US 20220055094A1

(19) **United States**

(12) **Patent Application Publication**

Suezawa et al.

(10) **Pub. No.: US 2022/0055094 A1**

(43) **Pub. Date: Feb. 24, 2022**

(54) **CASTING MOLD**

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(21) Appl. No.: **17/407,199**

(22) Filed: **Aug. 20, 2021**

(30) **Foreign Application Priority Data**

Aug. 24, 2020 (JP) 2020-140941

Publication Classification

(51) **Int. Cl.**

B22C 9/08 (2006.01)

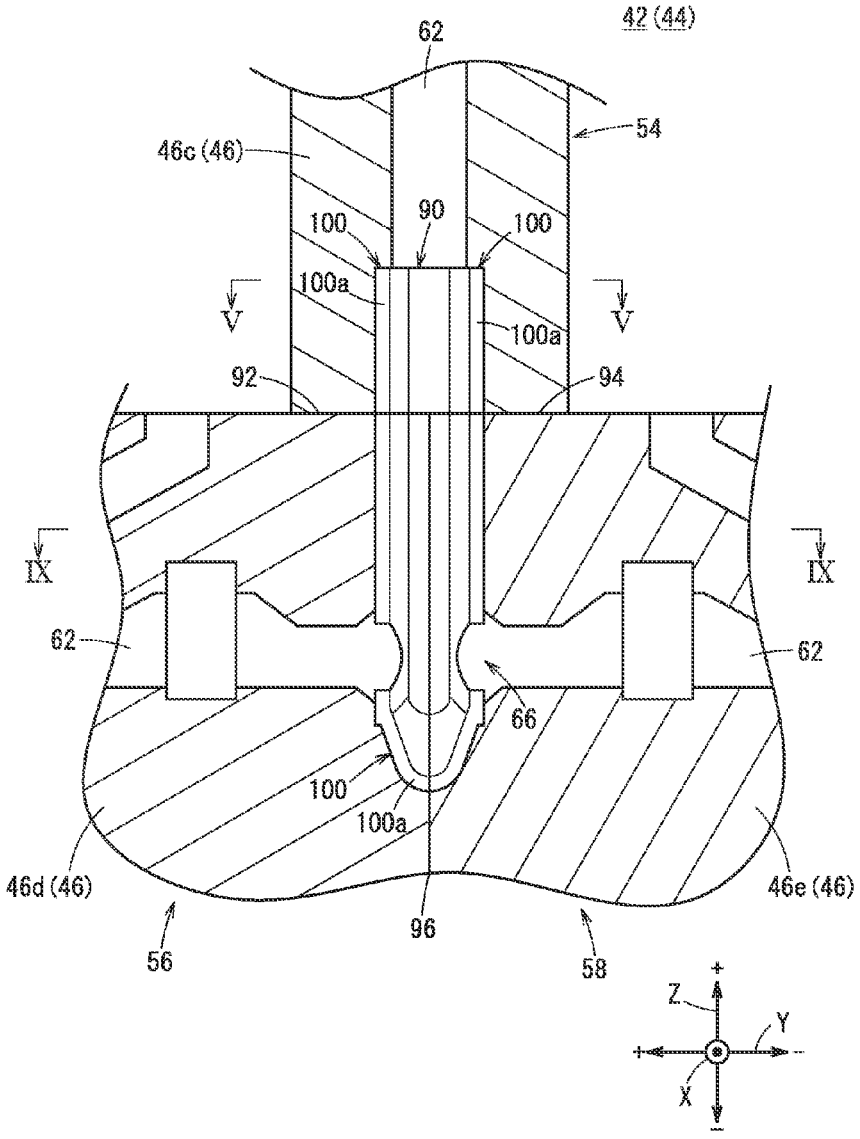
B22C 9/06 (2006.01)

(52) **U.S. Cl.**

CPC . ***B22C 9/08*** (2013.01); ***B22C 9/06*** (2013.01)

(57) **ABSTRACT**

A casting mold includes a cavity for molding a product, and a pouring basin and a passageway that guide molten metal into the cavity. The passageway includes, at portions thereof positioned below the pouring basin and the cavity, bent portions (a first bent portion, a second bent portion) that change the advancing direction of the molten metal, and the casting mold further includes a cover member, which covers the inner wall of the bent portion, allows the passageway positioned on the upstream side of the bent portion to communicate with the passageway positioned on the downstream side of the bent portion, and has a lower thermal conductivity than the base material of the mold.



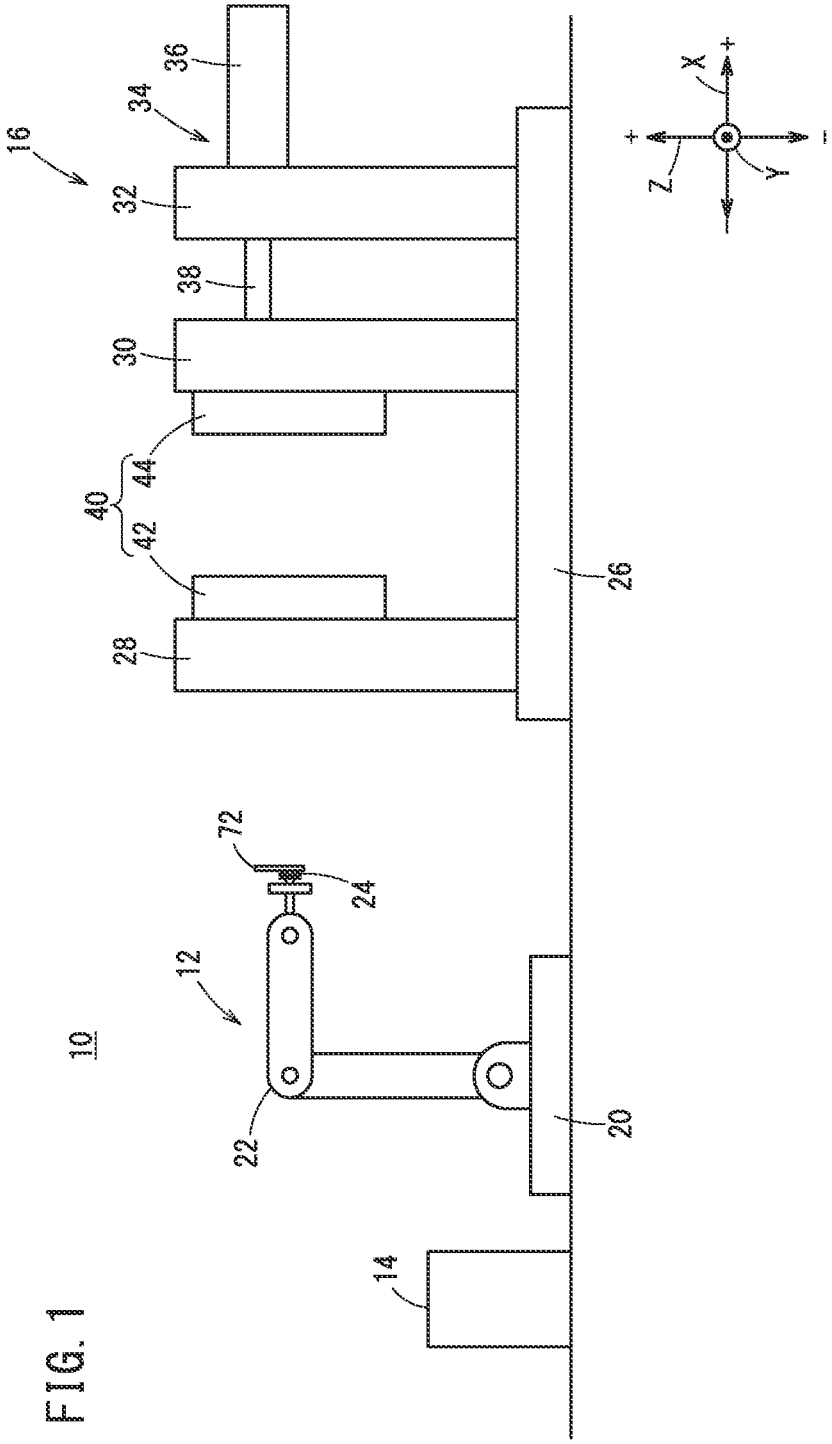


FIG. 1

FIG. 2

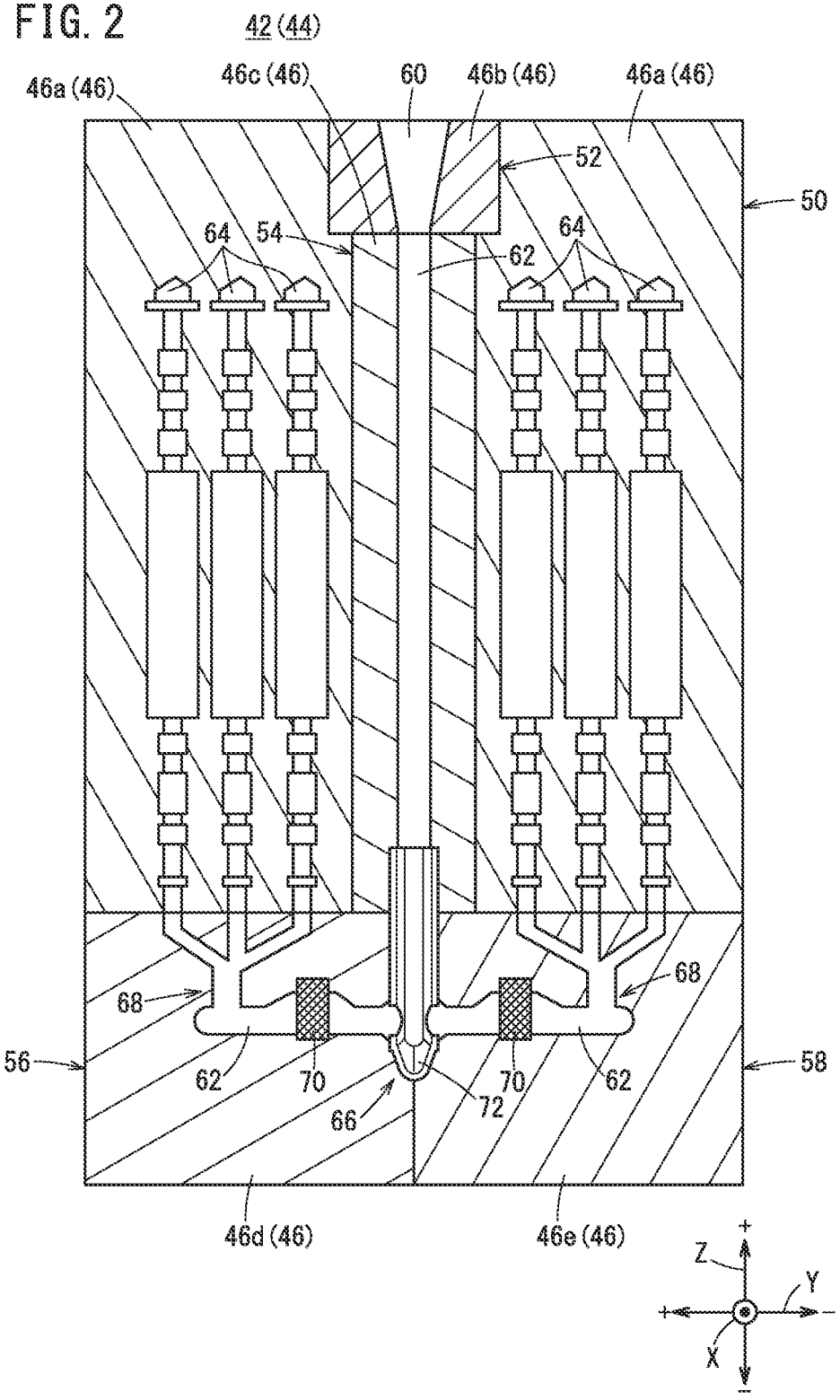

42 (44)
46a (46)
46c (46)
60
46b (46)
46a (46)
52
50
64
54
62
64
68
68
56
58
62
70
70
62
72
66
46d (46)
46e (46)
Z
Y
X

FIG. 3C

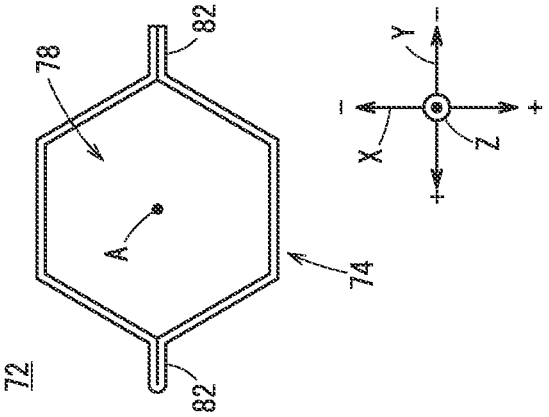


FIG. 3B

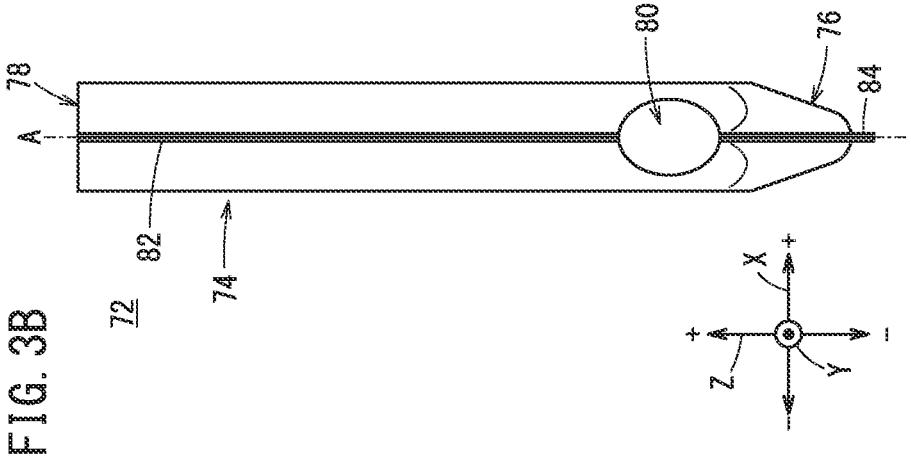


FIG. 3A

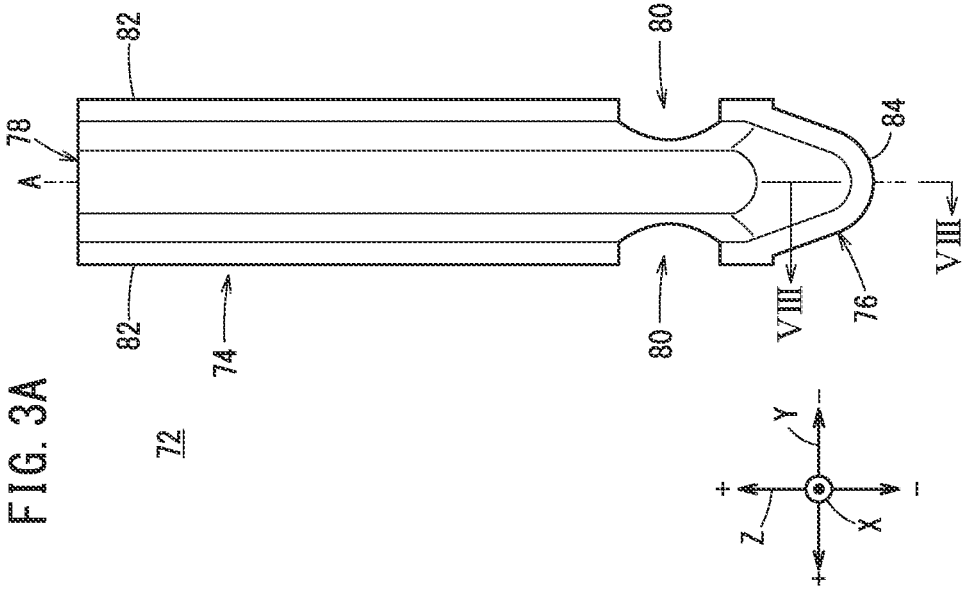
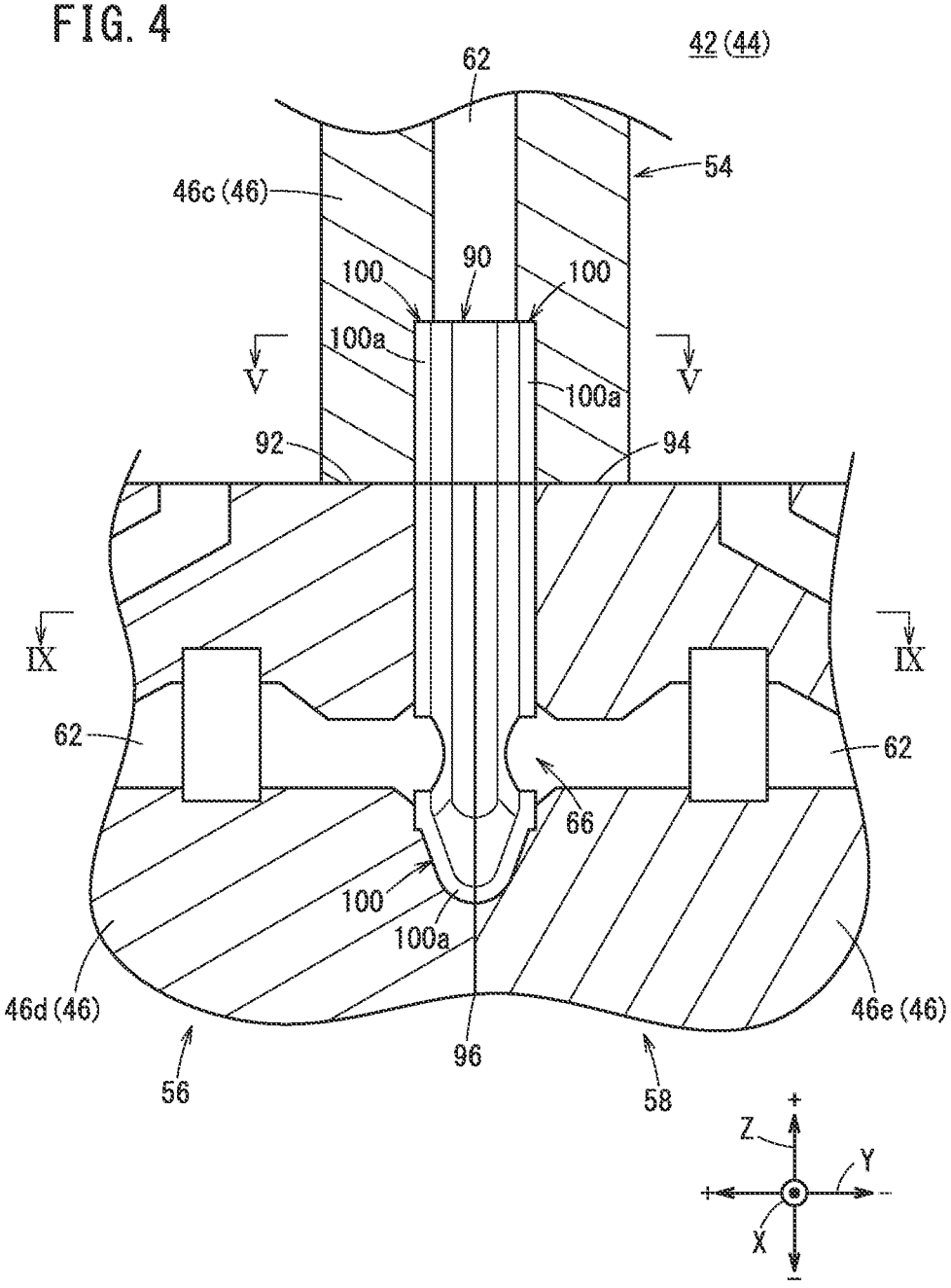


FIG. 4


42 (44)
62
54
46c (46)
90
100
100
100a
100a
V
V
92
94
IX
IX
62
62
66
100
100a
46d (46)
46e (46)
96
56
58
Z
Y
X

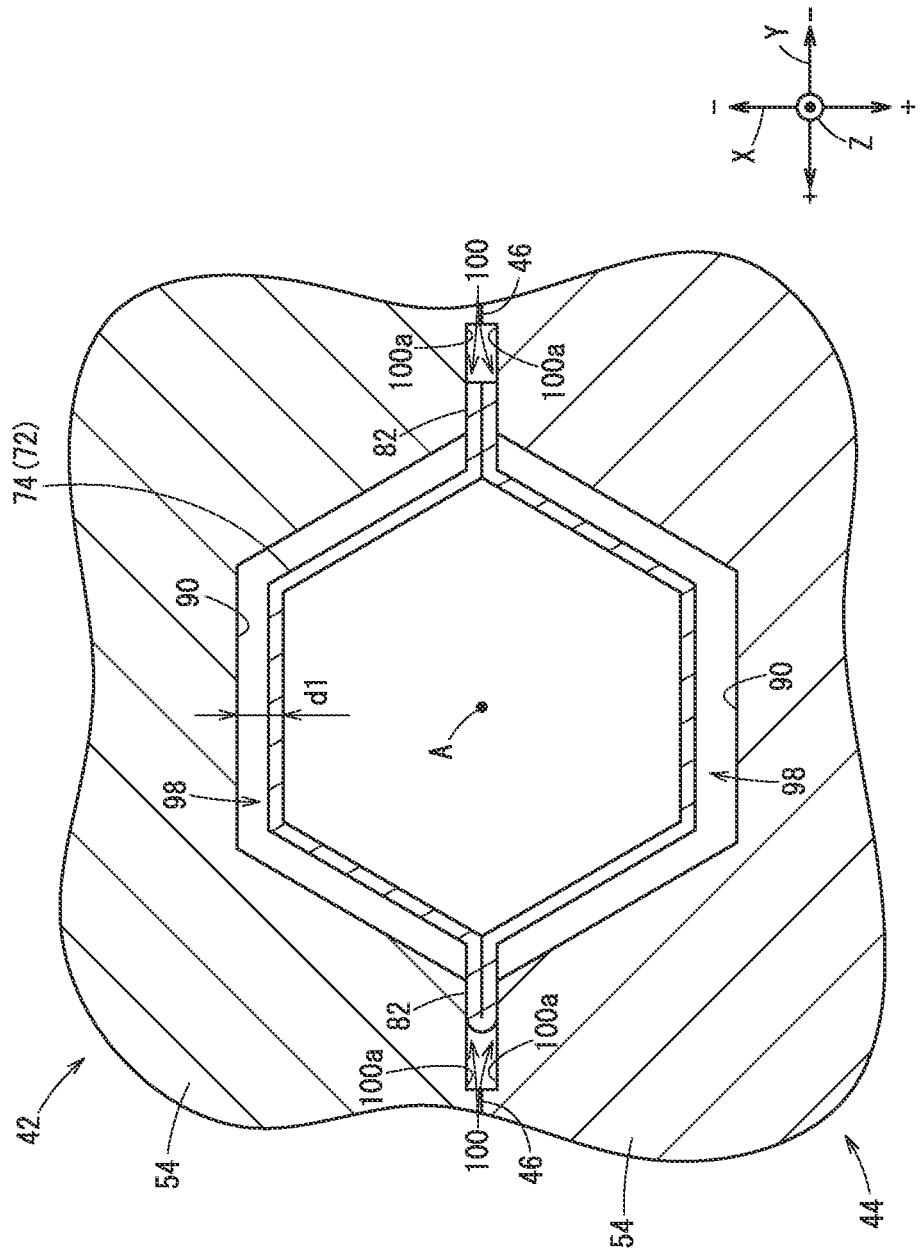

Y
X
Z
100
46
100a
100a
82
74 (72)
90
d1
A
98
90
98
82
100a
100a
42
54
100
46
54
44

FIG. 5

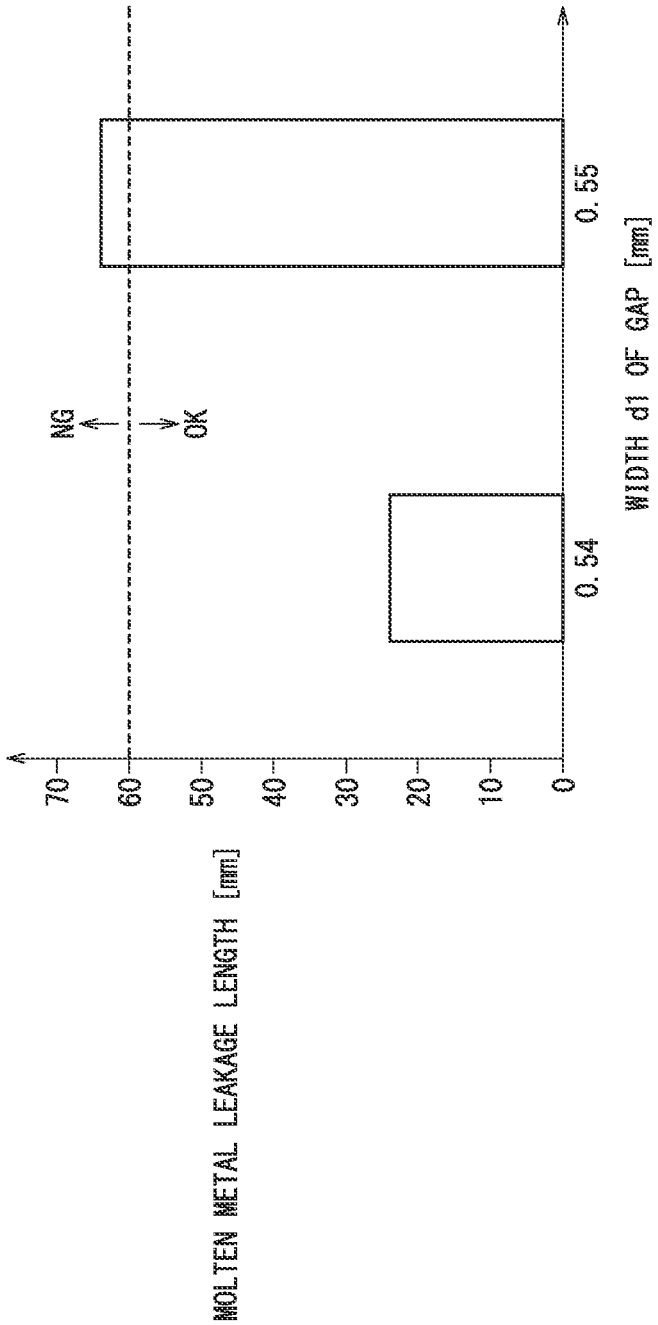

MOLTEN METAL LEAKAGE LENGTH [mm]
70
60
50
40
30
20
10
0
NG
OK
0.54
0.55
WIDTH d1 OF GAP [mm]

FIG. 6

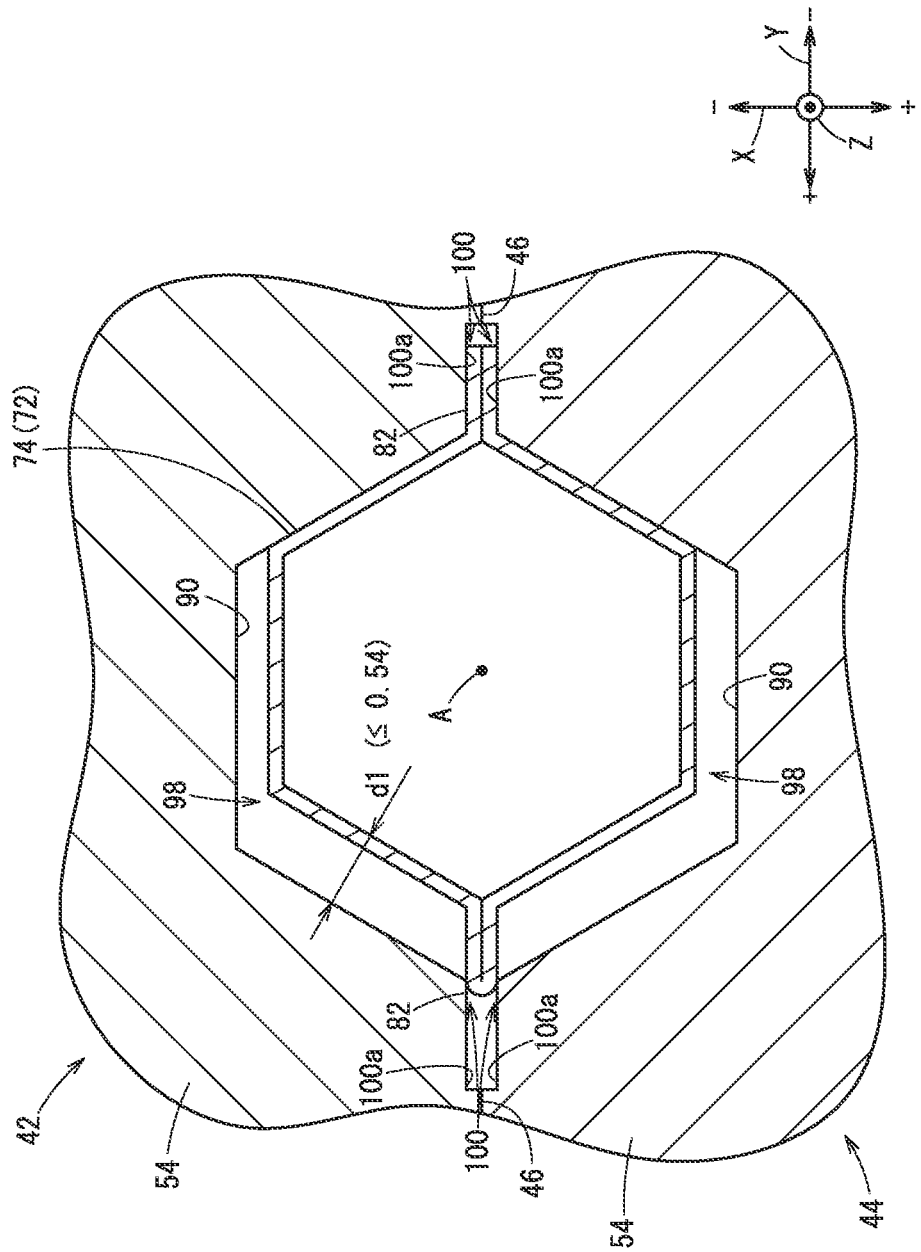
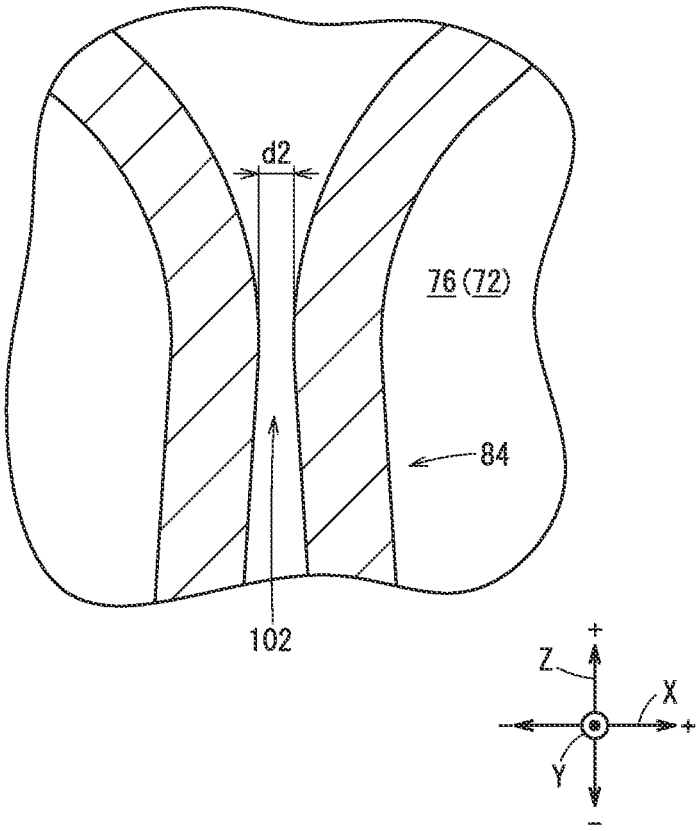


FIG. 7

FIG. 8



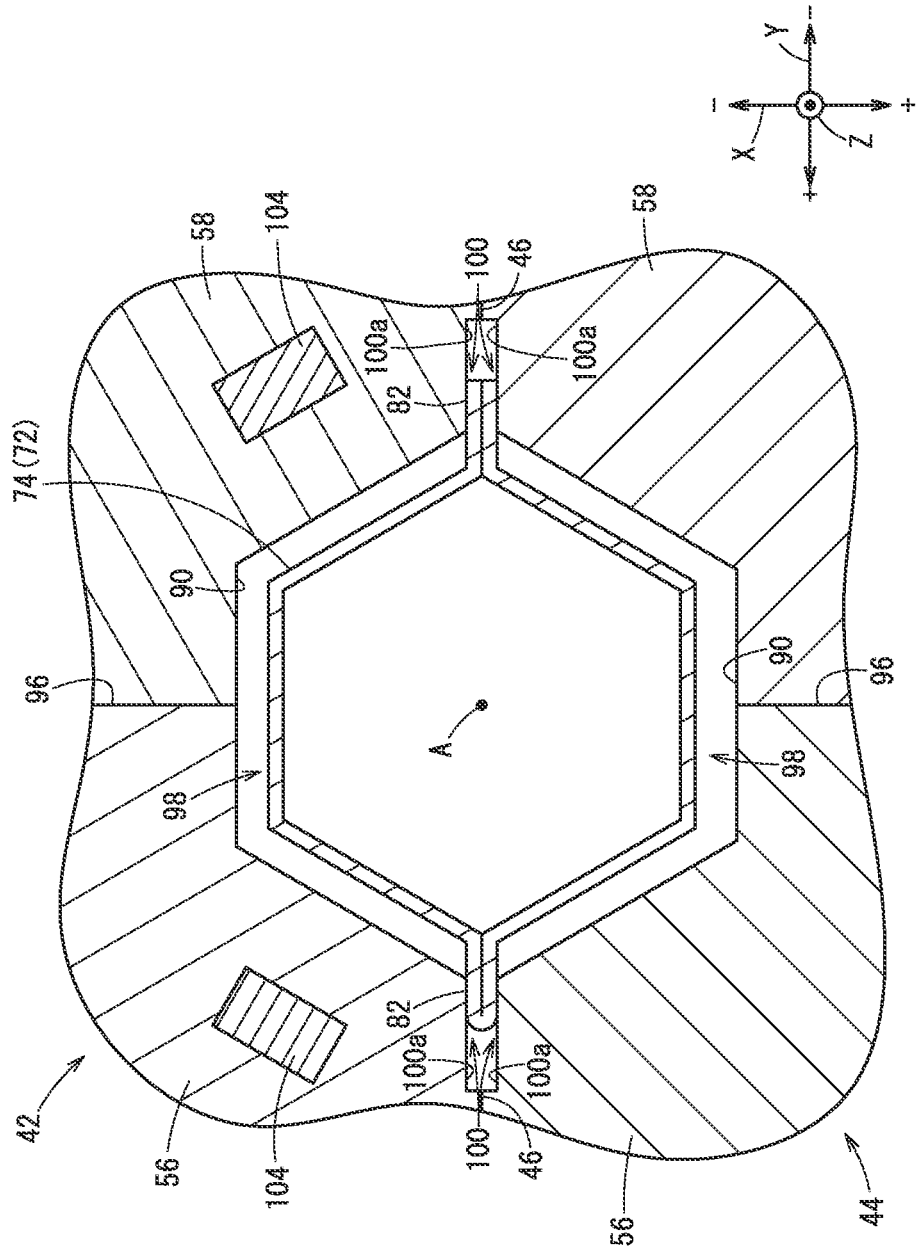

Y
X
Z
58
104
100
46
58
100a
100a
82
74 (72)
90
96
90
96
A
98
98
82
100a
100a
42
56
104
100
46
56
44

FIG. 9

FIG. 10

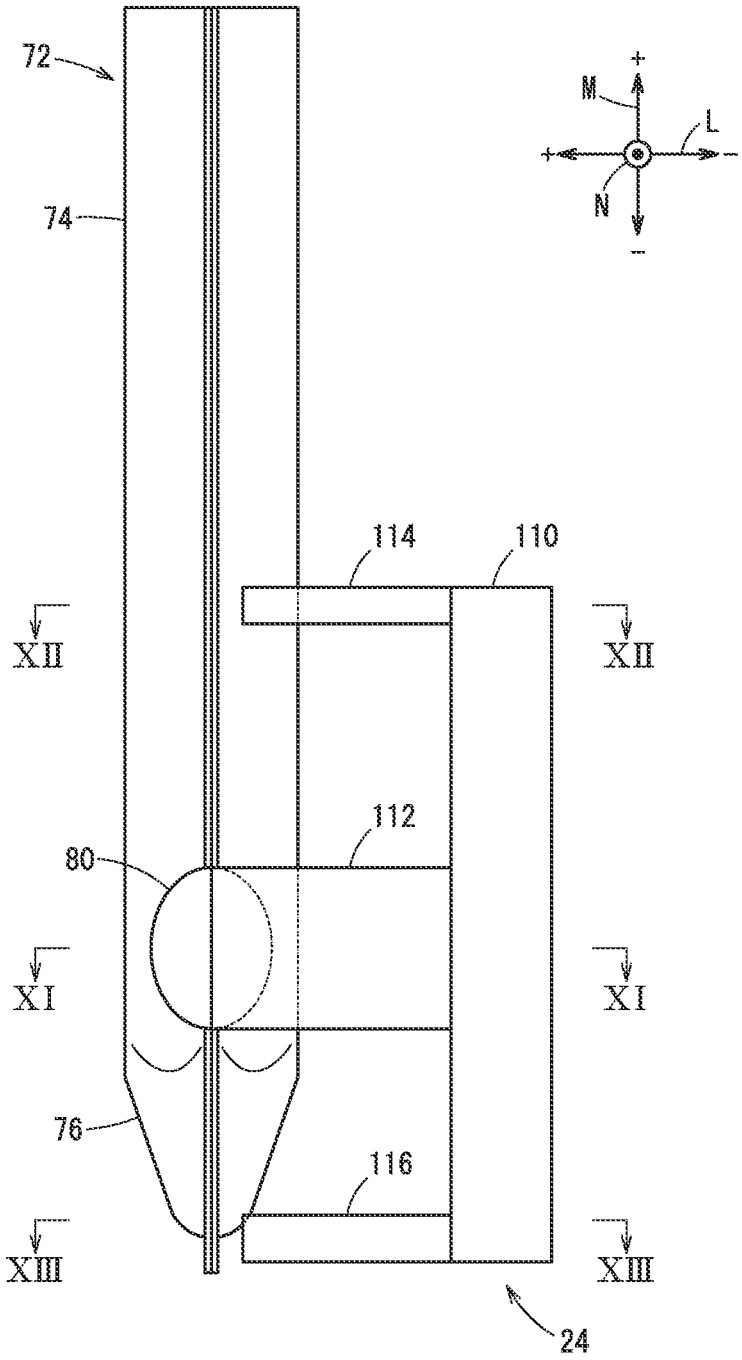


FIG. 11

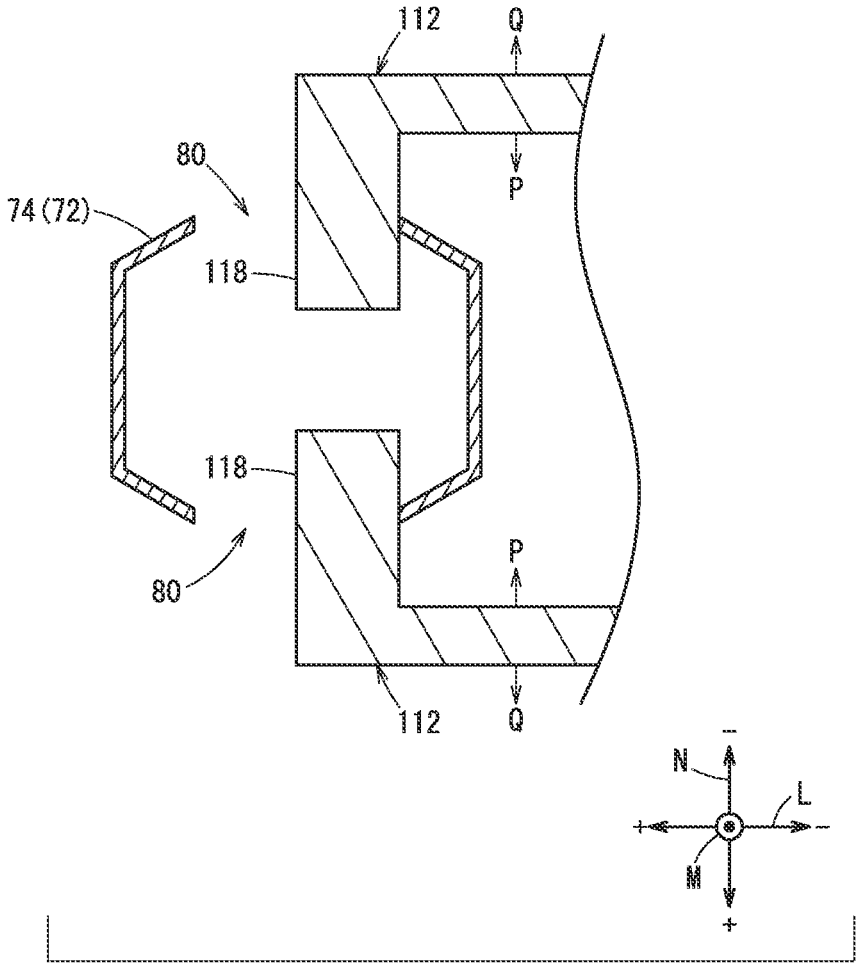


FIG. 12

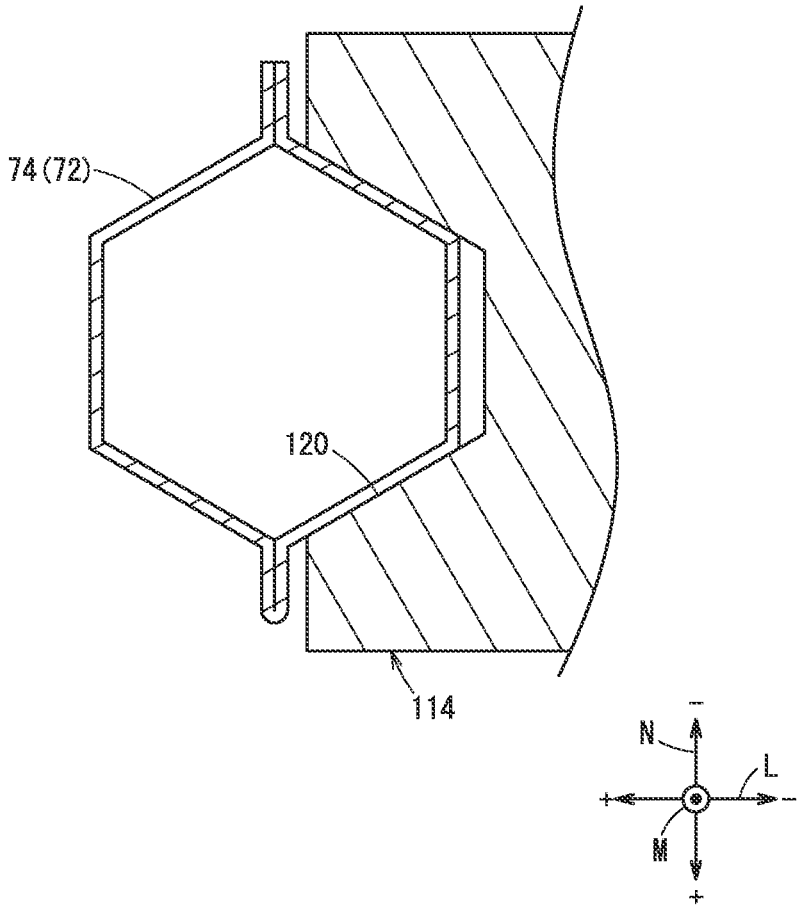


FIG. 13

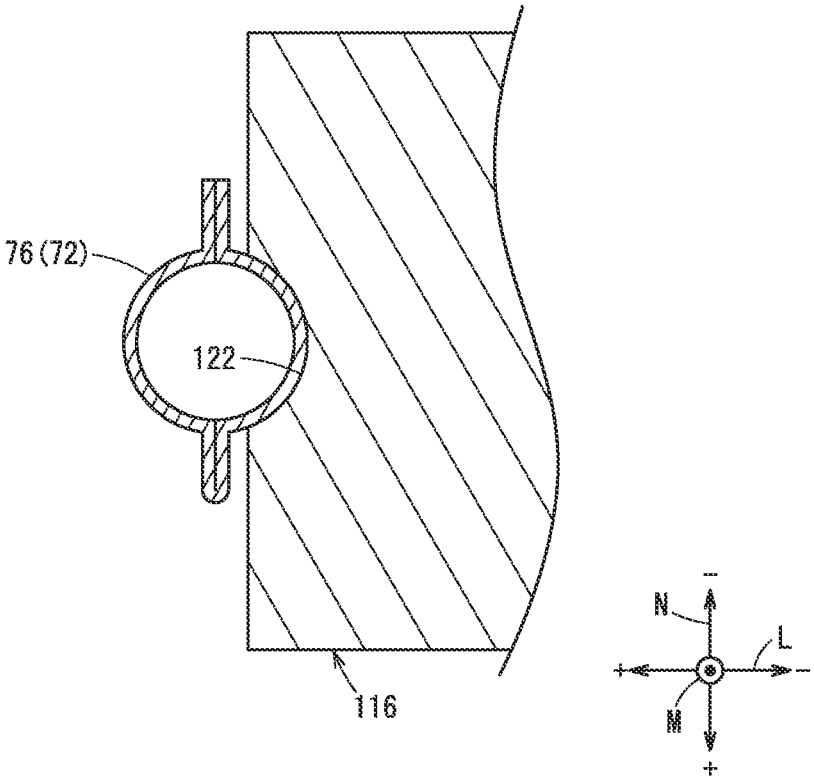


FIG. 14

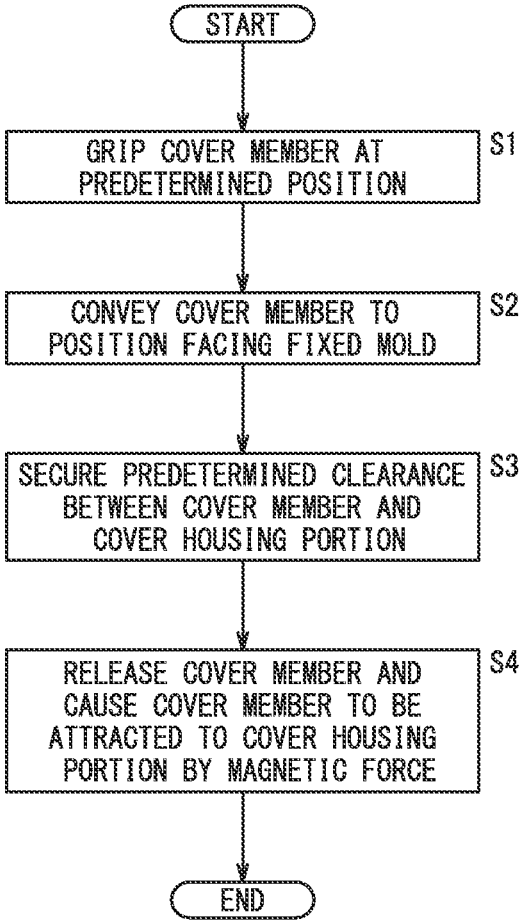

START
GRIP COVER MEMBER AT PREDETERMINED POSITION
S1
CONVEY COVER MEMBER TO POSITION FACING FIXED MOLD
S2
SECURE PREDETERMINED CLEARANCE BETWEEN COVER MEMBER AND COVER HOUSING PORTION
S3
RELEASE COVER MEMBER AND CAUSE COVER MEMBER TO BE ATTRACTED TO COVER HOUSING PORTION BY MAGNETIC FORCE
S4
END

FIG. 15C

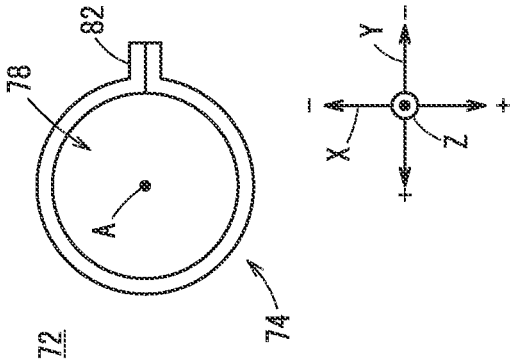


FIG. 15B

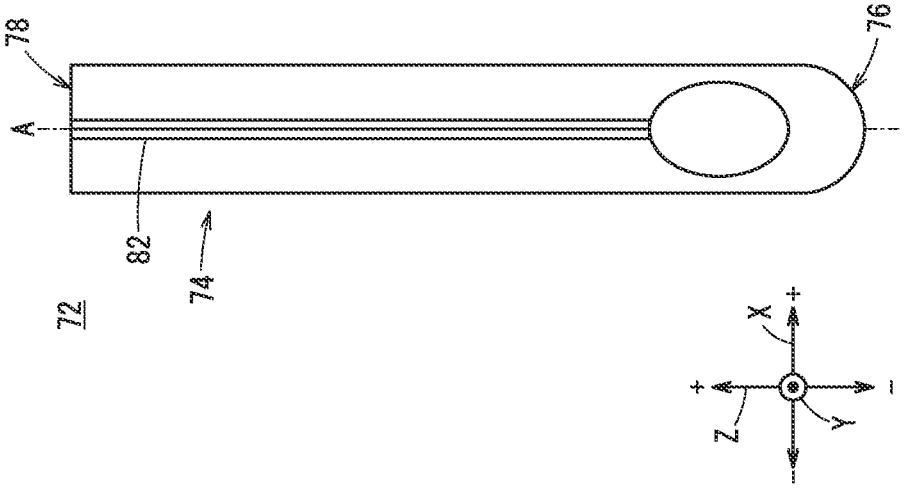
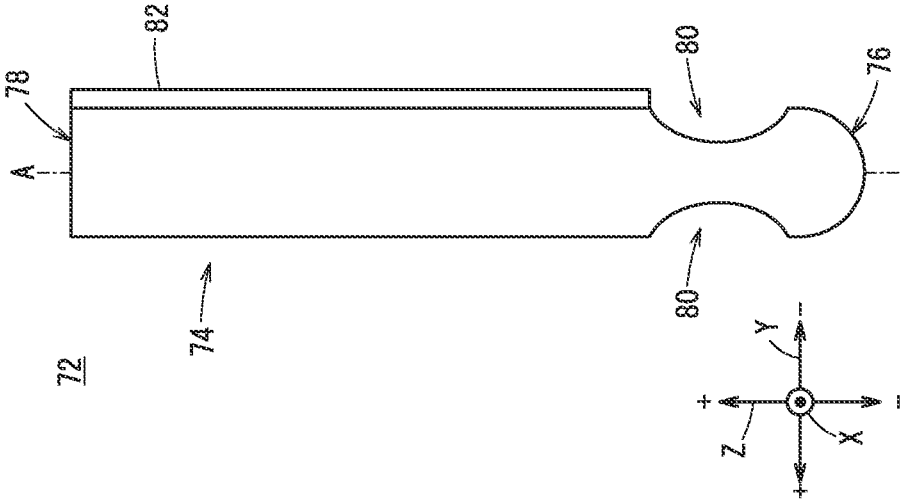


FIG. 15A



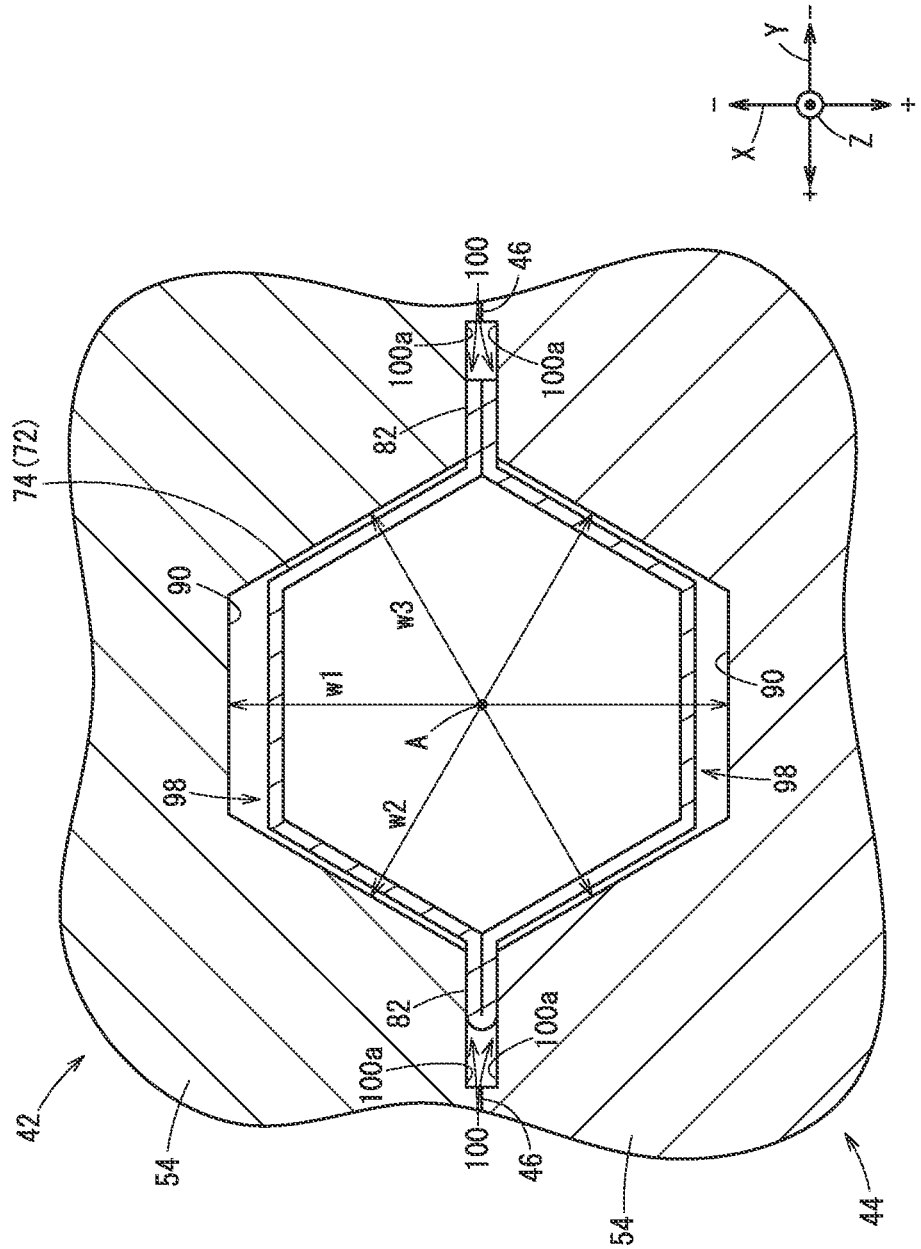


FIG. 16

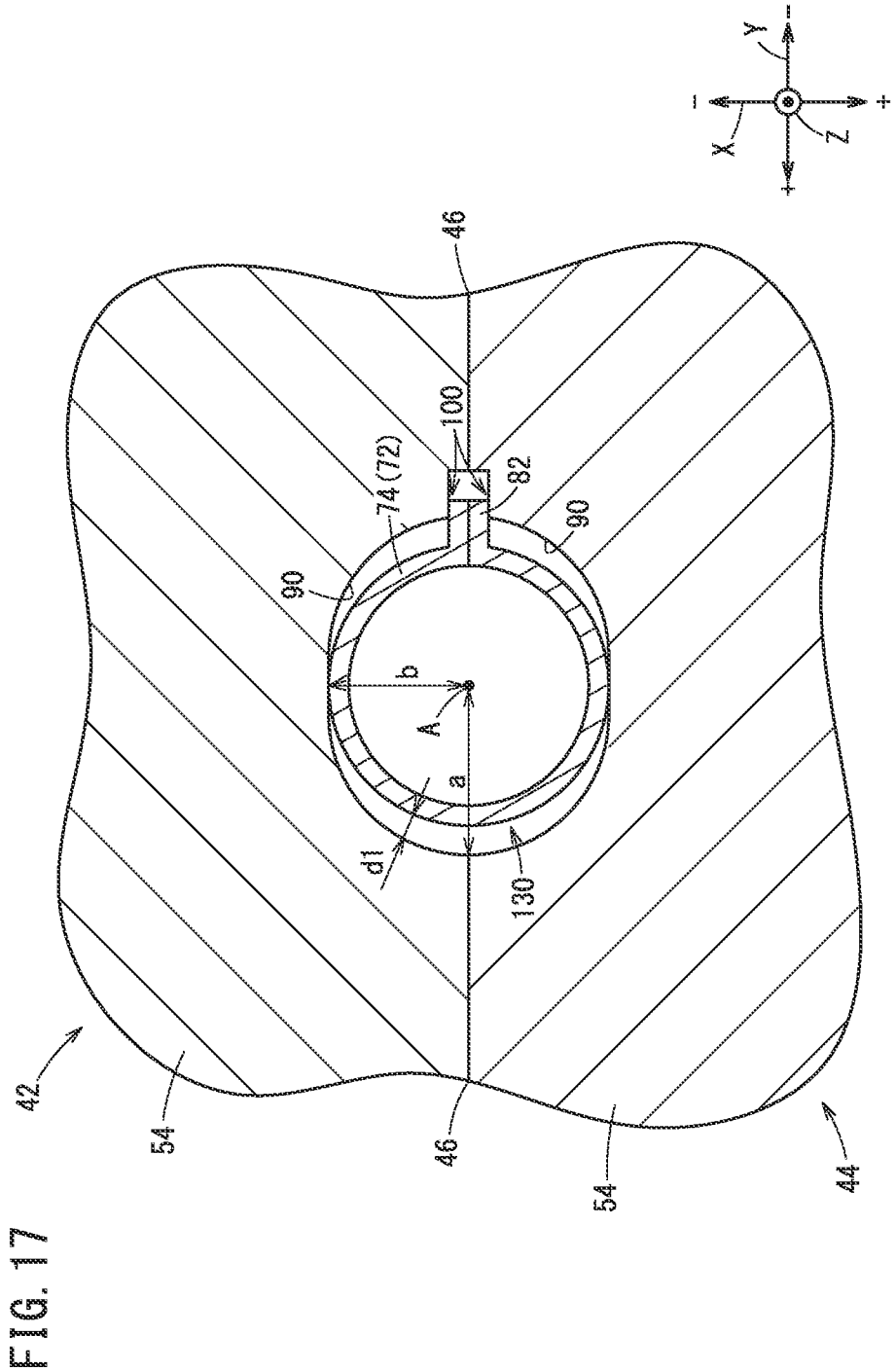


FIG. 17

CASTING MOLD

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2020-140941 filed on Aug. 24, 2020, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to a casting mold used in casting.

Description of the Related Art

[0003] Various metal products are used for power trains or the like of a vehicle. For example, metal products are formed by casting. JP 6029444 B2 discloses a casting mold used in a gravity casting method or a low pressure casting method. This casting mold includes a branch portion forming body made of a tungsten alloy on the upstream side of a branch point. This structure improves the heat resistance of the portion upstream of the branch point.

SUMMARY OF THE INVENTION

[0004] The passageway (corresponding to the sprue, the runner, and the gate) of the casting mold is heated by molten metal and expands. Further, the passageway of the casting mold is cooled by a cooling device and shrinks. When the casting mold is constrained, the inner wall of the passageway is compressed as the mold expands. Therefore, the inner wall of the passageway is easily deformed. Further, the inner wall of the passageway is pulled out along with the shrinkage of the mold. Therefore, the inner wall of the passageway is likely to crack.

[0005] In the passageway, the molten metal is less likely to flow in the bent portion where the advancing direction of the molten metal is changed to the lateral direction or the upward direction, than in portions other than the bent portion. Therefore, the temperature of the bent portion becomes higher than that of the portions other than the bent portion. In particular, the bent portion immediately below the pouring basin has the highest temperature. Therefore, cracks tend to occur in the bent portion. When the crack extends, penetration into the crack (a phenomenon in which molten metal enters the crack) occurs. Then, the solidified metal adheres to the inner wall of the bent portion. In this case, maintenance work for removing the adhered metal and maintenance work for filling the crack are required. During maintenance work, the casting mold is out of operation. Therefore, the production amount of the product is reduced. An object of the present invention is to solve the above-described problems.

[0006] An aspect of the invention is a casting mold comprising a cavity configured to mold a product, and a pouring basin and a passageway that are configured to guide molten metal into the cavity, wherein the passageway includes, at a portion thereof positioned below the pouring basin and the cavity, at least one bent portion configured to change an advancing direction of the molten metal, and the casting mold further comprises a cover member configured to cover an inner wall of the bent portion and allow the passageway positioned on an upstream side of the bent portion to communicate with the passageway positioned on a downstream side of the bent portion, the cover member having a lower thermal conductivity than a base material of the mold.

[0007] According to the present invention, it is possible to reduce the number of maintenance operations due to adhesion of metal.

[0008] The above and other objects features and advantages of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings in which a preferred embodiment of the present invention is shown by way of illustrative example.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a view showing an overall configuration of an insert mounting device;

[0010] FIG. **2** is a view showing a fixed mold (movable mold) viewed from a separation surface side;

[0011] FIGS. **3**A, **3**B and **3**C are views respectively showing a front surface, a left side surface, and a plane of a cover member;

[0012] FIG. **4** is a view showing a cover housing portion and its peripheral structure viewed from the separation surface side;

[0013] FIG. **5** is a cross-sectional view of the periphery of the cover member of a closed mold taken along line V-V (XY plane) in FIG. **4**;

[0014] FIG. **6** is a graph showing the relationship between the width of a gap and the molten metal leakage length;

[0015] FIG. **7** is a view showing a state in which the cover member is displaced in the cross section shown in FIG. **5**;

[0016] FIG. **8** is a cross-sectional view of the bottom portion of the cover member taken along line VIII-VIII (XY plane) in FIG. **3**A;

[0017] FIG. **9** is a cross-sectional view of the periphery of the cover member of the closed mold taken along line IX-IX (XY plane) in FIG. **4**;

[0018] FIG. **10** is a view showing the cover member and a hand;

[0019] FIG. **11** is a cross-sectional view of the cover member and the hand taken along line XI-XI in FIG. **10**;

[0020] FIG. **12** is a cross-sectional view of the cover member and the hand taken along line XII-XII of FIG. **10**;

[0021] FIG. **13** is a cross-sectional view of the cover member and the hand taken along line XIII-XIII in FIG. **10**;

[0022] FIG. **14** is a flowchart of a series of operations for mounting the cover member to the cover housing portion.

[0023] FIGS. **15**A, **15**B and **15**C are views respectively showing a front surface, a left side surface, and a plane of a cover member having a different form from that of the cover member of FIGS. **3**A, **3**B and **3**C;

[0024] FIG. **16** is a cross-sectional view of another embodiment different from the embodiment shown in FIG. **5**; and

[0025] FIG. **17** is a cross-sectional view of another embodiment different from the embodiment shown in FIG. **5**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0026] In the following description, directions such as an X direction, a Y direction, and a Z direction are used. The X direction and the Y direction are orthogonal to each other. The X direction and the Y direction are parallel to the horizontal direction. The Z direction is orthogonal to the X direction and the Y direction. The Z direction is parallel to the up-down direction (vertical direction). The forward direction of each direction is defined as +, and the reverse direction thereof is defined as −.

[1. Insert Mounting Device **10**]

[0027] An insert mounting device **10** will be described with reference to FIG. **1**. The insert mounting device **10** mounts an insert in a casting mold **40** by using a robot **12**. In the present embodiment, the insert mounted in the casting mold **40** is a cover member **72**.

[0028] The insert mounting device **10** includes the robot **12**, a controller **14**, and a casting machine **16**. In FIG. **1**, the robot **12** and the casting machine **16** are shown separated from each other. However, the robot **12** is actually disposed at a position where a hand **24** can reach the casting mold **40**.

[2. Robot **12**]

[0029] The robot **12** is an industrial robot. The robot **12** includes a robot base **20**, an arm **22**, and the hand (gripping portion) **24**. The arm **22** is attached to the robot base **20**. The arm **22** has a plurality of joints and a plurality of links. The hand **24** is attached to the distal end of the arm **22**. The hand **24** will be described in [11] below. The operation of the robot **12** is controlled by the controller **14**.

[3. Controller **14**]

[0030] The controller **14** is a computer including an input device, an arithmetic device, and a storage device (none of which are shown). The input device is a man-machine interface. For example, the arithmetic device is a processor. For example, the storage device is a memory such as a RAM and a ROM. The controller **14** stores the operation of the robot **12** by teaching performed in advance. The operation of the robot **12** includes a mounting operation of mounting the insert (cover member **72**) in the casting mold **40**. The controller **14** causes the robot **12** to reproduce various operations in accordance with predetermined operations performed by a user using the input device (not shown).

[4. Casting Machine **16**]

[0031] The casting machine **16** includes a casting base **26**, a fixed platen **28**, a movable platen **30**, a cylinder support **32**, a cylinder **34**, and the casting mold **40**. The casting mold **40** has a fixed mold **42** and a movable mold **44**. On the casting base **26**, for example, the fixed platen **28**, the movable platen **30**, and the cylinder support **32** are arranged in this order from the −X direction toward the +X direction. The fixed platen **28** is fixed to the casting base **26**. The movable platen **30** is movable in the −X direction and the +X direction along a guide (not shown) provided in the casting base **26**. The casting mold **40** is disposed between the fixed platen **28** and the movable platen **30**. The fixed mold **42** is attachable to and detachable from the surface of the fixed platen **28** facing in the +X direction. The movable mold **44** is attachable to and detachable from the surface of the movable platen **30** facing in the −X direction. The cylinder support **32** is fixed to the casting base **26**. A cylinder tube **36** of the cylinder **34** is fixed to the surface of the cylinder support **32** facing in the +X direction. The cylinder support **32** has formed therein a hole (not shown) penetrating therethrough along the X direction. A piston rod **38** is inserted through the hole. An end portion of the piston rod **38** in the −X direction is fixed to the surface of the movable platen **30** facing in the +X direction. An end portion (not shown) of the piston rod **38** in the +X direction is fixed to a piston (not shown). The piston is slidable in the cylinder tube **36** along the X direction.

[0032] When fluid is supplied to a first fluid chamber (not shown) of the cylinder tube **36**, the piston is pushed in the −X direction. Then, the piston rod **38** and the movable platen **30** move in the −X direction to close the casting mold **40**. When fluid is supplied to a second fluid chamber (not shown) of the cylinder tube **36**, the piston is pushed in the +X direction. Then, the piston rod **38** and the movable platen **30** move in the +X direction to open the casting mold **40**.

[5. Casting Mold **40**]

[0033] The casting mold **40** will be described with reference to FIG. **2**. As described above, the casting mold **40** includes the fixed mold **42** and the movable mold **44**. In a state where the casting mold **40** is closed, the fixed mold **42** and the movable mold **44** are symmetrical with respect to a mold mating surface (separation surface **46**). Therefore, the fixed mold **42** will be described below, and the description of the movable mold **44** will be omitted. When the following description is read as the description of the movable mold **44**, the +Y direction and the −Y direction in FIG. **2** are reversed.

[0034] The fixed mold **42** includes a first mold **50**, a second mold **52**, a third mold **54**, a fourth mold **56**, and a fifth mold **58**. Each mold is made of, for example, copper. The first mold **50** is a main body (mold main body) of the fixed mold **42**. The first mold **50** has a first separation surface **46***a*. The first separation surface **46***a* is a part of the separation surface **46**. The first mold **50** further includes an attachment surface (not shown) recessed in the −X direction from the first separation surface **46***a*. The second mold **52** to the fifth mold **58** are components (partial molds) attached to the attachment surface (not shown) of the first mold **50** by bolts or the like. The second mold **52** has a second separation surface **46***b*. The third mold **54** has a third separation surface **46***c*. The fourth mold **56** has a fourth separation surface **46***d*. The fifth mold **58** has a fifth separation surface **46***e*. The second separation surface **46***b* to the fifth separation surface **46***e* are parts of the separation surface **46**. In a state in which the second mold **52** to the fifth mold **58** are attached to the first mold **50**, the first separation surface **46***a* to the fifth separation surface **46***e* are flush with each other. Thus, the separation surface **46** of the fixed mold **42** is formed by the first separation surface **46***a* to the fifth separation surface **46***e*.

[0035] The first mold **50** has two first separation surfaces **46***a*. One of the first separation surfaces **46***a* and the other of the first separation surfaces **46***a* are separated from each other in the +Y direction. The second mold **52** is positioned at the center of the upper portion of the fixed mold **42**. The second separation surface **46***b* is located between one of the first separation surfaces **46***a* and the other of the first

separation surfaces **46***a*. The second mold **52** has a lower surface facing in the −Z direction. The third mold **54** abuts against the lower surface of the second mold **52**. The third separation surface **46***c* is located immediately below the second separation surface **46***b*. The third separation surface **46***c* is located between one of the first separation surfaces **46***a* and the other of the first separation surfaces **46***a*. The fourth mold **56** is positioned in the lower portion of the fixed mold **42**. The fourth separation surface **46***d* is located immediately below one of the first separation surfaces **46***a*. The fourth separation surface **46***d* is located immediately below the third separation surface **46***c*. The fifth mold **58** is positioned in the lower portion of the fixed mold **42**. The fifth separation surface **46***e* is located immediately below the other of the first separation surfaces **46***a*. The fifth separation surface **46***e* is located immediately below the third separation surface **46***c*. The position (height position) of the fourth mold **56** in the Z direction is the same as the position (height position) of the fifth mold **58** in the Z direction. The third mold **54**, the fourth mold **56**, and the fifth mold **58** form a passageway **62** described later. The third mold **54**, the fourth mold **56**, and the fifth mold **58** are arranged along the flow direction of the molten metal.

[0036] The fixed mold **42** includes a half of a pouring basin **60**, a half of the passageway **62** (corresponding to a sprue, a runner, and a gate), and a half of a cavity **64**. Each half is recessed in the −X direction from the separation surface **46**. When the casting mold **40** is closed, the halves are mated together. As a result, the pouring basin **60**, the passageway **62** and the cavity **64** are formed.

[0037] The pouring basin **60** is formed in the second mold **52**. The pouring basin **60** opens in the +Z direction (upward direction). The pouring basin **60** has a tapered shape whose diameter decreases toward the −Z direction (downward direction).

[0038] The cavity **64** is formed in the first mold **50**. Six cavities **64** are shown in FIG. **2**. For example, a camshaft or balancer shaft of a vehicle is formed using the cavity **64**. Three cavities **64** are formed in one of the first separation surfaces **46***a*. Three cavities **64** are also formed in the other of the first separation surfaces **46***a*.

[0039] The passageway **62** is formed across the third mold **54**, the fourth mold **56**, and the fifth mold **58**. A first bent portion **66** and two second bent portions **68** are formed in the passageway **62**. The first bent portion **66** and the two second bent portions **68** are located below the pouring basin **60** and the cavities **64**. The passageway **62** extends downward (−Z direction) from the pouring basin **60** and branches in the lateral direction (±Y direction) at the first bent portion **66**. The passageway **62** extends in the +Y direction from the first bent portion **66** and is bent upward (in the +Z direction) at the second bent portion **68** on the +Y direction side. The passageway **62** extends upward from the second bent portion **68** and branches into three. The three passageways **62** are directly connected to lower end portions of the three cavities **64** formed in one of the first separation surfaces **46***a*. Further, the passageway **62** extends in the −Y direction from the first bent portion **66** and is bent upward (in the +Z direction) at the second bent portion **68** on the −Y direction side. The passageway **62** extends upward from the second bent portion **68** and branches into three. The three passageways **62** are directly connected to lower end portions of the three cavities **64** formed in the other of the first separation surfaces **46***a*.

[0040] The molten metal supplied from the pouring basin **60** flows downward (−Z direction) in the passageway **62**. The advancing direction of the molten metal is changed to the lateral direction (±Y direction) at the first bent portion **66**. Further, the molten metal flows through the passageway **62** in the lateral direction (±Y direction) and passes through filters **70**. The advancing direction of the molten metal is changed to the upward direction (+Z direction) at the second bent portions **68**. The molten metal flows into each cavity **64** in the upward direction (+Z direction).

[0041] The passageway **62** is more likely to deteriorate than portions other than the passageway **62**. In the present embodiment, when the passageway **62** deteriorates, the third mold **54** to the fifth mold **58** are replaced. Meanwhile, the first mold **50** and the second mold **52** are continuously used. Further, the passageway **62** is divided into three parts across the third mold **54** to the fifth mold **58** with the first bent portion **66** as the center. Therefore, the vertical stress and the lateral stress generated in the fixed mold **42** are reduced.

[6. Cover Member **72**]

[0042] The cover member **72** is mounted inside the first bent portion **66**. The cover member **72** is an insert. The cover member **72** covers the inner wall of the first bent portion **66** and the inner wall of the passageway **62** around the first bent portion **66**. In addition, the cover member **72** allows the passageway **62** positioned on the upstream side of the first bent portion **66** to communicate with the passageway **62** positioned on the downstream side of the first bent portion **66**. The cover member **72** is formed of a material having a lower thermal conductivity than the member of the fixed mold **42** (base material of the mold). For example, when an iron-based component is cast using the casting mold **40**, the cover member **72** is made of an iron-based alloy such as a cold-rolled steel plate (SPCC). When both the cover member **72** and the molten metal are iron-based alloys, the cover member **72** may be re-melted and reused together with the casting design parts (the third mold **54**, the fourth mold **56**, and the fifth mold **58**) separated from the product part (the first mold **50**) after casting.

[0043] The cover member **72** will be described with reference to FIGS. **3**A to **3**C. The cover member **72** is formed of a single steel plate. The steel plate is subjected to shearing, drawing, and bending. The first end of the steel plate and the second end of the steel plate are joined to each other. Thus, the steel plate is formed into a bottomed cylindrical shape having an axis A. As shown in FIG. **3**C, the outer peripheral shape of the cover member **72** viewed from the +Z direction is a substantially regular hexagonal shape when side wall flanges **82** described later are ignored.

[0044] The cover member **72** has a body portion **74** and a bottom portion **76**. The body portion **74** has a tubular shape. The axis A of the body portion **74** extends in the up-down direction (Z direction). The bottom portion **76** extends downward from the lower end of the body portion **74**. The cross-sectional area of the bottom portion **76** in the XY plane decreases in the downward direction. An upper hole **78** is formed in an upper end of the body portion **74**. The upper hole **78** opens upward. Two lateral holes **80** are formed in the side wall of the body portion **74** above the bottom portion **76**. The two lateral holes **80** open in the lateral direction (+Y direction and −Y direction). The upper hole **78** is an inlet of a flow path formed in the cover member **72**. The two lateral holes **80** are outlets of the flow path formed in the cover

member **72**. The upper hole **78** is directly connected to the passageway **62** (the passageway **62** of the third mold **54**) positioned on the upstream side of the cover member **72**. One of the lateral holes **80** is directly connected to the passageway **62** (the passageway **62** of the fourth mold **56**) positioned on the downstream side of the cover member **72**. The other of the lateral holes **80** is directly connected to the passageway **62** (the passageway **62** of the fifth mold **58**) positioned on the downstream side of the cover member **72**. The inner diameter of the upper hole **78** (and the inner diameter of the flow path formed in the cover member **72**) are equal to or larger than the inner diameter of the passageway **62** (the passageway **62** of the third mold **54**) positioned on the upstream side of the cover member **72**. Each inner diameter is preferably the same.

[0045] The cover member **72** has a flange. Specifically, the body portion **74** of the cover member **72** has the side wall flange **82** on each of the side walls on both sides in the Y direction. Each side wall flange **82** extends in the up-down direction (Z direction) from the upper hole **78** to the lateral hole **80**. Each side wall flange **82** projects outwardly from the outer wall of the cover member **72**. Each sidewall flange **82** is parallel to the YZ plane. One of the sidewall flanges **82** is shifted 180 degrees about the axis A relative to the other of the sidewall flanges **82**. A bottom flange **84** is formed on the outer wall of the bottom portion **76**. The bottom flange **84** extends from the two lateral holes **80** to the lower end of the bottom portion **76**. The side wall flange **82** projecting in the +Y direction is a bent part formed by bending a substantially central portion of the steel plate. The side wall flange **82** projecting in the −Y direction is an abutment part formed by the first end of the steel plate and the second end of the steel plate abutting against each other. At the abutment part, the first end of the steel plate and the second end of the steel plate are joined to each other. On the other hand, the bottom flange **84** includes a bent part and an abutment part.

[7. Cover Housing Portion **90**]

[0046] The cover housing portion **90** will be described with reference to FIGS. **4** and **5**. FIG. **4** shows a part of the fixed mold **42** in which the cover member **72** and the filters **70** shown in FIG. **2** are not mounted. In the passageway **62**, the cover housing portion **90** is formed from the first bent portion **66** over a predetermined range on the upstream side thereof (in the +Z direction). The cover housing portion **90** houses the cover member **72** (FIG. **2**). The cover housing portion **90** is more widely recessed than the passageway **62** adjacent to the cover housing portion **90**. The inner diameter of the cover housing portion **90** is larger than the inner diameter of the passageway **62** positioned on the upstream side of the cover housing portion **90**.

[0047] The cover housing portion **90** is formed across the third mold **54**, the fourth mold **56**, and the fifth mold **58**. Therefore, the cover housing portion **90** includes abutment portions where two molds abut against each other. Specifically, the cover housing portion **90** includes a first abutment portion **92**, a second abutment portion **94**, and a third abutment portion **96**. At the first abutment portion **92**, the third mold **54** and the fourth mold **56** abut against each other. At the second abutment portion **94**, the third mold **54** and the fifth mold **58** abut against each other. At the third abutment portion **96**, the fourth mold **56** and the fifth mold **58** abut against each other.

[0048] Flange housing grooves **100** are formed in an edge of the cover housing portion **90** adjacent to the separation surface **46** (the third separation surface **46***c*, the fourth separation surface **46***d*, and the fifth separation surface **46***e*). In the present embodiment, the flange housing groove **100** that houses the side wall flange **82** projecting in the +Y direction is formed across the third mold **54** and the fourth mold **56**. The flange housing groove **100** that houses the side wall flange **82** projecting in the −Y direction is formed across the third mold **54** and the fifth mold **58**. The flange housing groove **100** that houses the bottom flange **84** is formed across the fourth mold **56** and the fifth mold **58**.

[0049] As shown in FIG. **5**, the inner peripheral shape of the cover housing portion **90** is similar to the outer peripheral shape of the cover member **72**. In the case of the present embodiment, the inner peripheral shape of the cover housing portion **90** is a substantially regular hexagonal shape when the flange housing grooves **100** are ignored. The size of the cover housing portion **90** is larger than the size of the thermally expanded cover member **72**. This prevents the thermally expanded cover member **72** from becoming larger than the cover housing portion **90**. Further, at low temperature, a gap **98** is formed between the outer wall of the cover member **72** and the inner wall of the cover housing portion **90**.

[0050] When the casting mold **40** is closed after the cover member **72** is mounted in the cover housing portion **90**, the side wall flanges **82** and the bottom flange **84** are housed in the flange housing grooves **100**. It is preferable that the side wall flanges **82** abut against a bottom surface **100***a* of the flange housing groove **100** of the fixed mold **42** and a bottom surface **100***a* of the flange housing groove **100** of the movable mold **44**.

[8. Gap **98** between Cover Member **72** and Cover Housing Portion **90**]

[0051] A width d**1** of the gap **98** will be described with reference to FIGS. **5** to **7**. When the gap **98** is formed, an air layer is formed around the cover member **72**. That is, the gap **98** has a heat insulating function. However, if the width d**1** of the gap **98** is too large, the molten metal may enter the gap **98**. In the worst case, the molten metal enters the abutment portions (the first abutment portion **92**, the second abutment portion **94**, and the third abutment portion **96**). In this case, the following problems occur.

[0052] When the molten metal is cooled and solidified, the metal product formed in the cavity **64**, the residual metal remaining in the passageway **62**, and the cover member **72** are integrated. Therefore, when the metal product is released from the mold, the residual metal and the cover member **72** are taken out from the mold together with the metal product. When the molten metal enters the abutment portions, burrs are generated around the cover member **72**. This makes it difficult to release the metal product from the mold. If the metal product is pushed by a pushing pin or the like in order to release the metal product from the mold, the metal product may be damaged or deformed. In order to prevent such a problem, the gap **98** is required to have a function of preventing the entry of the molten metal.

[0053] Therefore, the present inventors studied an appropriate width d**1** of the gap **98**. In the study, the inventors measured the amount of molten metal leaking from the upper end of the cover member **72** to the gap **98**. Specifically, the inventors measured the molten metal leakage length extending downward (in the −Z direction) from the

upper end of the cover member **72**. Further, the inventors set the threshold value of the allowable molten metal leakage length to 60 [mm]. FIG. **6** shows the measurement results. Concerning the width d**1** shown in FIG. **6**, the third decimal place is rounded off.

[0054] As shown in FIG. **6**, when the width d**1** of the gap **98** at low temperature is 0.54 [mm] or less, the molten metal leakage length becomes smaller than the threshold value. When the width d**1** of the gap **98** at low temperature is 0.55 [mm] or more, the molten metal leakage length becomes larger than the threshold value. From this measurement result, it is understood that, when the width d**1** of the gap **98** at low temperature is 0.54 [mm] or less, it is acceptable even if the molten metal enters the gap **98**. Further, when the width d**1** of the gap **98** at low temperature is larger than 0 [mm], an air layer is formed around the cover member **72**. Therefore, a heat insulating effect can be expected. However, even if the width d**1** is 0 [mm], since the cover member **72** is formed of a material having low thermal conductivity as described above, heat insulating effect can be expected to a certain degree. From the above study, the inventors have reached the following conclusion. By setting the width d**1** of the gap **98** at low temperature to 0 [mm] or more and 0.54 [mm] or less, both the heat insulating function and the function of preventing the entry of the molten metal can be achieved. The inventors have confirmed that this numerical range is applicable to a plurality of casting molds **40** having different structures and sizes.

[0055] As shown in FIG. **7**, there is a possibility that the cover member **72** is displaced in the Y direction in the cover housing portion **90**. In the present embodiment, the outer peripheral shape of the cover member **72** and the inner peripheral shape of the cover housing portion **90** are substantially regular hexagonal shapes. In this case, in order to set the width d**1** of the gap **98** to 0.54 [mm] or less over the entire range, it is necessary to consider the deviation in the Y direction. As shown in FIG. **7**, it is preferable to design the sizes of the cover member **72** and the cover housing portion **90** so that the width d**1** of the gap **98** which becomes widest in a state where the cover member **72** is maximally displaced in the −Y direction (or the +Y direction) is 0.54 [mm] or less.

[9. Flange Gap **102**]

[0056] As shown in FIG. **8**, a gap **102** is formed between the first end of the steel plate and the second end of the steel plate at the distal end of the bottom flange **84**. If a width d**2** of the gap **102** is too large, there is a possibility that the leakage of the molten metal from the bottom flange **84** exceeds an allowable level. Therefore, the gap **102** also has an appropriate width d**2**.

[0057] In order to determine an appropriate width d**2** of the gap **102**, the inventors confirmed the condition of the molten metal leakage for each width d**2** of the gap **102**. As a result, the inventors reached the following conclusion. When the width d**2** of the gap **102** at low temperature is 0.3 [mm] or less, the leakage of the molten metal from the bottom flange **84** can be prevented. This conclusion also applies to the sidewall flange **82**.

[10. Magnet **104** for Attracting Cover Member **72**]

[0058] As shown in FIG. **9**, a heat-resistant magnet **104** is embedded in the cover housing portion **90** of one of the fixed mold **42** and the movable mold **44**. The magnet **104** attracts the cover member **72**. In the present embodiment, the magnet **104** is embedded in each of the fourth mold **56** of the fixed mold **42** and the fifth mold **58** of the fixed mold **42**. The magnet **104** of the fourth mold **56** and the magnet **104** of the fifth mold **58** are provided at symmetrical positions with respect to the XZ plane passing through the axis A. In a case where the fixed mold **42** is not divided into the fourth mold **56** and the fifth mold **58** but is integrally formed, one magnet **104** may be provided.

[11. Hand **24** of Robot **12**]

[0059] The hand **24** provided in the robot **12** (FIG. **1**) will be described with reference to FIGS. **10** to **13**. In the following description, directions such as an L direction, an M direction, and an N direction are used. The L direction and the M direction are orthogonal to each other. The N direction is orthogonal to the L direction and the M direction. The forward direction of each direction is defined as +, and the reverse direction thereof is defined as −.

[0060] The hand **24** can grip the cover member **72** at a predetermined position of the equipment. The hand **24** includes a hand body **110**, a pair of movable portions **112**, an upper holding portion **114**, and a lower holding portion **116**.

[0061] The hand body **110** is attached to the distal end portion of the arm **22** (FIG. **1**). The hand body **110** supports the pair of movable portions **112**, the upper holding portion **114**, and the lower holding portion **116**. The pair of movable portions **112**, the upper holding portion **114**, and the lower holding portion **116** project from the hand body **110** in the +L direction. The upper holding portion **114** is positioned on the downstream side of the pair of movable portions **112** in the +M direction. The lower holding portion **116** is positioned on the downstream side of the pair of movable portions **112** in the −M direction.

[0062] As shown in FIG. **11**, the first movable portion **112** is arranged on the downstream side of the second movable portion **112** in the +N direction. A holding claw **118** is formed at the tip of each movable portion **112** in the +L direction. The first movable portion **112** and the second movable portion **112** can approach each other. Arrows P shown in FIG. **11** indicate directions in which the first movable portion **112** and the second movable portion **112** approach each other. The first movable portion **112** and the second movable portion **112** can move away from each other. Arrows Q shown in FIG. **11** indicate directions in which the first movable portion **112** and the second movable portion **112** move away from each other. The holding claw **118** of the first movable portion **112** and the holding claw **118** of the second movable portion **112** protrude toward each other. The pair of movable portions **112** can move in the ±N directions according to the operation of a motor or the like. The pair of movable portions **112** operate in directions (arrows P) approaching each other. Further, the pair of movable portions **112** grip the cover member **72** by inserting the holding claws **118** into the lateral holes **80** of the cover member **72**. Further, the pair of movable portions **112** operate in directions (arrows Q) away from each other. Further, the pair of movable portions **112** release the cover member **72** by pulling out the holding claws **118** from the lateral holes **80** of the cover member **72**.

[0063] When the cover member **72** is attached to the cover housing portion **90**, the cover member **72** is moved in the −X direction to approach the cover housing portion **90**. At this time, each of the holding claws **118** inserted into the lateral

holes **80** is positioned in front of the passageway **62**. Therefore, even if the cover member **72** is brought close to the cover housing portion **90**, there is a low possibility that each of the holding claws **118** comes into contact with the separation surface **46**. Thus, according to the present embodiment, the cover member **72** can be brought further closer to the inner wall of the cover housing portion **90**. Further, according to the present embodiment, there is a low possibility that the holding claw **118** comes into contact with the separation surface **46** after the cover member **72** is attached to the cover housing portion **90**.

[0064] As shown in FIG. **12**, an upper abutment portion **120** is formed at the tip of the upper holding portion **114** in the +L direction. The upper abutment portion **120** abuts against the body portion **74** of the cover member **72**. With this structure, when the pair of movable portions **112** grip the cover member **72**, the cover member **72** is prevented from wobbling.

[0065] As shown in FIG. **13**, a lower abutment portion **122** is formed at the tip of the lower holding portion **116** in the +L direction. In the LN plane, the shape of the lower abutment portion **122** coincides with a part of the outer peripheral shape of the bottom portion **76** of the cover member **72**. Similarly to the bottom portion **76** of the cover member **72**, the diameter of the lower abutment portion **122** decreases from the upper side (+M direction) toward the lower side (−M direction). The lower abutment portion **122** abuts against the bottom portion **76** of the cover member **72**. The lower abutment portion **122** prevents the cover member **72** from wobbling when the pair of movable portions **112** grip the cover member **72**. Further, the lower abutment portion **122** prevents the cover member **72** from displacing downward when the pair of movable portions **112** grip the cover member **72**.

[12. Operation of Mounting Cover Member **72** in Cover Housing Portion **90**]

[0066] A series of operation procedures in which the robot **12** mounts the cover member **72** in the cover housing portion **90** of the fixed mold **42** will be described with reference to FIG. **14**. The controller **14** controls the operation of the robot **12** to perform the following series of operations.

[0067] In step S**1**, the robot **12** moves the hand **24** to a predetermined position in which the cover member **72** is supplied, and grips the cover member **72** with the hand **24**. At this time, the robot **12** operates the pair of movable portions **112** in the directions as indicated by the arrows P in FIG. **11** to insert the holding claws **118** into the lateral holes **80** of the cover member **72**.

[0068] In step S**2**, the robot **12** conveys the cover member **72** to a position facing the fixed mold **42** while gripping the cover member **72** with the hand **24**. The separation surface **46** of the fixed mold **42** is parallel to the up-down direction (Z direction). The robot **12** brings the cover member **72** close to the cover housing portion **90**. At this time, the robot **12** directs the upper hole **78** of the cover member **72** upward (in the +Z direction). Further, the robot **12** makes the axis A of the cover member **72** parallel to the up-down direction (Z direction).

[0069] In step S**3**, the robot **12** positions the cover member **72** with respect to the cover housing portion **90**. At this time, the robot **12** secures a predetermined clearance between the cover member **72** and the cover housing portion **90**. The robot **12** may perform positioning based on a detection value of a sensor that detects a distance between the cover member **72** and the cover housing portion **90**. Further, the robot **12** may perform positioning using a camera.

[0070] In step S**4**, the robot **12** releases the cover member **72** and causes the cover member **72** to be attracted to the cover housing portion **90** by the magnetic force of the magnets **104**. At this time, the robot **12** operates the pair of movable portions **112** in the directions as indicated by the arrows Q in FIG. **11** to pull out the holding claws **118** from the lateral holes **80** of the cover member **72**. Since the predetermined clearance is secured between the cover member **72** and the cover housing portion **90**, the cover member **72** is attracted to the cover housing portion **90** without falling.

[0071] The robot **12** mounts the filters **70** in the fixed mold **42** before or after mounting the cover member **72** in the cover housing portion **90**. After the robot **12** mounts the cover member **72** and the filters **70**, the casting machine **16** closes the casting mold **40**.

[13. Other Embodiments]

[0072] The outer peripheral shape of the cover member **72** may be a polygonal shape other than the substantially regular hexagonal shape. For example, as shown in FIGS. **15**A to **15**C, the outer peripheral shape of the cover member **72** may be circular. In the cover member **72** shown in FIGS. **15**A to **15**C, the same components as those of the cover member **72** shown in

[0073] FIGS. **3**A to **3**C are denoted by the same reference numerals. The cover member **72** having a circular outer peripheral shape has a side wall flange **82** projecting in the −Y direction and corresponding to the abutment part. The bottom portion **76** is formed by drawing.

[0074] In the above embodiment, the inner peripheral shape of the cover housing portion **90** is similar to the outer peripheral shape of the cover member **72**. Alternatively, the inner peripheral shape of the cover housing portion **90** and the outer peripheral shape of the cover member **72** may not be similar to each other. For example, as shown in FIG. **16**, the outer peripheral shape of the cover member **72** may be a substantially regular hexagonal shape, and the inner peripheral shape of the cover housing portion **90** may be a hexagonal shape elongated in the X direction. In the embodiment shown in FIG. **16**, a diameter w**1** of the cover housing portion **90** is longer than a diameter w**2** and a diameter w**3** thereof.

[0075] Further, the outer peripheral shape of the cover member **72** may be another polygonal shape, and the inner peripheral shape of the cover housing portion **90** may be a polygonal shape elongated in the X direction.

[0076] Further, as shown in FIG. **17**, the outer peripheral shape of the cover member **72** may be substantially circular, and the inner peripheral shape of the cover housing portion **90** may be an oval (including an ellipse). A minor axis b of the ellipse may be orthogonal to the separation surface **46** (mold mating surface). A major axis a of the ellipse may be parallel to the separation surface **46** (mold mating surface). For example, a gap **130** is formed between the inner wall of the cover housing portion **90** and the outer wall of the cover member **72**. The maximum value of a width d**1** of the gap **130** is preferably 0 [mm] or more and 0.54 [mm] or less.

[0077] In the embodiment described above, the cover member **72** is mounted in the first bent portion **66**. Not only the first bent portion **66** but also the second bent portion **68**

may be mounted with the cover member **72** having a shape corresponding to the shape of the second bent portion **68**.

[0078] In the above-described embodiment, the passageway **62** branches in the +Y direction and the −Y direction at the first bent portion **66**. Alternatively, the passageway **62** may be bent only in one direction without branching.

[0079] In the above embodiment, the side wall flange **82** is formed by joining both ends of the steel plate. Alternatively, the side wall flange **82** may be formed by bringing both ends of the steel plate into close contact with each other. For example, both ends of the steel plate may be sandwiched between the bottom surface **100***a* of the flange housing groove **100** of the fixed mold **42** and the bottom surface **100***a* of the flange housing groove **100** of the movable mold **44** to be in close contact with each other.

[0080] In the above embodiment, the cover member **72** is formed of one steel plate. Alternatively, the cover member **72** may be formed of two steel plates. For example, a steel plate recessed in the +X direction and a steel plate recessed in the −X direction may be joined together.

[14. Technical Idea Obtained from Embodiment]

[0081] Technical ideas that can be grasped from the above embodiments will be described below.

[0082] An aspect of the present invention is the casting mold **40** comprising the cavity **64** for molding a product, and the pouring basin **60** and the passageway **62** that guide molten metal into the cavity **64**, wherein the passageway **62** includes, at a portion thereof positioned below the pouring basin **60** and the cavity **64**, the bent portion (the first bent portion **66**, the second bent portion **68**) that changes the advancing direction of the molten metal, and the casting mold further comprises the cover member **72**, which covers the inner wall of the bent portion, allows the passageway **62** positioned on the upstream side of the bent portion to communicate with the passageway **62** positioned on the downstream side of the bent portion, and has a lower thermal conductivity than the base material of the mold.

[0083] In the above-described configuration, the cover member **72** is provided inside the bent portion (the first bent portion **66** and the second bent portion **68**) of the passageway **62** where the molten metal tends to stagnate. The thermal conductivity of the cover member **72** is lower than the thermal conductivity of the casting mold **40**. According to the above configuration, the cover member **72** suppresses temperature rise and expansion of the bent portion. Therefore, the cover member **72** can suppress the occurrence of cracks in the bent portion. Further, the cover member **72** can suppress the extension of the cracks. As a result, the number of maintenance operations due to adhesion of metal is reduced. Further, the life of the casting mold **40** is extended. Furthermore, according to the above configuration, the protective member covering the entire passageway **62** is not provided in the passageway **62**, but the cover member **72** is provided only in the bent portion. Therefore, the cost for protecting the mold is reduced. In addition, the cover member **72** can be easily replaced.

[0084] In the above-described aspect, the passageway **62** may extend downward from the pouring basin **60** and be bent in the lateral direction at the bent portion (the first bent portion **66**), and the cover member **72** may have a bottomed cylindrical shape having an axis A extending in the up-down direction, include the upper hole **78** provided at an upper end thereof and opening upward, and include the lateral hole **80** provided on a side wall thereof and opening in the lateral direction.

[0085] In the above configuration, the cover member **72** is provided in the first bent portion **66** located below the pouring basin **60**. The first bent portion **66** is a portion where the molten metal poured from the pouring basin **60** first stagnates. According to the above configuration, the cover member **72** is provided in the first bent portion **66** where cracks are most likely to occur. Therefore, the casting mold **40** is hardly damaged. As a result, the number of maintenance operations of the casting mold **40** is reduced. Further, the life of the casting mold **40** is extended.

[0086] In the above-described aspect, the passageway **62** may be formed with the cover housing portion **90** that houses the cover member **72** from the bent portion (the first bent portion **66**, the second bent portion **68**) over a predetermined range on the upstream side of the bent portion, the inner diameter of the cover housing portion **90** may be larger than the inner diameter of the passageway **62** positioned on the upstream side of the predetermined range, and the inner diameter of the cover member **72** may be equal to or larger than the inner diameter of the passageway **62** positioned on the upstream side of the predetermined range.

[0087] In the above configuration, the inner diameter of the cover housing portion **90** is larger than the inner diameter of the passageway **62** positioned on the upstream side of the predetermined range. This makes positioning of the cover member **72** easy when mounting the cover member **72** in the mold (the fixed mold **42** or the movable mold **44**). In the above configuration, the inner diameter of the cover member **72** is equal to or larger than the inner diameter of the passageway **62** positioned on the upstream side of the predetermined range. Therefore, the cover member **72** does not hinder the flow of the molten metal.

[0088] In the above aspect, the casting mold may further include a mold main body (first mold **50**) and a plurality of partial molds (second mold **52** to fifth mold **58**) attached to the mold main body, the passageway **62** may be formed by arranging the plurality of partial molds along the direction of the flow of the molten metal, and the cover housing portion **90** may be formed across the plurality of partial molds (third mold **54** to fifth mold **58**).

[0089] In the above configuration, the cover housing portion **90** is formed across the plurality of partial molds (the third mold **54** to the fifth mold **58**). According to the above configuration, the cover member **72** covers the abutment portions (the first abutment portion **92** to the third abutment portion **96**) between the partial molds included in the cover housing portion **90**. Therefore, the cover member **72** prevents the molten metal from entering the abutment portion. When the molten metal enters the abutment portion between the partial molds, it is difficult to separate the partial molds from each other. Further, burrs are generated. By suppressing the entry of the molten metal into the abutment portion, the partial molds can be easily separated from each other. In addition, the number of deburring steps is reduced.

[0090] In the above aspect, the passageway **62** may extend downward from the pouring basin **60** to the first bent portion **66**, be bent in the lateral direction at the first bent portion **66**, extend in the lateral direction from the first bent portion **66** to the second bent portion **68**, be bent upward at the second bent portion **68**, and extend upward from the second bent

portion **68** to the cavity **64**, and the cover member **72** may be provided on at least one of the first bent portion **66** and the second bent portion **68**.

[0091] The casting mold according to the present invention is not limited to the above-described embodiments, and various configurations can be adopted without departing from the gist of the present invention.

What is claimed is:

1. A casting mold comprising a cavity configured to mold a product, and a pouring basin and a passageway that are configured to guide molten metal into the cavity, wherein

the passageway includes, at a portion thereof positioned below the pouring basin and the cavity, at least one bent portion configured to change an advancing direction of the molten metal, and

the casting mold further comprises a cover member configured to cover an inner wall of the bent portion and allow the passageway positioned on an upstream side of the bent portion to communicate with the passageway positioned on a downstream side of the bent portion, the cover member having a lower thermal conductivity than a base material of the mold.

2. The casting mold according to claim **1**, wherein

the passageway extends downward from the pouring basin and is bent in a lateral direction at the bent portion, and

the cover member has a bottomed cylindrical shape having an axis extending in an up-down direction, includes an upper hole provided at an upper end thereof and opening upward, and includes a lateral hole provided on a side wall thereof and opening in the lateral direction.

3. The casting mold according to claim **1**, wherein

the passageway includes a cover housing portion configured to house the cover member from the bent portion over a predetermined range on the upstream side of the bent portion,

an inner diameter of the cover housing portion is larger than an inner diameter of the passageway positioned on an upstream side of the predetermined range, and

an inner diameter of the cover member is equal to or larger than the inner diameter of the passageway positioned on the upstream side of the predetermined range.

4. The casting mold according to claim **3**, further comprising:

a mold main body; and

a plurality of partial molds attached to the mold main body, wherein

the passageway is formed by arranging the plurality of partial molds along a direction of flow of the molten metal, and

the cover housing portion is formed across a part of the plurality of partial molds or all of the plurality of partial molds.

5. The casting mold according to claim **1**, wherein

the at least one bent portion includes a first bent portion and a second bent portion,

the passageway extends downward from the pouring basin to the first bent portion, is bent in a lateral direction at the first bent portion, extends in the lateral direction from the first bent portion to the second bent portion, is bent upward at the second bent portion, and extends upward from the second bent portion to the cavity, and

the cover member is provided in at least one of the first bent portion and the second bent portion.

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