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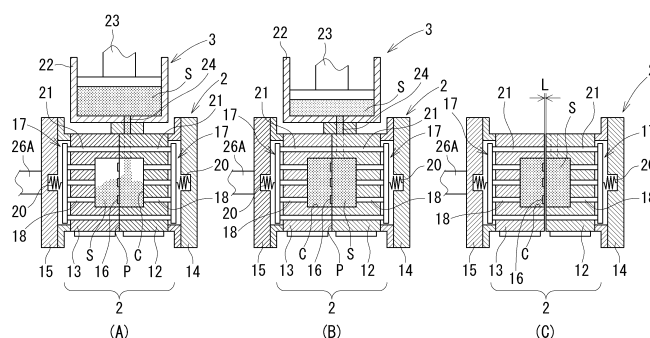
(54) **SAND-MOLD MOLDING METHOD AND SAND-MOLD MOLDING APPARATUS**

(57) When a molded article is obtained by which foamed sand is packed into a metallic mold, heated and solidified, vapor and gas that have been generated through the heating and solidification of the foamed sand are smoothly discharged from the cavity.

A cavity C is formed by clamping a metallic mold 2, and foamed sand S is packed into the cavity C. When heating and solidifying the foamed sand S, a mold clamping force is reduced to form a slight gap L in the metallic

mold 2 while maintaining the cavity C. Gas and water vapor that are generated when heating and solidifying the foamed sand S can be smoothly discharged from within the cavity C to the outside through the gap L, and thus the baking time of the foamed sand S can be shortened. Even if solidified binder accumulates on slits 16, gas and water vapor can be reliably discharged from within the cavity C to the outside via the gap.

FIG. 2



Description

Technical Field

[0001] The present invention relates to a sand-mold molding method and a sand-mold molding apparatus in which a foamed sand is packed into a metallic mold and solidified to mold a sand mold such as a sand core.

Background Art

[0002] When casting a cylinder block, a cylinder head, or the like of an engine, a collapsible sand core (sand mold) is used for forming a hollow part such as a water jacket, an intake and exhaust port, or the like. The sand core is formed into a predetermined shape by, for example, blowing a shell sand coated with a thermoplastic resin into a metallic mold by compressed air from a nozzle of a sand blowing device to pack the shell sand into a cavity and then heating and solidifying it.

[0003] In contrast, there is a technology for molding a sand mold such as a core using foamed sand that is foamed by stirring water and an water-soluble binder with an aggregate. In this way, when the foamed sand is molded by packing it into a cavity of a metallic mold, the internal pressure of the cavity increases due to evaporation of moisture and thermal expansion of air bubbles during the course of heating and hardening (baking) of the foamed sand. Thus, in the molded article, the water-soluble binder and the aggregate accumulate to form a dense hardened layer with high strength in a surface layer part, while a fragile brittle part with low density is formed in an inner part. Therefore, a core molded by foamed sand can ensure sufficient strength as a core during casting, and exhibits excellent collapsibility such that it can be easily removed from the casted article after casting.

[0004] When heating and hardening foamed sand within a metallic mold, water vapor and gas are produced, and thus it is necessary to smoothly discharge such water vapor and gas to the outside of the cavity of the metallic mold. Thus, slits or passages for discharging water vapor and gas are provided in metallic molds used for molding foamed sand. Also, although not in relation to foamed sand, JP 2002-192305 A discloses providing gas venting holes to a metallic mold so as to discharge from the cavity of the metallic mold any gas that is produced when baking shell sand in the cavity of the metallic mold.

Citation

Patent Literature

[0005] Patent Literature 1: JP 2002-192305 A

Summary of Invention

Technical Problem to be solved

[0006] The following problems may occur when molding a sand mold using foamed sand.

[0007] In order to shorten the heating and hardening time (baking time) of foamed sand, how quickly water vapor can be discharged from the cavity of the metallic mold is important. However, since the water-soluble binder flows out together with water vapor and gas from the slits or passages for gas venting during the course of heating and hardening the foamed sand, solidified binder may accumulate on the slits or passages for gas venting due to repeated moldings, and this may obstruct the discharge of water vapor and gas. Thus, there has been a problem in that the baking of the foamed sand may require more time if the smooth discharge of water vapor and gas becomes obstructed.

[0008] The present invention was created in consideration of the above-described problems, and an object thereof is to shorten a hardening time by smoothly discharging water vapor and gas from within the cavity when heating and hardening foamed sand within a cavity of a metallic mold.

Means to solve Problems

[0009] To solve the above-described problems, the present invention provides a sand-mold molding method in which a molded article is obtained by packing foamed sand, which has been foamed by stirring a binder with an aggregate, into a cavity of a metallic mold and then heating and solidifying the foamed sand, wherein, after forming the cavity by clamping the metallic mold and packing the foamed sand into the cavity, the metallic mold is opened slightly to provide a gap in the metallic mold while maintaining the cavity.

(Embodiments of the Invention)

[0010] Hereinafter, several examples of embodiments of the invention for which it is recognized that a patent claim is possible in the present invention (may also be referred to as "claimable inventions" below) are described below. The embodiments below are divided into aspects similar to the claims, and each aspect is assigned a number and described in a format where other aspect numbers may be cited as necessary. This division into aspects is for facilitating the understanding of the claimable inventions, and the combinations of components that constitute the claimable inventions are not limited to those described below in the following aspects. In other words, the claimable inventions should be interpreted upon referring to the descriptions in each aspect below and the descriptions of any examples and the like. As long as it is in line with such interpretations, the claimable inventions may include embodiments in which further

components are added to the embodiments of each aspect or components are deleted from the embodiments of each aspect. The contents of (1) to (6) below correspond respectively to claims 1 to 6.

(1) A sand-mold molding method in which a molded article is obtained by packing foamed sand, which has been foamed by stirring a binder with an aggregate, into a cavity of a metallic mold and then heating and solidifying the foamed sand, wherein, after forming the cavity by clamping the metallic mold and packing the foamed sand into the cavity, the metallic mold is opened slightly to provide a gap in the metallic mold while maintaining the cavity.

(2) The sand-mold molding method according to (1), wherein a mold clamping force of the metallic mold is reduced so that the gap is provided in the metallic mold by a counterforce from the metallic mold.

(3) The sand-mold molding method according to (1) or (2), wherein the gap in the metallic mold ranges from 0.22 mm to 0.36 mm.

(4) A sand-mold molding apparatus including: a metallic mold in which a cavity is formed by mold clamping; a mold clamping device that opens/closes the metallic mold; a packing device that packs a foamed sand, which has been foamed by stirring a binder with an aggregate, into the cavity; and a heating device that heats the foamed sand within the cavity, wherein the mold clamping device slightly opens the metallic mold after the foamed sand has been packed into the cavity so as to form a gap in the metallic mold while maintaining the cavity.

(5) The sand-mold molding apparatus according to (4), wherein the mold clamping device reduces a mold clamping force so that the gap is provided in the metallic mold by a counterforce from the metallic mold.

(6) The sand-mold molding apparatus according to (4) or (5), wherein the gap in the metallic mold ranges from 0.22 mm to 0.36 mm.

With the structure of (1) and (4), by providing a fine gap in the metallic mold, water vapor and gas are smoothly discharged to the outside from the gap in the metallic mold during heating and hardening of the foamed sand within the cavity of the metallic mold, and thus the hardening time can be shortened. Even if solidified binder accumulates in a passage through which water vapor and gas are discharged from the cavity of the metallic mold, the water vapor and gas can be reliably discharged to the outside from the cavity by the gap in the metallic mold.

At this time, since the gap in the metallic mold is sufficiently small and the shape and dimensions of the cavity are maintained, the dimensional precision of the molded article is not affected.

With the structure of (2) and (5), the gap in the metallic mold can be adjusted according to a counterforce from the metallic mold.

With the structure of (3) and (6), the gap can be optimized to carry out preferable molding.

(7) The sand-mold molding apparatus of (5) or (6), in which the mold clamping device clamps the metallic mold by an air cylinder and reduces a pressure of compressed air supplied to the air cylinder so as to reduce a mold clamping force.

Advantageous Effects of Invention

[0011] According to the present invention, water vapor and gas can be smoothly discharged from within the cavity through a gap in the metallic mold during heating and hardening of foamed sand within a cavity of a metallic mold, and thereby the hardening time can be shortened.

Brief Description of Drawings

[0012]

FIG. 1 is a schematic view illustrating a sand-mold molding apparatus according to an embodiment of the present invention;

FIGS. 2A to 2C illustrate the steps for molding foamed sand with the sand-mold molding apparatus shown in FIG. 1;

FIG. 3 is a table illustrating the relationship between a mold clamping set pressure and a gap in a metallic mold in the sand-mold molding apparatus shown in FIG. 1;

FIG. 4 is a graph illustrating the relationship between a mold clamping set pressure and a gap in a metallic mold in the sand-mold molding apparatus shown in FIG. 1;

FIG. 5 is a table illustrating the relationship between a mold clamping set pressure and the quality of a molded article in the sand-mold molding apparatus shown in FIG. 1;

FIGS. 6A and 6B are image views illustrating a composition of foamed sand; and

FIGS. 7A and 7B are explanatory views illustrating the course of heating and hardening of foamed sand within a cavity of a metallic mold.

Embodiments for carrying out the Invention

[0013] An embodiment of the present invention will now be explained below in detail based on the drawings.

[0014] As shown in FIG. 1, a sand-mold molding apparatus 1 according to the present embodiment solidifies foamed sand to mold a sand core (sand mold), and includes a metallic mold 2 that forms a cavity C, a packing device 3 for packing foamed sand S into the cavity C of the metallic mold 2, and a mold clamping device 4 that opens and closes the metallic mold 2.

[0015] The foamed sand S used in the present embodiment is obtained by mixing and kneading sand, which serves as an aggregate, with a water-soluble inorganic

binder including water glass (sodium silicate), water, and a surfactant to foam the sand. An image of the state of the particles that constitute the foamed sand S is shown in FIGS. 6A and 6B. FIG. 6A illustrates a state in which bubbles 8 are adsorbed to the surface of a sand particle 7, and FIG. 6B illustrates an enlarged portion of a bubble 8. As shown in FIG. 6B, the foamed sand S is foamed by coating the surface of a water glass aqueous solution (10 denotes water and 11 denotes water glass) with a surfactant 9 to form bubbles 8 and then adsorbing the bubbles 8 to the surface of a sand particle 7 via the surfactant 9, and the foamed sand S has suitable viscosity. Herein, the foamed sand S having suitable viscosity can be obtained by setting the molar ratio and weight ratio of the water glass relative to the sand to approximately 1.0 to 3.0 and 0.4 to 3.0% respectively, setting the weight ratio of the water relative to the sand to approximately 1.5 to 5.0%, and setting the weight ratio of the surfactant relative to the sand to approximately 0.003 to 2.0%.

[0016] Referring to FIG. 1, the metallic mold 2 includes a stationary mold 12 and a movable mold 13 that are divided by a parting line P. A cavity C is formed by clamping the stationary mold 12 and the movable mold 13. The stationary mold 12 is fixed to a stationary base 14. The movable mold 13 is fixed to a movable base 15 that is movable, and the movable mold 13 moves together with the movable base 15 to open and close the metallic mold 2. The stationary mold 12 and the movable mold 13 are heated to approximately 150°C to 300°C by a heating device H such as a heater, and thereby moisture of the foamed sand S packed into the cavity C is evaporated to solidify the foamed sand S. In the metallic mold 2, discharge passages such as slits 16 for discharging gas and water vapor to the outside during heating and hardening of the foamed sand S may be provided within the cavity C.

[0017] A releasing device 17 is provided to each of the stationary mold 12 and the movable mold 13 of the metallic mold 2. Each releasing device 17 includes a plurality of extruding pins 18 provided such that they can move towards/away from the inside of the cavity C, an extruding plate 19 connected to the bases of the plurality of extruding pins 18, and an extruding spring 20 provided between the fixed base 14/movable base 15 and the extruding plate 19. The plurality of extruding pins 18 are compressed via the extruding plate 19 by the spring force of the extruding spring 20 to make the distal ends of the extruding pins 18 protrude into the cavity C. Retracting pins 21 whose distal ends oppose each other are attached to the extruding plates 19 on both sides. When the stationary mold 12 and the movable mold 13 are closed, the distal ends of the retracting pins 21 abut each other to move the extruding plates 19 counter to the spring force of the extruding springs 20, which causes the extruding pins 18 to retract from the cavity C. Thereby, the extruding pins 18 move together with the opening/closing of the metallic mold 2, such that they retract from within the cavity C when the metallic mold 2 is

closed, and protrude into the cavity C when the metallic mold 2 is opened to release the molded core.

[0018] The packing device 3 includes a sand tank 22 in which the foamed sand S is kneaded and stored, a pressurization mechanism 23 that pressurizes the foamed sand S within the sand tank 22, and a packing port 24 that connects the sand tank 22 to the cavity C of the metallic mold 2. The sand tank 22 is set onto the metallic mold 2 upon closing and clamping the stationary mold 12 and the movable mold 13, and by pressurizing the foamed sand S within the sand tank 22 by the pressurization mechanism 23, the foamed sand S is packed into the cavity C of the metallic mold 2 through the packing port 24.

[0019] The mold clamping device 4 includes a double-acting air cylinder 26 that drives the movable base 15, an air source 27 that supplies compressed air to the air cylinder 26, a switching valve 28 that switches the supply of compressed air from the air source 27 to the air cylinder 26 to make the movable base 15 advance forward or retract backward, a pressure adjusting valve 29 that adjusts the pressure of the compressed air to be supplied to the air cylinder, a pressure gauge 30 that detects the pressure of the compressed air supplied to the air cylinder 26, and a control device 31 that controls the operation of the switching valve 28 and the pressure adjusting valve 29.

[0020] The control device 31 controls the switching valve 28 to switch the supply of compressed air so as to elongate/retract an activation rod 26A of the double-acting air cylinder 26. Thereby, the movable mold 13 is made to advance/retract together with the movable base 15 to open/close the metallic mold 2. The pressure adjusting valve 29 is operated based on a detected pressure of the pressure gauge 30 during mold clamping to adjust the pressure of the compressed air to be supplied to the air cylinder 26, and thereby the mold clamping force is adjusted. Thereby, when heating and hardening the foamed sand S within the cavity C of the metallic mold 2, if the mold clamping force by the air cylinder 26 is decreased, the movable mold 13 will retract slightly due to the pressure within the cavity C, the spring force of the extruding springs 20 of the releasing devices 17, and a counterforce by warping of the metallic mold 2. Thus, a fine gap L (refer to FIG. 2C) is formed on the parting line P between the stationary mold 12 and the movable mold 13, and this gap L can be adjusted.

[0021] Next, the steps for molding a sand core with the sand-mold molding apparatus 1 will be explained.

[0022] As shown in FIG. 2A, the movable mold 13 is driven by the mold clamping device 4 to close and clamp the metallic mold 2 to form the cavity C, and then the packing device 3 is set onto the metallic mold 2. At this time, the extruding pins 18 of the releasing devices 17 move together with the mold clamping so as to retract from the cavity C as explained above. In a state in which the metallic mold 2 has been preheated by the heating device H, the pressurization mechanism 23 of the pack-

ing device 3 is operated to pack the foamed sand S within the sand tank 22 into the cavity C of the heated metallic mold 2 through the packing port 24. FIG. 2B illustrates a state in which the packing of the foamed sand S into the cavity C has been completed. The foamed sand S that has been packed into the cavity C of the metallic mold 2 is then hardened by evaporating the moisture therein via heating.

[0023] Herein, the course of heating and hardening the foamed sand S packed into the cavity C will now be explained referring to FIGS. 7A and 7B. As shown in FIG. 7A, in the cavity C of the metallic mold 2, the air bubbles 8 of the foamed sand S expand due to heating, leading to an increase in the internal pressure of the cavity C. As shown in FIG. 7B, the air bubbles 8 move along the inner wall of the cavity C of the metallic mold 2 and are discharged to the outside via the passages formed by the slits 16 or the like that are provided on the parting line P. At this time, the water glass (binder) and aggregate that constitute the foamed sand S are pushed towards the inner wall side of the cavity C, and thus the density of water glass and aggregate near the inner wall of the cavity C increases. As a result, in a sand core W that has solidified within the cavity C, a dense hardened layer 33 in which the density of the water glass and the aggregate is high is formed in a surface layer part that is in contact with the inner wall of the cavity C, whereas the inner density is low such that an easily-collapsible brittle part 34 is formed in a center part.

[0024] The water glass (binder) that is pushed toward the inner wall side of the cavity C penetrates into the passages consisting of the slits 16 or the like together with the water vapor and gas and is released to the outside. Binder that has penetrated into the passages may harden and adhere to the passages. If the passages become blocked due to accumulation of binder that adheres to the passages, the smooth discharge of water vapor and gas may become obstructed, leading to an increase in the baking time and poor molding.

[0025] In the present embodiment, after completion of packing of the foamed sand S into the cavity C of the metallic mold 2, the pressure adjusting valve 29 is operated by the control device 31 of the mold clamping device 4 based on the detected pressure of the pressure gauge 30 to reduce the pressure of the compressed air supplied to the air cylinder 26 by a predetermined pressure so as to decrease the mold clamping force. Thereby, as shown in FIG. 2C, the movable mold 13 retracts slightly due to the pressure within the cavity C that has increased due to heating and hardening of the foamed sand S, the spring force of the extruding springs 20 of the releasing devices 17, and a counterforce by warping of the metallic mold 2. Thus, a fine gap L is formed on the parting line P between the stationary mold 12 and the movable mold 13. Gas and water vapor that are generated during heating and hardening of the foamed sand S within the cavity C of the metallic mold 2 is smoothly discharged to the outside through the fine gap L. As a result, solidification of

the foamed sand S can be accelerated, and the baking time can be shortened.

[0026] At this time, the fine gap L is a slight gap of a size such that gas and water vapor can be smoothly discharged, and the amount of movement of the movable mold 13 is also small. Thus, the shape and dimensions of the cavity C are maintained, and the shape and dimensional precision of the core that is molded is not affected. Also, since the movable mold 13 is moved slightly by the pressure within the cavity C, the spring force of the extruding springs 20 of the releasing devices 17, and a counterforce by warping of the metallic mold 2 to form the fine gap L between the stationary mold 12 and the movable mold 13, a constant fine gap L can be secured regardless of the amount of accumulation of binder on the parting line P or the slits 16 in the metallic mold 2. As a result, gas and water vapor that are generated during heating and hardening of the foamed sand S can be reliably discharged to the outside, and thus the baking time can be shortened and a molded article of good quality can be obtained.

[0027] After the foamed sand S within the cavity C of the metallic mold 2 has solidified, the switching valve 28 is operated by the control device 31 to switch the supply of compressed air to the double-acting air cylinder 26 and make the movable mold 13 retract together with the movable base 15 so as to open the metallic mold 2 and remove the molded sand core. At this time, the distal ends of the retracting pins 21 of the releasing devices 17 separate from each other together with the mold opening, and thus the extruding plates 19 move by the spring force of the extruding springs 20 and the extruding pins 18 protrude into the cavity C to release the molded sand core.

[0028] Next, in the above-described steps, the relationships between the pressure of the compressed air supplied to the air cylinder 26 when forming the gap L on the parting line P in the metallic mold 2 (refer to FIG. 2C) with the size of the gap L and with the quality of the sand core that is molded will be explained referring to FIGS. 3 to 5.

[0029] As shown in FIGS. 3 and 4, by reducing the pressure of the compressed air supplied to the air cylinder 26 during mold clamping from a pressure of 0.35 MPa to a pressure of 0.15 MPa, 0.10 MPa, and 0.05 MPa, the gap L became on average 0.22 mm, 0.25 mm, and 0.36 mm respectively. Thereby, as shown in FIG. 5, when the pressure of the compressed air that is supplied was kept unchanged at 0.35 MPa during mold clamping so that no gap L is provided, 60% of the molded articles were of good quality and 40% were of poor quality, whereas when the pressure of the compressed air that is supplied was reduced to 0.10 MPa so that the gap L is provided, 80% of the molded articles were of good quality and 20% were of poor quality. When the pressure of the compressed air that is supplied was further reduced to 0.05 MPa so as to increase the gap L, 100% good quality could be obtained.

[0030] In the above-described embodiment, the pres-

sure of compressed air supplied to the air cylinder 26 of the mold clamping device 4 (the mold clamping force) is reduced to form the gap L between the stationary mold 12 and the movable mold 13 by warping in the metallic mold 2. However, a predetermined gap L can also be formed by directly controlling the amount of movement of the movable mold 13.

6. The sand-mold molding apparatus according to claim 4 or claim 5, wherein the gap in the metallic mold ranges from 0.22 mm to 0.36 mm.

Explanation for References

[0031] 1: Sand-mold Molding Apparatus 2: Metallic Mold C: Cavity H: Heating Device L: Gap S: Foamed Sand

Claims

1. A sand-mold molding method in which a molded article is obtained by packing foamed sand, which has been foamed by stirring a binder with an aggregate, into a cavity of a metallic mold and then heating and solidifying the foamed sand, wherein, after forming the cavity by clamping the metallic mold and packing the foamed sand into the cavity, the metallic mold is opened slightly to provide a gap in the metallic mold while maintaining the cavity.
2. The sand-mold molding method according to claim 1, wherein a mold clamping force of the metallic mold is reduced so that the gap is provided in the metallic mold by a counterforce from the metallic mold.
3. The sand-mold molding method according to claim 1 or claim 2, wherein the gap in the metallic mold ranges from 0.22 mm to 0.36 mm.
4. A sand-mold molding apparatus comprising:
 - a metallic mold in which a cavity is formed by mold clamping;
 - a mold clamping device that opens/closes the metallic mold;
 - a packing device that packs a foamed sand, which has been foamed by stirring a binder with an aggregate, into the cavity; and
 - a heating device that heats the foamed sand within the cavity,
 - wherein the mold clamping device slightly opens the metallic mold after the foamed sand has been packed into the cavity so as to form a gap in the metallic mold while maintaining the cavity.
5. The sand-mold molding apparatus according to claim 4, wherein the mold clamping device reduces a mold clamping force so that the gap is provided in the metallic mold by a counterforce from the metallic mold.

FIG. 1

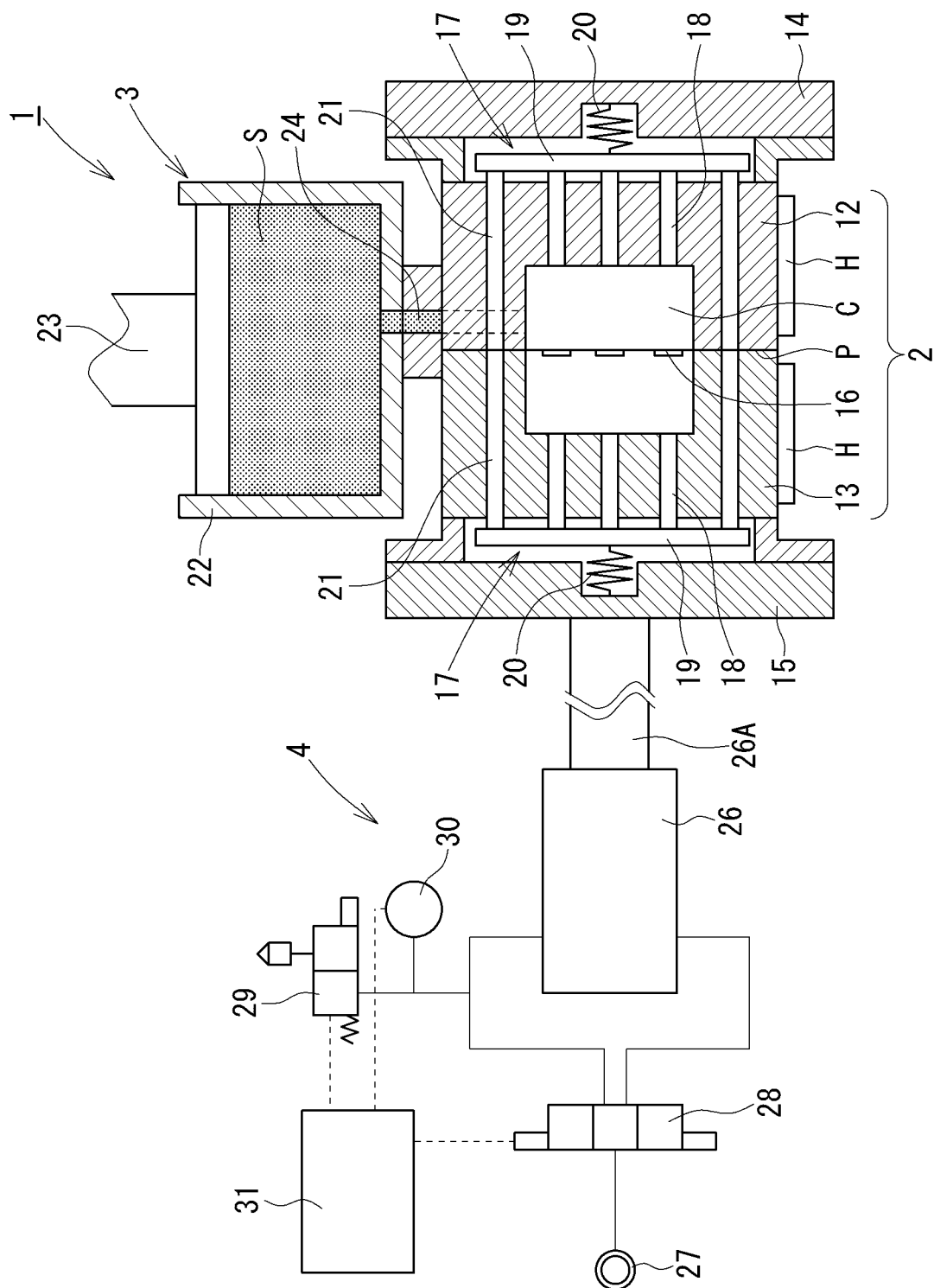


FIG. 2

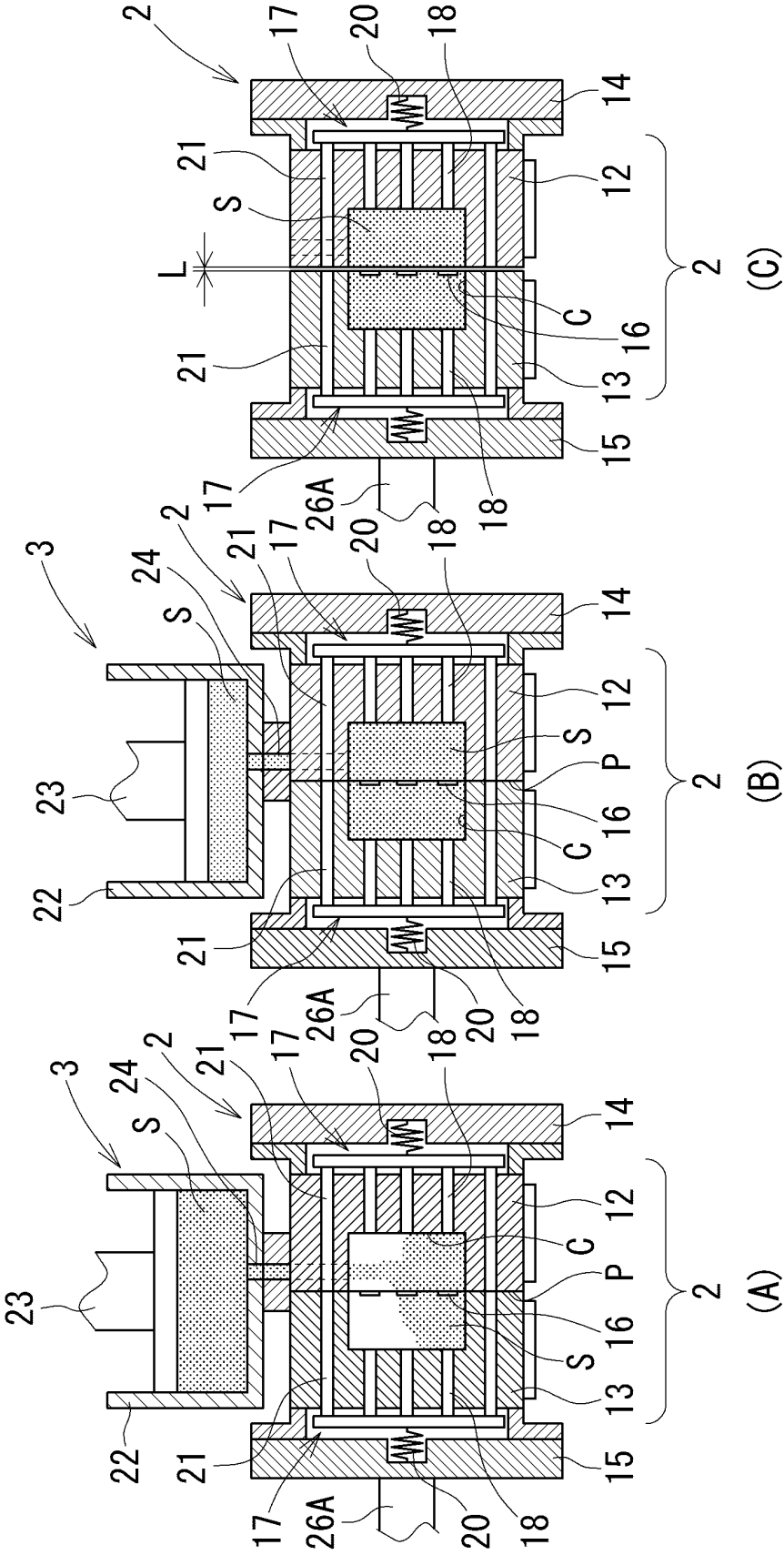


FIG. 3

MOLD CLAMPING PRESSURE (MPa)	GAP L (mm)		
	AVERAGE	MAXIMUM	MINIMUM
0.15	0.22	0.26	0.18
0.10	0.25	0.30	0.18
0.05	0.36	0.43	0.31

FIG. 4

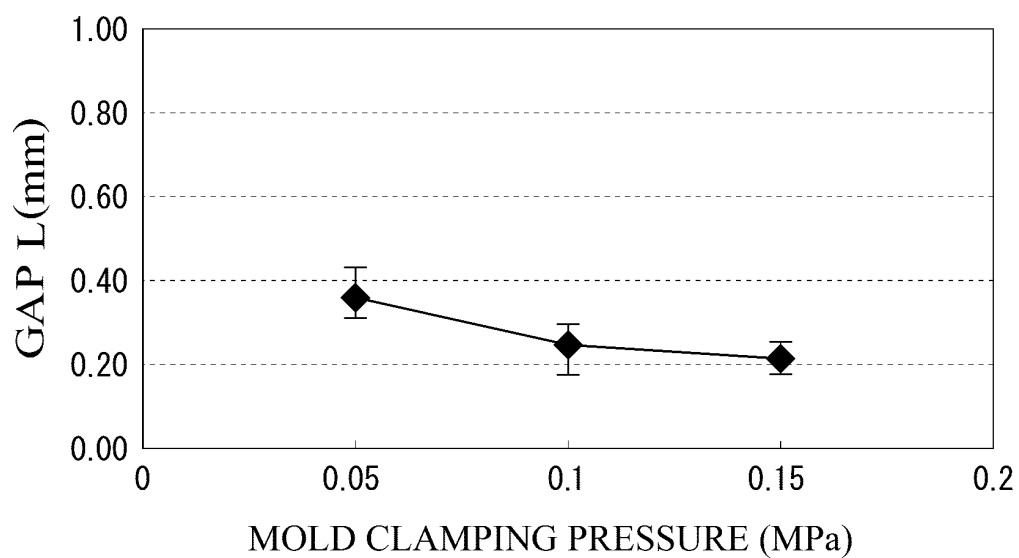


FIG. 5

		POOR QUALITY	GOOD QUALITY
MOLD CLAMPING PRESSURE (MPa)	0.35	40%	60%
PRESSURE DURING REDUCED PRESSURE (MPa)	0.10	20%	80%
	0.05	0%	100%

FIG. 6

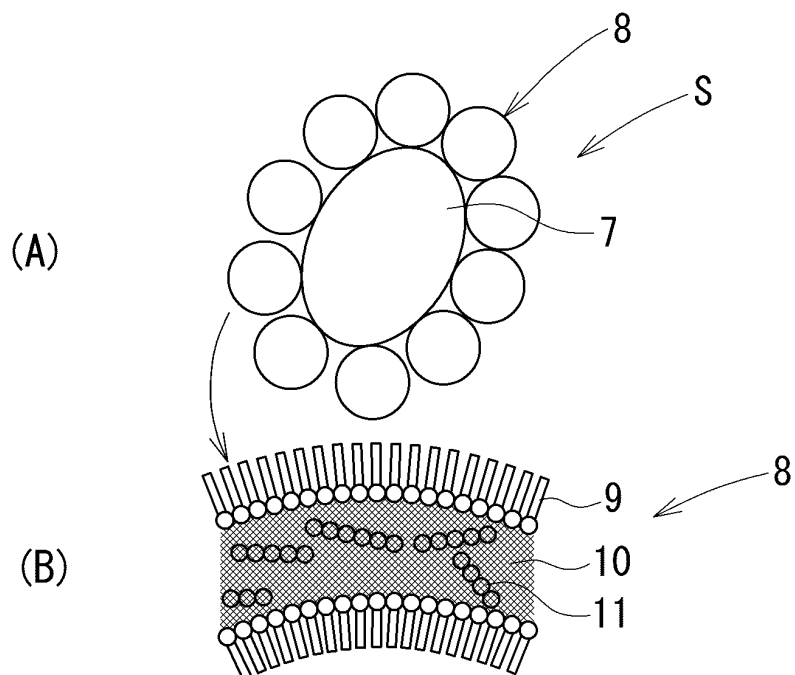
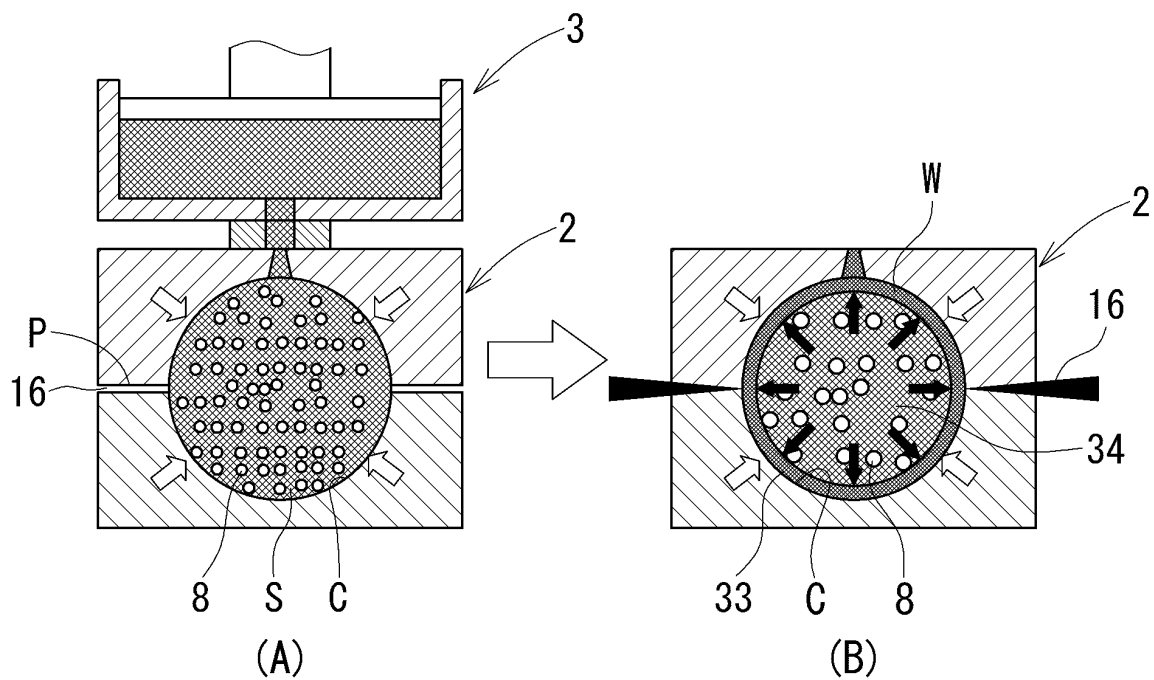


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/051273

A. CLASSIFICATION OF SUBJECT MATTER

B22C9/02 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B22C9/02

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2014

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2007-522947 A (Hormel Foods, LLC), 16 August 2007 (16.08.2007), all pages; all drawings & US 2005/0178520 A1 & EP 1720674 A1 & WO 2005/081785 A2	1-6
A	JP 10-263745 A (Noritake Co., Ltd.), 06 October 1998 (06.10.1998), all pages; all drawings (Family: none)	1-6

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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Date of the actual completion of the international search
27 March, 2014 (27.03.14)Date of mailing of the international search report
08 April, 2014 (08.04.14)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

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

REFERENCES CITED IN THE DESCRIPTION

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