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(54) **HOISTING-TYPE CONTINUOUS CASTING DEVICE AND HOISTING-TYPE CONTINUOUS CASTING METHOD**

(57) A pulling-up-type continuous casting apparatus according to the present invention includes a molten-metal holding furnace (101) that holds molten metal (M1), a starter (ST) that draws the molten metal (M1) held in the molten-metal holding furnace (101) from a molten-metal surface of the molten metal (M1), and a shape defining member (102) that defines a cross-sectional shape of a

cast-metal article (M3) to be cast by applying an external force to the held molten metal (M2) drawn by the starter (ST), in which the starter (ST) includes a body part (107) and a tip part (108), the tip part (108) including a tip (109) having a horizontal cross section smaller than that of the body part (107).

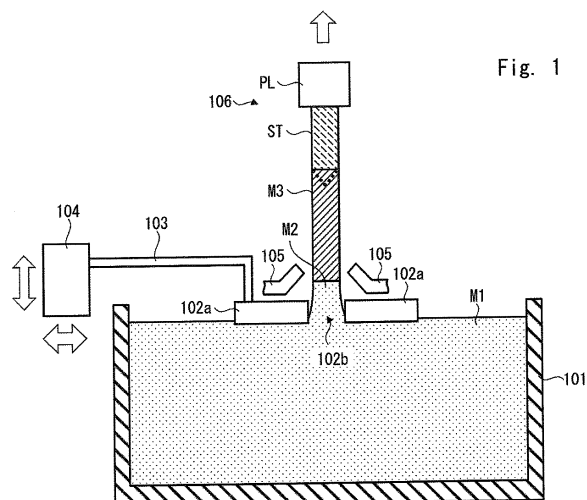


Fig. 1

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] The inventors of the present application have proposed, in Patent Literature 1, a free casting method as a revolutionary continuous casting method that does not require any mold. 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 in the longitudinal direction as well as the shape 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. Namely, in the free casting method disclosed

in Patent Literature 1, there is a problem that the molten-metal drawing property of the starter is unsatisfactory.

[0007] 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 and a pulling-up-type continuous casting method capable of improving the molten-metal drawing property of the starter by contriving (or designing) the shape of the starter.

Solution to Problem

[0008] A pulling-up-type continuous casting apparatus according to an aspect of the present invention includes: a holding furnace that holds molten metal; a drawing member that draws the molten metal held in the holding furnace from a molten-metal surface of the molten metal; and a shape defining member that defines a cross-sectional shape of a cast-metal article to be cast by applying an external force to the molten metal drawn by the drawing member, in which the drawing member includes a body part and a tip part, the tip part including a tip having a horizontal cross section smaller than that of the body part. As a result, it is possible to submerge the starter (drawing member) by making the starter (drawing member) break through an oxide film formed on the molten-metal surface of the molten metal, thus improving the molten-metal drawing property of the starter.

[0009] The tip part preferably has a tapered shape such that the tip part becomes narrower toward its tip.

[0010] The angle of the tip is preferably 45 degrees or smaller.

[0011] The tip part preferably includes a plurality of tips.

[0012] The drawing member preferably further includes at least one of a first protrusion part protruding from a side of the tip part or the body part and a first recessed part recessed from the side of the tip part or the body part.

[0013] The protrusion length of the first protrusion part or the recess depth of the first recessed part is preferably 1 mm or larger.

[0014] The drawing member preferably includes a plurality of first protrusion parts or a plurality of first recessed parts.

[0015] The tip part preferably further includes an opening opened from the tip, and at least one of a second protrusion part protruding from a side of the opening and a second recessed part recessed from the side of the opening.

[0016] The protrusion length of the second protrusion part or the recess depth or the second recessed part is preferably 1 mm or larger.

[0017] The tip part preferably includes a plurality of second protrusion parts or a plurality of second recessed parts.

[0018] A pulling-up-type continuous casting apparatus according to another aspect of the present invention includes: a holding furnace that holds molten metal; a draw-

ing member that draws the molten metal held in the holding furnace from a molten-metal surface of the molten metal; and a shape defining member that defines a cross-sectional shape of a cast-metal article to be cast by applying an external force to the molten metal drawn by the drawing member, in which the drawing member includes a body part, and at least one of a first protrusion part protruding from a side of the body part and a first recessed part recessed from the side of the body part. As a result, it is possible to improve the bonding force between the starter (drawing member) and the molten metal, thus improving the molten-metal drawing property of the starter.

[0019] The protrusion length of the first protrusion part or the recess depth of the first recessed part is preferably 1 mm or larger.

[0020] The drawing member preferably includes a plurality of first protrusion parts or a plurality of first recessed parts.

[0021] The body part preferably further includes an opening opened from the tip, and at least one of a second protrusion part protruding from a side of the opening and a second recessed part recessed from the side of the opening.

[0022] The protrusion length of the second protrusion part or the recess depth of the second recessed part is preferably 1 mm or larger.

[0023] The body part preferably includes a plurality of second protrusion parts or a plurality of second recessed parts.

[0024] A pulling-up-type continuous casting method according to an aspect of the present invention includes: a step of submerging a drawing member into a molten-metal surface of molten metal held in a holding furnace; and a step of drawing the molten metal by the drawing member and making the drawn molten metal pass through a shape defining member, the shape defining member being configured to define a cross-sectional shape of a cast-metal article to be cast, in which the drawing member is formed from a body part and a tip part, the tip part including a tip having a horizontal cross section smaller than that of the body part. As a result, it is possible to easily submerge the starter (drawing member) into the molten metal by making the starter (drawing member) break through an oxide film formed on the molten-metal surface of the molten metal, thus improving the molten-metal drawing property of the starter.

[0025] The tip part preferably has a tapered shape such that the tip part becomes narrower toward its tip.

[0026] The angle of the tip is preferably 45 degrees or smaller.

[0027] The tip part preferably includes a plurality of tips.

[0028] The drawing member preferably further includes at least one of a first protrusion part protruding from a side of the tip part or the body part and a first recessed part recessed from the side of the tip part or the body part.

[0029] The protrusion length of the first protrusion part or the recess depth of the first recessed part is preferably

1 mm or larger.

[0030] The drawing member preferably includes a plurality of first protrusion parts or a plurality of first recessed parts.

[0031] The tip part preferably further includes an opening opened from the tip, and at least one of a second protrusion part protruding from a side of the opening and a second recessed part recessed from the side of the opening.

[0032] The protrusion length of the second protrusion part or the recess depth of the second recessed part is preferably 1 mm or larger.

[0033] The tip part preferably includes a plurality of second protrusion parts or a plurality of second recessed parts.

[0034] A pulling-up-type continuous casting method according to another aspect of the present invention includes: a step of submerging a drawing member into a molten-metal surface of molten metal held in a holding furnace; and a step of drawing the molten metal by the drawing member and making the drawn molten metal pass through a shape defining member, the shape defining member being configured to define a cross-sectional shape of a cast-metal article to be cast, in which the drawing member is formed from a body part, and at least one of a first protrusion part protruding from a side of the body part and a first recessed part recessed from the side of the body part. As a result, it is possible to improve the bonding force between the starter (drawing member) and the molten metal, thus improving the molten-metal drawing property of the starter.

[0035] The protrusion length of the first protrusion part or the recess depth of the first recessed part is preferably 1 mm or larger.

[0036] The drawing member preferably includes a plurality of first protrusion parts or a plurality of first recessed parts.

[0037] The body part preferably further includes an opening opened from the tip, and at least one of a second protrusion part protruding from a side of the opening and a second recessed part recessed from the side of the opening.

[0038] The protrusion length of the second protrusion part or the recess depth of the second recessed part is preferably 1 mm or larger.

[0039] The body part preferably includes a plurality of second protrusion parts or a plurality of second recessed parts.

Advantageous Effects of Invention

[0040] The present invention can improve the molten-metal drawing property of the starter.

Brief Description of Drawings

[0041]

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

Fig. 2 is a plane view of a shape defining member 102 provided in the free casting apparatus shown in Fig. 1;

Fig. 3 is a perspective view showing a configuration example of a starter ST provided in a free casting apparatus according to the first exemplary embodiment;

Fig. 4 shows a molten-metal drawing method for a free casting apparatus according to the first exemplary embodiment;

Fig. 5 is a perspective view showing another configuration example of the starter ST;

Fig. 6 is a perspective view showing another configuration example of the starter ST;

Fig. 7 is a cross section showing a configuration example of a free casting apparatus according to a second exemplary embodiment;

Fig. 8 is a perspective view showing a configuration example of a starter ST provided in a free casting apparatus according to the second exemplary embodiment;

Fig. 9 shows a molten-metal drawing method for a free casting apparatus according to the second exemplary embodiment;

Fig. 10 is a perspective view showing another configuration example of the starter ST;

Fig. 11 is a perspective view showing another configuration example of the starter ST;

Fig. 12 is a perspective view showing another configuration example of the starter ST;

Fig. 13 is a perspective view showing another configuration example of the starter ST;

Fig. 14 is a perspective view showing another configuration example of the starter ST;

Fig. 15 is a perspective view showing another configuration example of the starter ST;

Fig. 16 is a perspective view showing another configuration example of the starter ST;

Fig. 17 is a graph showing results of drawing success rate experiments according to the tip angle of the starter ST shown in Fig. 16;

Fig. 18 shows photograms showing results of the drawing success rate experiments according to the tip angle of the starter ST shown in Fig. 16;

Fig. 19 is a graph showing results of drawing success rate experiments according to the protrusion length of the protrusion part of the starter ST shown in Fig. 16;

Fig. 20 shows photographs showing results of a drawing success rate experiments according to the protrusion length of the protrusion part of the starter ST shown in Fig. 16;

Fig. 21 is a cross section showing another configuration example of a free casting apparatus according to the present invention; and

Fig. 22 is a plane view of a shape defining member 102 provided in the free casting apparatus shown in Fig. 17.

5 Description of Embodiments

[0042] 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.

15 <First exemplary embodiment>

[0043] Firstly, a free casting apparatus (pulling-up-type continuous casting apparatus) according to a first exemplary embodiment is explained with reference to Fig. 1.

20 Fig. 1 is a cross section showing a configuration example 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 (holding furnace) 101, an outer-shape defining member 102a, a support rod 103, an actuator 104, a cooling nozzle 105, and a drawing section 106.

25 [0044] The molten-metal holding furnace 101 contains, for example, molten metal M1 such as aluminum or its alloy, and maintains the molten metal M1 at a predetermined temperature. This exemplary embodiment is explained by using an example where the molten metal M1 is aluminum. Note that needless to say, the molten metal M1 may be a metal other than aluminum or an alloy thereof. 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.

30 [0045] The outer-shape defining member 102a is made of ceramic or stainless, for example, and disposed in the vicinity of the molten-metal surface. In the example shown in Fig. 1, the outer-shape defining member 102a is disposed so that the outer-shape defining member 102a is in contact with the molten-metal surface. However, the outer-shape defining member 102a may be disposed so that its bottom main surface (molten-metal surface side) is not in contact with the molten-metal surface. Specifically, the outer-shape defining member 102a may be disposed so that a predetermined gap (e.g., about 0.5mm) is formed between the bottom main surface and the molten-metal surface.

35 [0046] The outer-shape defining member 102a defines the outer shape of a cast metal M3 to be cast. The cast metal M3 shown in Fig. 1 is a rectangular-column cast-

metal article having a rectangular shape in a horizontal cross section (hereinafter referred to as "lateral cross section"). That is, more specifically, the outer-shape defining member 102a defines the outer diameter on the lateral cross section of the cast metal M3.

[0047] Fig. 2 is a plane view of the outer-shape defining member 102a. Note that the cross section of the outer-shape defining member 102a shown in Fig. 1 corresponds to a cross section taken along the line I-I in Fig. 2. As shown in Fig. 2, the outer-shape defining member 102a has, for example, a rectangular shape in the plan view, and has a rectangular opening at the center. This opening serves as a molten-metal passage section 102b through which molten metal passes. In this manner, the outer-shape defining member 102a and the molten-metal passage section 102b constitute a shape defining member 102.

[0048] The drawing section 106 includes a starter (drawing member) ST that is submerged into the molten metal M1, and a pulling-up machine PL that drives the starter ST, for example, in the vertical direction.

[0049] As shown in Fig. 1, after the molten metal M1 adheres to the submerged starter ST, the molten metal M1 follows the starter ST and is pulled up by the starter ST while maintaining its outer shape by its surface film and/or the surface tension. Then, the molten metal M1 passes through the molten-metal passage section 102b. Note that the molten metal that follows the starter ST (or the cast metal M3 that is formed as the molten metal M1 drawn by the starter ST solidifies) and is pulled up from the molten-metal surface by the surface film of the molten metal M1 and/or the surface tension is called "held molten metal M2". Further, the interface between the cast metal M3 and the held molten metal M2 is the solidification interface.

[0050] The starter ST is formed of, for example, material having a high melting point equal to or higher than the melting point of the molten metal M1. By doing so, the erosion of the starter can be prevented to some extent. This exemplary embodiment is explained by using an example where the starter ST is made of aluminum, i.e., the same material as the molten metal M1. Note that the material for the starter ST is not limited to aluminum. That is, the starter ST may be formed of stainless, iron, an alloy thereof, ceramic, or the like.

[0051] Fig. 3 is a perspective view showing a configuration example of the starter ST according to the first exemplary embodiment. The starter ST shown in Fig. 3 is composed of a body part 107 and a tip part 108. Note that the body part 107 and the tip part 108 are integrally formed. In the example shown in Fig. 3, the body part 107 has a rectangular-column shape. Further, the tip part 108 includes a tip 109 that is the first to come into contact with the molten metal M1 when the starter ST is lowered, and the other end (i.e., the other tip) connected to the body part 107. Note that the horizontal cross section (lateral cross section) of the tip 109 of the tip part 108 is smaller than that of the body part 107. In the example

shown in Fig. 3, the tip part 108 has a tapered shape (pointed shape) such that the tip part 108 becomes narrower toward the tip 109. As a result, since the starter ST can be easily submerged into the molten metal M1 by making the starter ST break through an oxide film formed on the molten-metal surface of the molten metal M1, the molten metal M1 drawing property of the starter ST can be improved.

[0052] The support rod 103 supports the outer-shape defining member 102a. Note that the support rod 103 is connected to the actuator 104.

[0053] The actuator 104 has a function of moving the outer-shape defining member 102a in the up/down direction (vertical direction) and in the horizontal direction through the support rod 103. In this manner, it is possible to move the outer-shape defining member 102a downward as the molten-metal surface is lowered due to the advance of the casting process. Further, since the outer-shape defining member 102a can be moved in the horizontal direction, the shape in the longitudinal direction of the cast metal M3 can be arbitrarily changed.

[0054] The cooling nozzle (cooling unit) 105 sprays a cooling gas (such as air, nitrogen, and argon) on the starter ST and/or the cast metal M3, and thereby cools the starter ST and/or the cast metal M3. By cooling the starter ST and/or the cast metal M3 by the cooling gas while pulling up the cast metal M3 by using the pulling-up machine PL connected to the starter ST, the held molten metal M2 located in the vicinity of the solidification interface is successively solidified and the cast metal M3 is continuously formed.

[0055] Next, a free casting method according to this exemplary embodiment is explained with reference to Figs. 1 to 4. Fig. 4 shows a molten-metal drawing method for a free casting apparatus according to the first exemplary embodiment.

[0056] Firstly, molten metal M1 is set (i.e., contained) in the molten-metal holding furnace 101 (S101 in Fig. 4).

[0057] Next, the pointed starter ST is lowered, and the tip part 108 of the starter ST is made to pass through the molten-metal passage section 102b and brought into contact with the molten-metal surface of the molten metal M1 (S102 in Fig. 4). After that, the starter ST is further lowered and submerged into the molten metal M1 by making the tip part 108 break through an oxide film formed on the molten-metal surface of the molten metal M1 (S103 in Fig. 4).

[0058] Next, the starter ST starts to be pulled up at a predetermined speed (S104 in Fig. 4). Note that even when the starter ST is pulled away from the molten-metal surface, the molten metal M1 follows the starter ST and is pulled up (drawn) from the molten-metal surface by the surface film and/or the surface tension. The pulled-up molten metal M1 forms held molten metal M2. As shown in Fig. 1, the held molten metal M2 is formed in the molten-metal passage section 102b. In other words, the held molten metal M2 is shaped into a given shape by the outer-shape defining member 102a.

[0059] Next, the starter ST and the cast metal M3 are cooled by a cooling gas sprayed from the cooling nozzle 105. As a result, the held molten metal M2 is successively solidified from its upper side toward its lower side, and hence the cast metal M3 grows. In this manner, the cast metal M3 can be continuously cast.

[0060] As described above, in the free casting apparatus according to this exemplary embodiment, the starter ST includes the (pointed) tip part including the tip having a horizontal cross section smaller than that of the body part. As a result, the free casting apparatus according to this exemplary embodiment can easily submerge the starter ST into the molten metal M1 by making the starter ST break through the oxide film formed on the molten-metal surface of the molten metal M1, thus making it possible to improve the molten metal M1 drawing property of the starter ST. When the starter ST is submerged into the molten metal M1, if the oxide film on the molten-metal surface adheres to the wall surface of the tip of the starter ST and the starter ST is pulled up with the oxide film attached to its wall surface, the adhesion of the molten metal to the wall surface of the starter ST is likely to deteriorate when the molten metal is drawn at the initial stage of the pull-up process. When the starter ST is submerged, if the tip of the starter ST enters into the non-oxidized molten metal by breaking through the oxide film, the oxide film is less likely to adhere to the wall surface of the tip of the starter ST and the non-oxidized molten metal adheres to the tip of the starter ST. When the non-oxidized molten metal adheres to the tip of the starter ST, the molten metal is more likely to be drawn in a relatively stable manner in the subsequent pulling-up process. Therefore, tearing in a part of the molten metal, which would otherwise occur halfway through the pulling-up process, is less likely to occur.

(Other configuration examples of starter ST according to first exemplary embodiment)

[0061] Other configuration examples of the starter ST are explained hereinafter with reference to Figs. 5 and 6. Figs. 5 and 6 are perspective views showing other configuration examples of the starter ST.

[0062] In a starter ST shown in Fig. 5, the tip part 108 has a rectangular-column shape whose horizontal cross section (lateral cross section) is smaller than that of the body part 107. In a starter ST shown in Fig. 6, the tip part 108 includes a plurality of tips 109. The use of the starter ST shown in Fig. 5 or 6 makes it possible to achieve an advantageous effect equivalent to that which is achieved when the starter ST shown in Fig. 3 is used. Note that the tip part 108 of the starter ST can be changed as appropriate to other structures whose horizontal cross sections (lateral cross sections) are smaller than that of the body part 107.

<Second exemplary embodiment>

[0063] Fig. 7 is a cross section showing a configuration example of a free casting apparatus according to a second exemplary embodiment. The free casting apparatus shown in Fig. 7 is different from the free casting apparatus shown in Fig. 1 in regard to the shape of the starter ST. The rest of the configuration of the free casting apparatus shown in Fig. 7 is similar to that of the free casting apparatus shown in Fig. 1, and therefore its explanation is omitted.

[0064] Fig. 8 is a perspective view showing a configuration example of the starter ST according to the second exemplary embodiment. The starter ST shown in Fig. 8 is composed of a body part (a body part having a rectangular-column shape in this example) 107 and protrusion parts (first protrusion parts) 110. Note that the body part 107 and the protrusion parts 110 are integrally formed. Note that the protrusion parts 110 are provided such that they protrude from sides of the body part 107. As a result, when the starter ST is pulled up, the molten metal M1 is raised by the protrusion parts 110. More specifically, when the starter ST is pulled up, a surface solidification layer formed near the molten-metal surface of the molten metal M1 is raised by the protrusion parts 110. That is, the bonding force between the starter ST and the molten metal M1 is improved. As a result, it is possible to prevent the drawn molten metal M1 from being torn apart due to the gravitational pull of the surface solidification layer. That is, the molten metal M1 drawing property of the starter ST can be improved.

[0065] Next, a free casting method according to this exemplary embodiment is explained with reference to Figs. 7 to 9. Fig. 9 shows a method for drawing molten metal in a free casting apparatus according to the second exemplary embodiment.

[0066] Firstly, molten metal M1 is set (i.e., contained) in the molten-metal holding furnace 101 (S201 in Fig. 9).

[0067] Next, the starter ST including the protrusion parts 110 is lowered, and then the starter ST is made to pass through the molten-metal passage section 102b and brought into contact with the molten-metal surface of the molten metal M1 (S202 in Fig. 9). After that, the starter ST is further lowered and the starter ST is submerged into the molten metal M1 (S203 in Fig. 9).

[0068] Next, the starter ST starts to be pulled up at a predetermined speed (S104 in Fig. 4). Note that even when the starter ST is pulled away from the molten-metal surface, the molten metal M1 follows the starter ST and is pulled up (drawn) from the molten-metal surface by the surface film and/or the surface tension. The pulled-up molten metal M1 forms held molten metal M2. Note that since the surface solidification layer formed near the molten-metal surface of the molten metal M1 is raised by the protrusion parts 110, the molten metal M1 forms the held molten metal M2 without being torn apart due to the gravitational pull of the surface solidification layer. As shown in Fig. 7, the held molten metal M2 is formed

in the molten-metal passage section 102b. In other words, the held molten metal M2 is shaped into a given shape by the outer-shape defining member 102a.

[0069] Next, the starter ST and the cast metal M3 are cooled by a cooling gas sprayed from the cooling nozzle 105. As a result, the held molten metal M2 is successively solidified from its upper side toward its lower side, and hence the cast metal M3 grows. In this manner, the cast metal M3 can be continuously cast.

[0070] As described above, in the free casting apparatus according to this exemplary embodiment, the starter ST includes the protrusion parts protruding from the sides of the body part 107. As a result, the free casting apparatus according to this exemplary embodiment can improve the bonding force between the starter ST and the molten metal M1, thus making it possible to improve the molten metal M1 drawing property of the starter ST. The fact that the contact area between the starter ST and the molten metal is increased by the steps of the protrusion parts of the starter ST and the molten metal is more likely to get snagged on the protrusion parts of the starter ST is considered to be one of the reasons for the improvement in the bonding force.

(Other configuration examples of starter ST according to second exemplary embodiment)

[0071] Other configuration examples of the starter ST are explained hereinafter with reference to Figs. 10 and 16. Figs. 10 and 16 are perspective views showing other configuration examples of the starter ST.

[0072] A starter ST shown in Fig. 10 includes a plurality of protrusion parts 110 protruding from the sides of the body part 107. A starter ST shown in Fig. 11 includes protrusion parts 110 that protrude toward the pulling-up direction from the sides of the body part 107. The use of the starter ST shown in Fig. 10 or 11 makes it possible to improve the bonding force between the starter ST and the molten metal M1 even further.

[0073] A starter ST shown in Fig. 12 includes, instead of the protrusion parts 110, recessed parts (first recessed parts) 111 recessed from the sides of the body part 107. A starter ST shown in Fig. 13 includes a plurality of recessed parts 111 recessed from the sides of the body part 107. The use of the starter ST shown in Fig. 12 or 13 makes it possible to improve the bonding force between the starter ST and the molten metal M1 as in the case of using the starter ST shown in Fig. 8 or 10 or the like.

[0074] A starter ST shown in Fig. 14 further includes an opening 112 opened from the center of the tip of the body part 107 and protrusion parts (second protrusion parts) 113 protruding from the side of the opening 112. Note that recessed parts (second recessed parts) recessed from the sides of the opening 112 may be provided instead of the protrusion parts 113. The use of the starter ST shown in Fig. 14 makes it possible to improve the bonding force between the starter ST and the molten

metal M1 as in the case of the above-shown other starters ST.

[0075] It should be noted that the shapes of the starters ST explained in the first exemplary embodiment may be combined with the shapes of the starters ST explained in the second exemplary embodiment. In such cases, for example, the protrusion parts 110 may protrude from the sides of the tip part 108 as well as from the sides of the body part 107. Further, the recessed parts 111 may be recessed from the sides of the tip part 108 as well as from the sides of the body part 107. Further, the opening 112 is opened from the tip of the tip part 108. As a result, the starter ST can be easily submerged into the molten metal M1 by making the starter ST break through the oxide film formed on the molten-metal surface of the molten metal M1 and the bonding force between the starter ST and the molten metal M1 can be improved.

[0076] Starters ST shown in Figs. 15 and 16 are examples in which the shapes of starters ST explained in the first and second exemplary embodiments are combined with each other. The starter ST shown in Fig. 15 includes protrusion parts 110 protruding from the sides of the body part 107 in addition to the shape of the starter ST shown in Fig. 3. As a result, the starter ST shown in Fig. 15 has an arrow-like shape in the front view. The starter ST shown in Fig. 16 resembles the starter ST shown in Fig. 15 and can be easily formed by hollowing out parts of the sides in the long-side direction of a plate material having a rectangular shape in the front view and cutting off two corners adjoining to the side in the short-side direction thereof.

(Experiment results)

[0077] Next, the inventors have conducted experiments for examining the molten metal M1 drawing property of the starter ST while variously changing the tip angle A of the starter ST and the protrusion length L of its protrusion parts 110. The results of the experiments are explained hereinafter.

[0078] Note that the starter ST shown in Fig. 16 was used in the experiments. The starter ST is made of an aluminum alloy (A5052) and kept at a normal temperature before it is submerged into the molten metal M1. Further, the molten metal M1 is also made of the aluminum alloy (A5052) and kept at 720°C. The pulling-up speed of the starter ST is 1 mm/sec.

[0079] Fig. 17 is a graph showing results of drawing success rate experiments according to the tip angle of the starter ST. Note that the term "drawing success rate" means the rate at which the starter ST was able to be submerged into the molten metal M1 by breaking through the oxide film formed on the molten-metal surface of the molten metal M1 (the success rate with respect to the total number of experiments).

[0080] As shown in Fig. 17, it can be seen that the smaller the tip angle A is, the higher the drawing success rate becomes. In particular, when the tip angle A is 45°

or smaller, the drawing success rate is increased to nearly 100%.

[0081] Fig. 18 shows photograms showing results of the drawing success rate experiments according to the tip angle A of the starter ST. The left photogram shows an example where the tip angle A was large and the molten metal M1 was not able to be successfully drawn. In this example, since the starter was not able to completely break through the oxide film formed on the molten-metal surface of the molten metal M1, the remaining oxide film adhered to the surface of the held molten metal M2 and affected the shape of the molded article. The right photogram shows an example where the tip angle A was small and the molten metal M1 was successfully drawn. In this example, since the starter was able to completely break through the oxide film formed on the molten-metal surface of the molten metal M1, the oxide film had no effect on the shape of the molded article.

[0082] Fig. 19 is a graph showing results of drawing success rate experiments according to the protrusion length L of the protrusion parts 110 of the starter ST. Note that the term "drawing success rate" means the rate at which the surface solidification layer formed near the molten-metal surface of the molten metal M1 was raised by the protrusion parts 110 and hence the molten metal M1 was able to be drawn with accuracy (the success rate with respect to the total number of experiments).

[0083] As shown in Fig. 19, it can be seen that the larger the protrusion length L is, the higher the drawing success rate becomes. In particular, when the protrusion length L is 1.0 mm or longer, the drawing success rate is increased to nearly 100%.

[0084] Fig. 20 shows photograms showing results of the drawing success rate experiments according to the protrusion length L of the protrusion parts 110 of the starter ST. The left photogram shows an example where the protrusion length L was short and the molten metal M1 was not able to be successfully drawn. In this example, the protrusion parts 110 cannot sufficiently support the gravitational pull (i.e., the weight) of the surface solidification layer and the drawn molten metal M1 is almost torn apart by the gravitational pull of the surface solidification layer. The right photogram shows an example where the protrusion length L was long and it was possible for the molten metal M1 to be successfully drawn. In this example, the protrusion parts 110 can support the gravitational pull (i.e., the weight) of the surface solidification layer and the molten metal M1 is drawn without causing the molten metal M1 to be torn apart due to the gravitational pull of the surface solidification layer.

[0085] As has been described above, in the free casting apparatuses according to the above-described first and second exemplary embodiments, the starter ST includes the tip part 108 including the tip 109 having a cross section smaller than that of the body part 107 or/and includes protrusion parts 111 protruding from the sides of the body part 107 or the like. As a result, in the free casting apparatuses according to the above-described first and

second exemplary embodiments, the starter ST can be easily submerged into the molten metal M1 by making the starter ST break through the oxide film formed on the molten-metal surface of the molten metal M1 or/and the bonding force between the starter ST and the molten metal M1 can be improved. Therefore, the molten metal M1 drawing property of the starter ST can be improved.

[0086] Although example cases where a cast-metal article having a rectangular-column shape (rectangular-column cast-metal article) is cast are explained in the above-described first to fourth exemplary embodiments, the present invention is not limited to such examples. The present invention can also be applied to cases where a cast-metal article having a rectangular-tubular shape, a cylindrical shape, a circular-tubular shape, or other shapes is cast. A case where a cast-metal article having a tubular shape is cast is briefly explained hereinafter with reference to Figs. 21 and 22.

[0087] Fig. 21 is a cross section showing another specific configuration example of a free casting apparatus according to the present invention. The free casting apparatus shown in Fig. 21 includes an inner-shape defining member 102c in addition to the outer-shape defining member 102a.

[0088] The inner-shape defining member 102c defines the inner shape of a cast metal M3 to be cast and the outer-shape defining member 102a defines the outer shape of the cast metal M3 to be cast. The cast metal M3 shown in Fig. 21 is a hollow cast-metal article having a ring shape in a horizontal cross section (hereinafter referred to as "lateral cross section") (that is, the cast metal M3 shown in Fig. 9 is a pipe). That is, more specifically, the inner-shape defining member 102c defines the inner diameter on the lateral cross section of the cast metal M3 and the outer-shape defining member 102a defines the outer diameter on the lateral cross section of the cast metal M3.

[0089] Fig. 22 is a plane view of the inner-shape defining member 102c and the outer-shape defining member 102a. Note that the cross section of the inner-shape defining member 102c and the outer-shape defining member 102a in Fig. 11 corresponds to a cross section taken along the line II-II in Fig. 22. As shown in Fig. 22, the outer-shape defining member 102a has, for example, a rectangular shape in the plan view, and has a rectangular opening at the center. The inner-shape defining member 102c has a rectangular shape in the plan view and is disposed at the center of the opening of the outer-shape defining member 102a. The gap between the inner-shape defining member 102c and the outer-shape defining member 102a serves as the molten-metal passage section 102b through which the molten metal passes. In this manner, the inner-shape defining member 102c, the outer-shape defining member 102a, and the molten-metal passage section 102b constitute a shape defining member 102. With this configuration, a cast-metal article having a rectangular-tubular shape is cast.

[0090] Note that the present invention is not limited to

the above-described first to fourth exemplary embodiments, and various modifications can be made without departing the spirit and scope of the present invention. For example, the above-described configuration examples may be combined and used at the same time.

[0091] This application is based upon and claims the benefit of priority from Japanese patent application No. 2013-158205, filed on July 30, 2413, the disclosure of which is incorporated herein in its entirety by reference.

Reference Signs List

[0092]

101	MOLTEN METAL HOLDING VESSEL
102	SHAPE DEFINING MEMBER
102a	OUTER-SHAPE DEFINING MEMBER
102b	MOLTEN-METAL PASSAGE SECTION
102c	INNER-SHAPE DEFINING MEMBER
103	SUPPORT ROD
104	ACTUATOR
105	COOLING NOZZLE
106	DRAWING SECTION
107	BODY PART
108	TIP PART
109	TIP
110	PROTRUSION PART
111	RECESSED PART
112	OPENING
M1	MOLTEN METAL
M2	HELD MOLTEN METAL
M3	CAST METAL
ST	STARTER
PL	PULLING-UP MACHINE

Claims

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

a holding furnace that holds molten metal;
a drawing member that draws the molten metal held in the holding furnace from a molten-metal surface of the molten metal; and
a shape defining member that defines a cross-sectional shape of a cast-metal article to be cast by applying an external force to the molten metal drawn by the drawing member, wherein the drawing member comprises a body part and a tip part, the tip part comprising a tip having a horizontal cross section smaller than that of the body part.

2. The pulling-up-type continuous casting apparatus according to Claim 1, wherein the tip part has a tapered shape such that the tip part becomes narrower toward its tip.

3. The pulling-up-type continuous casting apparatus according to Claim 2, wherein the angle of the tip is 45 degrees or smaller.

4. The pulling-up-type continuous casting apparatus according to any one of Claims 1 to 3, wherein the tip part comprises a plurality of tips.

5. The pulling-up-type continuous casting apparatus according to any one of Claims 1 to 4, wherein the drawing member further comprises at least one of a first protrusion part protruding from a side of the tip part or the body part and a first recessed part recessed from the side of the tip part or the body part.

6. The pulling-up-type continuous casting apparatus according to Claim 5, wherein the protrusion length of the first protrusion part or the recess depth of the first recessed part is 1 mm or larger.

7. The pulling-up-type continuous casting apparatus according to Claim 5 or 6, wherein the drawing member comprises a plurality of first protrusion parts or a plurality of first recessed parts.

8. The pulling-up-type continuous casting apparatus according to any one of Claims 1 to 7, wherein the tip part further comprises:

an opening opened from the tip; and
at least one of a second protrusion part protruding from a side of the opening and a second recessed part recessed from the side of the opening.

9. The pulling-up-type continuous casting apparatus according to Claim 8, wherein the protrusion length of the second protrusion part or the recess depth of the second recessed part is 1 mm or larger.

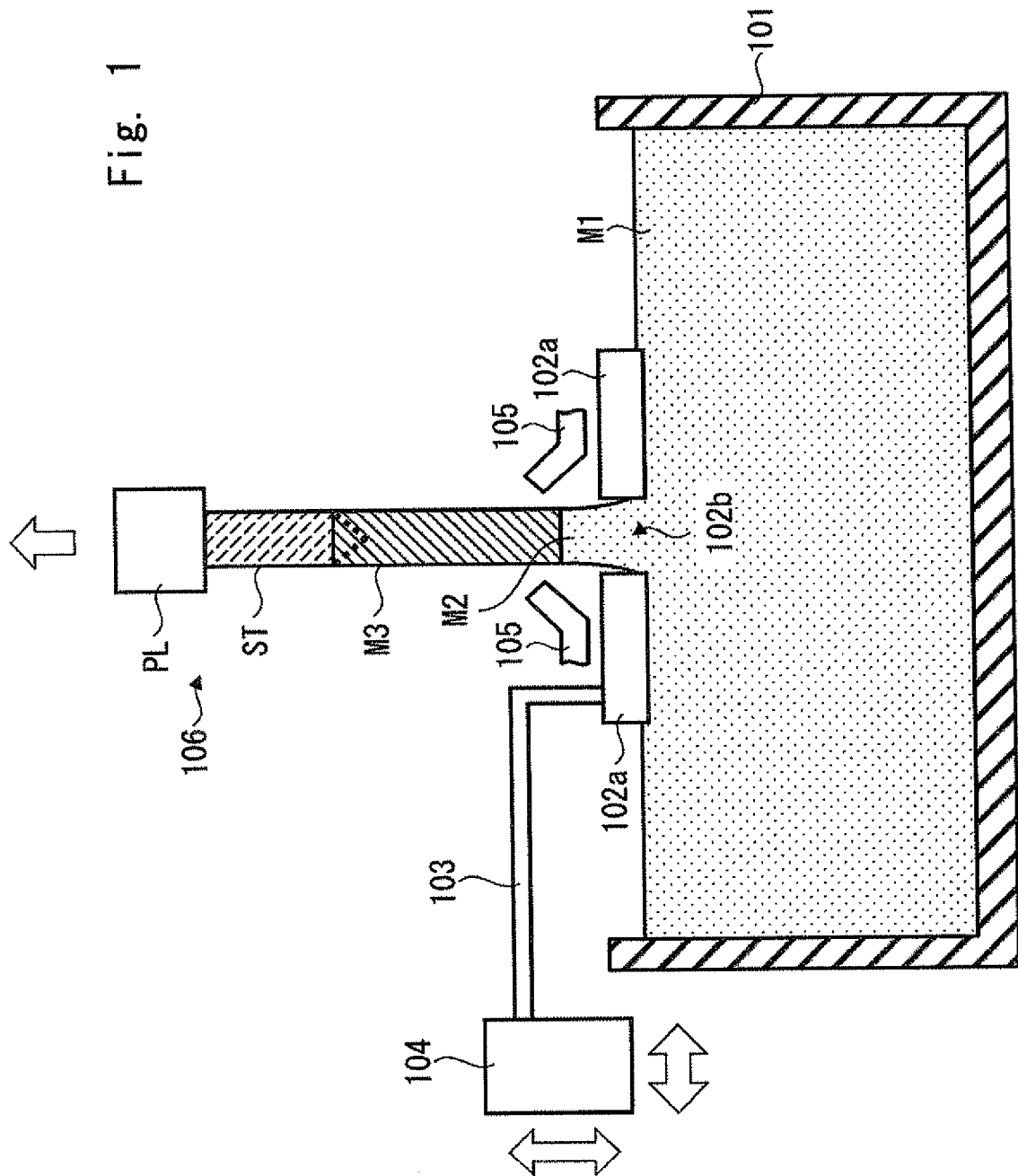
10. The pulling-up-type continuous casting apparatus according to Claim 8 or 9, wherein the tip part comprises a plurality of second protrusion parts or a plurality of second recessed parts.

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

a holding furnace that holds molten metal;
a drawing member that draws the molten metal held in the holding furnace from a molten-metal surface of the molten metal; and
a shape defining member that defines a cross-sectional shape of a cast-metal article to be cast by applying an external force to the molten metal drawn by the drawing member, wherein the drawing member comprises a body part, and at least one of a first protrusion part protruding

- from a side of the body part and a first recessed part recessed from the side of the body part.
12. The pulling-up-type continuous casting apparatus according to Claim 11, wherein the protrusion length of the first protrusion part or the recess depth of the first recessed part is 1 mm or larger.
 13. The pulling-up-type continuous casting apparatus according to Claim 11 or 12, wherein the drawing member comprises a plurality of first protrusion parts or a plurality of first recessed parts.
 14. The pulling-up-type continuous casting apparatus according to any one of Claims 11 to 13, wherein the body part further comprises:
 - an opening opened from the tip; and
 - at least one of a second protrusion part protruding from a side of the opening and a second recessed part recessed from the side of the opening.
 15. The pulling-up-type continuous casting apparatus according to Claim 14, wherein the protrusion length of the second protrusion part or the recess depth of the second recessed part is 1 mm or larger.
 16. The pulling-up-type continuous casting apparatus according to Claim 14 or 15, wherein the body part comprises a plurality of second protrusion parts or a plurality of second recessed parts.
 17. A pulling-up-type continuous casting method comprising:
 - a step of submerging a drawing member into a molten-metal surface of molten metal held in a holding furnace; and
 - a step of drawing the molten metal by the drawing member and making the drawn molten metal pass through a shape defining member, the shape defining member being configured to define a cross-sectional shape of a cast-metal article to be cast, wherein the drawing member is formed from a body part and a tip part, the tip part comprising a tip having a horizontal cross section smaller than that of the body part.
 18. The pulling-up-type continuous casting method according to Claim 17, wherein the tip part has a tapered shape such that the tip part becomes narrower toward its tip.
 19. The pulling-up-type continuous casting method according to Claim 18, wherein the angle of the tip is 45 degrees or smaller.
 20. The pulling-up-type continuous casting method according to any one of Claims 17 to 19, wherein the tip part comprises a plurality of tips.
 21. The pulling-up-type continuous casting method according to any one of Claims 17 to 20, wherein the drawing member further comprises at least one of a first protrusion part protruding from a side of the tip part or the body part and a first recessed part recessed from the side of the tip part or the body part.
 22. The pulling-up-type continuous casting method according to Claim 21, wherein the protrusion length of the first protrusion part or the recess depth of the first recessed part is 1 mm or larger.
 23. The pulling-up-type continuous casting method according to Claim 21 or 22, wherein the drawing member comprises a plurality of first protrusion parts or a plurality of first recessed parts.
 24. The pulling-up-type continuous casting method according to any one of Claims 17 to 23, wherein the tip part further comprises: an opening opened from the tip; and at least one of a second protrusion part protruding from a side of the opening and a second recessed part recessed from the side of the opening.
 25. The pulling-up-type continuous casting method according to Claim 24, wherein the protrusion length of the second protrusion part or the recess depth of the second recessed part is 1 mm or larger.
 26. The pulling-up-type continuous casting method according to Claim 24 or 25, wherein the tip part comprises a plurality of second protrusion parts or a plurality of second recessed parts.
 27. A pulling-up-type continuous casting method comprising:
 - a step of submerging a drawing member into a molten-metal surface of molten metal held in a holding furnace; and
 - a step of drawing the molten metal by the drawing member and making the drawn molten metal pass through a shape defining member, the shape defining member being configured to define a cross-sectional shape of a cast-metal article to be cast, wherein the drawing member is formed from a body part, and at least one of a first protrusion part protruding from a side of the body part and a first recessed part recessed from the side of the body part.

28. The pulling-up-type continuous casting method according to Claim 27, wherein the protrusion length of the first protrusion part or the recess depth of the first recessed part is 1 mm or larger. 5
29. The pulling-up-type continuous casting method according to Claim 27 or 28, wherein the drawing member comprises a plurality of first protrusion parts or a plurality of first recessed parts. 10
30. The pulling-up-type continuous casting method according to any one of Claims 27 to 29, wherein the body part further comprises:
- an opening opened from the tip; and 15
- at least one of a second protrusion part protruding from a side of the opening and a second recessed part recessed from the side of the opening. 20
31. The pulling-up-type continuous casting method according to Claim 30, wherein the protrusion length of the second protrusion part or the recess depth of the second recessed part is 1 mm or larger. 25
32. The pulling-up-type continuous casting method according to Claim 30 or 31, wherein the body part comprises a plurality of second protrusion parts or a plurality of second recessed parts. 30
- 35
- 40
- 45
- 50
- 55



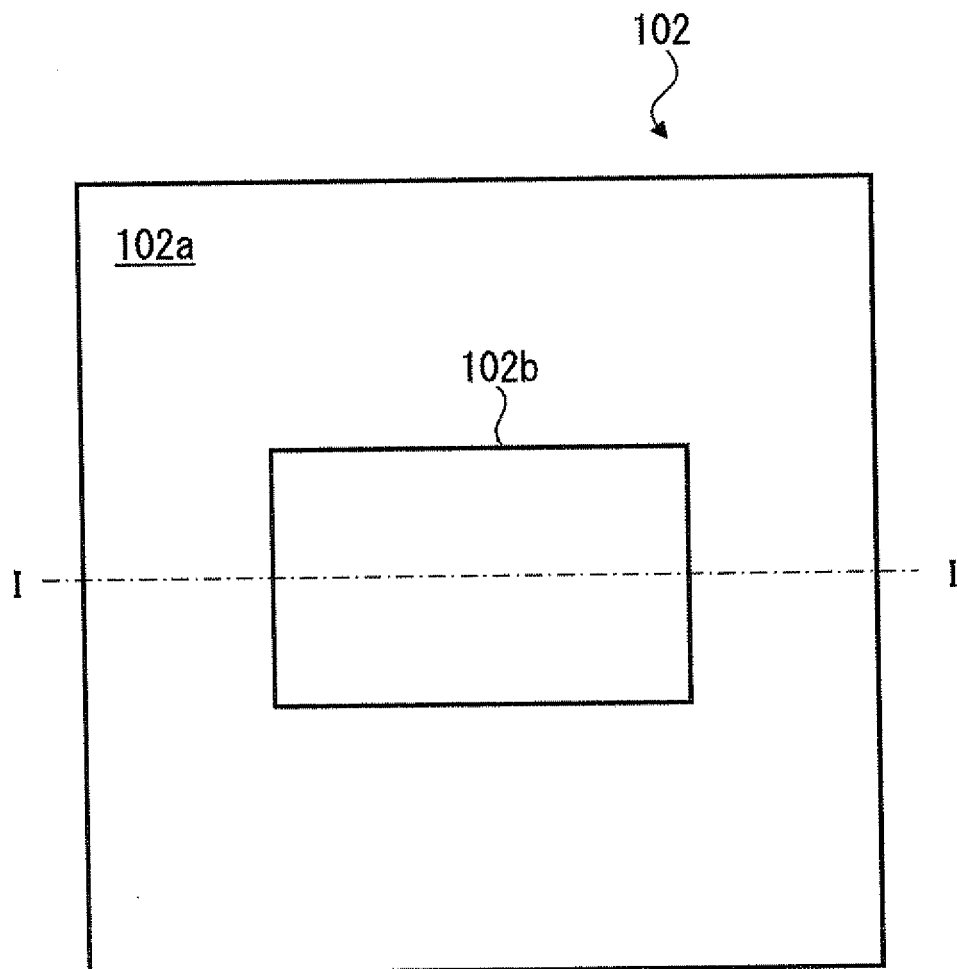


Fig. 2

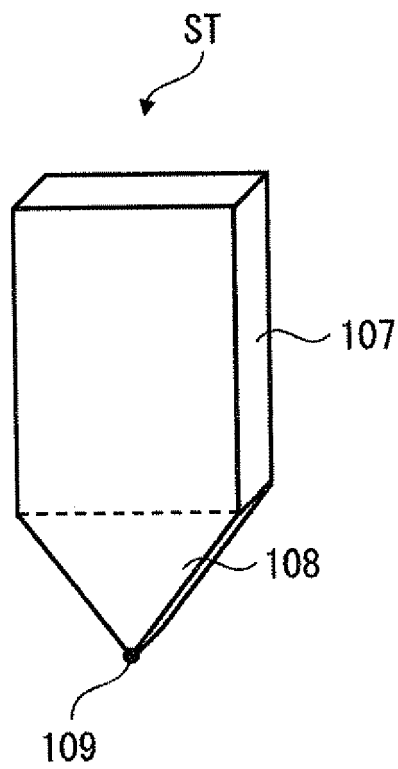


Fig. 3

Fig. 4

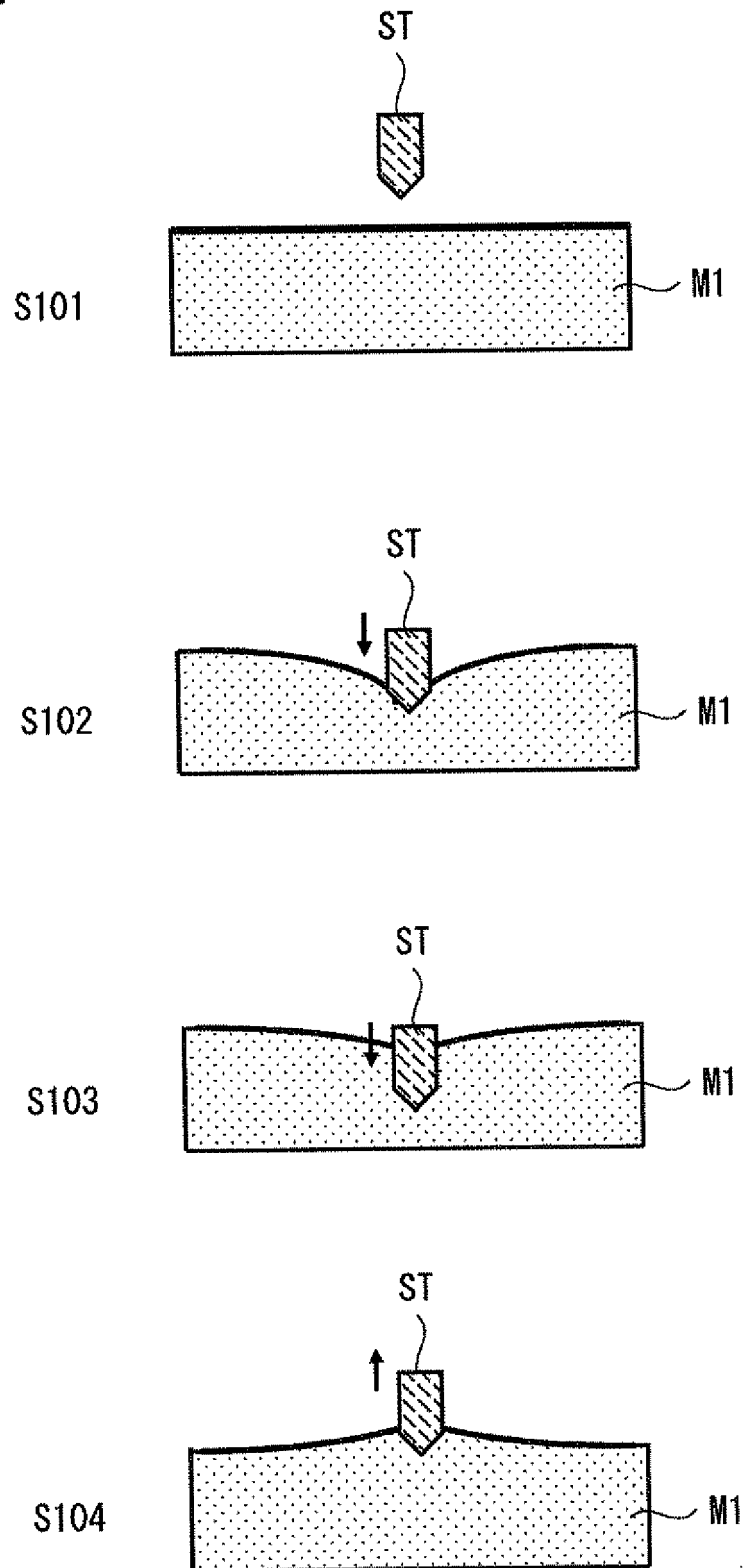


Fig. 5

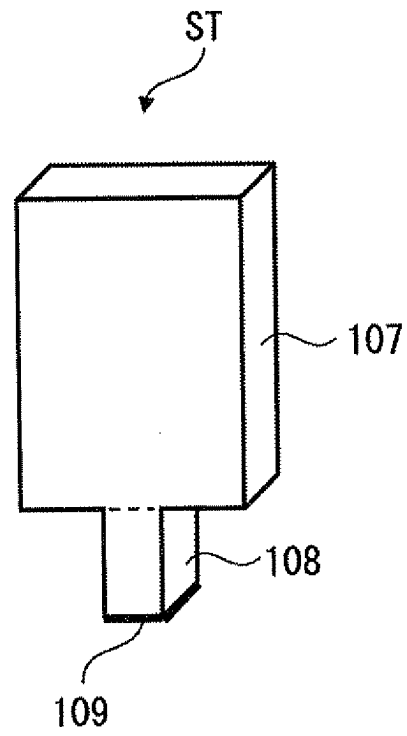
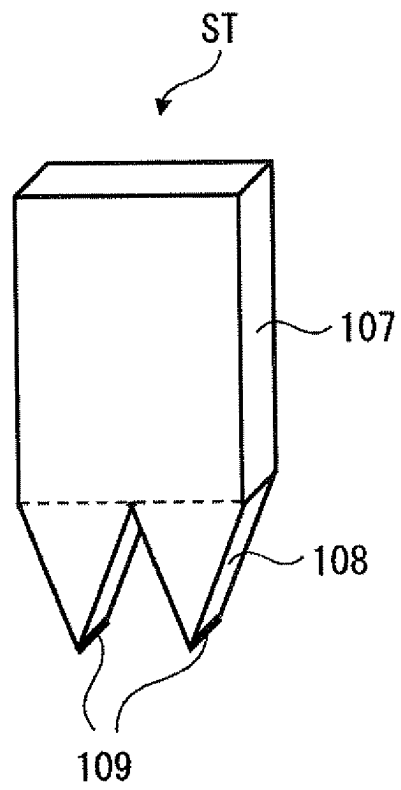
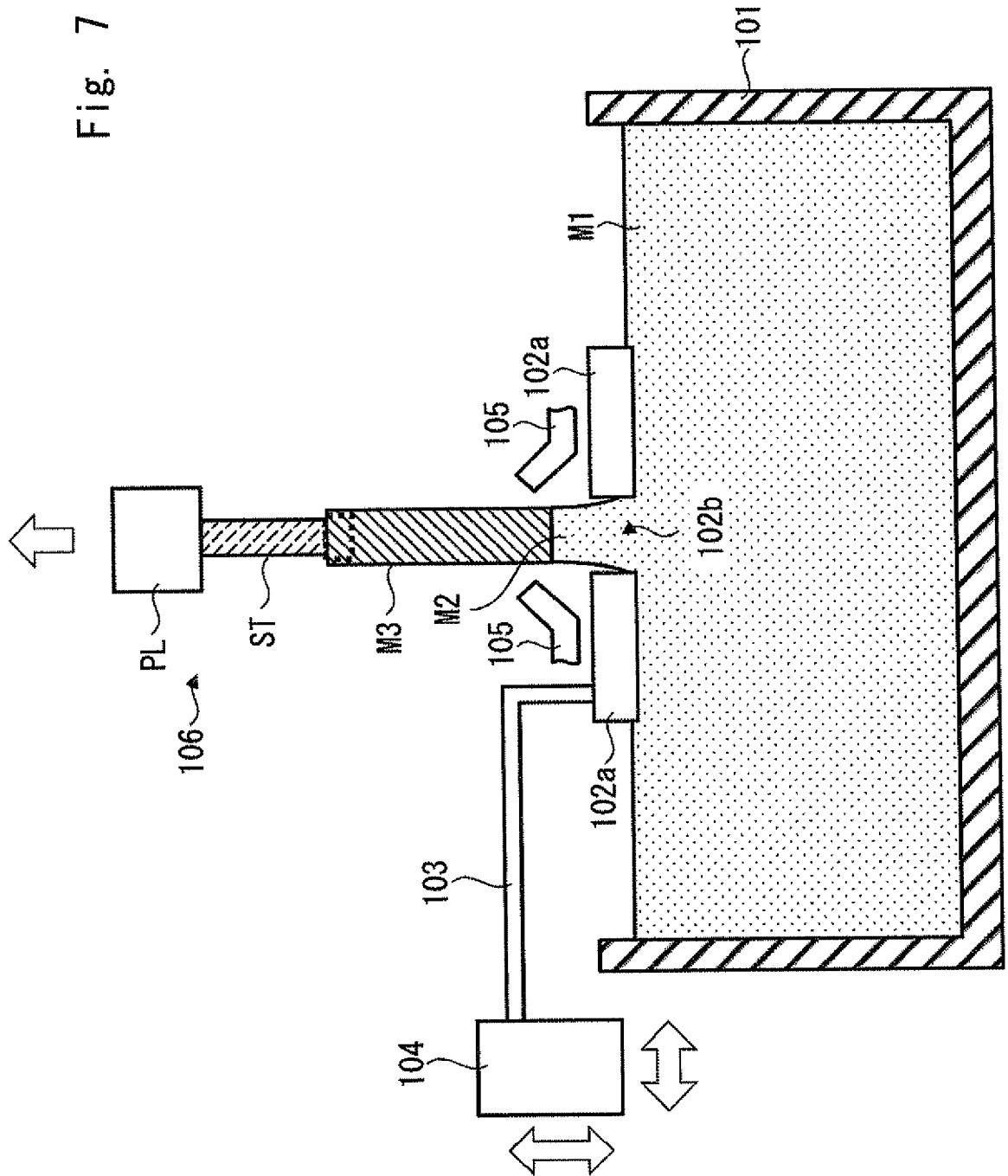


Fig. 6





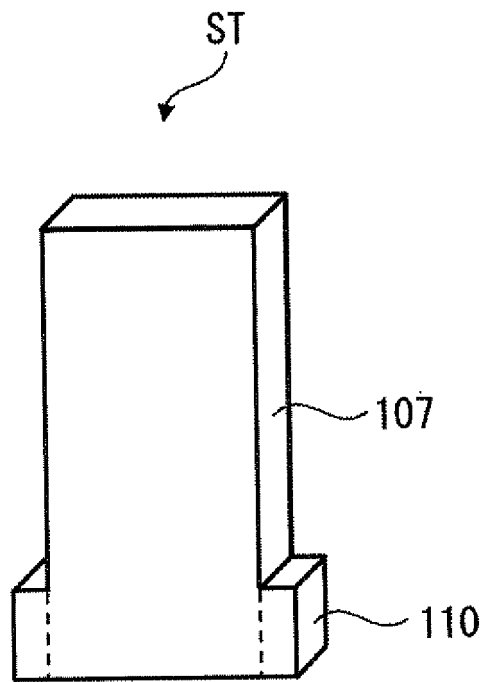


Fig. 8

Fig. 9

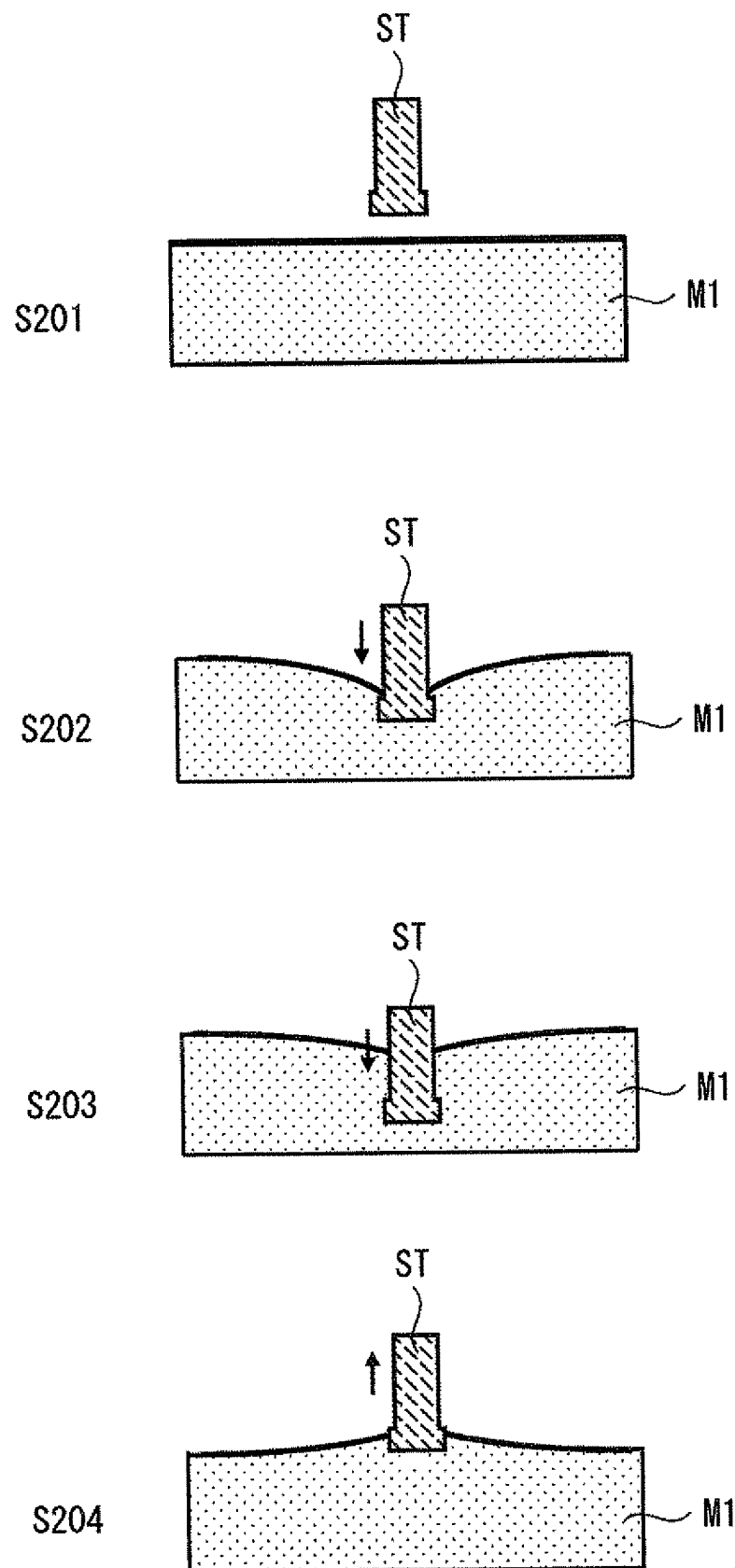


Fig. 10

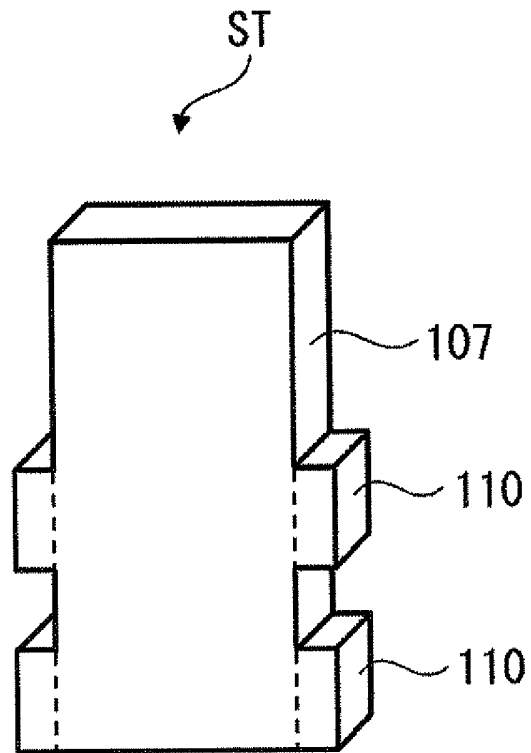


Fig. 11

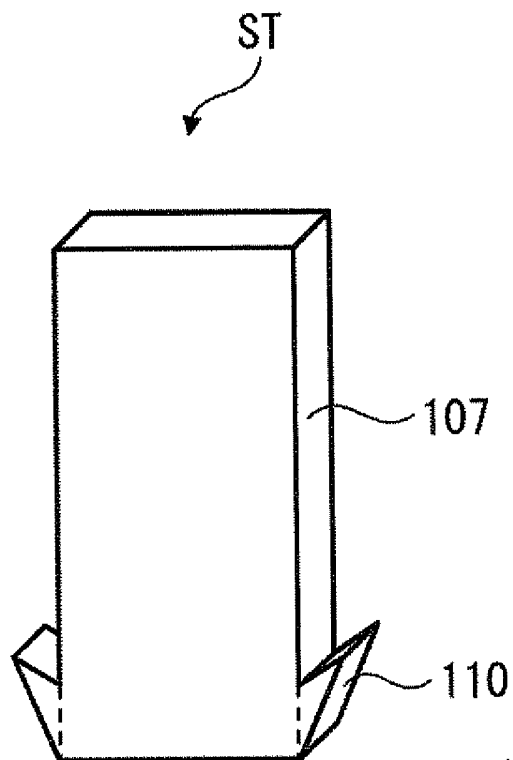


Fig. 12

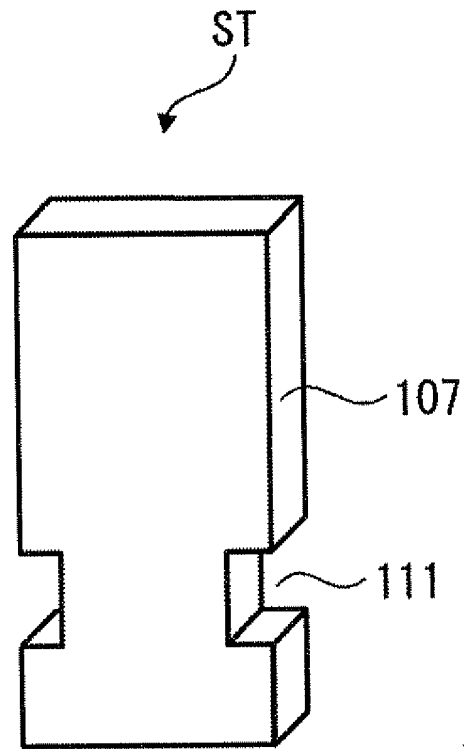


Fig. 13

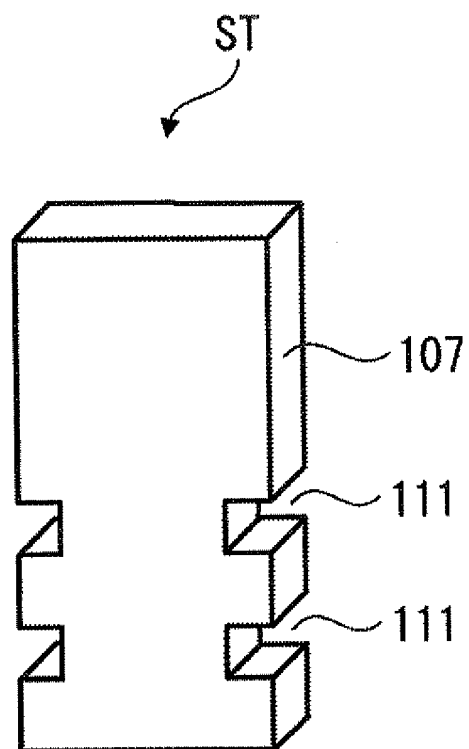


Fig. 14

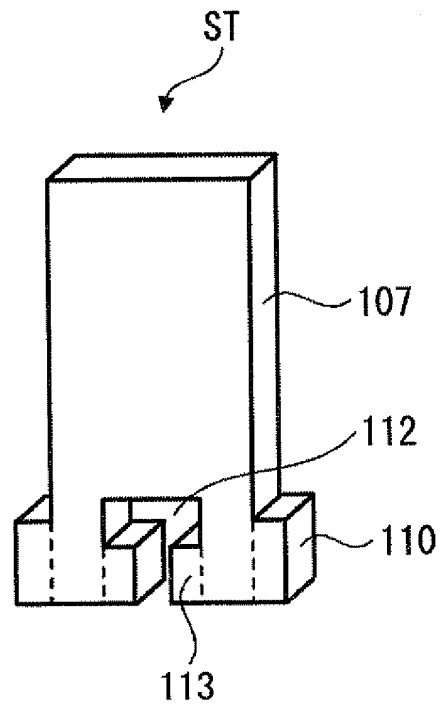


Fig. 15

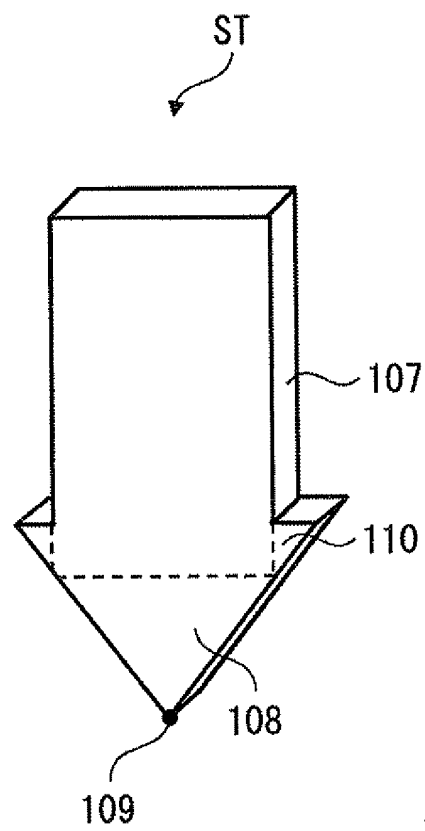


Fig. 16

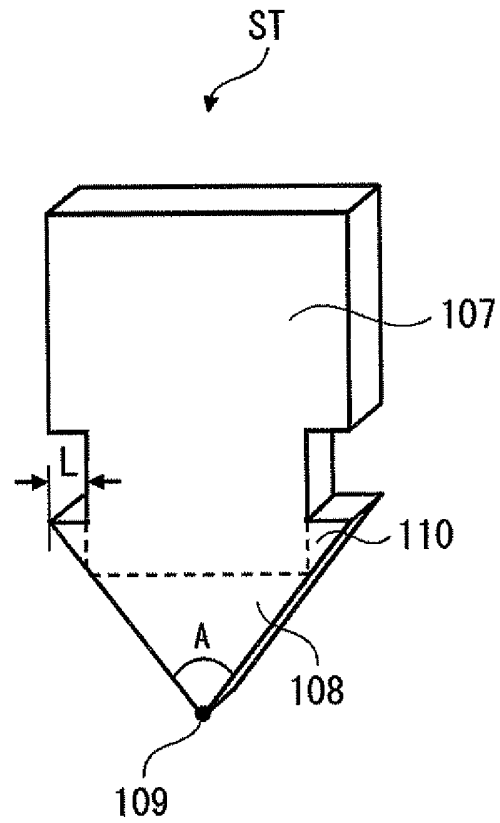
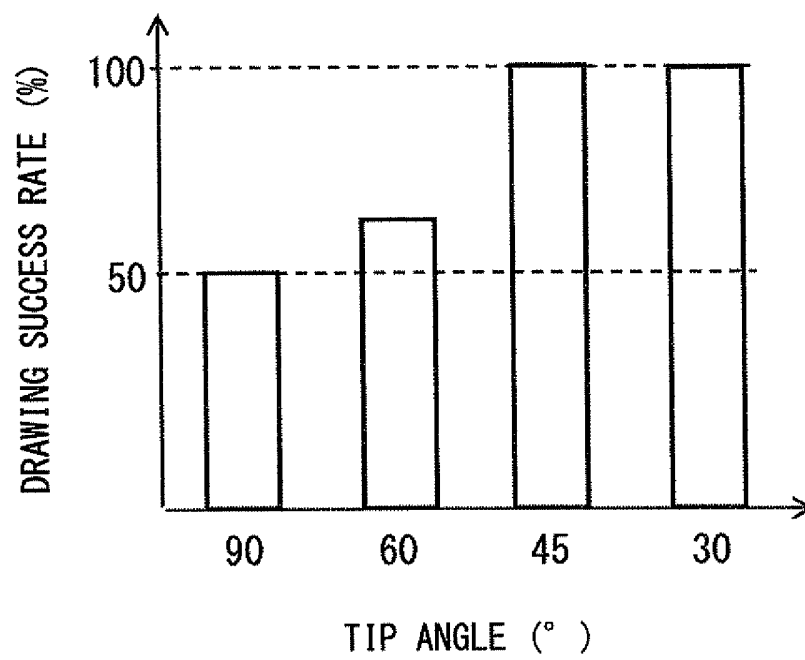
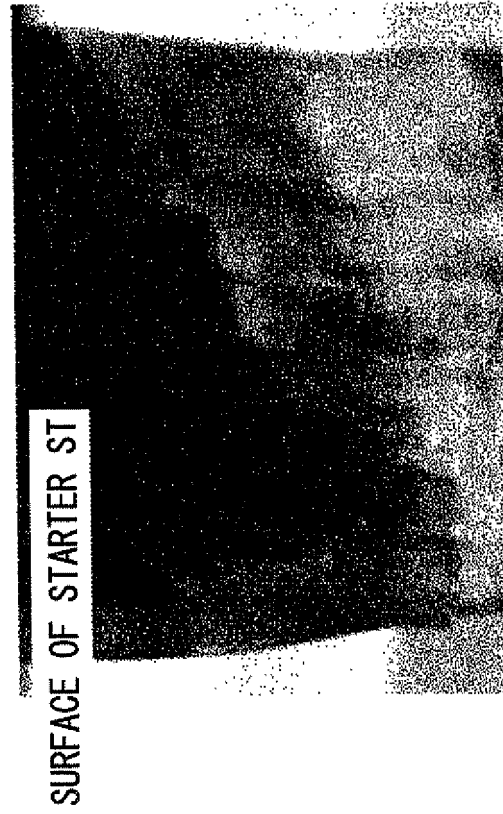


Fig. 17



OK EXAMPLE



STARTER BREAKS THROUGH OXIDE FILM
AND EFFECT ON MOLDED ARTICLE
CAUSED BY OXIDE FILM IS REDUCED

NG EXAMPLE



STARTER CANNOT BREAK THROUGH OXIDE FILM
AND REMAINING OXIDE FILM
AFFECTS MOLDED ARTICLE

Fig. 18

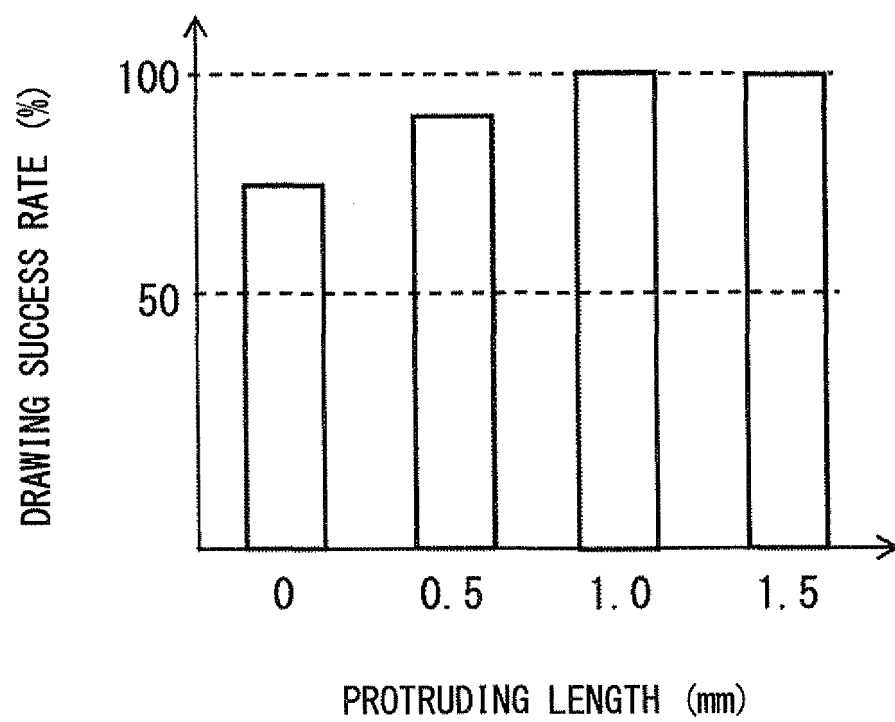
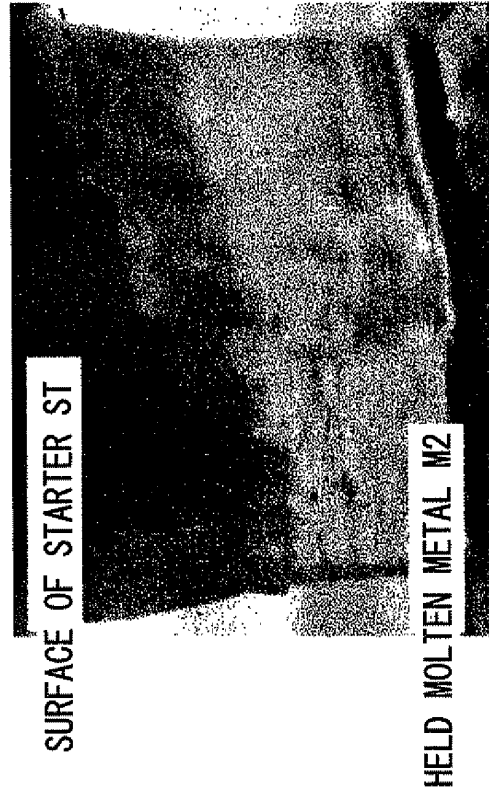


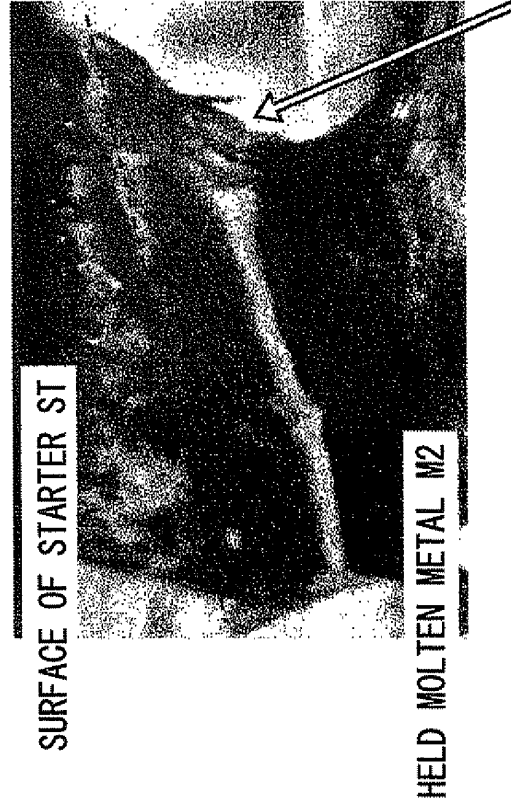
Fig. 19

OK EXAMPLE



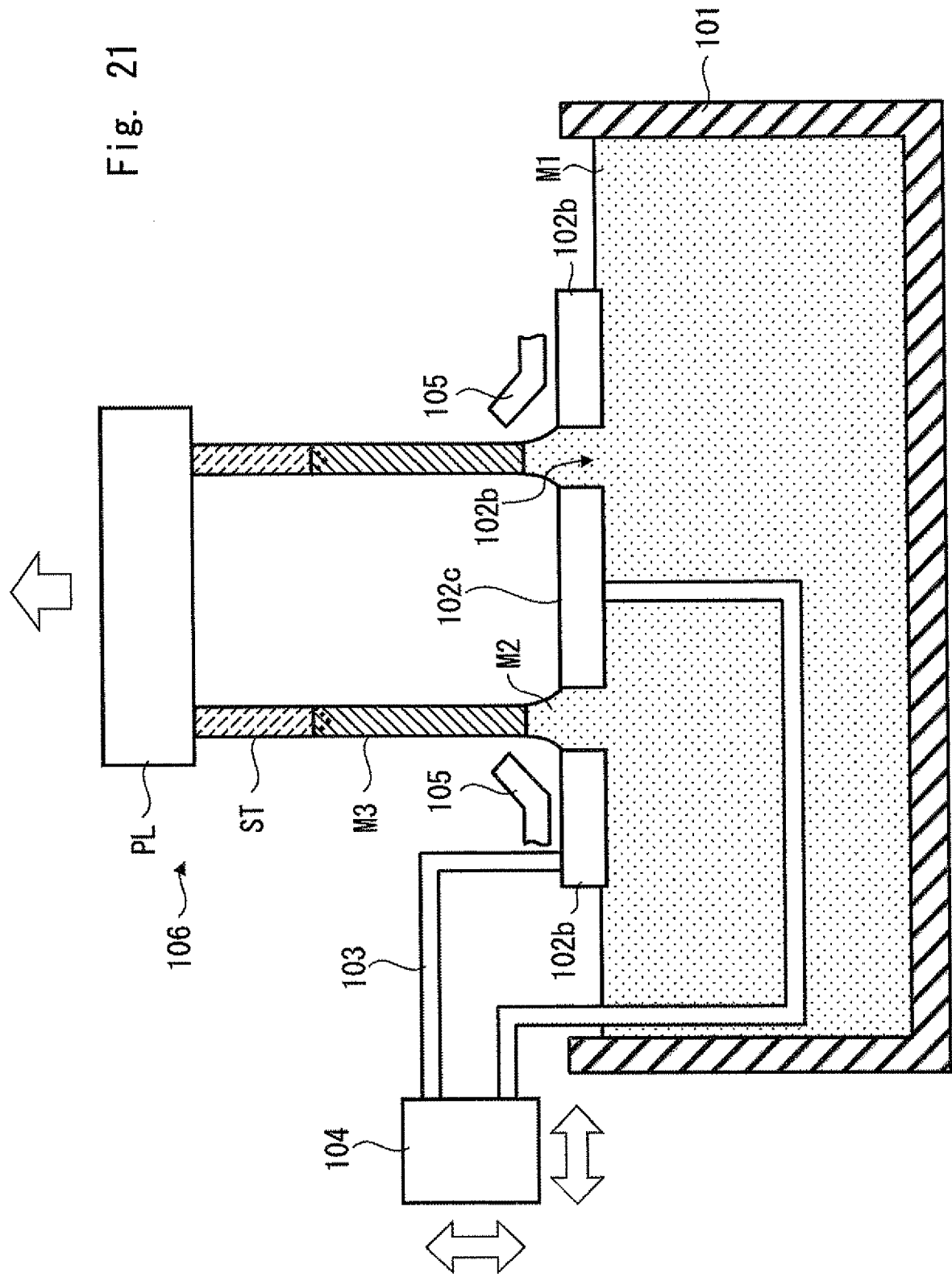
SINCE PROTRUSION PART SUPPORTS
GRAVITY OF SURFACE SOLIDIFICATION LAYER,
MOLTEN METAL DRAWING PROPERTY IS IMPROVED

NG EXAMPLE



MOLTEN METAL DRAWING PROPERTY DETERIORATES
DUE TO GRAVITY OF SURFACE SOLIDIFICATION LAYER

Fig. 20



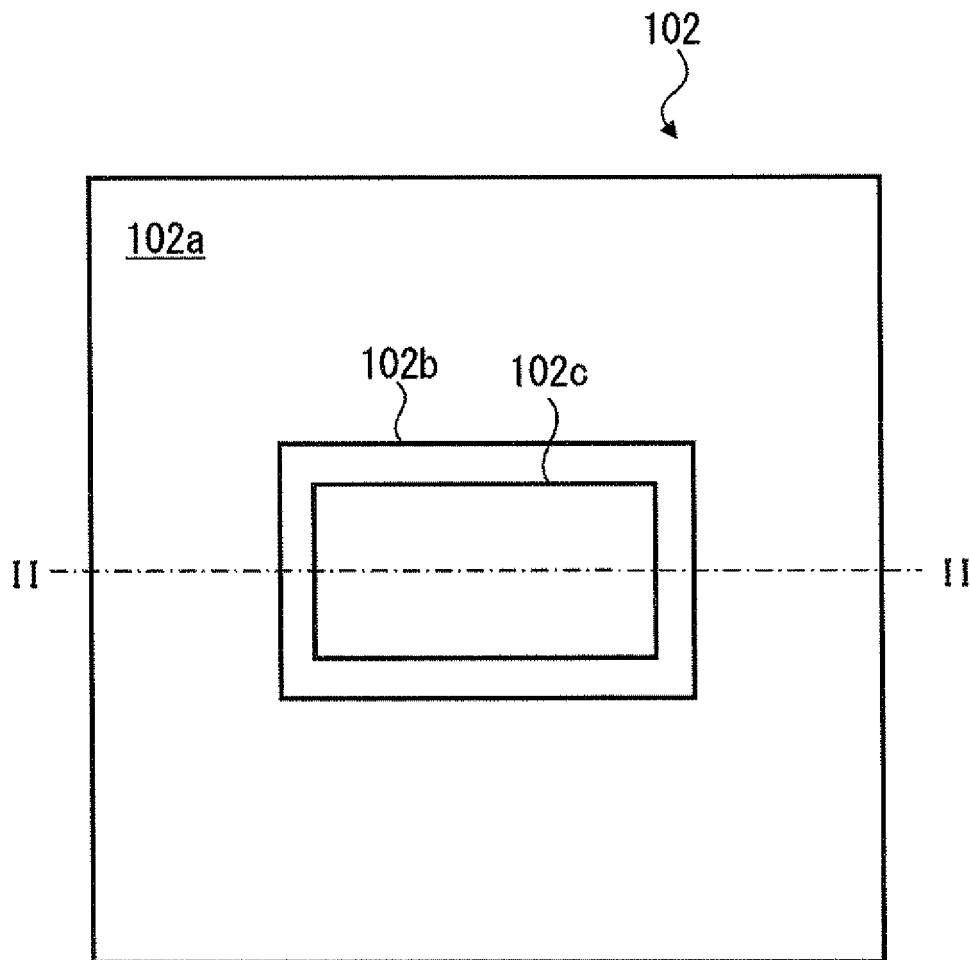


Fig. 22

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/003205

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	1996-2014
Kokai Jitsuyo Shinan Koho	1971-2014	Toroku Jitsuyo Shinan Koho	1994-2014

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 2-205232 A (Director General of National Research Institute for Science and Technology Agency), 15 August 1990 (15.08.1990), entire text (Family: none)	1-32
A	JP 2-251341 A (Kubota Tekko Kabushiki Kaisha), 09 October 1990 (09.10.1990), entire text (Family: none)	1-32



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

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"T"

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"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y"

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

"&"

document member of the same patent family

Date of the actual completion of the international search
25 June, 2014 (25.06.14)Date of mailing of the international search report
15 July, 2014 (15.07.14)Name and mailing address of the ISA/
Japanese Patent Office

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2012061518 A [0005]
- JP 2013158205 A [0091]
- JP JULY302413 B [0091]