US 20160101460A1

(19) United States
(12) Patent Application Publication
SUZUKI
(10) Pub. No.: US 2016/0101460 A1
(43) Pub. Date: Apr. 14, 2016

(54) CASTING APPARATUS WHOSE COOLING FLOW PASSAGE IS FORMED BY WELDING AND METHOD FOR MANUFACTURING THE SAME

(71) Applicant: **Suzukiseiki Corporation**, Aichi-ken (JP)

(72) Inventor: **Kikuo SUZUKI**, Aichi-ken (JP)

(21) Appl. No.: **14/854,438**

(22) Filed: **Sep. 15, 2015**

(30) **Foreign Application Priority Data**

Oct. 14, 2014 (JP) 2014-210324

Publication Classification

(51) **Int. Cl.**
B22C 9/00 (2006.01)
B22D 30/00 (2006.01)

(52) **U.S. Cl.**
CPC .. *B22C 9/00* (2013.01); *B22D 30/00* (2013.01)

(57) **ABSTRACT**

A casting apparatus for manufacturing a cast product from molten metal includes a molten metal and a cooling portion. The molten metal contacts a surface for contact with the molten metal. The cooling portion forms a cooling flow passage. The cooling flow passage is configured to cool the molten metal contacting surface. At least a part of an inner surface of the cooling flow passage is constituted of a welding portion formed by welding, the welding portion sealing the cooling flow passage. The welding portion is constituted such that an exposure to the molten metal becomes equal to or less than a predetermined ratio with respect to an area of the welding portion constituting the inner surface of the cooling flow passage.

FIRST EMBODIMENT

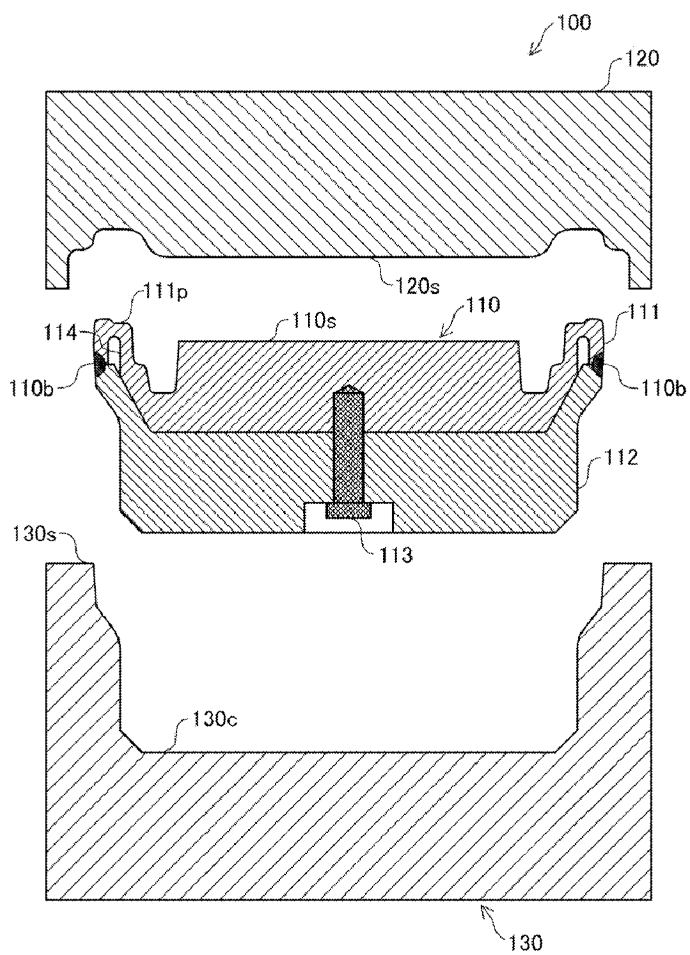


Fig. 1

FIRST EMBODIMENT

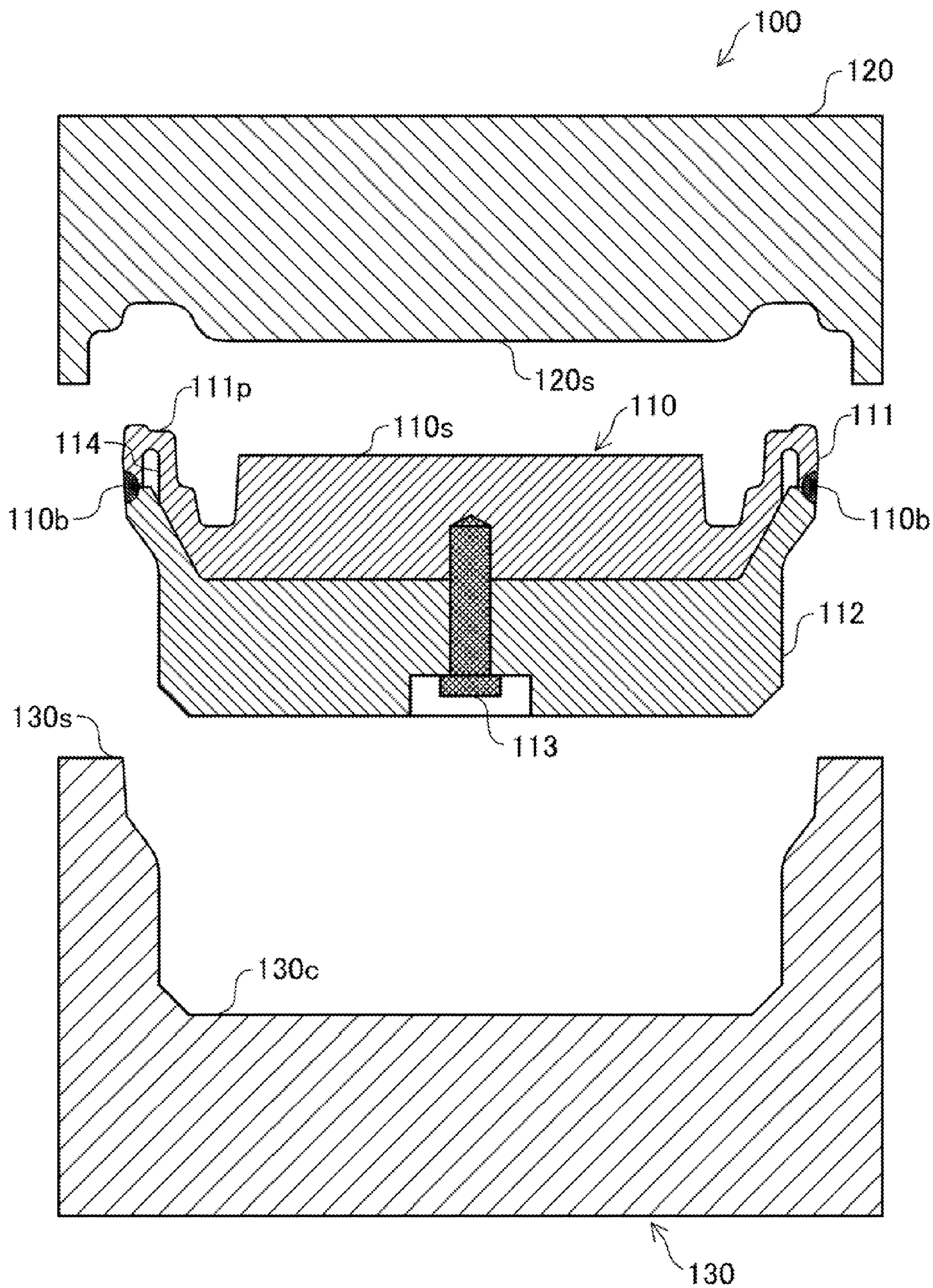


Fig. 2

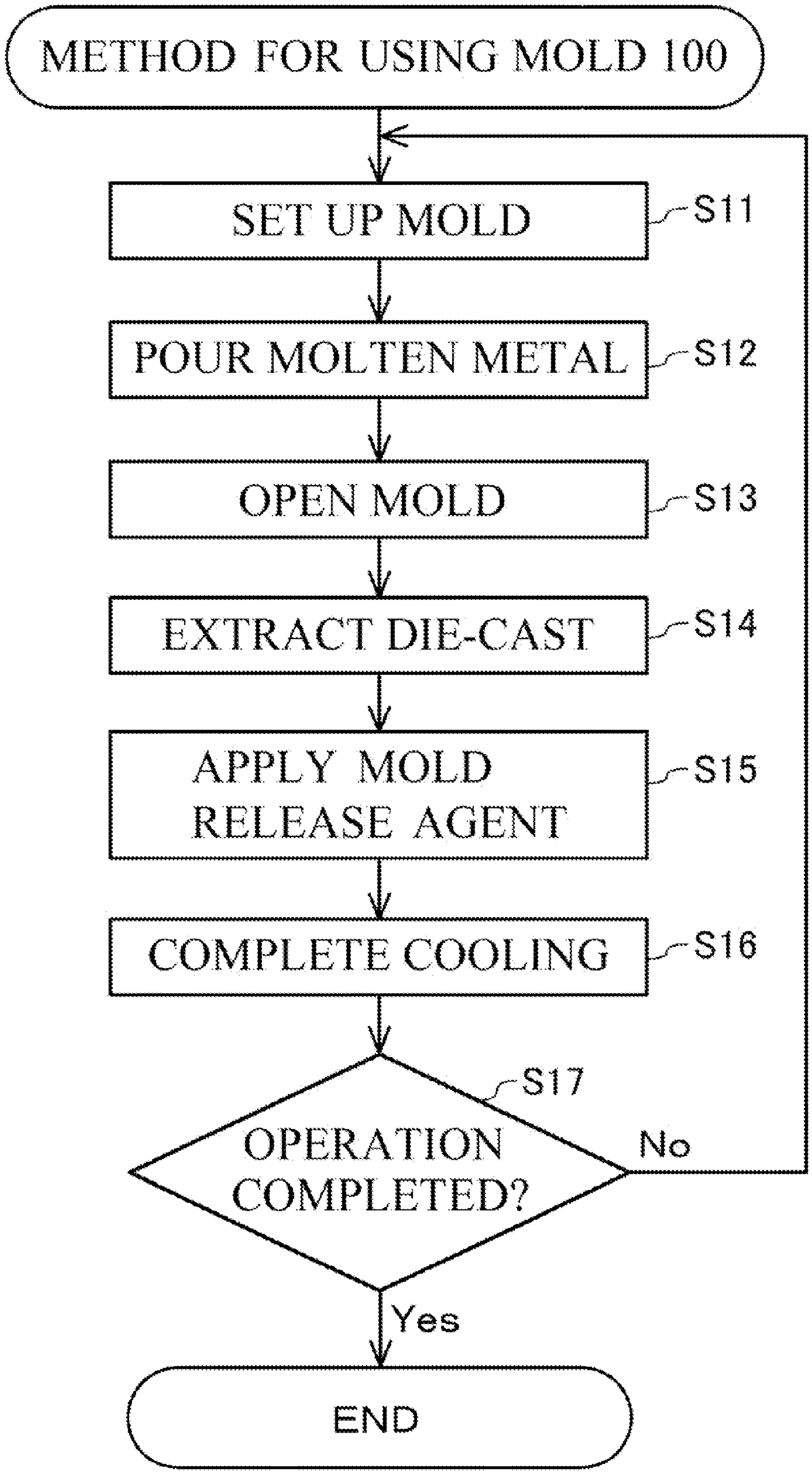

METHOD FOR USING MOLD 100
SET UP MOLD
S11
POUR MOLTEN METAL
S12
OPEN MOLD
S13
EXTRACT DIE-CAST
S14
APPLY MOLD RELEASE AGENT
S15
COMPLETE COOLING
S16
S17
OPERATION COMPLETED?
No
Yes
END

Fig. 3A

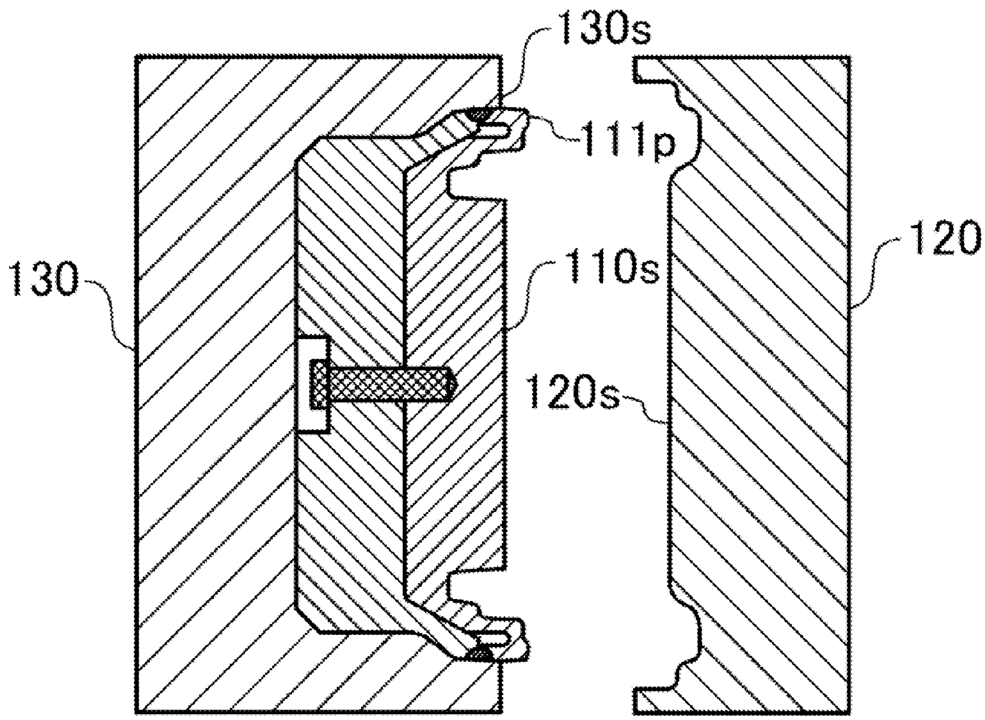
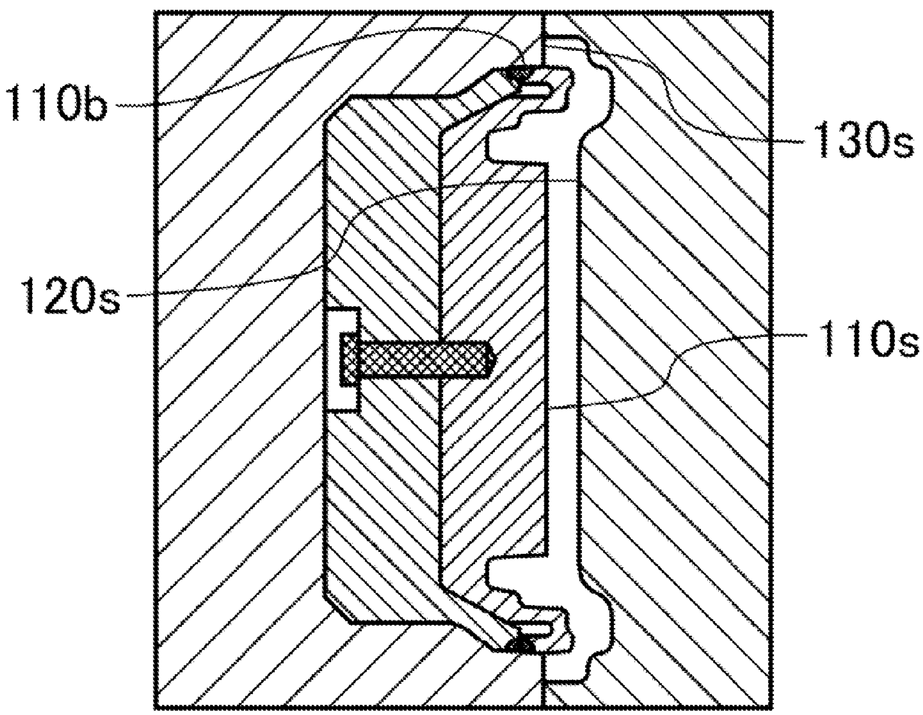


Fig. 3B



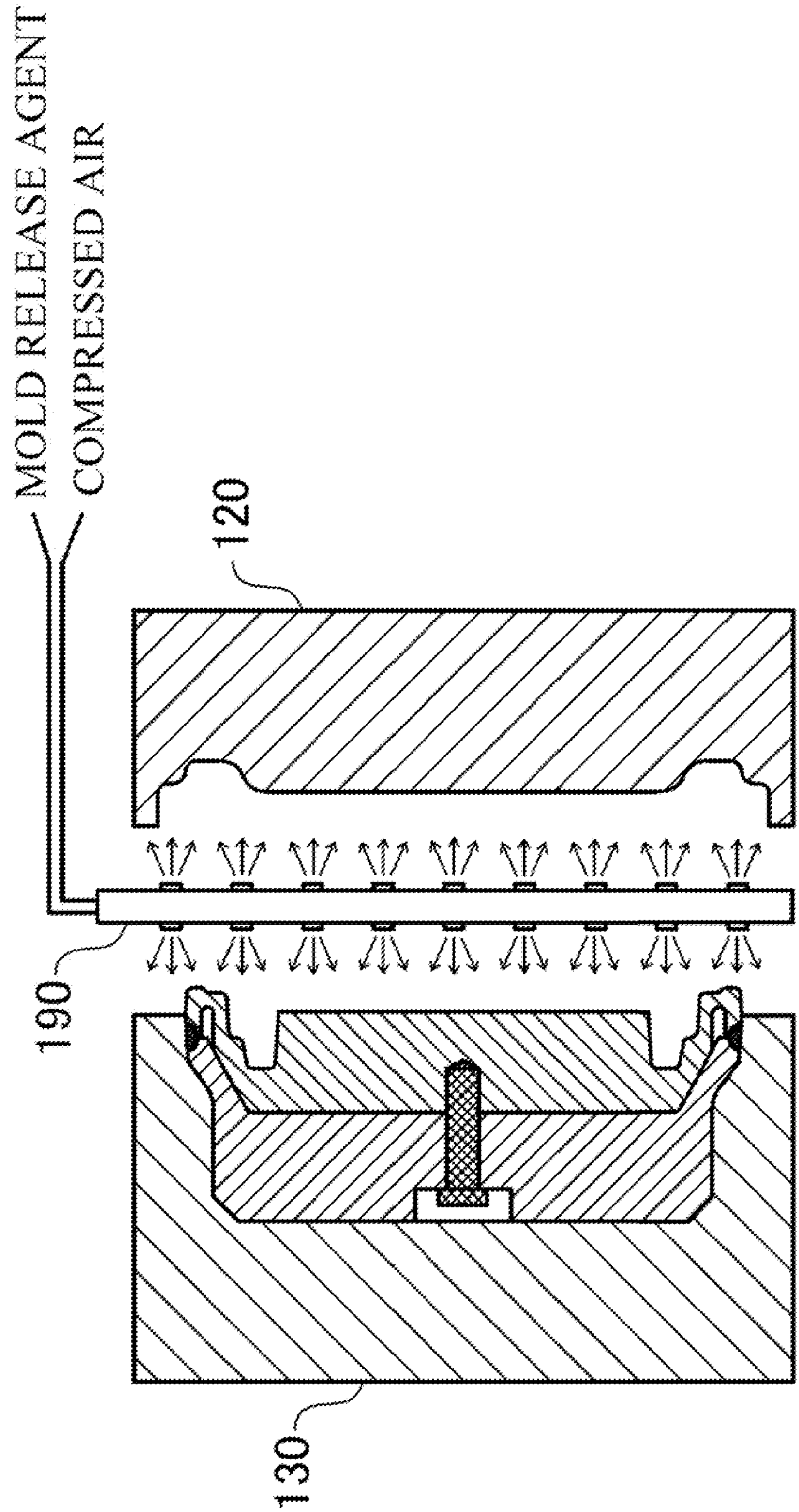


Fig. 3C

Fig. 4

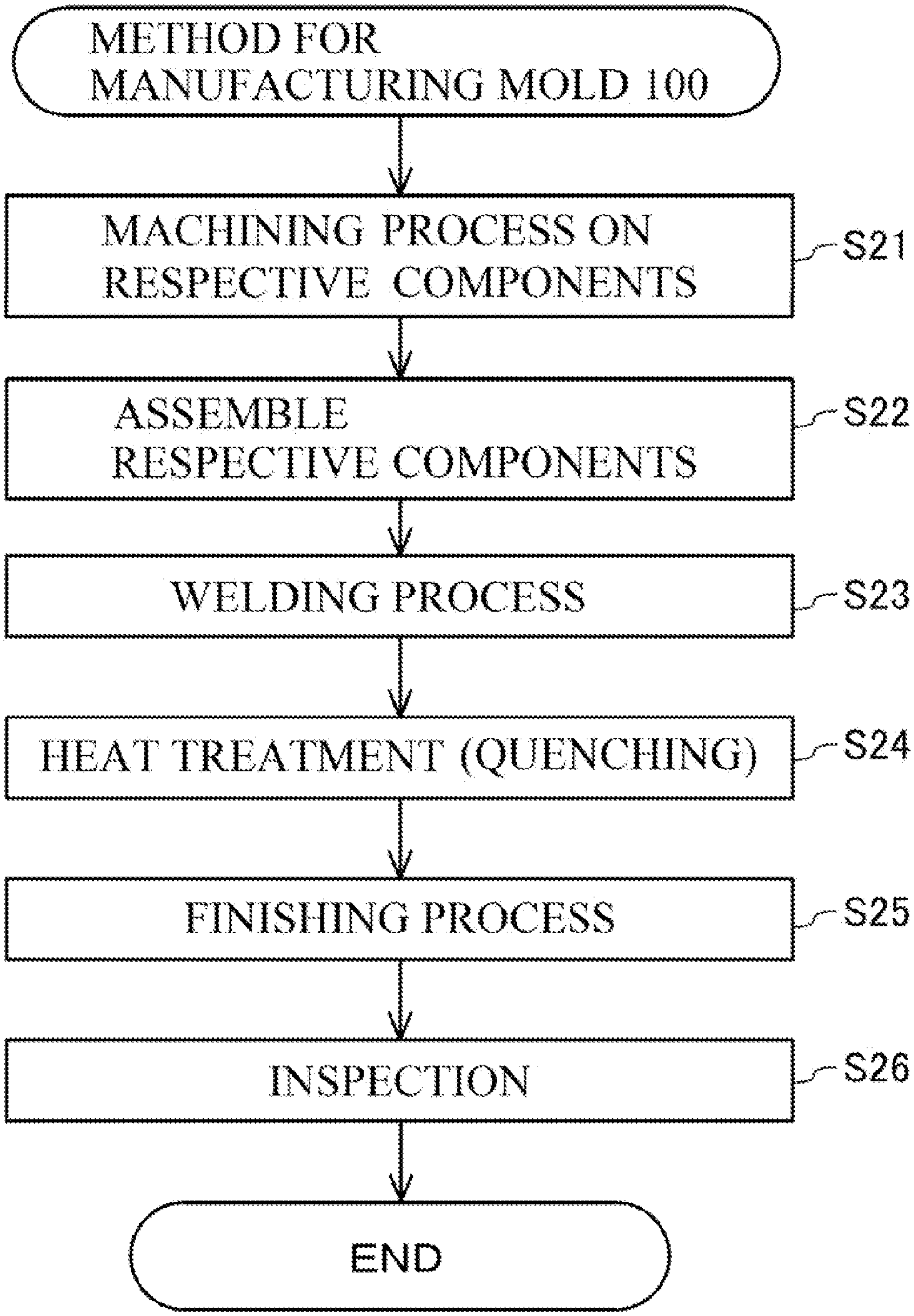
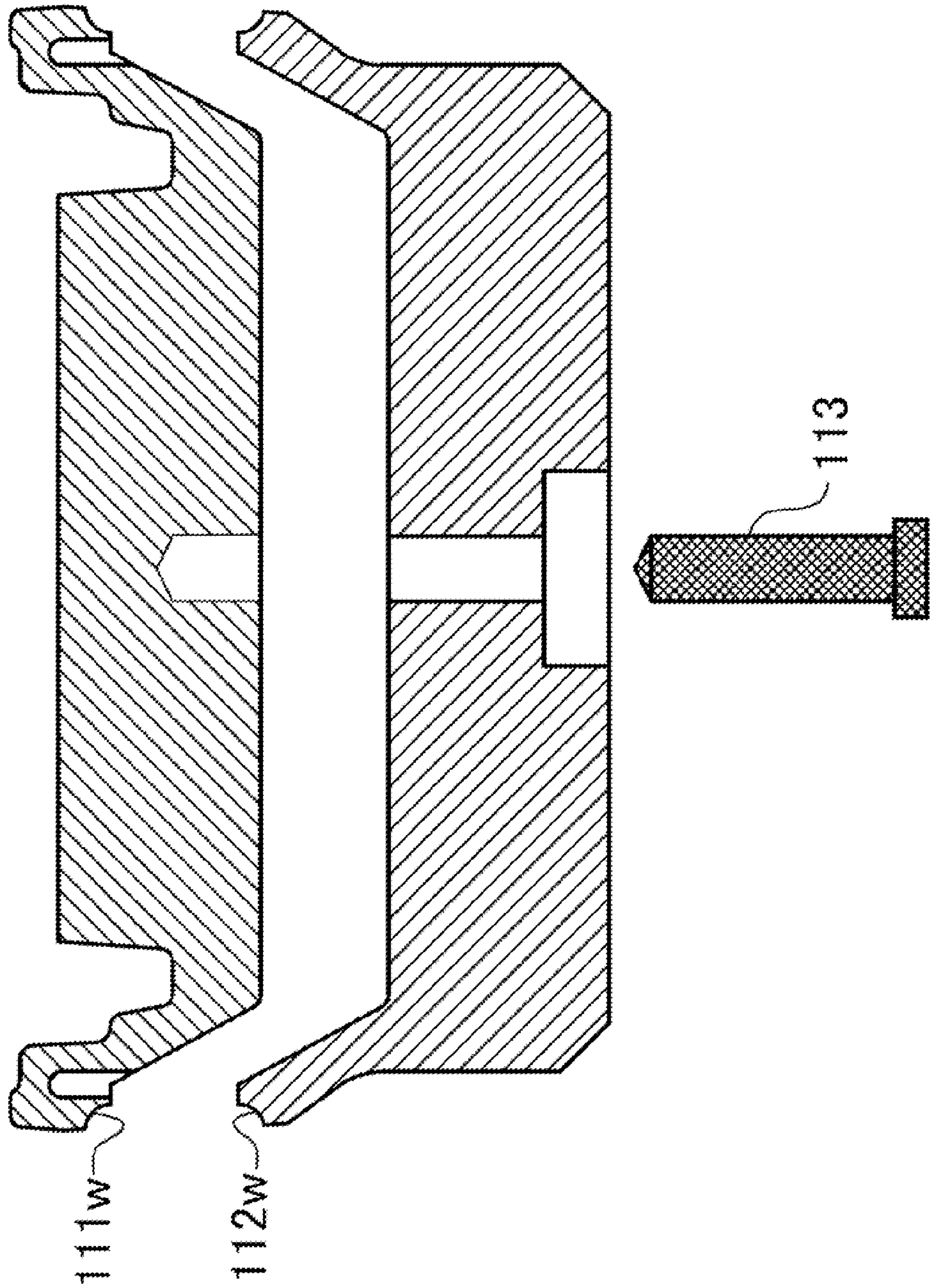

METHOD FOR MANUFACTURING MOLD 100
MACHINING PROCESS ON RESPECTIVE COMPONENTS
S21
ASSEMBLE RESPECTIVE COMPONENTS
S22
WELDING PROCESS
S23
HEAT TREATMENT (QUENCHING)
S24
FINISHING PROCESS
S25
INSPECTION
S26
END

Fig. 5A



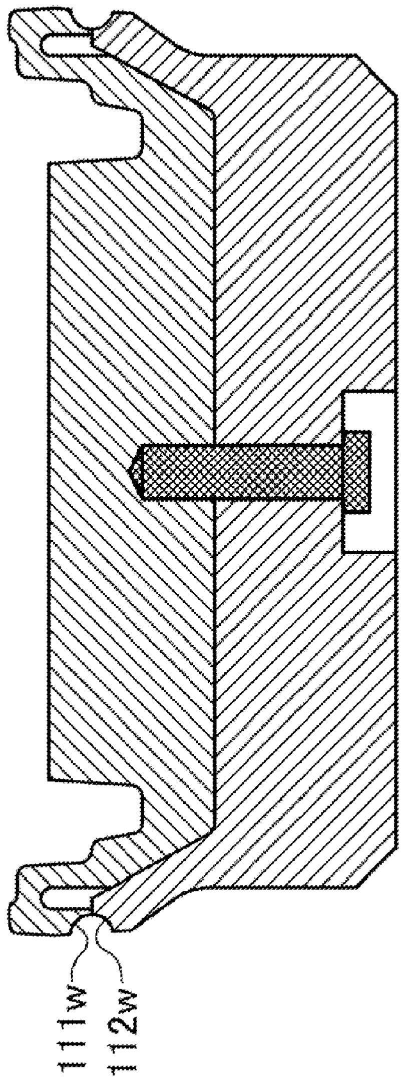


Fig. 5B

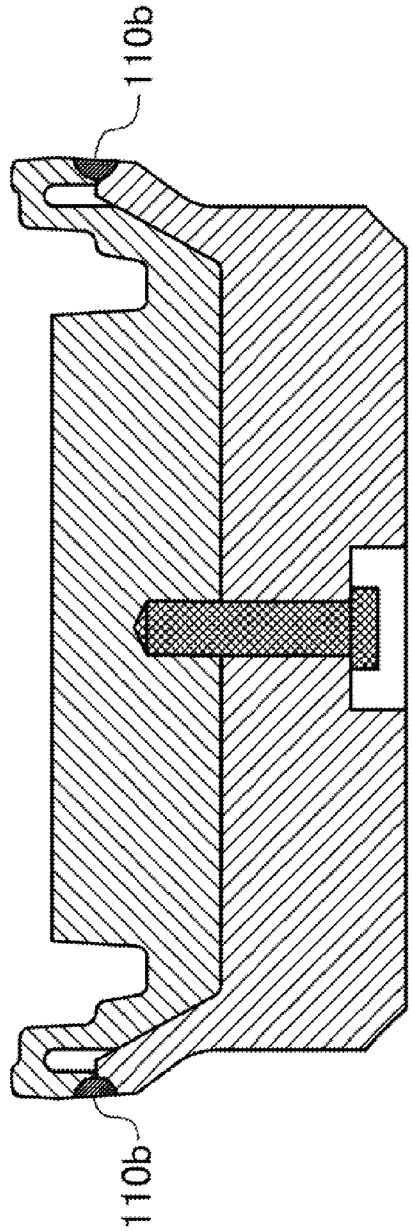


Fig. 5C

Fig. 6

SECOND EMBODIMENT

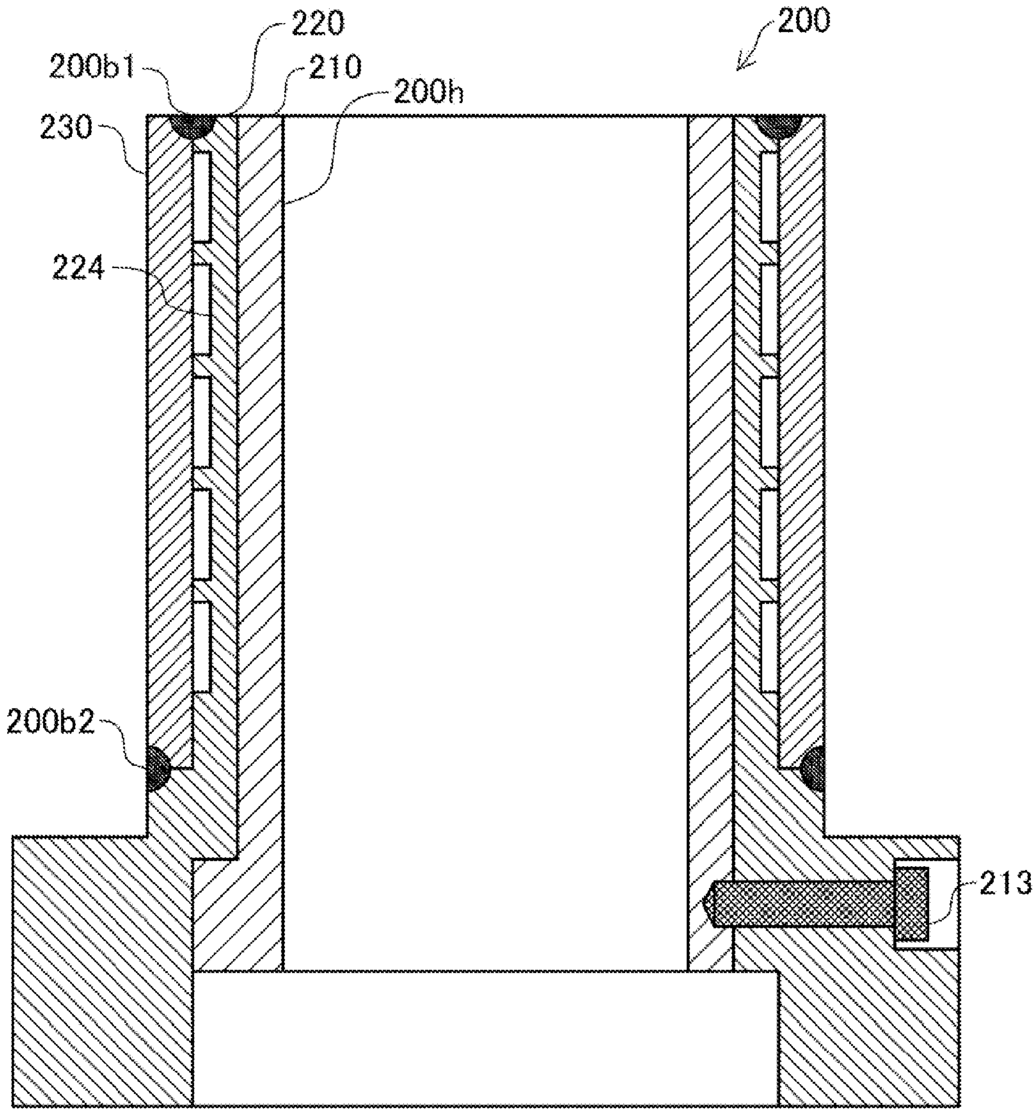


Fig. 7

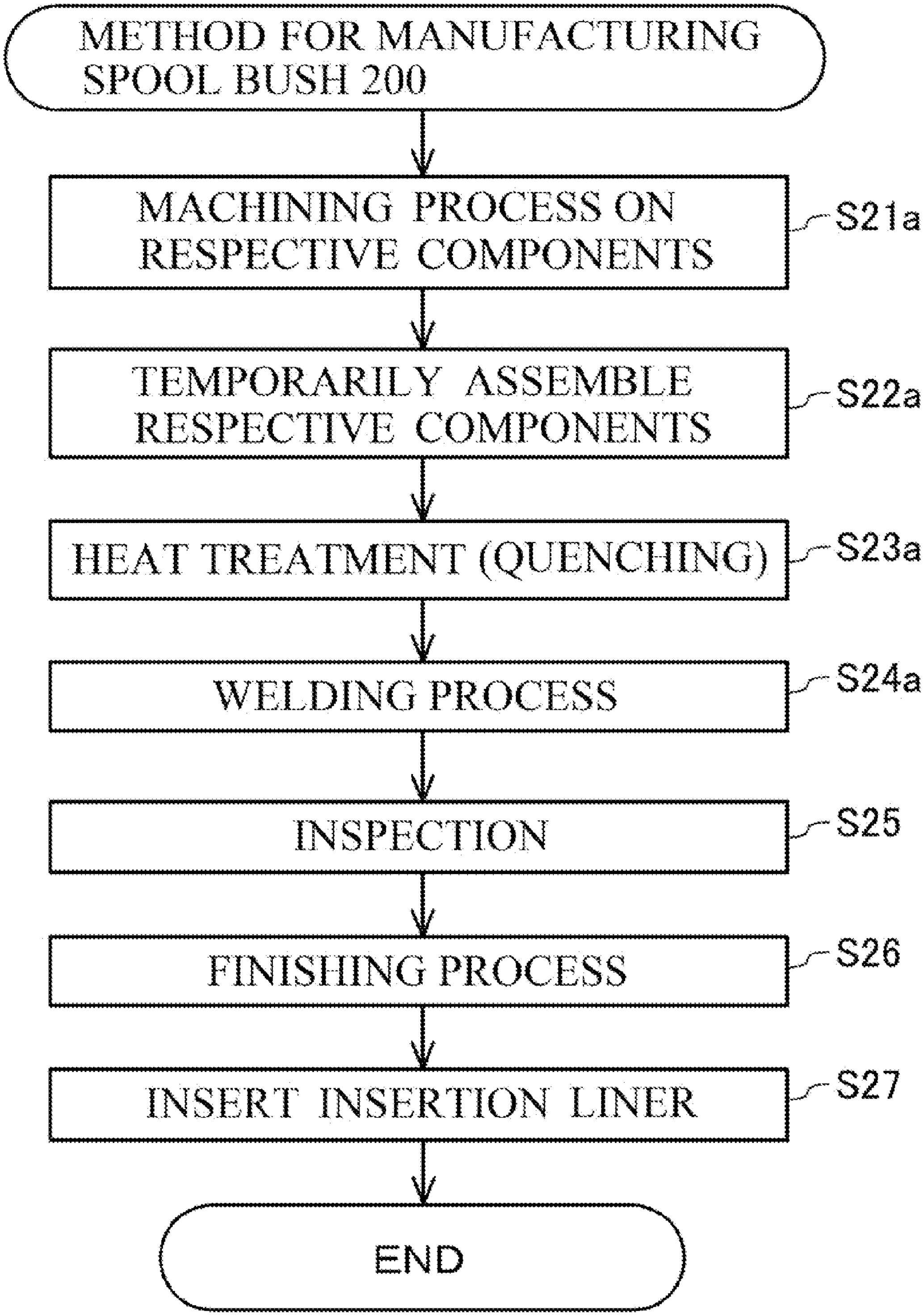

METHOD FOR MANUFACTURING SPOOL BUSH 200
MACHINING PROCESS ON RESPECTIVE COMPONENTS
S21a
TEMPORARILY ASSEMBLE RESPECTIVE COMPONENTS
S22a
HEAT TREATMENT (QUENCHING)
S23a
WELDING PROCESS
S24a
INSPECTION
S25
FINISHING PROCESS
S26
INSERT INSERTION LINER
S27
END

Fig. 8

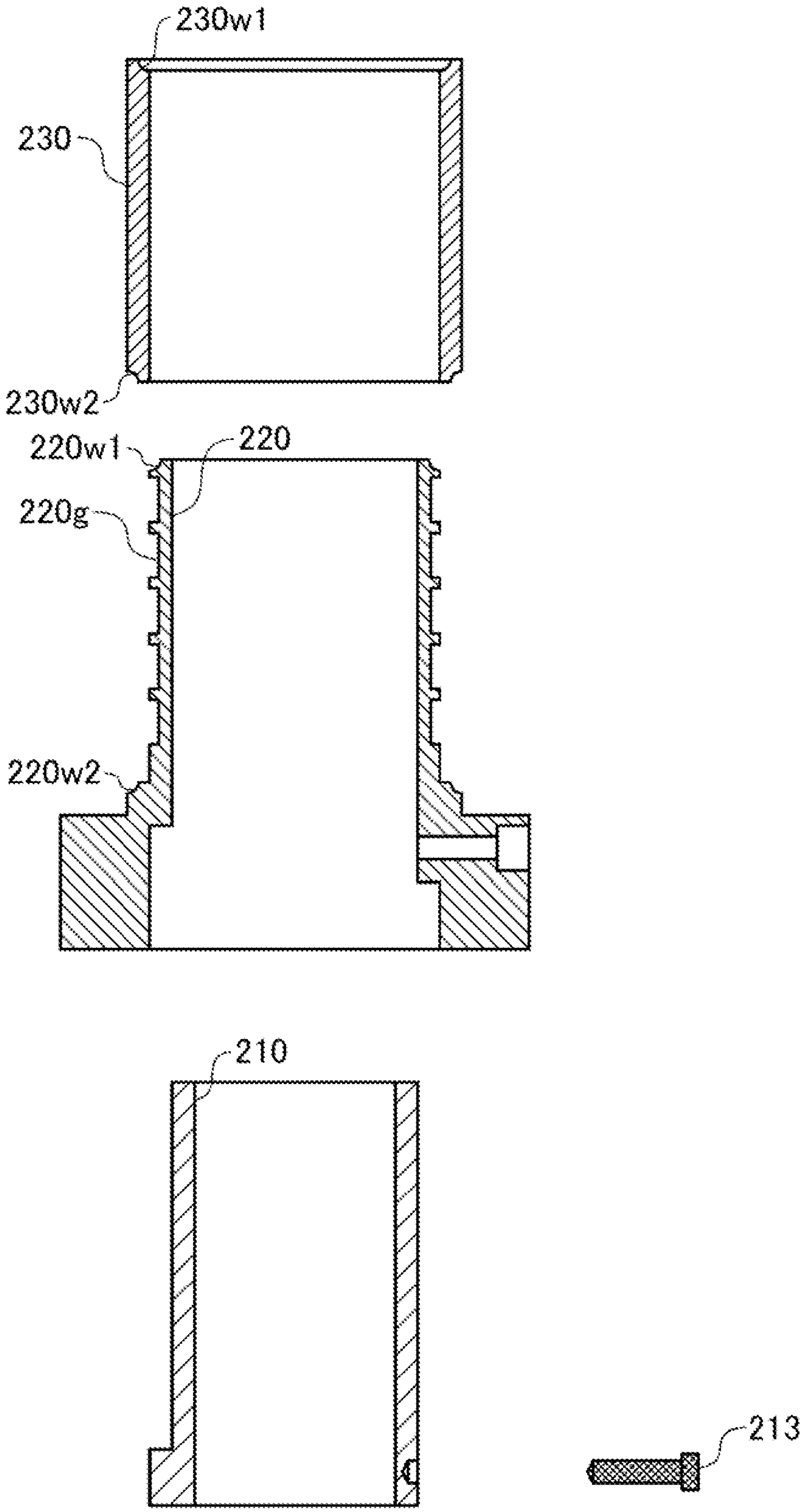


Fig. 9

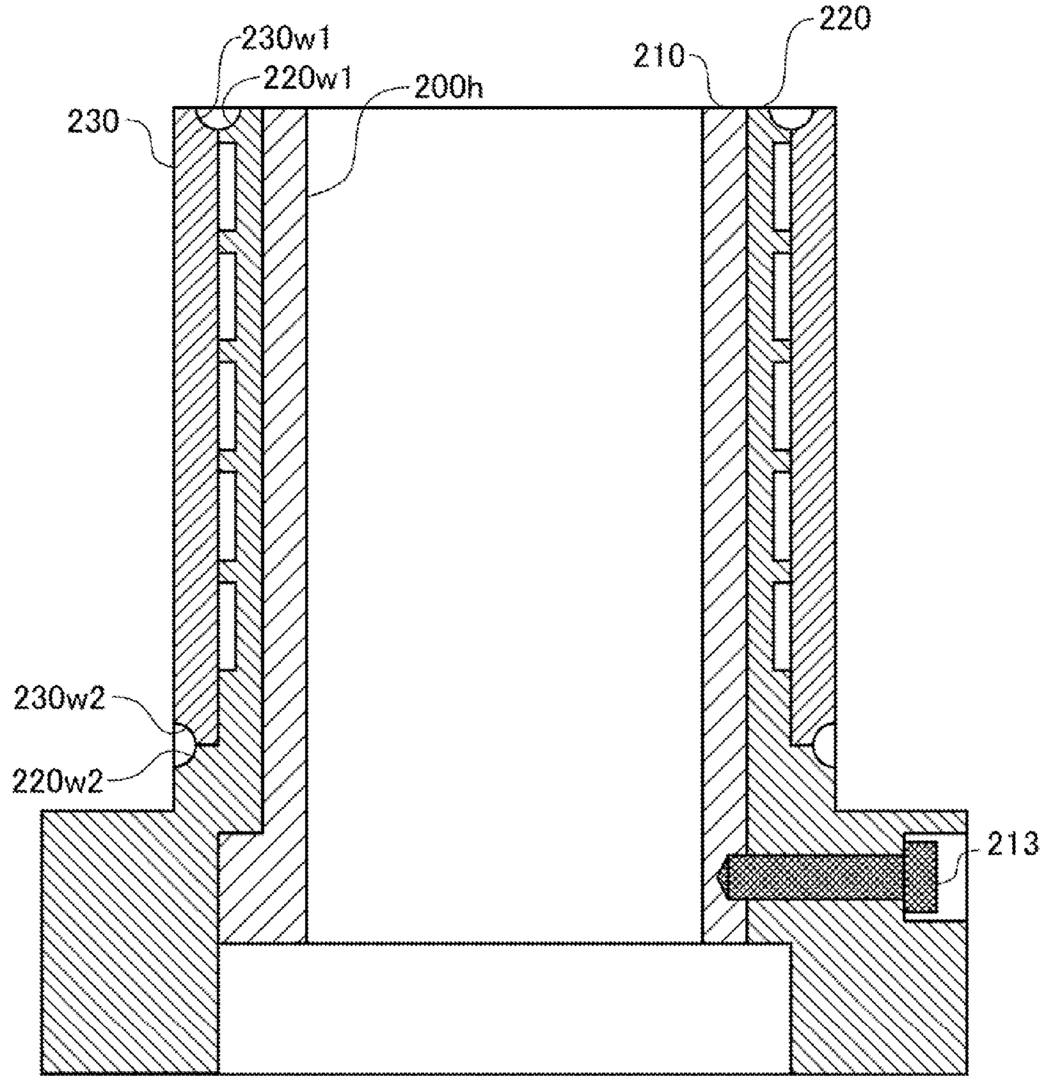


Fig. 10A

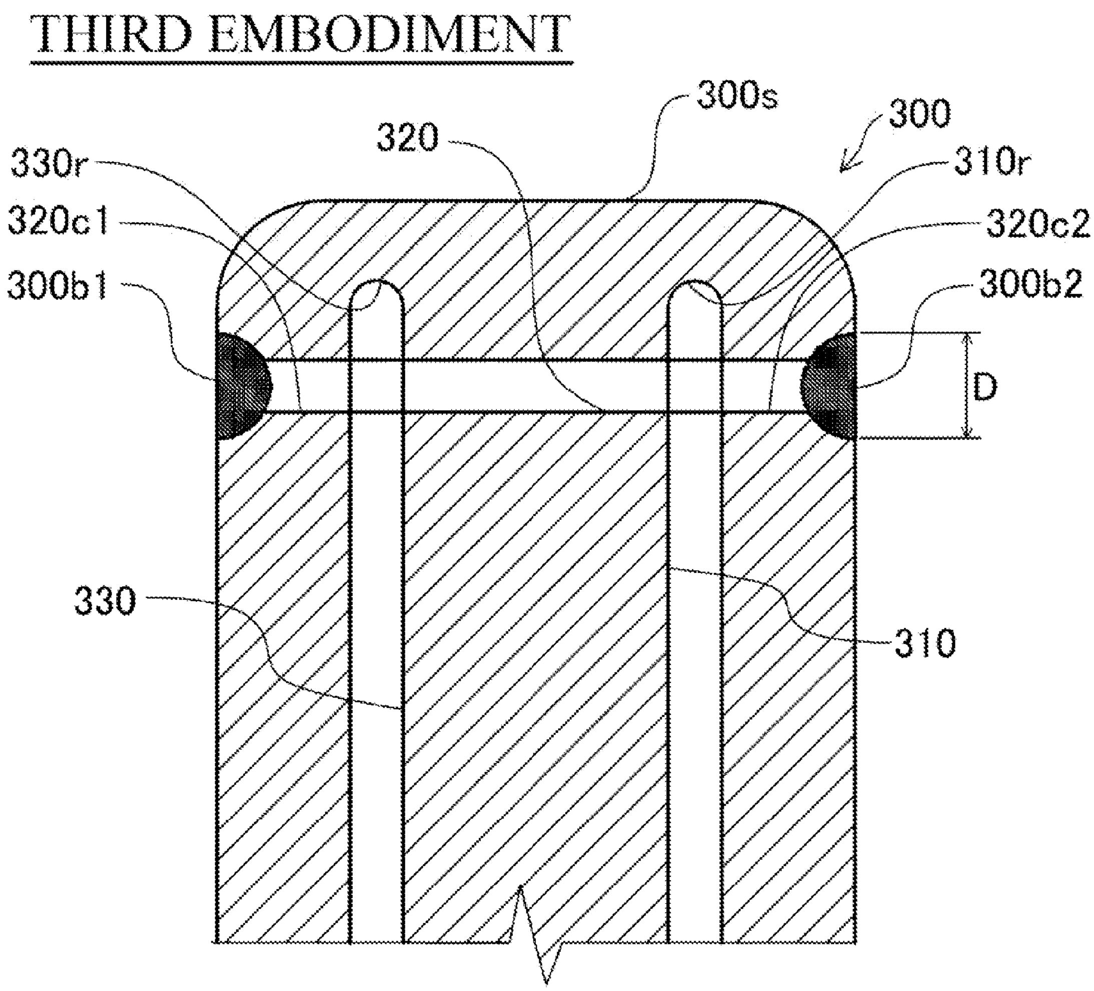

THIRD EMBODIMENT
300s
300
320
330r
310r
320c1
320c2
300b1
300b2
D
330
310

Fig. 10B

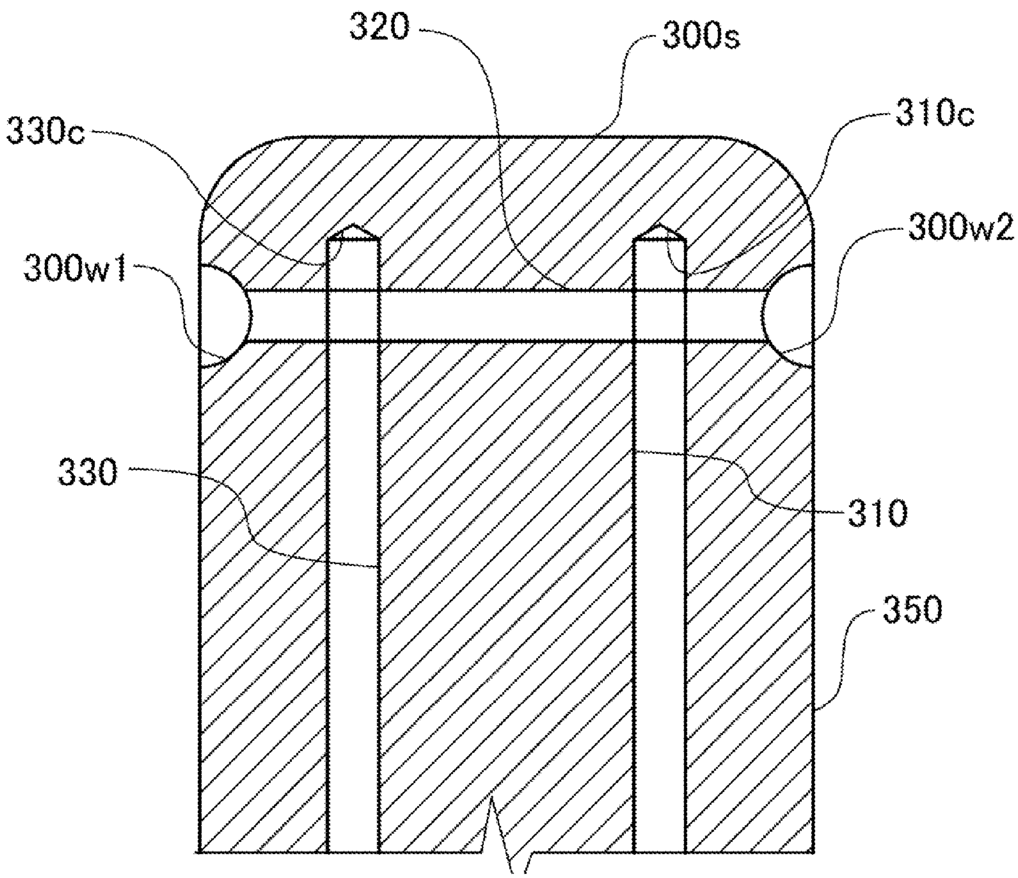
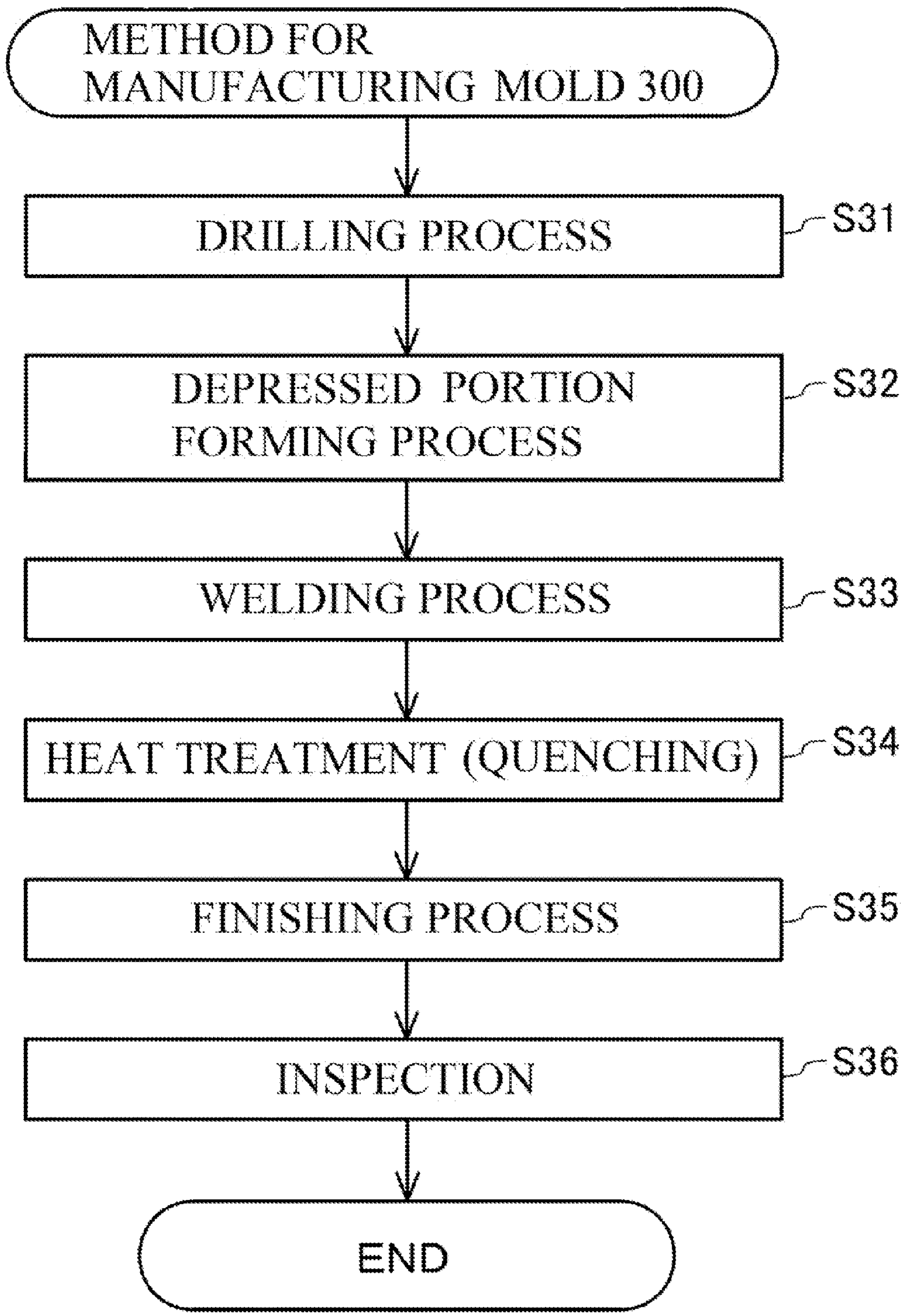


Fig. 11


METHOD FOR MANUFACTURING MOLD 300
DRILLING PROCESS
S31
DEPRESSED PORTION FORMING PROCESS
S32
WELDING PROCESS
S33
HEAT TREATMENT (QUENCHING)
S34
FINISHING PROCESS
S35
INSPECTION
S36
END

CASTING APPARATUS WHOSE COOLING FLOW PASSAGE IS FORMED BY WELDING AND METHOD FOR MANUFACTURING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from Japanese Patent Application No. 2014-210324 filed with the Japan Patent Office on Oct. 14, 2014, the entire content of which is hereby incorporated by reference.

BACKGROUND

[0002] 1. Technical Field

[0003] The present invention relates to a casting apparatus, such as a mold and a sprue bushing, used for die-cast casting or a similar casting and a method for manufacturing the casting apparatus. More specifically, the present invention relates to the casting apparatus that internally includes cooling flow passages for cooling the casting apparatus and the method for manufacturing the casting apparatus.

[0004] 2. Related Art

[0005] Conventionally, build-up welding has been performed to repair molds, and there has been proposed an improvement of the method (for example, Japanese Unexamined Patent Application Publication No. 2011-115807). In manufacturing the molds as well, to expand a freedom of design for forming a flow passage, the manufacturing method using the build-up welding has been proposed (for example, Japanese Unexamined Patent Application Publication No. 2004-34133, Japanese Unexamined Patent Application Publication No. H05-309468, and Japanese Unexamined Patent Application Publication No. 2005-52892). Meanwhile, a spread of water-soluble mold release agent for die-casting or a similar agent allows rapidly cooling the molds. While shortening of a manufacturing cycle is achieved, a problem of a heat check and a crack is likely to occur. Furthermore, it has been known as technical common knowledge that the welding repair is one cause of reduction in mold life ("Measures For Service Life Of Mold For Die-Casting", written by Masahiko Hihara, published by NIKKAN KOGYO SHIMBUN, LTD., Feb. 28, 2003, p. 289). The introduction of a cooling flow passage has been proposed also for the casting apparatus other than the mold such as the sprue bushing (Japanese Unexamined Patent Application Publication No. 2003-10953).

[0006] However, while a welding process is suitable for manufacturing the cooling flow passage, which is required to feature air tightness, from the aspect of durability of the casting apparatus, sufficient examination has been required to the welding process.

SUMMARY

[0007] One or more embodiments provide a casting apparatus manufactured using the welding process for manufacturing the cooling flow passages while minimizing deterioration of durability of the casting apparatus and a method for manufacturing the casting apparatus.

[0008] One or more embodiments of the present invention provides a casting apparatus for manufacturing cast products from molten metal. The casting apparatus includes a molten metal contacting surface and a cooling portion. The molten metal contacting surface is in contact with the molten metal. The cooling portion forms a cooling flow passage. The cooling flow passage is configured to cool the molten metal contacting surface. At least a part of an inner surface of the cooling flow passage is constituted of a welding portion formed by welding. The welding portion seals the cooling flow passage. The welding portion is constituted such that an exposure to the molten metal becomes equal to or less than a predetermined ratio with respect to an area of the welding portion constituting the inner surface of the cooling flow passage.

[0009] With the casting apparatus of one or more embodiments according to the present invention, at least a part of the inner surface of the cooling flow passage is constituted of the welding portion formed by welding. This allows minimizing excessive temperature rise by casting and also allows minimizing rapid temperature fall by cooling with a mold release agent. Meanwhile, the welding portion is constituted such that the exposure to the molten metal becomes equal to or less than the predetermined ratio with respect to the area of the welding portion constituting the inner surface of the cooling flow passage. This allows minimizing an influence of fatigue degradation caused by a temperature cycle by sufficient cooling. Consequently, the reduction in durability of the casting apparatus caused by the welding process can be minimized. The predetermined ratio can be set appropriately depending on the operating state and the design of the casting apparatus.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. **1** is a cross-sectional view illustrating a constitution of a mold **100** according to a first embodiment of the present invention;

[0011] FIG. **2** is a flowchart illustrating a method for using the mold **100** according to the first embodiment;

[0012] FIG. **3**A is a process drawing illustrating the method for using the mold **100** according to the first embodiment;

[0013] FIG. **3**B is a process drawing illustrating the method for using the mold **100** according to the first embodiment;

[0014] FIG. **3**C is a process drawing illustrating the method for using the mold **100** according to the first embodiment;

[0015] FIG. **4** is a flowchart illustrating a method for manufacturing the mold **100** according to the first embodiment;

[0016] FIG. **5**A is a process drawing illustrating the method for manufacturing the mold **100** according to the first embodiment;

[0017] FIG. **5**B is a process drawing illustrating the method for manufacturing the mold **100** according to the first embodiment;

[0018] FIG. **5**C is a process drawing illustrating the method for manufacturing the mold **100** according to the first embodiment;

[0019] FIG. **6** is a cross-sectional view illustrating a constitution of a die-cast-casting-machine use spool bush **200** according a second embodiment;

[0020] FIG. **7** is a flowchart illustrating a method for manufacturing the spool bush **200** according to the second embodiment;

[0021] FIG. **8** is an exploded view illustrating the method for manufacturing the spool bush **200** according to the second embodiment;

[0022] FIG. **9** is a process drawing illustrating an assembled state (before welding) of a bush body **220** and an outer liner **230** according to the second embodiment;

[0023] FIG. **10**A is a cross-sectional view illustrating a part of a constitution of a mold **300** according to a third embodiment;

[0024] FIG. **10**B is a process drawing illustrating a state after a machining process (before welding) of the mold **300** according to the third embodiment; and

[0025] FIG. **11** is a flowchart illustrating the method for manufacturing the mold **300** according to the third embodiment.

DETAILED DESCRIPTION

[0026] The following describes respective embodiments of the present invention in the following order. It will be understood that the scope of the present invention is not limited to the described embodiments, unless otherwise stated.

A. Constitution of Casting Apparatus (Mold) in First Embodiment:

B. Method for Using Mold in First Embodiment:

C. Method for Manufacturing Mold in First Embodiment:

D. Constitution of Casting Apparatus (Spool Bush) in Second Embodiment:

E. Method for Manufacturing Spool Bush in Second Embodiment:

F. Constitution of Casting Apparatus (Mold) in Third Embodiment:

G. Method for Manufacturing Mold in Third Embodiment:

H. Modification:

A. Constitution of Casting Apparatus (Mold) in First Embodiment

[0027] FIG. **1** is a cross-sectional view illustrating a constitution of a mold **100** according to a first embodiment of the present invention. The mold **100** includes an insert die **110**, a fixed-side main mold **120**, and a movable-side main mold **130**. The insert die **110** has a product shape forming surface **110***s*, which forms the shape of a cast product. The fixed-side main mold **120** has a product shape forming surface **120***s*. The movable-side main mold **130** has a product shape forming surface **130***s* and a depressed portion **130***c*. The three product shape forming surfaces **110***s*, **120***s*, and **130***s* can form an enclosed space for casting cast products in a mold-set-up state, which will be described later. This enclosed space will be described later. The mold **100** is the casting apparatus used for casting.

[0028] The insert die **110** includes a first part **111**, a second part **112**, and a bolt **113**. The first part **111** has the product shape forming surface **110***s*. The second part **112** has an outer surface fitted to the depressed portion **130***c* of the movable-side main mold **130**. The bolt **113** permanently fastens the first part **111** and the second part **112**. In this embodiment, when viewed from the axial direction of the bolt **113**, all the three product shape forming surfaces **110***s*, **120***s*, and **130***s* have a circular shape around its axial center. The product shape forming surfaces **110***s*, **120***s*, and **130***s* are also referred to as molten metal contacting surfaces.

[0029] The product shape forming surface **110***s* of the insert die **110** has protrusions **111***p*. The protrusion **111***p* is a shaping part disposed upon request of outer specification of cast products. Focusing on the shape of the protrusion **111***p*, the protrusion **111***p* has a property of likely to be a high temperature during a molten metal pouring process and likely to be rapidly cooled during cooling. This is because that while the protrusion **111***p* is surrounded by molten metal and cooling water, a heat conduction path to the movable-side main mold **130** is narrow.

[0030] The insert die **110** includes cooling water passages **114** (which corresponds to a cooling portion in the appended claims) to reduce the above-described temperature change. The cooling water passage **114** has an annular, circulating shape viewed from the axial direction of the bolt **113**. The cooling water passage **114** communicates with a cooling water inlet and a cooling water discharge port (not illustrated). The cooling water passages **114** are formed by covering openings of the annular depressed portions, which are formed at the first part **111**, with the second part **112**. The cooling water passage **114** is sealed from the outside of the cooling water passage **114** with a weld bead **110***b* (also referred to as a welding portion or a weld-overlay portion), which joins the first part **111** and the second part **112**.

[0031] The fixed-side main mold **120**, the movable-side main mold **130**, the first part **111**, and the second part **112** are all made of an SKD 61 and/or other tool steels. The weld bead **110***b* is a part over which deposited metal with a composition similar to the SKD 61 is overlaid. This build-up welding is formed by TIG welding using a TIG welding rod (for example, DS-61G). The combination of a plurality of components forms the movable-side main mold **130** and the insert die **110**, thus constituting one side of the mold **100**.

[0032] The entire outer surface of the weld bead **110***b* is in contact with the inner surface of the depressed portion **130***c* of the movable-side main mold **130**. Thus, the mold **100** is constituted such that the weld bead **110***b* is not to be exposed to the molten metal. Since the weld bead **110***b* is not exposed to the molten metal, this allows preventing a heat cycle caused by the contact of the weld bead **110***b* with the molten metal. Furthermore, the entire outer surface of the weld bead **110***b* is in contact with the movable-side main mold **130**, this allows exchanging heat remarkably effective between the outer surface and the movable-side main mold **130**. Accordingly, partial excessive temperature change only at the outer surface of the weld bead **110***b* can be minimized. This allows minimizing a heat check and a crack.

B. Method for Using Mold in First Embodiment

[0033] FIG. **2** is a flowchart illustrating a method for using the mold **100** according to the first embodiment. FIG. **3**A to FIG. **3**C are process drawings illustrating the method for using the mold **100** according to the first embodiment. To produce cast products, the mold **100** is used in the following method.

[0034] Step **S11** performs a mold-setting-up process. The mold-setting-up process forms a mold with the fixed-side main mold **120** and the movable-side main mold **130** from which the cast product has been taken out and where the cooling has been completed (see FIG. **3**A). The mold-setting-up process moves the movable-side main mold **130** having the insert die **110**, and forms the enclosed space (see FIG. **3**B). The enclosed space is to cast the cast products with the three product shape forming surfaces **110***s*, **120***s*, and **130***s*, which are provided to the fixed-side main mold **120**, the insert die **110**, and the movable-side main mold **130**, respectively.

[0035] Step S**12** performs the molten metal pouring process. The molten metal pouring process press-fits a high-temperature molten metal to the mold. As the molten metal, for example, an aluminum alloy is used. This heightens the temperatures of all the product shape forming surfaces **110***s*, **120***s*, and **130***s*. Meanwhile, the molten metal hardens and an aluminum die-cast product (not illustrated) is casted. After completion of solidification, the process proceeds to the next process.

[0036] Step S**13** performs a mold opening process. The mold opening process moves the movable-side main mold **130** to separate the movable-side main mold **130** from the fixed-side main mold **120** to allow extraction of the aluminum die-cast product (not illustrated). Step S**14** extracts the aluminum die-cast product. Then, the manufacturing process for aluminum die-cast products with the mold **100** is completed. The manufacturing process for aluminum die-cast products proceeds to the next process, which does not use the mold **100**.

[0037] Step S**15** applies a mold release agent to the insert die **110**, the fixed-side main mold **120**, and the movable-side main mold **130** with a spray device **190** (see FIG. **3**C). This embodiment uses a water-soluble mold release agent for die-casting (for example, TX-2400 and GL-3700) as the mold release agent. The mold release agent is applied by spraying the water-soluble mold release agent for die-casting to the product shape forming surfaces **110***s*, **120***s*, and **130***s* (see FIG. **3**C). After completion of the cooling (Step S**16**), in the case where the aluminum die-cast product is not an end product, the process can be returned to the mold-setting-up process (Step S**10**) (Step S**17**). In the case where the aluminum die-cast product is the end product, the process is terminated.

[0038] The water-soluble mold release agent for die-casting forms mold-releasing films over the product shape forming surfaces **110***s*, **120***s*, and **130***s*. Meanwhile, evaporation of the water vapor allows the product shape forming surfaces **110***s*, **120***s*, and **130***s* to be rapidly cooled. This allows achieving the short cycle time of the casting process.

[0039] The rapid cooling of the product shape forming surfaces **110***s*, **120***s*, and **130***s* increases the problem of thermal fatigue, causing the heat check and the crack. Specifically, according to the knowledge of the inventor of this application, in a process where the product shape forming surfaces **110***s*, **120***s*, and **130***s* whose temperatures become high by the molten metal pouring process are rapidly cooled and contracted by the evaporation of the water vapor of the water-soluble mold release agent for die-casting, the heat check and the crack occur. This is because that the rapid contraction of the surface generates a thermal expansion difference between the surface part and the inner part, resulting in a strain.

[0040] In this embodiment, focusing on its shape, especially the protrusion **111***p* provided with the product shape forming surface **110***s*, has a property likely to be a high temperature during the molten metal pouring process. This is because that while the protrusion **111***p* is surrounded by the molten metal, the heat conduction path to the movable-side main mold **130** is narrow. However, in this embodiment, since the cooling water passages **114** are formed at the inside of the protrusions **111***p*, this allows minimizing the excessively high temperature of the protrusions **111***p*. Furthermore, while the process continues from the molten metal pouring process (Step S**12**) to the mold opening process (Step S**13**) and then proceeds to the application of the mold release agent (Step S**15**), the protrusion **111***p* can also be cooled with the cooling water passage **114**. This allows effectively minimizing the heat check and the crack, which are caused by the cooling by the application of the mold release agent.

[0041] In this embodiment, the cooling water passages **114** are sealed by the weld beads **110***b*. With general technical common knowledge, it is considered that a mold life of a part of a die-casting mold where the welding repair has been performed is remarkably reduced compared with a non-welded portion (for example, Measures For Service Life Of Mold For Die-Casting, written by Masahiko Hihara, NIKKAN KOGYO SHIMBUN, LTD.). However, in this embodiment, it is less likely that the weld bead **110***b* causes the reduction in mold life at least due to the following reasons. The other reasons will be described later.

(1) Since the weld bead **110***b* seals the cooling water passage **114**, the weld bead **110***b* is not in an excessively high temperature state.

(2) The weld bead **110***b* does not form the product shape forming surface **110***s* (not exposed to the enclosed space (see FIG. **3**B), which is to cast the cast product). Accordingly, the weld bead **110***b* does not become a high temperature excessively and is not exposed under a rapid temperature decrease, which is caused by application of the mold release agent.

(3) The weld bead **110***b* is in contact with the movable-side main mold **130**. Accordingly, the weld bead **110***b* and the movable-side main mold **130** do not form a thermal boundary and do not generate excessively large heat gradient.

[0042] Accordingly, the mold **100** having the constitution of the first embodiment uses the welding process for manufacturing a cooling flow passage **140** while minimizing the deterioration of durability of the mold **100**. This achieves the appropriate cooling flow passage, ensuring achieving the mold **100** having long life.

C. Method for Manufacturing Mold in First Embodiment

[0043] FIG. **4** is a flowchart illustrating the method for manufacturing the mold **100** according to the first embodiment. FIG. **5**A to FIG. **5**C are process drawings illustrating the method for manufacturing the mold **100** according to the first embodiment. To achieve the above-described constitution, the mold **100** is manufactured by the following method. Step S**21** performs the machining process on the respective components (see FIG. **5**A). Especially, the respective components of the first part **111** and the second part **112**, which constitute the insert die **110**, are all manufactured by performing the machining process on materials, which is the SKD 61, before quenching.

[0044] On the outer periphery of the first part **111**, depressed portions **111***w*, which have a depressed shape for build-up welding, are formed. On the outer periphery of the second part **112**, depressed portions **112***w*, which have a depressed shape for build-up welding, are formed.

[0045] Step S**22** assembles the respective components. Specifically, the first part **111** and the second part **112**, which constitute the insert die **110**, are combined. The combined first part **111** and second part **112** are fastened by the bolt **113**. This forms the depressed portions **111***w* and **112***w* (see FIG. **5**B) to form the weld beads **110***b* across the peripheral areas of the first part **111** and the second part **112**. The depressed portions **111***w* and **112***w* have a semicircular cross section.

[0046] Step S**23** performs the welding process. As described above, the welding process is performed by forming the weld bead **110***b* (see FIG. **1** and FIG. **5**C) by the TIG welding using the TIG welding rod (for example, the DS-61G). The weld bead **110***b* is appropriately melted into both the first part **111** and the second part **112**, thus constituting a gradient metal.

[0047] Note that the TIG welding rod (for example, the DS-61G) forms the weld-overlay portion by the deposited metal with the composition similar to the SKD 61, and different from the welding repair, the first part **111** and the second part **112** are in the state of before quenching. Accordingly, the weld bead **110***b* forms the gradient metal having extremely smooth gradient by including a heating process. Accordingly, the first part **111** and the second part **112** are combined and fastened by the bolt **113**, thus manufacturing a welded half-finished product of the insert die **110**.

[0048] Step S**24** performs the heat treatment (the quenching) on the half-finished product of the insert die **110**. By this process, the insert die **110** has sufficient toughness and rigidity. In this respect, the first part **111**, the second part **112**, and the weld bead **110***b* before quenching are all integratedly quenched. Therefore, the weld bead **110***b* has a physical property significantly similar to the first part **111** and the second part **112**. Accordingly, a physical property boundary hardly occurs between the weld beads **110***b* and the first part **111** and the second part **112** as the base material, ensuring effectively minimizing the thermal fatigue generated caused by the boundary.

[0049] Step S**25** performs a finishing process. The finishing process includes the machining process to form the outer shape of the weld bead **110***b* into a shape so as to fit the depressed portion **130***c* of the movable-side main mold **130**. Furthermore, the finishing process includes the overall machining process of the outer surface and the surface treatment to achieve an appropriate fitting state between the insert die **110** on which thermal distortion is generated and the movable-side main mold **130**. Furthermore, the finishing process includes the machining process and the surface treatment to achieve the appropriate fitting state between the fixed-side main mold **120**, the movable-side main mold **130**, and the insert die **110**.

[0050] Step S**26** inspects the mold **100**. This inspection includes a pressure resistance inspection, an X-ray inspection, or a similar inspection on the cooling water passage **114**. These processes allow manufacturing the mold **100** having the constitution of the first embodiment.

[0051] This manufacturing process starts manufacturing the respective components of all the first part **111** and the second part **112**, which constitute the insert die **110**, from the process of the machining process on the materials, which is the SKD 61, before quenching, and after welding and joining the first part **111** and the second part **112**, the first part **111** and the second part **112** are integratedly quenched. Furthermore, the welding process forms the weld-overlay portion with the deposited metal with the composition similar to the SKD 61. Accordingly, the physical property boundary hardly occurs between the weld beads **110***b* and the first part **111** and the second part **112** as the base material. As a result, the thermal fatigue generated caused by the boundary can be effectively minimized.

D. Constitution of Casting Apparatus (Spool Bush) in Second Embodiment

[0052] FIG. **6** is an explanatory view illustrating the constitution of a die-cast-casting-machine use spool bush **200** (hereinafter simply referred to as a spool bush) according the second embodiment. The spool bush **200** is a component to cause the molten metal to pass through itself and to pour (supply) molten metal to the mold (for example, the mold **100**). The spool bush **200** has its central axis in the vertical direction in the drawing and has a cylindrical shape including a hollow part. The spool bush **200** is the casting apparatus used for casting.

[0053] The spool bush **200** includes insertion liners **210**, a bush body **220**, outer liners **230**, and a bolt **213**. On the inner surfaces of the insertion liners **210**, plunger holes **200***h* are formed. Through the plunger hole **200***h*, a plunger (not illustrated), which pushes the molten metal, passes. The insertion liner **210** is a replacement component. The inner surface of the plunger hole **200***h* is also referred to as the molten metal contacting surface.

[0054] The spool bush **200** is constituted as follows. The bolt **213** fastens the insertion liner **210** and the bush body **220**. The outer liner **230** and the bush body **220** are permanently fastened with two weld beads **200***b***1** and **200***b***2** (also referred to as welding portions). The two weld beads **200***b***1** and **200***b***2** are each formed into a ring shape around the central axis of the spool bush **200**.

[0055] The spool bush **200** includes cooling water passages **224** (which corresponds to the cooling portion in the appended claims). The cooling water passage **224** is formed of the inner surface of the outer liner **230** and a cooling groove **220***g* (see FIG. **8**). The cooling groove **220***g* is formed on the outer diameter surface of the bush body **220**. The cooling water passages **224** are each formed into the ring shape around the central axis of the spool bush **200** and partially communicate with one another in the central axis direction of the spool bush **200**. In the cooling water passage **224**, the cooling water inlet (not illustrated) communicates with the cooling water discharge port (not illustrated). Accordingly, the cooling water passage **224** is constituted as a circulation path. This quickly solidifies a molten metal, allowing shortening the cycle time of casting.

[0056] The spool bush **200** is constituted such that the two weld beads **200***b***1** and **200***b***2** are not exposed to the molten metal during the operation. Thus, the two weld beads **200***b***1** and **200***b***2** are not exposed to the molten metal. This allows preventing a heat cycle, which is caused by the two weld beads **200***b***1** and **200***b***2** in contact with the molten metal.

E. Method for Manufacturing Spool Bush in Second Embodiment

[0057] FIG. **7** is a flowchart illustrating a method for manufacturing the spool bush **200** according to the second embodiment. FIG. **8** is a process drawing illustrating the method for manufacturing the spool bush **200** according to the second embodiment. FIG. **9** is a process drawing illustrating an assembled state (before welding) of the bush body **220** and the outer liners **230** according to the second embodiment. To achieve the above-described constitution, the spool bush **200** is manufactured by the following method. Step S**21***a* performs the machining process of the bush body **220** and the outer liners **230** (see FIG. **8**). Similar to the first embodiment, these respective components are all manufactured by performing the machining process on materials, which is the SKD 61, before quenching.

[0058] On the inner periphery at the upper end and on the outer periphery at the lower end of the outer liner **230**, a depressed portion **230***w***1** and a depressed portion **230***w***2**, which have a depressed shape for build-up welding, are formed, respectively. On the outer periphery at the upper end and on the inner periphery at the lower end of the bush body **220**, a depressed portion **220***w***1** and a depressed portion **220***w***2**, which have a depressed shape for build-up welding, are formed, respectively (see FIG. **9**).

[0059] Step S**22***a* temporarily assembles the respective components **220** and **230**. Specifically, Step S**22***a* combines the bush body **220** and the outer liners **230**. In this respect, the depressed portions **220***w***1** and **230***w***1** to form the weld beads **200***b***1** (also referred to as the welding portions or the weld-overlay portions) are formed across the upper ends of the bush body **220** and the outer liners **230**. The depressed portions **220***w***1** and **230***w***1** have a semicircular cross section. Furthermore, the depressed portions **220***w***2** and **230***w***2** to form the weld beads **200***b***2** are formed across the lower portion of the bush body **220** and the lower end of the outer liner **230**. The depressed portions **220***w***2** and **230***w***2** have a semicircular cross section.

[0060] Step S**23***a* performs the heat treatment (the quenching) on the respective components **220** and **230**. This embodiment performs the heat treatment before the welding process in a state where the respective components **220** and **230** are disassembled. This is because that, regarding the shapes of the respective components **220** and **230**, performing the heat treatment with the respective components **220** and **230** combined results in excessive internal stress, which is generated by the heat treatment.

[0061] Step S**24***a* performs the welding process. Note that a finish machining process is performed before the welding process to assemble the respective components **220** and **230**. This does not cause excessive internal stress after the heat treatment (in the form of a product). As described above, the welding process is performed by forming the weld beads **200***b***1** and **200***b***2** (see FIG. **6**) by the TIG welding using the TIG welding rod (for example, the DS-61G). The weld beads **200***b***1** and **200***b***2** are appropriately melted into both the bush body **220** and the outer liner **230**, thus constituting a gradient metal. This manufactures the half-finished product of the spool bush **200**.

[0062] Similar to the first embodiment, Step S**25** performs the finishing process. The finishing process includes the machining process. The machining process forms the inner surface shape of the bush body **220** into a shape so as to fit the outer surface shape of the insertion liner **210**, which is the replacement component. Similar to the first embodiment, Step S**26** inspects the mold **100**. Step S**27** inserts the insertion liner **210** to the inside of the bush body **220**, and the bolt **213** fastens both.

[0063] This manufacturing process forms the weld-overlay portions at all the respective components of the bush body **220** and the outer liner **230** with the deposited metal with the composition similar to the SKD 61. This ensures effectively minimizing the thermal fatigue.

[0064] The die-cast-casting-machine use spool bush **200** of the second embodiment uses the cooling water passages **224** to quickly solidify the molten metal, thus ensuring shortening the cycle time for casting. Furthermore, without the use of an O-ring or a similar component, the weld beads **200***b***1** and **200***b***2** where thermal fatigue is effectively minimized can constitute the cooling water passages **224**. This allows enhancing the durability of the spool bush **200**.

F. Constitution of Casting Apparatus (Mold) in Third Embodiment

[0065] FIG. **10**A is a cross-sectional view illustrating a part of a constitution of a mold **300** according to the third embodiment. The mold **300** has convex portions (illustrated) and internally has cooling flow passages **310**, **320**, and **330** (which corresponds to the cooling portion in the appended claims). The two linear cooling flow passages **310** and **330** extend parallel toward the proximity of a product shape forming surface **300***s* of the mold **300**. On the other hand, the linear cooling flow passage **320** communicates with both the two cooling flow passages **310** and **330**. Accordingly, the three linear cooling flow passages **310**, **320**, and **330** are mutually communicated and form a circulation path. The product shape forming surface **300***s* is also referred to as the molten metal contacting surface.

[0066] The cooling flow passage **320** is sealed by weld beads **300***b***1** and **300***b***2** at both ends. This forms columnar flow passages **320***c***1** and **300***c***2** at respective both ends of the cooling flow passage **320**. The one end of the columnar flow passage **320***c***1** is sealed by the weld bead **300***b***1** and the other end is coupled to the circulation path. On the other hand, the one end of a columnar flow passage **320***c***2** is sealed by the weld bead **300***b***2** and the other end is coupled to the circulation path.

[0067] The weld beads **300***b***1** and **300***b***2** seal the one ends of both the columnar flow passages **320***c***1** and **300***c***2**. Therefore, according to the usual viewpoint of hydromechanics, this structure forms a stagnation; therefore, cooling cannot be expected. However, according to analysis of the inventor of this application, the following has been found. Since the cooling water spouts and flows in at constant cycles by evaporation (in another technical field, this has been known as a so-called pop pop boat principle), this structure features high cooling capacity contrary to common sense.

G. Method for Manufacturing Mold in Third Embodiment

[0068] FIG. **10**B is a process drawing illustrating a state after a machining process (before welding) of the mold **300** according to the third embodiment. FIG. **11** is a flowchart illustrating the method for manufacturing the mold **300** according to the third embodiment. To achieve the above-described constitution, the mold **300** is manufactured by the following method.

[0069] Step S**31** performs a drilling process (see FIG. **10**B). In this embodiment, performing the machining process on a mold base metal **350** before quenching the SKD 61 manufactures the mold **300**. A drill with a diameter of 6 mm forms three holes. The three holes include holes **310** and **330** and one through-hole **320**. The two holes **310** and **330** are dug toward the product shape forming surface **300***s* up to the proximity of the product shape forming surface **300***s*. This constitution allows forming the circulation path inside the mold **300**.

[0070] The drilling process includes a boring process and a rounding process. The boring process forms the holes **310** and **330** with a drill for boring (not illustrated). The rounding process rounds most depressed portions **310***c* and **330***c* (see FIG. **10**B) of the bored holes to form rounded most depressed portions **310***r* and **330***r* (see FIG. **10**A). The rounding process uses a dedicated tool whose distal end is rounded. The rounding process is performed to enhance the durability.

[0071] Step S**32** performs a depressed portion forming process. The depressed portion forming process forms depressed portions **300***w***1** and **300***w***2** for build-up welding at both the end portions of the through-hole **320**. The depressed portions **300***w***1** and **300***w***2** (see FIG. **10**B) are formed into hemispherical depressed portions (see FIG. **10**A) such that each diameter D of the weld beads **300***b***1** and **300***b***2** for build-up welding (also referred to as the welding portions or the weld-overlay portions) becomes twice as large as the hole diameter, which is 12 mm in this embodiment.

[0072] According to the analysis of the inventor of this application, the larger the diameter D is, the larger the pressure resistance of the cooling flow passage while reduction in durability caused by welding becomes remarkable. Contrary, the smaller the diameter D is, the lower the pressure resistance of the cooling flow passage while the reduction in the durability caused by welding becomes small. Therefore, the diameters D of the weld beads **300***b***1** and **300***b***2** are the most preferable to be 1.5 times to twice the hole diameter viewed from the axial directions of the columnar flow passages **320***c***1** and **300***c***2**, and are also preferable to be 1 time to 2.5 times of the hole diameter.

[0073] Note that the embodiment can be achieved even outside the range. From the aspect of durability, the weld beads **300***b***1** and **300***b***2** can achieve sufficient cooling as long as the exposure to the molten metal is constituted so as to be equal to or less than a predetermined ratio with respect to areas of the weld beads **300***b***1** and **300***b***2**, which constitute the inner surfaces of the columnar flow passages **320***c***1** and **300***c***2**. The predetermined ratio can be determined according to the operating form (the temperature of molten metal and the shape of the mold).

[0074] Step S**33** performs the welding process. As described above, the welding process is performed by forming the weld beads **300***b***1** and **300***b***2** by the TIG welding using the TIG welding rod (for example, the DS-61G). The weld beads **300***b***1** and **300***b***2** are appropriately melted into the mold base metal **350**, thus constituting a gradient metal. Thus, the half-finished product of the mold **300** is manufactured.

[0075] Step S**34** performs the heat treatment (the quenching) of the half-finished product of the mold **300**. With this embodiment as well, a physical property boundary hardly occurs between the weld beads **300***b***1** and **300***b***2** and the mold base metal **350**, ensuring effectively minimizing the thermal fatigue, which is generated caused by the boundary.

[0076] Step S**35** performs the finishing process. Step S**36** inspects the mold **300**. This inspection includes the pressure resistance inspection, the X-ray inspection, or a similar inspection on the cooling flow passages **310**, **320**, and **330**. These processes can manufacture the mold **300** having the constitution of the third embodiment.

[0077] According to this manufacturing process, similar to the first embodiment and the second embodiment, the physical property boundary hardly occurs between the weld beads **300***b***1** and **300***b***2** and the mold base metal **350**. Furthermore, since the cooling water spouts and flows in at constant cycles in the columnar flow passages **320***c***1** and **300***c***2** by evaporation, the weld beads **300***b***1** and **300***b***2** can be effectively cooled. Additionally, it is constituted such that the exposure of the weld beads **300***b***1** and **300***b***2** to the molten metal becomes equal to or less than the predetermined ratio with respect to the areas of the weld beads **300***b***1** and **300***b***2**, which constitute the inner surfaces of the columnar flow passages **320***c***1** and **300***c***2**, to ensure sufficiently cooling. As a result, the thermal fatigue generated caused by the boundary with the weld beads **300***b***1** and **300***b***2** can be effectively minimized.

H. Modification

[0078] In the above-described embodiment, this build-up welding is formed by the TIG welding using the TIG welding rod; however, another welding method may be employed. Note that since the TIG welding can obtain beautiful, high-quality weld beads (weld-overlay portions) and therefore is preferable in terms of allowing application to welding of various metals.

[0079] The casting apparatus may be constituted as follows. The casting apparatus has a plurality of components including a welding component having the welding portion. With the plurality of components assembled, the welding portion is constituted not to be exposed to the molten metal.

[0080] The casting apparatus may be constituted as follows. The casting apparatus is a mold. The molten metal contacting surface constitutes a part of the mold as a product shape forming surface. The product shape forming surface forms a shape of the cast product set in advance. An outer surface of the welding portion is constituted so as not to be exposed to the molten metal by contact with any of outer surfaces of the plurality of components.

[0081] The casting apparatus may be constituted as follows. The cooling portion is manufactured by welding a material before quenching and subsequently quenching the material.

[0082] The casting apparatus may be constituted as follows. The casting apparatus is a mold. The cooling flow passage includes a columnar flow passage. One end of the columnar flow passage is sealed by the welding portion. Another end of the columnar flow passage communicates with a circulation path. The circulation path causes a cooling medium to circulate. The welding portion has a diameter 1.5 times to 2.5 times of a diameter of the columnar flow passage viewed from an axial direction of the columnar flow passage such that the diameter becomes equal to or less than the predetermined ratio.

[0083] The casting apparatus may be constituted as follows. A length of the columnar flow passage from the one end to the other end is longer than the diameter of the columnar flow passage.

[0084] The casting apparatus may be constituted as follows. The casting apparatus is a sprue bushing. The molten metal contacting surface constitutes a path to cause the molten metal to pass through to supply the molten metal to the mold.

[0085] The casting apparatus may be constituted as follows. The columnar flow passage is a mold whose length from the one end to the other end is longer than the diameter of the columnar flow passage.

[0086] While one or more embodiments of the present invention seals the cooling flow passage by the welding process, the reduction in durability of the casting apparatus caused by the welding process can be minimized.

What is claimed is:

1. A casting apparatus for manufacturing a cast product from molten metal, the casting apparatus comprising:

a molten metal contacting surface for contact with the molten metal; and

a cooling portion forming a cooling flow passage, the cooling flow passage being configured to cool the molten metal contacting surface, wherein

at least a part of an inner surface of the cooling flow passage is constituted of a welding portion formed by welding, the welding portion sealing the cooling flow passage, and

the welding portion is constituted such that an exposure to the molten metal becomes equal to or less than a predetermined ratio with respect to an area of the welding portion constituting the inner surface of the cooling flow passage.

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

the casting apparatus has a plurality of components including a welding component having the welding portion, and

with the plurality of components assembled, the welding portion is constituted not to be exposed to the molten metal.

3. The casting apparatus according to claim **2**, wherein

the casting apparatus is a mold,

the molten metal contacting surface constitutes a part of the mold as a product shape forming surface, the product shape forming surface forming a shape of the cast product set in advance, and

an outer surface of the welding portion is constituted so as not to be exposed to the molten metal by contact with any of outer surfaces of the plurality of components.

4. The casting apparatus according to claim **1**, wherein

the cooling portion is manufactured by welding a material before quenching and subsequently quenching the material.

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

the casting apparatus is a mold,

the cooling flow passage includes a columnar flow passage, one end of the columnar flow passage being sealed by the welding portion, another end of the columnar flow passage communicating with a circulation path, the circulation path causing a cooling medium to circulate, and

the welding portion has a diameter 1.5 times to 2.5 times of a diameter of the columnar flow passage viewed from an axial direction of the columnar flow passage such that the diameter becomes equal to or less than the predetermined ratio.

6. The casting apparatus according to claim **5**, wherein

the columnar flow passage is a mold whose length from the one end to the other end is longer than the diameter of the columnar flow passage.

7. The casting apparatus according to claim **1**, wherein

the casting apparatus is a sprue bushing, and

the molten metal contacting surface constitutes a path to cause the molten metal to pass through to supply the molten metal to a mold.

8. A method for manufacturing a casting apparatus for manufacturing a cast product from molten metal, the method comprising:

providing a molten metal contacting surface for contact with the molten metal and a material before quenching, a part of a cooling flow passage being formed at the material, the cooling flow passage being configured to cool the molten metal contacting surface, wherein

welding at least a part of an inner surface of the cooling flow passage to form a welding portion configured to seal the cooling flow passage, and

the welding portion is constituted such that an exposure to the molten metal becomes equal to or less than a predetermined ratio with respect to an area of the welding portion constituting the inner surface of the cooling flow passage.

9. The casting apparatus according to claim **2**, wherein

the cooling portion is manufactured by welding a material before quenching and subsequently quenching the material.

10. The casting apparatus according to claim **3**, wherein

the cooling portion is manufactured by welding a material before quenching and subsequently quenching the material.

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