up-drawing continuous casting method described in JP 2012-61518 A is a so-called batch-wise method. This requires a starter per product, which requires high cost, and further takes time to attach the starter per product, which has a possibility that productivity is low.

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SUMMARY OF THE INVENTION

[0005] The present invention provides an up-drawing continuous casting method and an up-drawing continuous casting apparatus each of which does not require to change a starter per product and each of which is excellent in low cost and productivity.

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[0006] An up-drawing continuous casting method according to one aspect of the present invention is an up-drawing continuous casting method for forming a casting while drawing up molten metal held in a holding furnace, and includes: a step of drawing up the molten metal by a first draw-up machine via a starter gripped by the first draw-up machine; a step of gripping, by a second draw-up machine, the casting drawn up by the first draw-up machine; a step of fusion cutting the casting between the first draw-up machine and the second draw-up machine; and a step of drawing up the molten metal by the second draw-up machine via the casting gripped by the second draw-up machine. The up-drawing continuous casting method according to the one aspect of the present invention includes: the step of gripping, by the second draw-up machine, the casting drawn up by the first draw-up machine; and the step of fusion cutting the casting between the first draw-up machine and the second draw-up machine. This makes it possible to cut off a casting while continue casting. Accordingly, it is not necessary to change a starter per product, and thus, the draw-up continuous casting method of the one aspect of the present invention is excellent in low cost and productivity.

[0007] In the step of drawing up the molten metal by the first draw-up machine,

the molten metal may be drawn up while being passed through a shape determining member placed on a molten metal surface of the molten metal and configured to determine a sectional shape of the casting. According to such a configuration, it is possible to form a casting with accuracy.

5 **[0008]** The draw-up continuous casting method of the one aspect of the present invention may further include, after the step of drawing up the molten metal by the second draw-up machine: a step of gripping, by the first draw-up machine, the casting drawn up by the second draw-up machine on a lower side relative to the second draw-up machine; a step of fusion cutting again the casting between the first draw-up machine and the second
10 draw-up machine; and a step of drawing up the molten metal by the first draw-up machine via the casting gripped by the first draw-up machine.

[0009] The casting may be fusion cut by laser fusion cutting. According to such a configuration, it is possible to form a casting with accuracy.

[0010] An up-drawing continuous casting apparatus according to one aspect of
15 the present invention is an up-drawing continuous casting apparatus for forming a casting while drawing up molten metal held in a holding furnace, and includes: a first draw-up machine configured to grip a starter and draw up the molten metal via the starter; a second draw-up machine configured to grip the casting drawn up by the first draw-up machine and draw up the molten metal via the casting; and a fusion cutting portion configured to fusion
20 cut the casting between the first draw-up machine and the second draw-up machine. The up-drawing continuous casting apparatus according to one aspect of the present invention includes: the second draw-up machine configured to grip the casting drawn up by the first draw-up machine and draw up the molten metal via the casting; and the fusion cutting portion configured to fusion cutting the casting between the first draw-up machine and the
25 second draw-up machine. This makes it possible to cut off a casting while continuing casting. Accordingly, it is not necessary to change a starter per product, and thus, the draw-up continuous casting apparatus of the one aspect of the present invention is excellent in low cost and productivity.

[0011] The draw-up continuous casting apparatus of the one aspect of the present

invention may further include a shape determining member placed on a molten metal surface of the molten metal and configured to determine a sectional shape of the casting, and the molten metal may be drawn up while being passed through the shape determining member. According to such a configuration, it is possible to form a casting with accuracy.

[0012] The fusion cutting portion may fusion cut the casting by laser fusion cutting. According to such a configuration, it is possible to cut the casting with accuracy. Particularly, the fusion cutting portion may include a first laser machining head slidably connected to the first draw-up machine, and a second laser machining head slidably connected to the second draw-up machine. According to such a configuration, position control of the laser machining heads can be easily performed.

[0013] In the up-drawing continuous casting apparatus, a plurality of shape determining members may be provided. According to such a configuration, a thickness and a width of the molten metal passage portion can be changed. Further, the plurality of shape determining members can move in a z-axis direction in sync with each other.

[0014] In the up-drawing continuous casting apparatus, when the starter is immersed into the molten metal surface of the molten metal and then the starter is drawn up therefrom, the molten metal may follow the starter due to a surface film and a surface tension of the molten metal and the molten metal may be led out, the molten metal may be led out via the shape determining member provided near the molten metal surface, and the molten metal may be cooled off so as to continuously cast the casting having a desired sectional shape.

[0015] According to the present invention, it is possible to provide an up-drawing continuous casting method and an up-drawing continuous casting apparatus each of which does not require to change a starter per product and each of which is excellent in low cost and productivity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Features, advantages, and technical and industrial significance of

exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a schematic side view of a free casting apparatus according to Embodiment 1;

5 FIG. 2 is a plan view of a shape determining member 102 according Embodiment 1;

FIG. 3 is a flow chart showing a free casting method according to Embodiment 1;

FIG. 4 is a side view illustrating an operation of a first draw-up machine 107, a second draw-up machine 108, and a laser machining head 111;

10 FIG. 5 is a side view illustrating the operation of the first draw-up machine 107, the second draw-up machine 108, and the laser machining head 111;

FIG. 6 is a side view illustrating the operation of the first draw-up machine 107, the second draw-up machine 108, and the laser machining head 111;

FIG. 7 is a side view illustrating the operation of the first draw-up machine 107, the second draw-up machine 108, and the laser machining head 111;

15 FIG. 8 is a top view of FIG. 7;

FIG. 9 is a side view illustrating the operation of the first draw-up machine 107, the second draw-up machine 108, and the laser machining head 111;

FIG. 10 is a side view illustrating the operation of the first draw-up machine 107, the second draw-up machine 108, and the laser machining head 111;

20 FIG. 11 is a side view illustrating the operation of the first draw-up machine 107, the second draw-up machine 108, and the laser machining head 111;

FIG. 12 is a side view illustrating the operation of the first draw-up machine 107, the second draw-up machine 108, and the laser machining head 111;

25 FIG. 13 is a plan view of a shape determining member 102 according a modification of Embodiment 1; and

FIG. 14 is a schematic side view of a free casting apparatus according to Embodiment 2.

DETAILED DESCRIPTION OF EMBODIMENTS

[0017] The following describes concrete embodiments to which the present invention is applied with reference to the drawings. However, the present invention is not limited to the following embodiments. Further, the following description and drawings are simplified appropriately for clarification of the description.

5 [0018] (Embodiment 1) First described is a free casting apparatus (an up-drawing continuous casting apparatus) according to Embodiment 1, with reference to FIG. 1. FIG. 1 is a schematic side view of a free casting apparatus according to Embodiment 1. As illustrated in FIG. 1, the free casting apparatus according to Embodiment 1 includes a molten metal holding furnace 101, a shape determining member 102, a support rod 104, an actuator 105, a coolant gas nozzle 106, a first draw-up machine 107, a second draw-up machine 108, a laser oscillator 109, an optical fiber 110, and a laser machining head 111. Note that, as for the molten metal holding furnace 101 and the shape determining member 102, FIG. 1 illustrates their sections. Further, naturally, the xyz right handed coordinate system in the following figures is illustrated for convenience of description of a positional relationship of constituents. A xy plane in the following figures constitutes a horizontal plane, and a positive side in a z-axis direction indicates a vertically upward direction.

[0019] The molten metal holding furnace 101 stores therein molten metal M1 of aluminum or its alloy, for example, and keeps the molten metal M1 at a predetermined temperature at which the molten metal M1 has fluidity. In the example in FIG 1, molten metal is not replenished into the molten metal holding furnace 101 during casting, so that a surface of the molten metal M1 (i.e., a molten metal surface) drops as the casting proceeds. However, molten metal may be replenished, as needed, into the molten metal holding furnace 101 during casting such that the molten metal surface is kept constant. Here, when a preset temperature of the molten metal holding furnace 101 is increased, a position of a solidification interface SIF can be raised. When the preset temperature of the molten metal holding furnace 101 is decreased, the position of the solidification interface SIF can be lowered. Naturally, the molten metal M1 may be of metal or its alloy other than aluminum.

[0020] The shape determining member 102 is made of ceramics or stainless, for

example, and is placed on the molten metal M1. The shape determining member 102 determines a sectional shape of a casting M3 to be casted. The casting M3 illustrated in FIG. 1 is a solid casting (a plate material) of which a horizontal section (hereinafter referred to as a transverse section) has a rectangular shape. Naturally, the sectional shape of the casting M3 is not limited in particular. The casting M3 may be a hollow casting such as a circular pipe or a square pipe.

[0021] In the example illustrated in FIG. 1, the shape determining member 102 is placed so that a principal plane (a bottom face) of a lower side of the shape determining member 102 makes contact with the molten metal surface. Accordingly, it is possible to prevent an oxide film formed on the surface of the molten metal M1 and foreign matters floating on the surface of the molten metal M1 from mixing into the casting M3. Further, the shape determining member 102 is easily warmed by the molten metal M1, which is preferable. Meanwhile, the shape determining member 102 may be placed so that its bottom face is distanced from the molten metal surface only by a predetermined distance (e.g., around 0.5 mm). In a case where the shape determining member 102 is placed so as to be distanced from the molten metal surface, heat deformation and erosion of the shape determining member 102 are restrained, so that durability of the shape determining member 102 is improved.

[0022] FIG. 2 is a plan view of the shape determining member 102 according to Embodiment 1. Here, the sectional view of the shape determining member 102 of FIG. 1 corresponds to a sectional view taken along a line I-I in FIG. 2. As illustrated in FIG. 2, the shape determining member 102 has a rectangular flat shape, for example, and has, in its central part, a rectangular opening (a molten metal passage portion 103) of a thickness $t1$ × width $w1$ and configured such that the molten metal passes therethrough.

[0023] As illustrated in FIG. 1, the molten metal M1 is drawn up following the casting M3 due to its surface film and its surface tension and passes through the molten metal passage portion 103 of the shape determining member 102. That is, when the molten metal M1 passes through the molten metal passage portion 103 of the shape determining member 102, an external force is applied to the molten metal M1 from the

shape determining member 102, so that a sectional shape of the casting M3 is determined. Here, the molten metal drawn up, from the molten metal surface, following the casting M3 due to the surface film and the surface tension of the molten metal is referred to as retained molten metal M2. Further, a boundary between the casting M3 and the molten metal M2 is the solidification interface SIF.

[0024] The support rod 104 supports the shape determining member 102. The support rod 104 is connected to the actuator 105. Due to the actuator 105, the shape determining member 102 is movable in an up-down direction (a vertical direction, that is, the z-axis direction) via the support rod 104. With such a configuration, the shape determining member 102 can be moved downward when the casting proceeds and the molten metal surface drops.

[0025] The coolant gas nozzle (cooling portion) 106 is cooling means configured to cool off the casting M3 by spraying, on the casting M3, coolant gas (e.g., air, nitrogen, argon, or the like) supplied from a coolant gas supply portion (not shown). When a flow rate of the coolant gas is increased, a position of the solidification interface SIF is lowered, and when the flow rate of the coolant gas is decreased, the position of the solidification interface SIF is raised. Note that the coolant gas nozzle 106 is also movable in the up-down direction (the vertical direction, that is, the z-axis direction) and in a horizontal direction (an x-axis direction and a y-axis direction). Accordingly, the coolant gas nozzle 106 can move downward along with the movement of the shape determining member 102, when the casting proceeds and the molten metal surface drops. Alternatively, the coolant gas nozzle 106 can move in the horizontal direction along with horizontal movement of the first draw-up machine 107 and the second draw-up machine 108.

[0026] The first draw-up machine 107 includes a gripper 107a, so as to grip a starter ST or the casting M3 by the gripper 107a to draw up the casting M3. The first draw-up machine 107 is placed on a negative side relative to the casting M3 in the x-axis direction, and grips the casting M3 from the negative side in the x-axis direction. Similarly, the second draw-up machine 108 includes a gripper 108a, so as to grip the starter ST or the casting M3 by the gripper 108a to draw up the casting M3. The second

draw-up machine 108 is placed on a positive side relative to the casting M3 in the x-axis direction, and grips the casting M3 from the positive side in the x-axis direction. In the meantime, the first draw-up machine 107 and the second draw-up machine 108 can release the starter ST or the casting M3 thus gripped. It is preferable that the first draw-up machine 107 and the second draw-up machine 108 be freely movable in the x-axis, y-axis and z-axis directions and be robot arms, for example.

[0027] In the example of FIG. 1, the starter ST is first gripped by the first draw-up machine 107, and draw up the casting M3. When the casting M3 is cooled off by the coolant gas, the retained molten metal M2 near the solidification interface SIF solidifies sequentially from an upper side (a positive side in the z-axis direction) to a lower side (a negative side in the z-axis direction), and thus, the casting M3 is formed. When generally one casting M3 is casted, a lower part of the casting M3 is gripped by the second draw-up machine 108. Then, the casting M3 near above the second draw-up machine 108 is laser-fusion cut by the laser machining head 111. Hereby, the casting M3 gripped by the first draw-up machine 107 is separated as a product. Here, casting can be continued by the second draw-up machine 108.

[0028] When a draw-up speed by the first draw-up machine 107 and the second draw-up machine 108 is increased, the position of the solidification interface SIF can be raised. When the draw-up speed is decreased, the position of the solidification interface SIF can be lowered. Further, it is possible to freely change a longitudinal shape of the casting M3 by drawing up the casting M3 while horizontally moving the first draw-up machine 107 and the second draw-up machine 108 (in the x-axis direction and the y-axis direction). Note that the longitudinal shape of the casting M3 may be changed freely by horizontally moving the shape determining member 102 instead of horizontally moving the first draw-up machine 107 and the second draw-up machine 108.

[0029] Here, in order to obtain the casting M3 that is excellent in dimension accuracy and surface quality, the solidification interface SIF is held at an appropriate position (height). That is, the casting is performed in a state where a solidification speed on the solidification interface SIF and the draw-up speed are generally balanced. From

the viewpoint of productivity, it is preferable that the draw-up speed be larger. However, if only the draw-up speed is increased while the solidification speed is kept constant, the solidification interface SIF would be raised and the retained molten metal M2 would break off. In order to increase the solidification speed (to lower the solidification interface SIF),
5 an amount of the coolant gas should be increased or a temperature of the molten metal temperature should be decreased, as described above.

[0030] The laser machining head (fusion cutting portion) 111 is scanned in the x-axis direction at a height between the first draw-up machine 107 and the second draw-up machine 108. It is possible to fusion cut the casting M3 with accuracy by a laser beam
10 LB (see FIG. 8) emitted from the laser machining head 111. At the time of fusion cutting, it is preferable that the laser machining head 111 be also movable in the z-axis direction according to a casting speed. This makes it possible to fusion cut the casting M3 horizontally.

[0031] The laser beam LB is generated by the laser oscillator 109 and emitted
15 from the laser machining head 111 via the optical fiber 110. As the laser beam LB, fiber laser, YAG laser, and the like can be used, for example.

[0032] Note that the free casting apparatus according to Embodiment 1 uses laser fusion cutting as a cutting method of the casting M3, but also can use noncontact cutting such as gas fusion cutting or arc fusion cutting. However, from the viewpoint of fusion
20 cutting accuracy, it is preferable to use the laser fusion cutting. Meanwhile, in order to restrain vibration to be given to the retained molten metal M2, it is preferable to use noncontact cutting as the cutting method of the casting M3.

[0033] The free casting apparatus according to Embodiment 1 includes the second draw-up machine 108 in addition to the first draw-up machine 107. Further, the free
25 casting apparatus includes the laser machining head 111 that can fusion cut the casting M3. This makes it possible to obtain a product by fusion cutting the casting M3 while continuing casting. That is, the free casting apparatus according to Embodiment 1 can save a starter and time to attach the starter because it is not necessary to change the starter per product, and thus, the free casting apparatus according to Embodiment 1 is excellent in

low cost and productivity. A detailed mechanism about the effect will be described later in the description about a free casting method according to Embodiment 1.

[0034] Next will be described the free casting method according to Embodiment 1, with reference to FIGS. 3 to 12. FIG. 3 is a flow chart showing the free casting method according to Embodiment 1. FIGS. 4 to 7, 9 to 12 are side views each illustrating an operation of the first draw-up machine 107, the second draw-up machine 108, and the laser machining head 111. FIG. 8 is a top view of FIG. 7. Initially, as shown in FIG. 3, the starter ST is gripped by one draw-up machine (step ST1). In the example of FIG. 4, the starter ST is gripped by the gripper 107a of the first draw-up machine 107 from the negative side in the x-axis direction. Then, a tip end (a lower end) of the starter ST is immersed into the molten metal M1 while the tip end of the starter ST is passed through the molten metal passage portion 103 of the shape determining member 102.

[0035] Subsequently, as shown in FIG. 3, the starter ST is drawn up at a predetermined speed, so as to cast one product (step ST2). Here, as illustrated in FIG. 4, even if the starter ST is distanced from the molten metal surface, the retained molten metal M2 drawn up, from the molten metal surface, following the starter ST due to the surface film and the surface tension is formed. As illustrated in FIG. 4, the retained molten metal M2 is formed by the molten metal passage portion 103 of the shape determining member 102. That is, a shape is given to the retained molten metal M2 by the shape determining member 102. Then, since the starter ST or the casting M3 is cooled off by the coolant gas as illustrated in FIG. 5, the retained molten metal M2 is cooled off indirectly and solidified sequentially from the upper side to the lower side, so that the casting M3 grows.

[0036] Then, as shown in FIG. 3, it is determined whether or not a product thus casted is a final product (step ST3). If the product is not the final product (NO in step ST3), a lower part of the casting M3 is gripped by the other draw-up machine (step ST4). In the example of FIG. 6, the second draw-up machine 108 that stands by on the positive side relative to the casting M3 in the x-axis direction in FIG. 5 moves toward the negative side in the x-axis direction, so that that part of the casting M3 which is near above the cooling portion is gripped by the gripper 108a. The second draw-up machine 108 moves

toward the positive side in the z-axis direction in sync with the first draw-up machine 107. It is preferable that a position, in the z-axis direction, of that part of the casting M3 which is gripped by the second draw-up machine 108 be above the cooling portion but as low as possible. As the position gripped by the second draw-up machine 108 is lower, vibration
5 of the retained molten metal M2 at the time when the casting M3 is gripped can be restrained more.

[0037] Then, as shown in FIG. 3, the casting M3 is laser-fusion cut between the first draw-up machine 107 and the second draw-up machine 108 (step ST5). More specifically, as illustrated in FIGS. 7, 8, the laser machining head 111 that stands by in an
10 end of the casting M3 on the negative side in the x-axis direction is scanned toward the positive direction in the x-axis direction over that part of the casting M3 which is near above the cooling portion, so that the casting M3 is fusion cut by the laser beam LB. Hereby, as illustrated in FIG. 9, a first product M31 gripped by the first draw-up machine 107 via the starter ST is separated from the casting M3. Although not illustrated herein,
15 the starter ST and the product M31 are released from the first draw-up machine 107 after that. Note that, as for the first product M31, it is necessary to cut off the starter ST therefrom.

[0038] Subsequently, as shown in FIG. 3, the process is returned to step ST2, so as to cast one product. More specifically, as illustrated in FIG. 10, the casting M3 is
20 gripped by the second draw-up machine 108, so casting of a second product is continued. In step ST4 related to the second product, as illustrated in FIG. 11, the first draw-up machine 107 that stands by on the negative side relative to the casting M3 in the x-axis direction in FIG. 10 moves toward the positive side in the x-axis direction, so that that part of the casting M3 which is near above the cooling portion is gripped by the gripper 107a.
25 The first draw-up machine 107 moves toward the positive side in the z-axis direction in sync with the second draw-up machine 108.

[0039] In next step ST5, as illustrated in FIG. 12, the laser machining head 111 that stands by in an end of the casting M3 on the positive side in the x-axis direction is scanned toward the negative side in the x-axis direction, so that the casting M3 is fusion

cut by the laser beam LB. Hereby, the second product M32 directly gripped by the second draw-up machine 108 is separated from the casting M3. In the meantime, the casting M3 is gripped by the first draw-up machine 107, so casting of a third product is continued. Thus, by using the first draw-up machine 107 and the second draw-up machine 108 alternately, it is possible to continue casting while cutting off a product.

[0040] If the product thus casted is the final product (YES in step ST3) in FIG. 3, casting is finished. At this time, the casting speed is increased, and the retained molten metal M2 is pulled off. Hereby, the final product can be obtained without laser fusion cutting. That is, it is necessary to perform laser fusion cutting on the final product.

10 [0041] As described above, in the free casting method according to Embodiment 1, it is possible to obtain a product by fusion cutting the casting M3 while continuing casting. That is, the free casting method according to Embodiment 1 can save a starter and time to attach the starter because it is not necessary to change the starter per product, and thus, the free casting method according to Embodiment 1 is excellent in low cost and productivity.

[0042] (Modification of Embodiment 1) Next will be described a free casting apparatus according to a modification of Embodiment 1, with reference to FIG. 13. FIG. 13 is a plan view of a shape determining member 102 according to the modification of Embodiment 1. The shape determining member 102 according to Embodiment 1 as illustrated in FIG. 2 is constituted by a single plate, so the thickness $t1$ and the width $w1$ of the molten metal passage portion 103 are fixed. On the other hand, the shape determining member 102 according to the modification of Embodiment 1 includes four rectangular shape determining plates 102a, 102b, 102c, 102d as illustrated in FIG. 13. That is, the shape determining member 102 according to the modification of Embodiment 1 is divided into a plurality of plates. With such a configuration, the thickness $t1$ and the width $w1$ of the molten metal passage portion 103 can be changed. Further, the four rectangular shape determining plates 102a, 102b, 102c, 102d can move in the z-axis direction in sync with each other.

[0043] As illustrated in FIG. 13, the shape determining plates 102a, 102b are

placed side by side in the x-axis direction so as to be opposed to each other. Further, the shape determining plates 102a, 102b are placed at the same height in the z-axis direction. An interval between the shape determining plates 102a, 102b determines the width w1 of the molten metal passage portion 103. Further, the shape determining plates 102a, 102b are independently movable in the x-axis direction, so the width w1 can be changed. Note that, in order to measure the width w1 of the molten metal passage portion 103, a laser displacement meter S1 may be provided on the shape determining plate 102a and a laser passive reflector S2 may be provided on the shape determining plate 102b, as illustrated in FIG. 13.

[0044] Further, as illustrated in FIG. 13, the shape determining plates 102c, 102d are placed side by side in the y-axis direction so as to be opposed to each other. Further, the shape determining plates 102c, 102d are placed at the same height in the z-axis direction. An interval between the shape determining plates 102c, 102d determines the thickness t1 of the molten metal passage portion 103. Further, the shape determining plates 102c, 102d are independently movable in the y-axis direction, so the thickness t1 can be changed. The shape determining plates 102a, 102b are placed so as to make contact with top faces of the shape determining plates 102c, 102d.

[0045] (Embodiment 2) Next will be described a free casting apparatus according to Embodiment 2, with reference to FIG. 14. FIG. 14 is a schematic side view of the free casting apparatus according to Embodiment 2. In the free casting apparatus according to Embodiment 2, a laser machining head 111a and a laser machining head 111b are slidably connected to a first draw-up machine 107 and a second draw-up machine 108, respectively. Since the other configuration is similar to the free casting apparatus according to Embodiment 1, description thereof is omitted.

[0046] More specifically, the first draw-up machine 107 includes a guide 107b extended in the x-axis direction, and the laser machining head 111a slides over the guide 107b in the x-axis direction. A laser beam is generated by a laser oscillator 109a, and emitted from the laser machining head 111a via an optical fiber 110a. Similarly, the second draw-up machine 108 includes a guide 108b extended in the x-axis direction, and

the laser machining head 111b slides over the guide 108b in the x-axis direction. A laser beam is generated by a laser oscillator 109b, and emitted from the laser machining head 111b via an optical fiber 110b.

[0047] In the free casting apparatus according to Embodiment 2, the laser machining heads 111a, 111b slide over the guides 107b, 108b, respectively, so a casting M3 can be automatically fusion cut in the horizontal direction. Accordingly, the laser machining heads 111a, 111b of the free casting apparatus according to Embodiment 1 can easily perform a position control as compared with the laser machining head 111 of the free casting apparatus according to Embodiment 1.

[0048] Note that the present invention is not limited to the above embodiments, and various modifications can be made within a range that does not deviate from a gist of the present invention. For example, the present invention is applicable to an up-drawing continuous casting method that does not use the shape determining member 102, provided that the method is an up-drawing continuous casting method for drawing up molten metal by use of a starter ST. However, the use of the shape determining member 102 makes it possible to form the casting M3 accurately, which is preferable.

CLAIMS:

1. An up-drawing continuous casting method for forming a casting while drawing up molten metal held in a holding furnace, the up-drawing continuous casting method comprising:

drawing up the molten metal by a first draw-up machine via a starter gripped by the first draw-up machine;

gripping, by a second draw-up machine, the casting drawn up by the first draw-up machine;

fusion cutting the casting between the first draw-up machine and the second draw-up machine; and

drawing up the molten metal by the second draw-up machine via the casting gripped by the second draw-up machine.

2. The up-drawing continuous casting method according to claim 1, wherein:

when the molten metal is drawn up by the first draw-up machine, the molten metal is drawn up while being passed through a shape determining member placed on a molten metal surface of the molten metal and configured to determine a sectional shape of the casting.

3. The up-drawing continuous casting method according to claim 1 or 2, wherein:

after the molten metal is drawn up by the second draw-up machine, the casting drawn up by the second draw-up machine is gripped by the first draw-up machine on a lower side relative to the second draw-up machine;

the casting is fusion cut again between the first draw-up machine and the second draw-up machine; and

the molten metal is drawn up by the first draw-up machine via the casting gripped by the first draw-up machine.

4. The up-drawing continuous casting method according to any one of claims 1 to 3, wherein:

the casting is fusion cut by laser fusion cutting.

5. The up-drawing continuous casting method according to any one of claims 1 to 4, wherein:

when the starter is immersed into a molten metal surface of the molten metal and then the starter is drawn up, the molten metal follows the starter due to a surface film and a surface tension of the molten metal and the molten metal is led out;

the molten metal is led out via a shape determining member provided near the molten metal surface; and

the molten metal is cooled off so as to continuously cast the casting having a desired sectional shape.

6. An up-drawing continuous casting apparatus for forming a casting while drawing up molten metal held in a holding furnace, the up-drawing continuous casting apparatus comprising:

a first draw-up machine configured to grip a starter and draw up the molten metal via the starter;

a second draw-up machine configured to grip the casting drawn up by the first draw-up machine and draw up the molten metal via the casting; and

a fusion cutting portion configured to fusion cut the casting between the first draw-up machine and the second draw-up machine.

7. The up-drawing continuous casting apparatus according to claim 6, further comprising:

a shape determining member placed on a molten metal surface of the molten metal and configured to determine a sectional shape of the casting, wherein:

the molten metal is drawn up while being passed through the shape determining

8. The up-drawing continuous casting apparatus according to claim 6 or 7, wherein:
the fusion cutting portion fusion cuts the casting by laser fusion cutting.

9. The up-drawing continuous casting apparatus according to claim 8, wherein:
the fusion cutting portion includes a first laser machining head slidably connected to the first draw-up machine, and a second laser machining head slidably connected to the second draw-up machine.

10. The up-drawing continuous casting apparatus according to any one of claims 6 to 9, wherein:
a plurality of shape determining members is provided.

11. The up-drawing continuous casting apparatus according to any one of claims 6 to 10, wherein:

when the starter is immersed into a molten metal surface of the molten metal and then the starter is drawn up, the molten metal follows the starter due to a surface film and a surface tension of the molten metal and the molten metal is led out;

the molten metal is led out via a shape determining member provided near the molten metal surface; and

the molten metal is cooled off so as to continuously cast the casting having a desired sectional shape.

FIG. 2

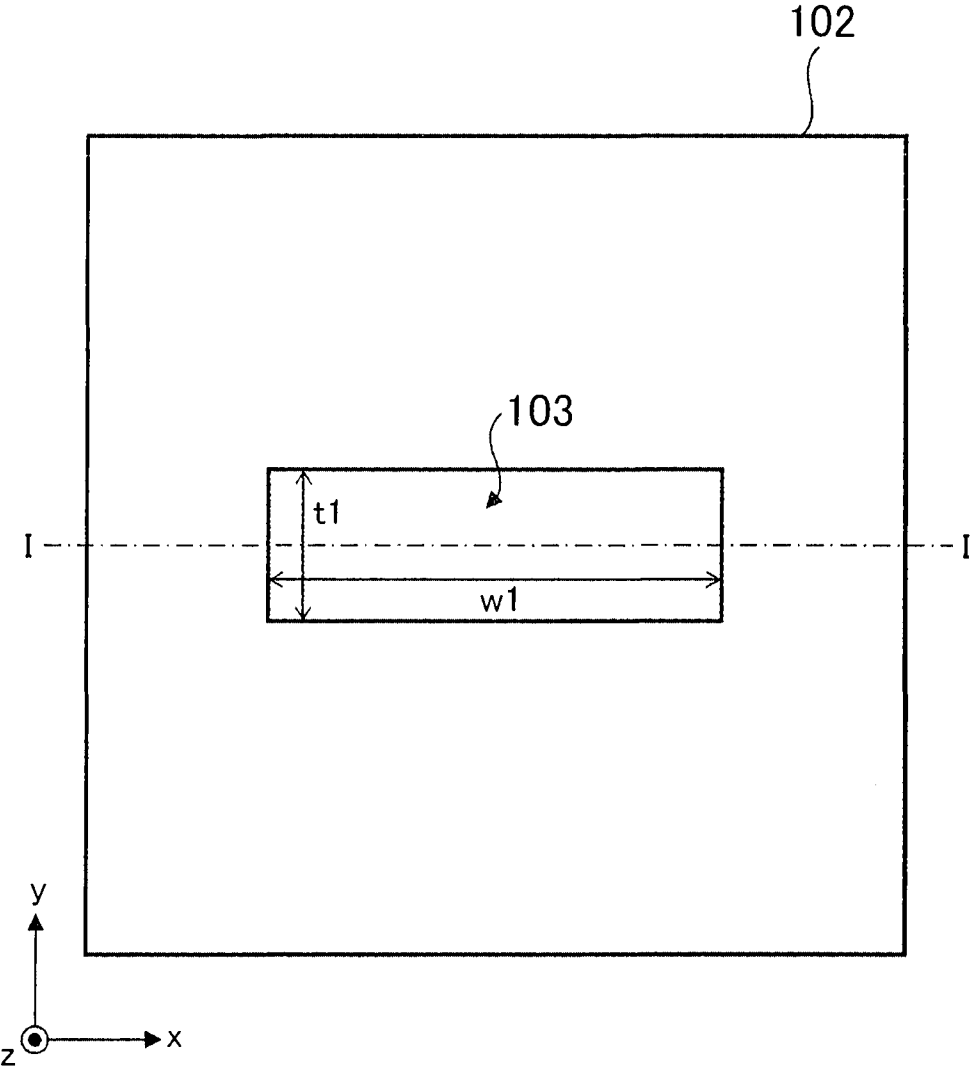


FIG. 3

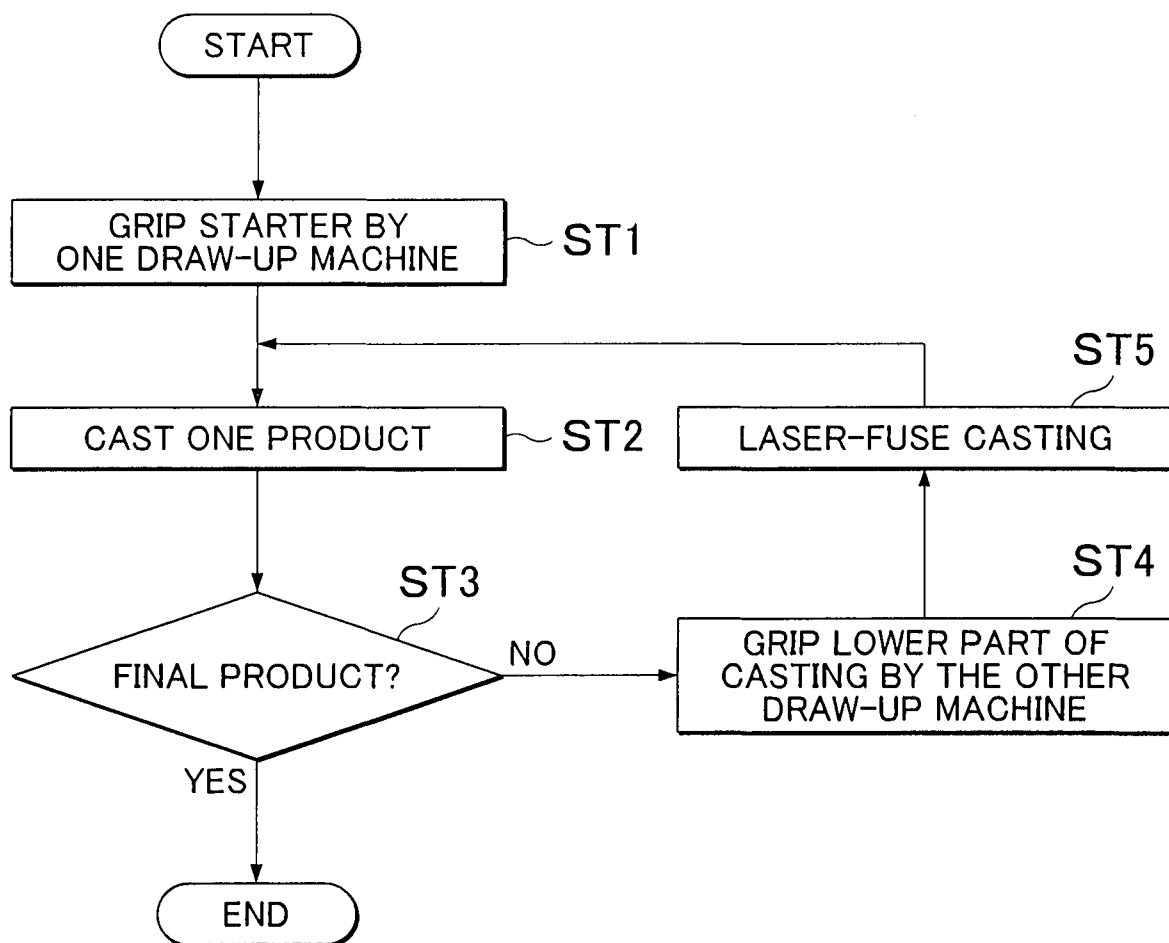


FIG. 4

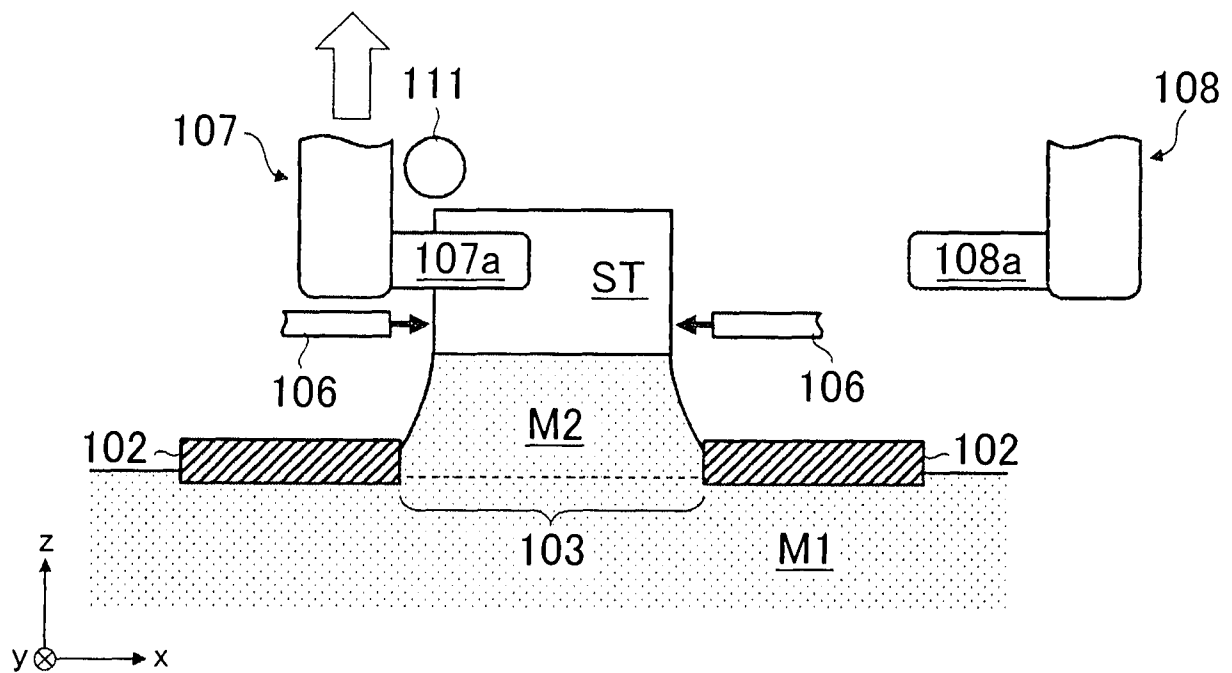


FIG. 5

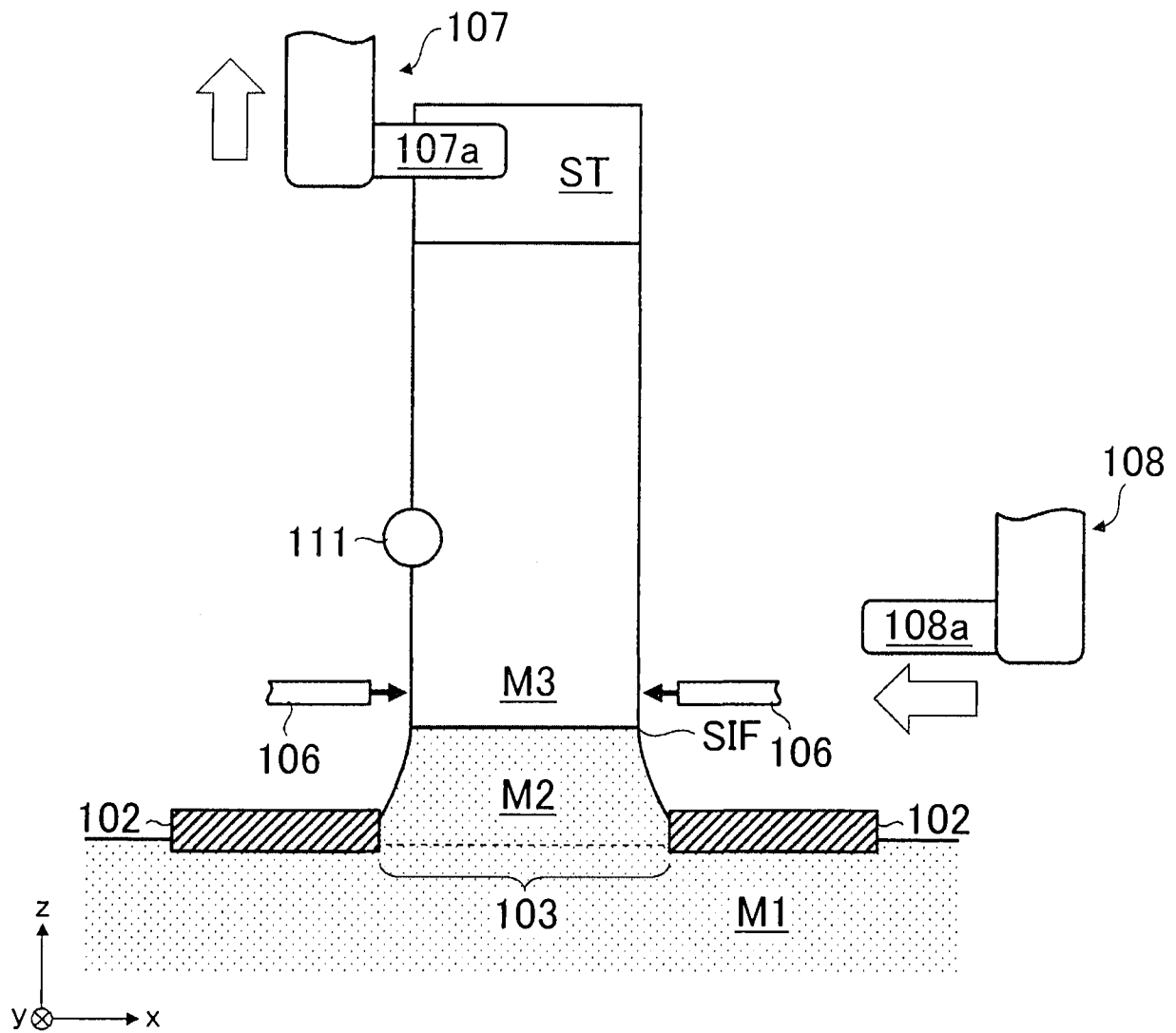


FIG. 6

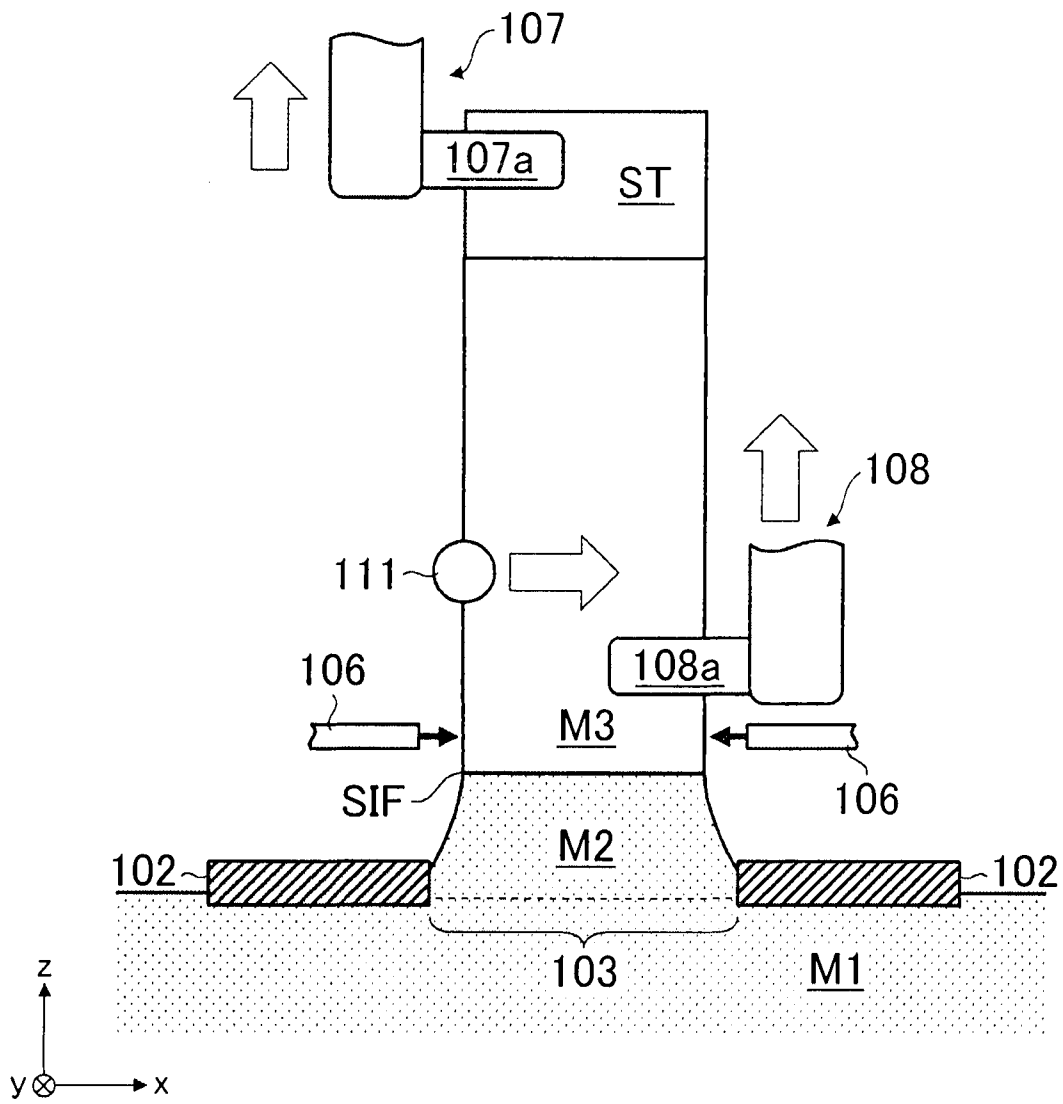


FIG. 7

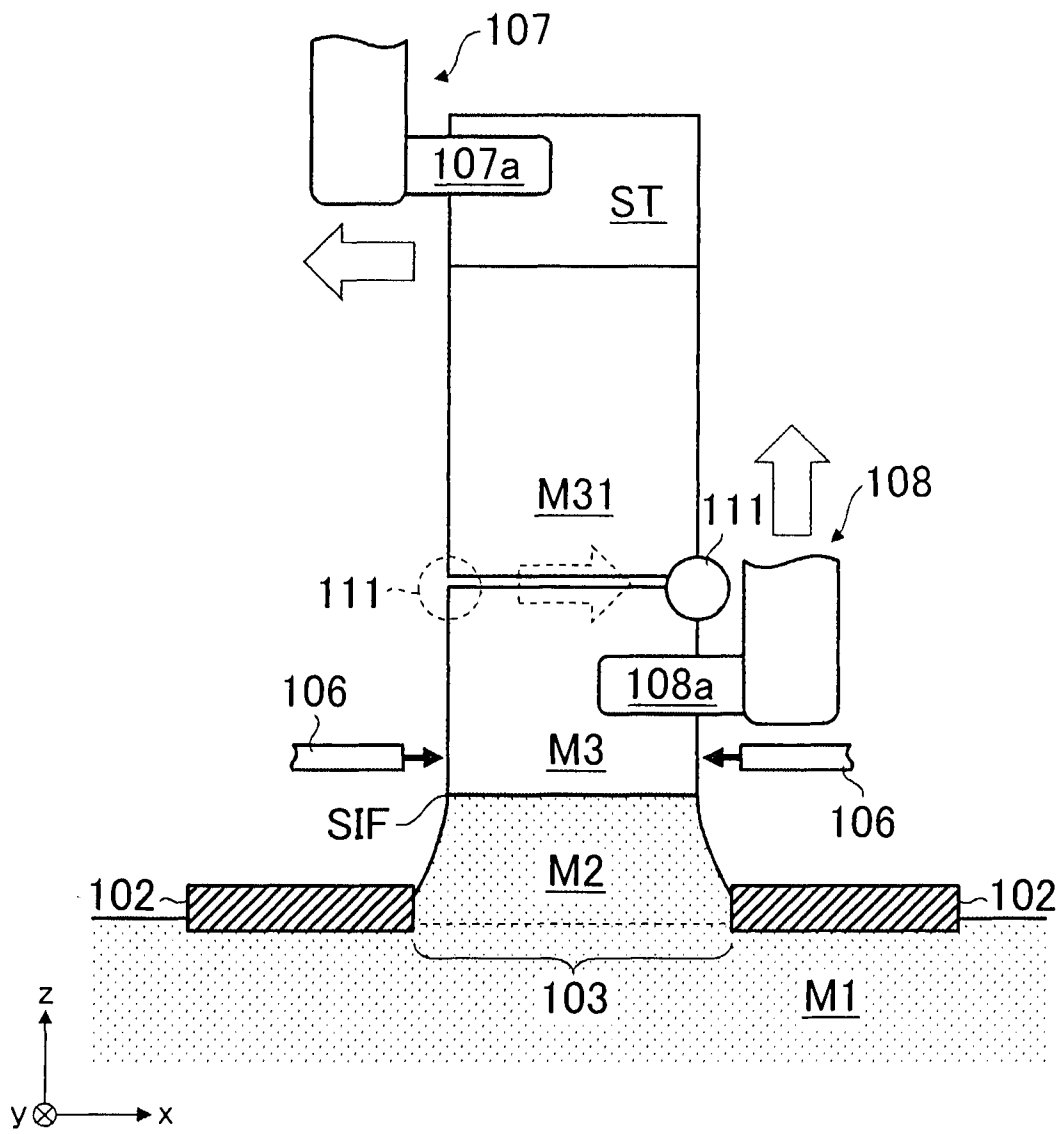


FIG. 8

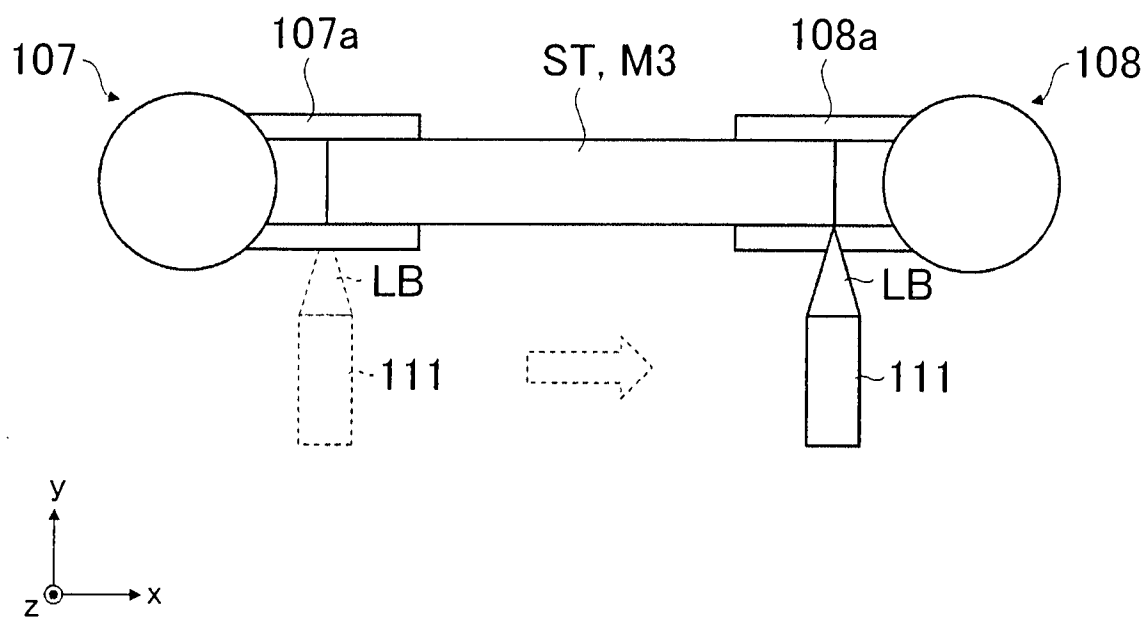


FIG. 10

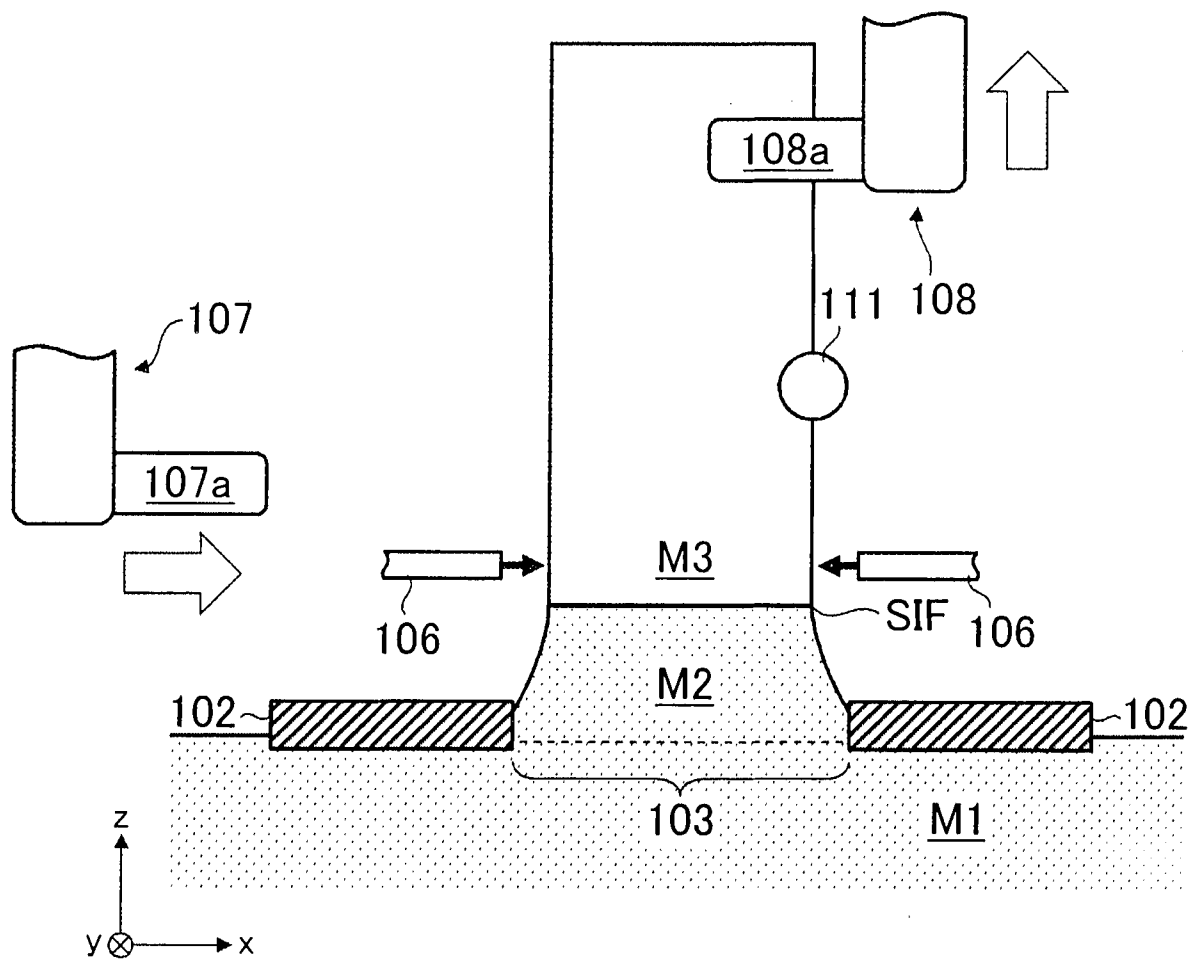


FIG. 11

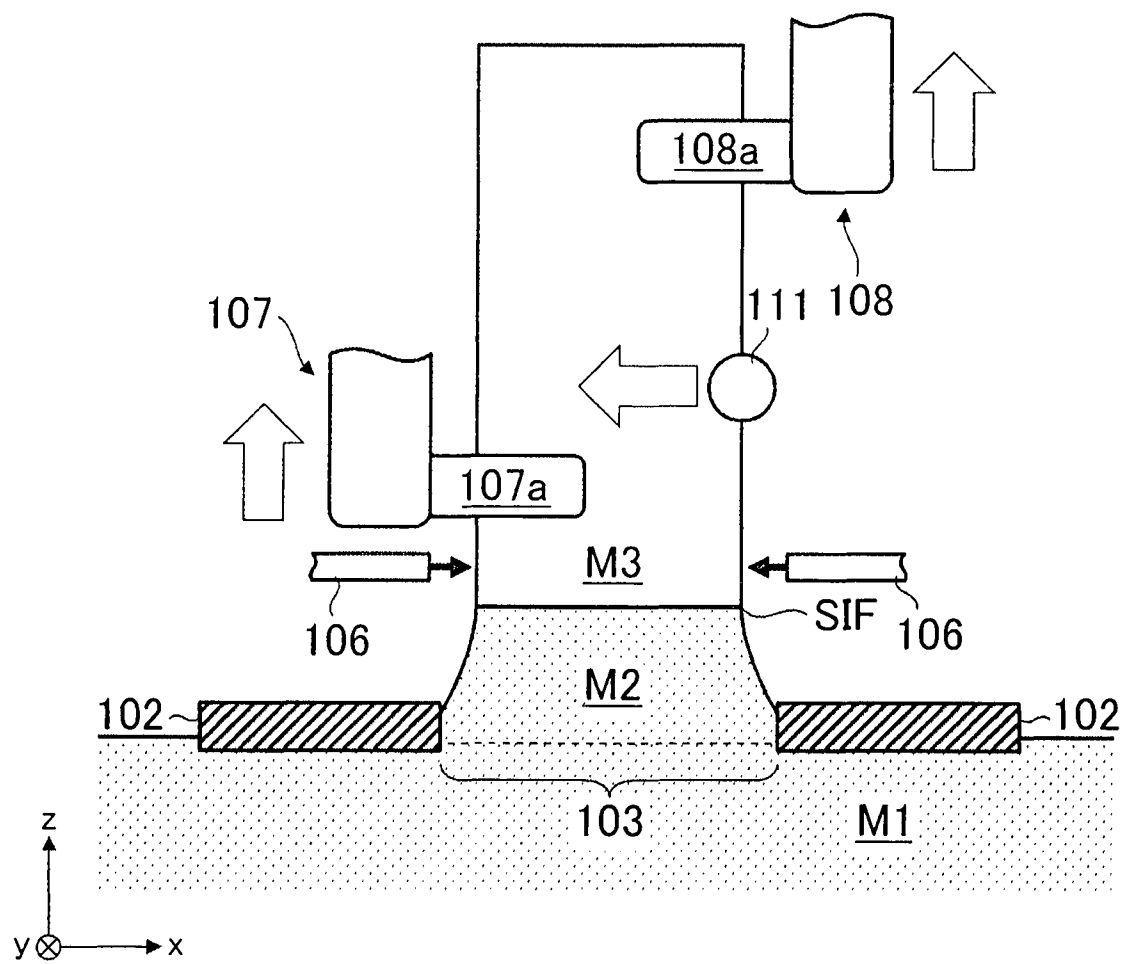


FIG. 12

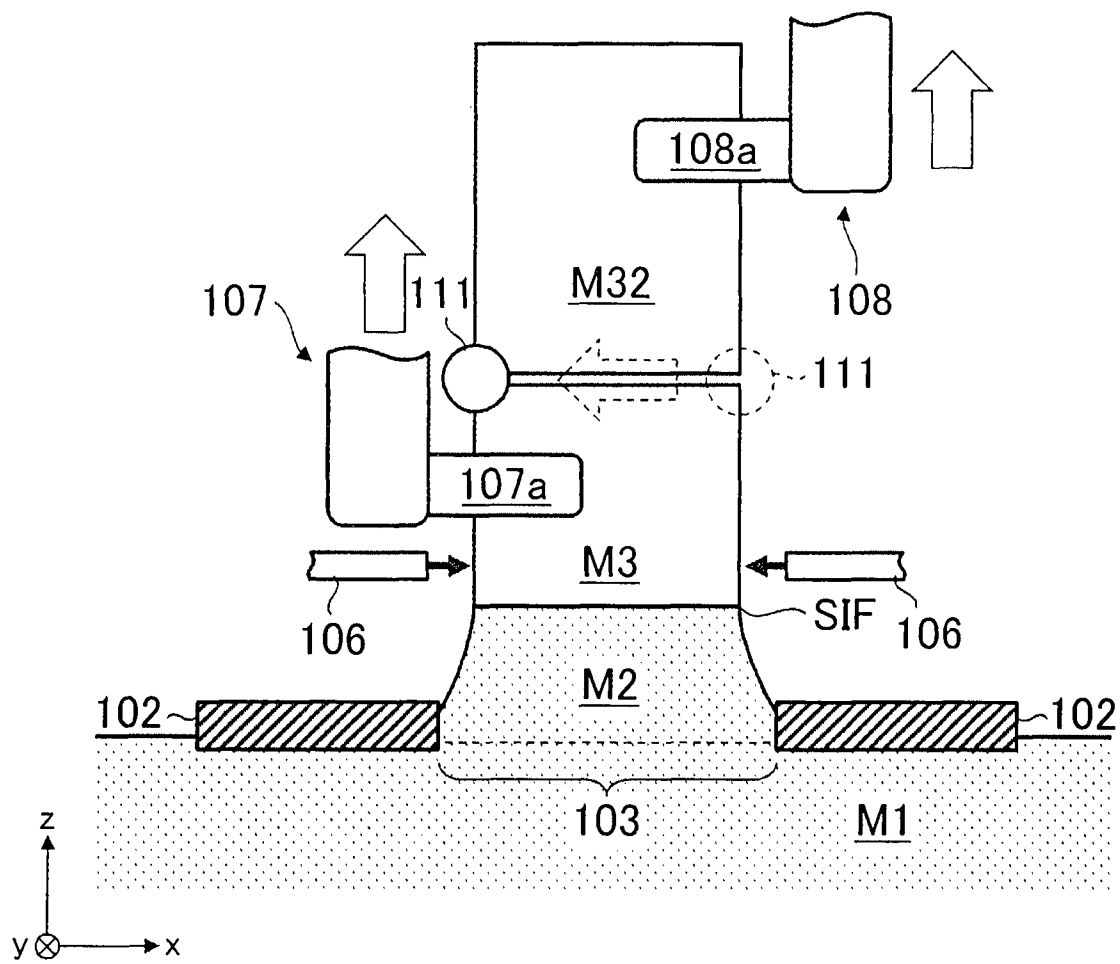


FIG. 13

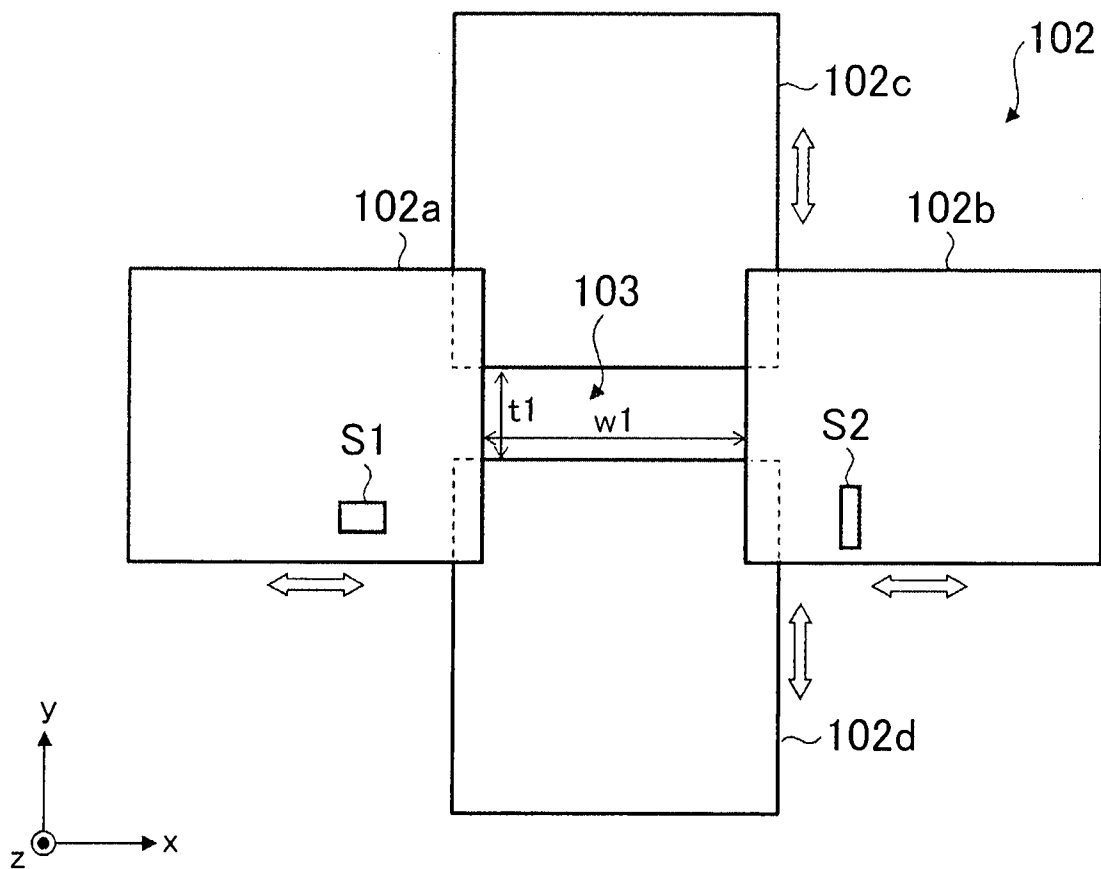
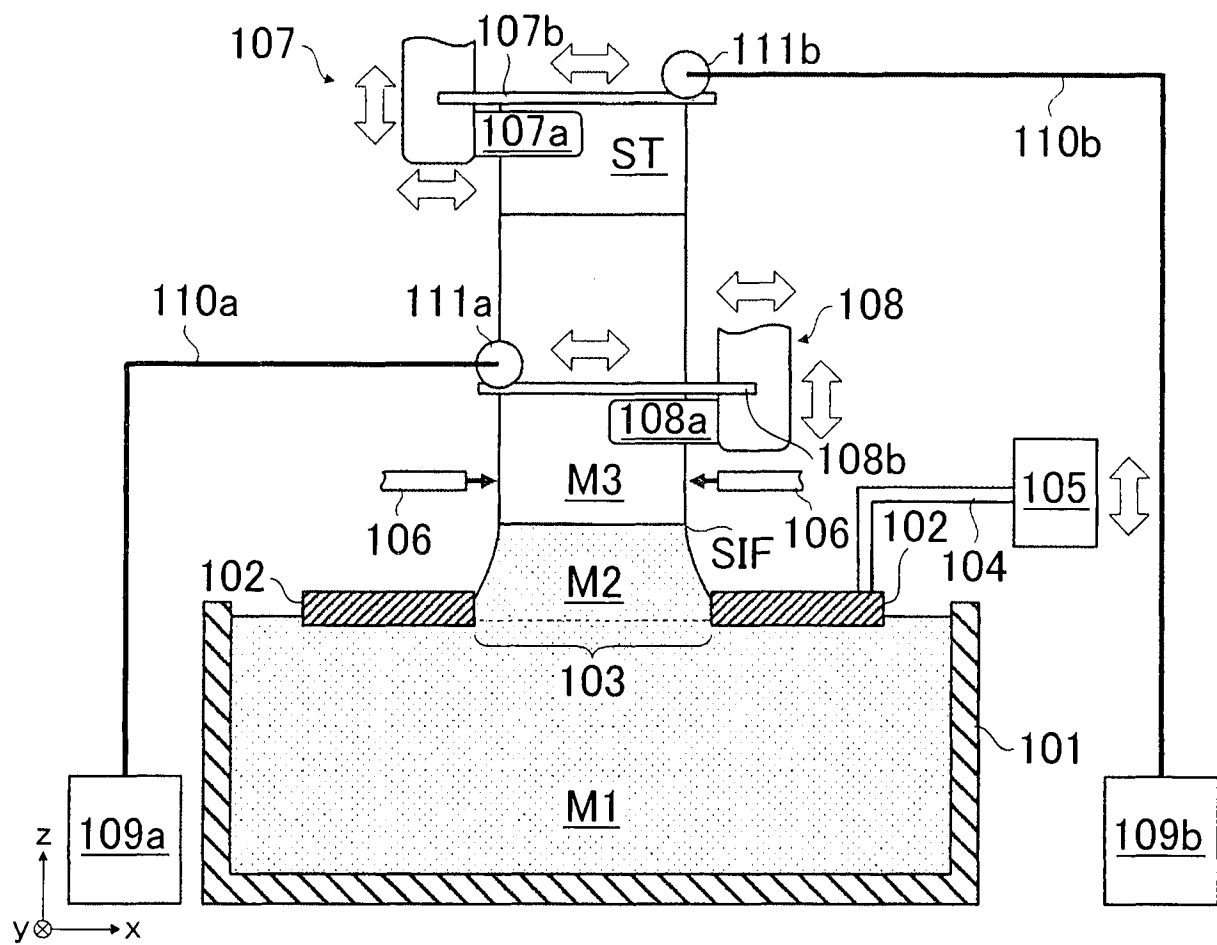


FIG. 14



INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2014/002850

A. CLASSIFICATION OF SUBJECT MATTER

INV. B22D11/14 C30B15/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B22D C30B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2012/035752 A1 (TOYOTA CHUO KENKYUSHO KK [JP]; TOYOTA MOTOR CO LTD [JP]; YAKAWA JUN []) 22 March 2012 (2012-03-22) cited in the application the whole document -----	1-11
A	US 4 185 684 A (ANISOVICH GENNADY A [SU] ET AL) 29 January 1980 (1980-01-29) the whole document -----	1-11
A	JP S59 97593 A (TOSHIBA KK) 5 June 1984 (1984-06-05) the whole document -----	1-11

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

26 March 2015

Date of mailing of the international search report

23/04/2015

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Scheid, Michael

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2014/002850

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