



EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
25.01.2023 Bulletin 2023/04

(21) Application number: **21771772.7**

(22) Date of filing: **13.01.2021**

(51) International Patent Classification (IPC):
B21D 26/033 ^(2011.01) **B21D 22/20** ^(2006.01)
B21D 24/00 ^(2006.01) **B21D 37/16** ^(2006.01)

(52) Cooperative Patent Classification (CPC):
B21D 22/20; B21D 24/00; B21D 26/033;
B21D 37/16

(86) International application number:
PCT/JP2021/000860

(87) International publication number:
WO 2021/186863 (23.09.2021 Gazette 2021/38)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **17.03.2020 JP 2020046649**

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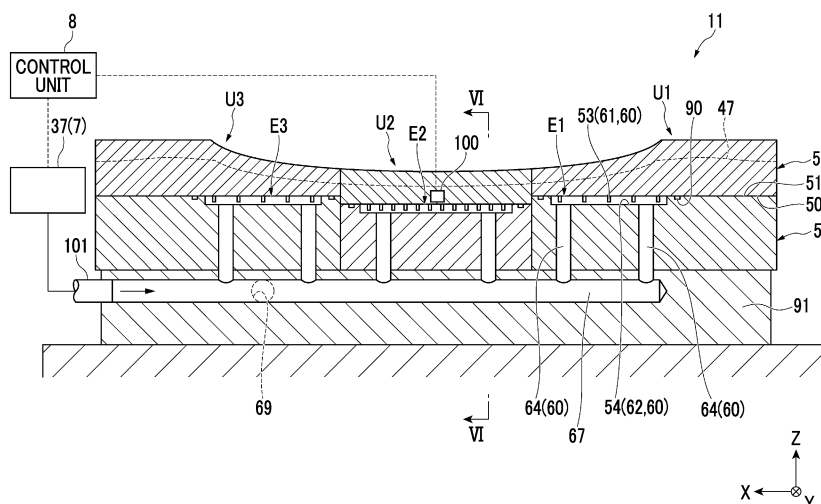
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(54) **MOLDING DEVICE AND MOLDING METHOD**

(57) Provided is a forming device that forms a heated metal material. The forming device includes a die that performs quench forming by coming into contact with the metal material; and a cooling unit that cools the die. The

cooling unit suppresses deterioration in hardenability to the metal material resulting from accumulation of heat to the die caused by repeated forming.

FIG. 5



Description

Solution to Problem

Technical Field

[0001] One aspect of the present invention relates to a forming device and a forming method.

Background Art

[0002] In the related art, forming devices that form a heated metal material have been known. For example, the following Patent Document 1 discloses a forming device including a die having a lower die and an upper die paired with each other, a gas supply portion that supplies gas into a metal pipe material held between the dies, and a heating unit that heats the metal pipe material by energization and heating. Such a forming device includes a cooling unit that causes water to flow through a flow path formed in the die in order to cool the heated metal pipe during forming. Accordingly, the forming device can perform quench forming by bringing the cooled die into contact with the metal pipe material.

Citation List

Patent Literature

[0003] [PTL 1] Japanese Unexamined Patent Publication No. 2009-220141

Summary of Invention

Technical Problem

[0004] The forming device as in the above related art performs quench forming of a new heated metal material when the quench forming of the heated metal material is completed. In this way, the forming device repeatedly performs the quench forming of the heated metal material. That is, the die repeatedly comes into contact with the metal material in a high-temperature state. In contrast, in the related art, it has not been considered that the repeated forming is performed in a case where the cooling unit cools the die. In this case, there is a possibility that heat is gradually accumulated in the die and hardenability to the metal material deteriorates. Accordingly, in a case where the repeated forming is performed, a problem occurs in that the stability of the quality of the formed product such as hardenability and formability deteriorate.

[0005] One aspect of the present invention has been made to solve such a problem, and an object of the present invention is to provide a forming device and a forming method capable of improving the stability of the quality of a formed product in a case where repeated forming is performed.

[0006] A forming device according to one aspect of the present invention is a forming device that forms a heated metal material. The forming device includes a die that performs quench forming by coming into contact with the metal material, and a cooling unit that cools the die. The cooling unit suppresses deterioration in hardenability to the metal material resulting from accumulation of heat to the die caused by repeated forming.

[0007] Such a forming device has the die that performs the quench forming by coming into contact with the metal material. The temperature of the die rises as the die and the heated metal material come into contact with each other. In contrast, as the cooling unit cools the die, the die can be brought into a state in which the quench forming is possible. Moreover, the cooling unit suppresses the deterioration of the hardenability to the metal material resulting from the accumulation of heat to the die caused by the repeated forming. Therefore, even though the die repeatedly receives the heat input from the metal material as the forming is repeated, the die can perform the repeated quench forming without deteriorating the hardenability. From the above, the forming device can improve the stability of the quality of the formed product in a case where the repeated forming is performed.

[0008] The cooling unit may make the temperatures of the die fall within a predetermined range. In this case, the cooling unit can make the pattern of temperature change of the die during forming close to constant. Therefore, the forming device can improve the stability of the quality of the formed product.

[0009] The cooling unit may increase a cooling capacity as the number of times of forming of the die increases. As the number of times of forming of the die increases, heat is more likely to be accumulated in the die. Therefore, the cooling unit can suppress the accumulation of heat in the die by increasing the cooling capacity as the number of times of forming of the die increases.

[0010] The cooling unit may increase a cooling capacity as a forming time of the die becomes longer. The longer the forming time of the die, the more easily heat is accumulated in the die. Therefore, the cooling unit can suppress the accumulation of heat to the die by increasing the cooling capacity as the forming time of the die becomes longer.

[0011] The forming device may include a temperature sensor that detects the temperatures of the die, and the cooling unit may adjust a cooling capacity on the basis of a detection result of the temperature sensor. In this case, the cooling unit can make the die have an appropriate temperature depending on the temperature of the die.

[0012] A forming device according to one aspect of the present invention is a forming device that forms a heated metal material. The forming device includes a die that performs quench forming by coming into contact with the metal material, and a cooling unit that cools the die. The

cooling unit makes an amount of heat removed from the die larger than an amount of input heat from the metal material to the die.

[0013] Such a forming device has the die that performs the quench forming by coming into contact with the metal material. The temperature of the die rises as the die and the heated metal material come into contact with each other. In contrast, as the cooling unit cools the die, the die can be brought into a state in which the quench forming is possible. Moreover, the cooling unit makes the amount of heat removed from the die larger than the amount of heat input to the die from the metal material. In this case, the cooling unit can suppress the temperature rise of the die or lower the temperature of the die that have risen. Accordingly, in a case where the repeated forming is performed, a change in hardenability resulting from the temperature of the die becoming excessively high can be suppressed. From the above, the forming device performs the repeated forming.

[0014] In this case, the stability of the quality of the formed product can be improved.

[0015] A forming method according to one aspect of the present invention may be a forming method of forming a heated metal material. The forming method may include a forming process of performing quench forming by bringing the metal material into contact with a die and a cooling process of cooling the die. In the cooling process, deterioration of hardenability to the metal material resulting from accumulation of heat to the die caused by repeated forming may be suppressed.

[0016] According to this forming method, it is possible to obtain the operation and effects having the same meaning as that of the above-described forming device.

[0017] A forming method according to one aspect of the present invention is a forming method of forming a heated metal material. The forming method includes a forming process of performing quench forming by bringing the metal material into contact with a die, and a cooling process of cooling the die. In the cooling process, an amount of heat removed from the die is made larger than an amount of input heat from the metal material to the die.

[0018] According to this forming method, it is possible to obtain the operation and effects having the same meaning as that of the above-described forming device.

Advantageous Effects of Invention

[0019] According to one aspect of the present invention, it is possible to provide the forming device capable of improving the stability of the quality of the formed product in a case where the repeated forming is performed.

Brief Description of Drawings

[0020]

Fig. 1 is a schematic diagram of a forming device according to an embodiment of the present inven-

tion.

Figs. 2A and 2B are enlarged cross-sectional views showing a state of a metal pipe material and a die during blow forming.

Fig. 3 is a plan view of a die.

Fig. 4 is a plan view of the die showing a state in which a first member is removed.

Fig. 5 is a cross-sectional view taken along line V-V shown in Fig. 3.

Fig. 6 is a cross-sectional view taken along line VI-VI shown in Fig. 5.

Figs. 7A and 7B are enlarged views of a flow path.

Figs. 8A and 8B are graphs showing a relationship between time and the temperature change of the die.

Figs. 9A and 9B are graphs showing a relationship between time and the temperature change of the die.

Figs. 10A and 10B are cross-sectional views showing a die of a forming device according to a modification example.

Description of Embodiments

[0021] Hereinafter, preferred embodiments of the present invention will be described with reference to the drawings. In addition, in the respective drawings, the same portions or corresponding portions are designated by the same reference numerals, and duplicated descriptions will be omitted.

[0022] Fig. 1 is a schematic diagram of a forming device 1 according to the present embodiment. As shown in Fig. 1, the forming device 1 is a device that forms a metal pipe having a hollow shape by blow forming. In the present embodiment, the forming device 1 is installed on a horizontal plane. The forming device 1 includes a forming die 2, a drive mechanism 3, a holding unit 4, a heating unit 5, a fluid supply unit 6, a cooling unit 7, and a control unit 8. In addition, in the present specification, the metal pipe refers to a hollow article after the forming in the forming device 1 is completed, and a metal pipe material 40 (metal material) refers to a hollow article before the forming in the forming device 1 is completed. The metal pipe material 40 is a steel type pipe material that can be hardened. Additionally, in the horizontal direction, a direction in which the metal pipe material 40 extends during forming may be referred to as a "longitudinal direction", and a direction perpendicular to the longitudinal direction may be referred to as a "width direction".

[0023] The forming die 2 is a die that forms the metal pipe material 40 into a metal pipe, and includes a lower die 11 and an upper die 12 that face each other in the vertical direction. The lower die 11 and the upper die 12 are made of steel blocks. Each of the lower die 11 and the upper die 12 is provided with a recessed portion in which the metal pipe material 40 is accommodated. With the lower die 11 and the upper die 12 in close contact with each other (die closed state), respective recessed portions thereof form a space having a target shape in which the metal pipe material is to be formed. Therefore,

the surfaces of the respective recessed portions become the forming surfaces of the forming die 2. The lower die 11 is fixed to a base stage 13 via a die holder or the like. The upper die 12 is fixed to a slide of the drive mechanism 3 via a die holder or the like.

[0024] The drive mechanism 3 is a mechanism that moves at least one of the lower die 11 and the upper die 12. In Fig. 1, the drive mechanism 3 has a configuration in which only the upper die 12 is moved. The drive mechanism 3 includes a slide 21 that moves the upper die 12 such that the lower die 11 and the upper die 12 are joined together, and a pull-back cylinder 22 serving as an actuator that generates a force for pulling the slide 21 upward, a main cylinder 23 serving as a drive source that downward-pressurizes the slide 21, and a drive source 24 that applies a driving force to the main cylinder 23.

[0025] The holding unit 4 is a mechanism that holds the metal pipe material 40 disposed between the lower die 11 and the upper die 12. The holding unit 4 includes a lower electrode 26 and an upper electrode 27 that hold the metal pipe material 40 on one end side in the longitudinal direction of the forming die 2, and a lower electrode 26 and an upper electrode 27 that holds the metal pipe material 40 on the other end side in the longitudinal direction of the forming die 2. The lower electrodes 26 and the upper electrodes 27 on both sides in the longitudinal direction hold the metal pipe material 40 by sandwiching the vicinity of an end portion of the metal pipe material 40 from the vertical direction. In addition, groove portions having a shape corresponding to an outer peripheral surface of the metal pipe material 40 are formed on an upper surface of the lower electrode 26 and a lower surface of the upper electrode 27. The lower electrode 26 and the upper electrode 27 are provided with drive mechanisms (not shown) and are movable independently in the vertical direction.

[0026] The heating unit 5 heats the metal pipe material 40. The heating unit 5 is a mechanism that heats the metal pipe material 40 by energizing the metal pipe material 40. The heating unit 5 heats the metal pipe material 40 in a state in which the metal pipe material 40 is spaced apart from the lower die 11 and the upper die 12 between the lower die 11 and the upper die 12. The heating unit 5 includes the lower electrodes 26 and the upper electrodes 27 on both sides in the longitudinal direction described above, and a power supply 28 that allows an electric current to flow to the metal pipe material through the electrodes 26 and 27. In addition, the heating unit may be disposed in the previous process of the forming device 1 and performs heating externally.

[0027] The fluid supply unit 6 is a mechanism that supplies a high-pressure fluid into the metal pipe material 40 held between the lower die 11 and the upper die 12. The fluid supply unit 6 supplies the high-pressure fluid to the metal pipe material 40 that has been brought into a high-temperature state by being heated by the heating unit 5, and expands the metal pipe material 40. The fluid supply unit 6 is provided on both end sides of the forming die 2

in the longitudinal direction. The fluid supply unit 6 includes a nozzle 31 that supplies fluid from an opening of an end portion of the metal pipe material 40 to the inside of the metal pipe material 40, a drive mechanism 32 that moves the nozzle 31 forward and backward with respect to the opening of the metal pipe material 40, and a supply source 33 that supplies the high-pressure fluid into the metal pipe material 40 via the nozzle 31. In the drive mechanism 32, the nozzle 31 is brought into close contact with the end portion of the metal pipe material 40 in a state in which the sealing performance is secured during fluid supply and exhaust, and at other times, the nozzle 31 is spaced apart from the end portion of the metal pipe material 40. In addition, the fluid supply unit 6 may supply a gas such as high-pressure air or an inert gas as the fluid. Additionally, the fluid supply unit 6 may be the same device including the heating unit 5 together with the holding unit 4 having a mechanism that moves the metal pipe material 40 in the vertical direction.

[0028] The cooling unit 7 is a mechanism that cools the forming die 2. By cooling the forming die 2, the cooling unit 7 can rapidly cool the metal pipe material 40 when the expanded metal pipe material 40 has come into contact with a forming surface of the forming die 2. The cooling unit 7 includes a flow path 36 formed inside the lower die 11 and the upper die 12, and a circulation mechanism 37 that supplies and circulates a cooling medium to the flow path 36.

[0029] The control unit 8 is a device that controls the entire forming device 1. The control unit 8 controls the drive mechanism 3, the holding unit 4, the heating unit 5, the fluid supply unit 6, and the cooling unit 7. The control unit 8 repeatedly performs an operation of forming the metal pipe material 40 with the forming die 2.

[0030] Specifically, the control unit 8 controls, for example, the transport timing from a transport device such as a robot arm to dispose the metal pipe material 40 between the lower die 11 and the upper die 12 in an open state. Alternatively, the control unit 8 may wait for a worker to manually dispose the metal pipe material 40 between the lower die 11 and the upper die 12. Additionally, the control unit 8 supports the metal pipe material 40 with the lower electrodes 26 on both sides in the longitudinal direction and then controls the actuator of the holding unit 4 so as to lower the upper electrode 27 to sandwich the metal pipe material 40. Additionally, the control unit 8 controls the heating unit 5 to energize and heat the metal pipe material 40. Accordingly, an axial electric current flows through the metal pipe material 40, and the electric resistance of the metal pipe material 40 itself causes the metal pipe material 40 itself to generate heat due to Joule heat.

[0031] The control unit 8 controls the drive mechanism 3 to lower the upper die 12 and bring the upper die 12 closer to the lower die 11 to close the forming die 2. On the other hand, the control unit 8 controls the fluid supply unit 6 to seal the openings of both ends of the metal pipe material 40 with the nozzle 31 and supply the fluid. Ac-

cordingly, the metal pipe material 40 softened by heating expands and comes into contact with the forming surface of the forming die 2. Then, the metal pipe material 40 is formed so as to follow the shape of the forming surface of the forming die 2. In addition, in a case where a metal pipe with a flange is formed, a part of the metal pipe material 40 is made to enter a gap between the lower die 11 and the upper die 12, and then the die is further closed to crush the entering portion to form a flange portion. When the metal pipe material 40 comes into contact with the forming surface, hardening of the metal pipe material 40 is performed by being quenched with the forming die 2 cooled by the cooling unit 7. Such a cooling method is referred to as die contact cooling or die cooling. Immediately after being quenched, austenite is transformed into martensite (hereinafter, the transformation of austenite into martensite is referred to as martensitic transformation). Since the cooling rate decreased in the latter half of the cooling, martensite is transformed into another tissue (troostite, sorbite, or the like) by recuperation. Therefore, it is not necessary to perform a separate tempering treatment. In addition, the content of control of the cooling unit 7 by the control unit 8 will be described below.

[0032] A forming procedure of the forming device 1 will be described with reference to Figs. 2A and 2B. As shown in Fig. 2A, the control unit 8 performs blow forming (primary blowing) by closing the forming die 2 and supplying the fluid to the metal pipe material 40 by the fluid supply unit 6. In the primary blowing, the control unit 8 forms a pipe portion 43 at a main cavity portion MC and causes a portion corresponding to a flange portion 44 to enter a sub-cavity portion SC. Then, as shown in Fig. 2B, the control unit 8 forms the flange portion 44 by further closing the forming die 2 and further crushing the portion that has entered the sub-cavity portion SC. Next, the control unit 8 performs die opening by raising the upper die 12 to space the upper die 12 apart from the metal pipe material 40. Accordingly, the metal pipe 41 is formed.

[0033] Next, the detailed configuration of the die 11 will be described with reference to Figs. 3 to 6. In addition, in the following description, the lower die 11 will be described. However, since the explanation having the same meaning is also valid for the upper die 12, the description will be omitted. Fig. 3 is a plan view of the die 11. Fig. 4 is a plan view of the die 11 showing a state in which the first member 50 is removed. Fig. 5 is a cross-sectional view taken along line V-V shown in Fig. 3. Fig. 6 is a cross-sectional view taken along line VI-VI shown in Fig. 5.

[0034] In addition, in the present embodiment, the forming device 1 can simultaneously form two metal pipe materials 40. Therefore, as shown in Fig. 3, the die 11 has a forming surface 47 that forms the two metal pipe materials 40 arranged in parallel with each other (see also Figs. 2A and 2B). In addition, the number of metal pipe materials 40 to be arranged is not limited, and may be one or three or more. The forming surface 47 has a

shape extending in the longitudinal direction so as to correspond to the longitudinal direction of the metal pipe material 40. In the following description, the longitudinal direction of the forming surface 47 may be referred to as an X-axis direction, the horizontal direction perpendicular to the longitudinal direction may be referred to as a Y-axis direction, and the vertical direction may be referred to as a Z-axis direction. Additionally, one side in the longitudinal direction is referred to as a positive side in the X-axis direction, one side in the direction perpendicular to the longitudinal direction is referred to as a positive side in the Y-axis direction, and the upper side is referred to as a positive side in the Z-axis direction.

[0035] As shown in Figs. 4 and 5, the die 11 is divided into three units U1, U2, and U3 in order from the positive side in the X-axis direction. The unit U2 is a unit corresponding to the central position of the die 11 in the X-axis direction. The units U1 and U3 are units on both end sides in the X-axis direction. The respective units U1, U2, and U3 have a cooling region E1 (first region), a cooling region E2 (second region), and a cooling region E3 (third region), respectively. The entire circumference of each of the cooling regions E1, E2, and E3 is surrounded in a plan view by a seal groove portion 90 in which an O-ring is disposed. In addition, in the units U1, U2, and U3 and the cooling regions E1, E2, and E3, the explanation having the same meaning shall be valid unless otherwise specified. In addition, in the embodiment, the die 11 has a structure divided into three parts by the units U1, U2, and U3, but the die 11 may be used as one unit in order to aim for uniform cooling including the cooling regions.

[0036] As shown in Figs. 4 to 6, a flow path 60 that allows the cooling medium (water) to flow therethrough is formed inside the die 11. The flow path 60 includes a plurality of cooling portions 61 (flow paths formed by slits), a supply jacket portion 62, a recovery jacket portion 63, a supply communication portion 64 (see Figs. 5 and 6), and a discharge communication portion 66 (Fig. 6). Additionally, a die holder 91 that supports the die 11 is formed with a supply portion 67 (see Figs. 5 and 6) and discharge portions 68 and 69 (see Fig. 6). In addition, the plurality of cooling portions 61, the supply jacket portion 62, the recovery jacket portion 63, the supply communication portion 64, and the discharge communication portion 66 are provided as individual flow paths for the units U1, U2, and U3 and the cooling regions E1, E2, and E3. On the other hand, the supply portion 67 and the discharge portions 68 and 69 are provided as a common flow path for the units U1, U2, and U3 and the cooling regions E1, E2, and E3.

[0037] The cooling portions 61 are portions that mainly function as portions for cooling the die 11. The cooling portions 61 are formed so as to extend in the Y-axis direction. The plurality of cooling portions 61 are disposed so as to be aligned in the X-axis direction. The supply jacket portion 62 is a portion that supplies the cooling medium to each cooling portion 61. The supply jacket portion 62 extends in the X-axis direction so as to be

connected to an end portion of each cooling portion 61 on the negative side in the Y-axis direction. The recovery jacket portion 63 is a portion that recovers the cooling medium from each cooling portion 61 (see Figs. 4 and 6). The recovery jacket portion 63 extends in the X-axis direction so as to be connected to an end portion of each cooling portion 61 on the positive side in the Y-axis direction.

[0038] The supply communication portion 64 is a portion that supplies the cooling medium from the supply portion 67 to the supply jacket portion 62 by connecting the supply jacket portion 62 and the supply portion 67. One or more supply communication portions 64 are provided for the supply jacket portion 62 and extend to the negative side in the Z-axis direction. The discharge communication portion 66 is a portion that discharges the cooling medium from the recovery jacket portion 63 to the discharge portion 68 by connecting the recovery jacket portion 63 and the discharge portion 68 (see Figs. 4 and 6) to each other. One or more discharge communication portions 66 are provided for the recovery jacket portion 63 and extend to the negative side in the Z-axis direction.

[0039] The supply portion 67 extends in the X-axis direction at the die holder 91 (see Figs. 5 and 6). An end portion of the supply portion 67 on the positive side in the X-axis direction opens from the die holder 91. A nozzle(not shown) that supplies the cooling medium is inserted into the opening. The supply portion 67 distributes the cooling medium to the supply communication portion 64 of each of the units U1, U2, and U3. The discharge portion 68 extends in the X-axis direction at the die holder 91 (see Fig. 6). The discharge portion 69 extends from the end portion of the discharge portion 68 on the positive side in the X-axis direction to the positive side in the Y-axis direction and opens from the die holder 91. A nozzle (not shown) that discharges the cooling medium is inserted into the opening. The discharge portions 68 and 69 commonly discharge the cooling medium from the discharge communication portion 66 of each of the units U1, U2, and U3.

[0040] The die 11 is divided into the first member 50 having the forming surface 47 for forming the metal pipe material 40, and a second member 51 that supports the first member 50 on a side opposite to the forming surface 47. The first member 50 has a dividing surface 50a on the negative side in the Z-axis direction. The second member 51 has a dividing surface 51a on the positive side in the Z-axis direction. The first member 50 and the second member 51 are joined to each other by bolts (or screws) in a state in which the dividing surfaces 50a and 51a overlap each other so as to come into contact with each other. By removing the bolts (or screws), the first member 50 can be removed from the second member 51 (see Figs. 7A and 7B). In addition, in the present embodiment, the dividing surfaces 50a and 51a are configured by a plane spreading in parallel with the XY plane.

[0041] The thickness of the first member 50 is smaller

than the thickness of the second member 51. The thickness herein is a dimension on the negative side in the Z-axis direction. In addition, the surface of the first member 50 on the positive side in the Z-axis direction is formed so as to be curved according to the shape of the forming surface 47. Thus, the thickness of the first member 50 varies depending on the location. The forming surface 47 is recessed to the most negative side in the Z-axis direction at the position of the unit U2. Therefore, the dividing surface 50a in the unit U2 is disposed on the negative side in the Z-axis direction with respect to the dividing surface 50a of the other units U1 and U3.

[0042] The material of the first member 50 has higher durability against forming than the material of the second member 51. As the material of the first member 50, a harder material and a higher-grade material having high wear resistance than the material of the second member 51 are used.

[0043] The second member 51 is formed with a slit 53 that extends along the dividing surface 51a and is open on the dividing surface 51a. The slit 53 constitutes the cooling portion 61 which is a part of the flow path 60 by joining the first member 50 and the second member 51 to each other. The dividing surface 50a of the first member 50 is formed as a smooth surface without forming a slit. Accordingly, the slit 53 defines a bottom surface 61a and a side surface 61b of the cooling portion 61, and the dividing surface 50a of the first member 50 defines an upper surface 61c of the cooling portion 61 (see Fig. 7B). That is, the cooling portion 61, which is a flow path having a rectangular cross-sectional shape, is formed by blocking the opening of the slit 53 with the first member 50.

[0044] The second member 51 is formed with a jacket groove 54 that extends along the dividing surface 51a and is open on the dividing surface 51a. The jacket groove 54 constitutes the supply jacket portion 62 and the recovery jacket portion 63, which are a part of the flow path 60, by joining the first member 50 and the second member 51 to each other. The dividing surface 50a of the first member 50 is formed as a smooth surface without forming a slit. Accordingly, the jacket groove 54 defines a bottom surface 62a and a side surface 62b of the supply jacket portion 62, and the dividing surface 50a of the first member 50 defines an upper surface 62c of the supply jacket portion 62 (see Fig. 7A). That is, the supply jacket portion 62, which is a flow path having a rectangular cross-sectional shape, is formed by blocking the opening of the jacket groove 54 with the first member 50. The same applies to the recovery jacket portion 63.

[0045] As shown in Fig. 4, the disposition of the slit 53 and the jacket groove 54 has the same meaning as the disposition of the cooling portion 61, the supply jacket portion 62, and the recovery jacket portion 63 described above. That is, the slit 53 extends in the Y-axis direction, and a plurality of the slits 53 are arranged in the X-axis direction. At both ends of the plurality of slits 53 in the Y-axis direction, a jacket groove 54 of the supply jacket portion 62 and a jacket groove 54 of the recovery jacket

portion 63 are formed for each slit 53. In addition, the slit 53 and the jacket groove 54 formed in each of the units U1, U2, and U3 are disposed within a range of the seal groove portion 90 that surrounds each of the cooling regions E1, E2, and E3.

[0046] The die 11 has the cooling regions E1, E2, and E3 at different positions in the X-axis direction. Then, in the cooling regions E1 and E3, the plurality of slits 53 are arranged at a first pitch P1. In the cooling region E2, the plurality of slits 53 are arranged at a second pitch P2 shorter than the first pitch P1. Accordingly, the slits 53 of the cooling region E2 are formed more densely than the slits 53 of the cooling regions E1 and E3.

[0047] The cross-sectional area of the cooling portion 61 as a single path by the slit 53 is smaller than the cross-sectional area of the supply jacket portion 62 and the recovery jacket portion 63 by the jacket groove 54. Specifically, as shown in Figs. 7A and 7B, a width dimension W1 of the slit 53 is narrower than a width dimension W2 of the jacket groove 54. Additionally, a height dimension H1 of the slit 53 is lower than a height dimension H2 of the jacket groove 54.

[0048] Next, the contents of control of the cooling unit 7 by the control unit 8 will be described in detail with reference to Figs. 5, 8A, and 8B. In addition, in the following description, the cooling for the die 11 is described, but the explanation having the same meaning will be valid for the cooling for the die 12. As shown in Fig. 5, the circulation mechanism 37 of the cooling unit 7 supplies the cooling medium to the supply portion 67. The circulation mechanism 37 is connected to an inlet portion of the supply portion 67 via a pipe 101. Additionally, the circulation mechanism 37 recovers the cooling medium discharged from the discharge portion 69. The circulation mechanism 37 cools the recovered cooling medium with a cooling device and supplies the cooling medium having a predetermined temperature to the supply portion 67.

[0049] The forming device 1 includes a temperature sensor 100 that detects the temperature of the die 11. The temperature sensor 100 transmits the detected temperature to the control unit 8. In Fig. 5, the temperature sensor 100 is provided at a position close to the forming surface inside the die 11. However, the temperature sensor 100 may be provided anywhere with respect to the die 11. For example, the temperature sensor 100 may be provided at a position different from that in Fig. 5 inside the die 11 or may be provided on the surface of the die 11.

[0050] The control unit 8 controls the cooling capacity of the cooling unit 7. Specifically, the control unit 8 controls the cooling capacity by adjusting the flow rate of the cooling medium supplied by the circulation mechanism 37. That is, the control unit 8 reduces the flow rate of the cooling medium in a case where the cooling capacity is lowered and increases the flow rate of the cooling medium in a case where the cooling capacity is increased. However, the control unit 8 may adjust the cooling capacity by adjusting not only the amount of water but also the temperature of the cooling medium. However, the

flow rate is easier to adjust than the temperature.

[0051] Here, how the temperature of the die 11 changes in a case where the forming device 1 repeatedly performs forming in order to manufacture a large number of metal pipes will be described with reference to Figs. 8A and 8B. Figs. 8A and 8B are graphs showing a relationship between time and the temperature change of the die 11. The horizontal axis of the coordinates in Figs. 8A and 8B indicates the time from the start of forming. Solid line graphs TG1 and TG2 are graphs showing the temperature change of the die 11. The vertical axis of the coordinates (vertical axis on the left side of the paper surface) indicates the temperature of the die 11 with respect to the graphs TG1 and TG2. In addition, the location where the temperature of the die 11 is measured may be set to any location, and may be anywhere on the forming surface or inside the die. Two-dot chain line graphs FG1 and FG2 are graphs showing the flow rate of the cooling medium. The vertical axis of the coordinates (vertical axis on the right side of the paper surface) indicates the flow rate of the cooling medium for the graphs FG1 and FG2.

[0052] As shown in Fig. 8A, when the forming device 1 performs first forming, the heated metal pipe material 40 comes into contact with the die 11. In this case, the heat possessed by the metal pipe material 40 is input to the die 11. Therefore, the temperature of the die 11 rises (see a portion "A" in the figure). In addition, the minimum point of the temperature at the start of the first forming is defined as "P1a". When the hardening of the metal pipe material 40 is completed and a metal pipe is removed from the die 11, the cooling unit 7 cools the metal pipe in a state in which there is no heat input to the die 11. Therefore, the temperature of the die 11 drops (see the portion "B" in the figure). The maximum point of temperature in the first forming is defined as "P1b". Next, at a preliminary stage where the temperature of the die 11 returns to the temperature at the start of forming, the forming device 1 performs second forming. Accordingly, the temperature of the die 11 rises again (see portion "C" in the figure). The minimum point of temperature at the start of the second forming is defined as "P2a". The maximum point obtained by the second forming is defined as "P2b". In this case, the temperature of the minimum point P2a in the second forming is higher than the temperature of the minimum point P1a in the first forming. Additionally, the temperature of the maximum point P2b in the second forming is higher than the maximum point P1b in the first forming. In this way, during a predetermined number of times of forming from the start of forming, the temperatures of the minimum points and the maximum points gradually increase whenever the forming is repeated.

[0053] When the forming is repeated equal to or more than a predetermined number of times, the temperature rise of the die 11 is brought into a saturation state. When this state is brought about, the temperatures of the minimum point Pma and the maximum point Pmb at a certain number of times of forming do not change from the temperatures of the minimum point Pna and the maximum

point Pnb in the previous forming. After that, the forming is repeatedly performed in a state in which the temperature of the minimum point and the temperature of the maximum point are constant. Such a state may be referred to as a "stable state" in the following description.

[0054] A graph La that passes through the minimum point in each forming and a graph Lb that passes through the maximum point in each forming are set. Since the graph FG1 shows the temperature change as described above, the graphs La and Lb have a shape like an asymptote that is curved upward toward the temperature in the stable state for a predetermined period after the start of forming and becomes a straight line that extends horizontally when the stable state is reached.

[0055] In contrast, the control unit 8 controls the cooling unit 7 so as to suppress the deterioration of the hardenability to the metal pipe material 40 resulting from the accumulation of heat to the die 11 caused by the repeated forming. For example, it is preferable that the temperature of the die 11 is set to a temperature T1 or lower in order to perform excellent hardening. The control unit 8 controls the cooling unit 7 such that the temperature of the die 11 in the stable state is the temperature T1 or lower. That is, the control unit 8 keeps the flow rate of the cooling medium constant at a high value such that the temperature of the die 11 in the stable state is not higher than the temperature T1 because the cooling capacity is too low (see graph FG1). The control unit 8 performs control such that the temperature of the minimum point in the saturation state is at least the temperature T1 or lower. In addition, the temperature T1 is a value appropriately set depending on the material and size of the die 11 and the metal pipe material 40. For example, when the temperature T1 is set, the durability of the die 11 may also be taken into consideration, and in a case where the durability is low, the temperature T1 may be kept low. For example, when the temperature of the die 11 becomes too high, there is a risk that the die strength may decrease due to tempering or the like and the abrasion may be promoted. However, such a risk can be reduced by setting the temperature T1 in consideration of the durability of the die 11.

[0056] Additionally, the control unit 8 controls the cooling unit 7 such that the temperature of the die 11 falls within a predetermined range. As described above, the graph TG1 shown in Fig. 8A falls within the range of the graph La composed of constant minimum values and the graph Lb composed of constant maximum values, in the stable state. However, even in the stable state, the maximum value and the minimum value in each forming may fluctuate slightly. In this case, the graphs La and Lb have a shape disordered from the straight line as shown in Fig. 8A. However, also in this case, it is preferable that the fluctuations of the maximum value and the minimum value fall within a predetermined error range as long as the stability of the hardenability of the metal pipe is not impaired.

[0057] The control unit 8 may increase the cooling ca-

capacity of the cooling unit 7 as the number of times of forming of the die 11 increases. Additionally, the control unit 8 may increase the cooling capacity of the cooling unit 7 as the forming time of the die 11 increases. For example, the control unit 8 may control the flow rate of the cooling medium so as to draw the graph FG2 shown in Fig. 8B. In this case, the control unit 8 keeps the flow rate of the cooling medium low at the start of forming and gradually increases the flow rate with the elapse of time. In this case, the control unit 8 increases the flow rate of the cooling medium as the number of times of forming increases and the forming time increases. In addition, the "forming time" herein is not the time required for single forming (the time for one mountain of graph TG2), but the total time for each forming in a case where a plurality of times of forming is performed. Then, the control unit 8 performs control such that the flow rate of the cooling medium is constant when the stable state is reached.

[0058] In the control method of Fig. 8B, the control unit 8 intentionally suppresses the cooling capacity of the cooling unit 7 at a forming start stage. Accordingly, the control unit 8 quickly brings the temperature change of the die 11 into the stable state. Specifically, at the forming start stage, the temperature rise of the graph TG2 is larger than the temperature rise of the graph TG1. Then, the time during which the graph TG2 is brought into the stable state is "t1", but the graph TG1 still continues the temperature rise at the stage of "t1". Then, the graph TG1 is brought into the stable state at the timing when a predetermined time has elapsed from "t1". That is, in the control method of Fig. 8B, the die 11 enables the forming in the stable state at an early stage, and the quality of a formed product can be stabilized at an early stage.

[0059] The control unit 8 may adjust the cooling capacity of the cooling unit 7 on the basis of the detection result of the temperature sensor 100. For example, in the control of Fig. 8B, the control unit 8 may detect that the stable state has been reached from the detection result of the temperature sensor 100. Accordingly, the control unit 8 can keep the flow rate of the cooling medium constant at an appropriate timing. Additionally, in a case where the temperature of the die 11 drops from the temperature in the stable state as the repeated forming is temporarily paused, the control unit 8 may identify the temperature drop on the basis of the detection result of the temperature sensor 100. In this case, the control unit 8 may raise the temperature of the die 11 so as to be brought into the stable state by reducing the cooling medium.

[0060] Next, the operation and effects of the forming device 1 according to the present embodiment will be described.

[0061] The forming device 1 according to the present embodiment has dies 11 and 12 that perform quench forming by coming into contact with a metal material. The temperature of the dies 11 and 12 rises as the dies 11 and 12 and the heated metal material come into contact with each other. In contrast, as the cooling unit 7 cools the dies 11 and 12, the dies 11 and 12 can be brought

into a state in which the quench forming is possible. Moreover, the cooling unit 7 suppresses the deterioration of the hardenability to the metal material resulting from the accumulation of heat to the dies 11 and 12 caused by the repeated forming. Therefore, even though the dies 11 and 12 repeatedly receive the heat input from the metal material as the forming is repeated, the dies 11 and 12 can perform the repeated quench forming without deteriorating the hardenability. From the above, the forming device 1 can improve the stability of the quality of the formed product in a case where the repeated forming is performed.

[0062] The cooling unit 7 may make the temperatures of the dies 11 and 12 fall within a predetermined range. In this case, the cooling unit 7 can make the pattern of temperature changes of the dies 11 and 12 during forming close to constant. Therefore, the forming device 1 can improve the stability of the quality of the formed product. That is, the pattern of the temperature change of the die 11 in the first forming of Fig. 8A and the pattern of the temperature change of the fifth die 11 are different from each other. For that reason, there is a difference in hardenability between a metal pipe produced by the first forming and a metal pipe by the fifth forming. In contrast, in the forming in the stable state, the dies 11 and 12 can perform forming in a constant temperature change pattern regardless of the number of times. Accordingly, the quality of the formed product is stabilized.

[0063] The cooling unit 7 may increase the cooling capacity as the number of times of forming of the dies 11 and 12 increases. As the number of times of forming of the dies 11 and 12 increases, heat is more likely to be accumulated in the dies 11 and 12. Therefore, the cooling unit 7 can suppress the accumulation of heat to the dies 11 and 12 by increasing the cooling capacity as the number of times of forming of the dies 11 and 12 increases.

[0064] The cooling unit 7 may increase the cooling capacity as the forming time of the dies 11 and 12 becomes longer. The longer the forming time of the dies 11 and 12, the more easily heat is accumulated in the dies 11 and 12. Therefore, the cooling unit 7 can suppress the accumulation of heat to the dies 11 and 12 by increasing the cooling capacity as the forming time of the dies 11 and 12 becomes longer.

[0065] The forming device 1 includes the temperature sensor 100 that detects the temperatures of the dies 11 and 12, and the cooling unit 7 may adjust the cooling capacity on the basis of the detection result of the temperature sensor 100. In this case, the cooling unit 7 can make the dies 11 and 12 have an appropriate temperature depending on the temperature of the dies 11 and 12.

[0066] The forming method according to the present embodiment may be a forming method of forming a heated metal material. The forming method includes a forming process of performing quench forming by bringing the metal material into contact with a die, and a cooling process of cooling the die. In the cooling process, dete-

rioration of hardenability to the metal material resulting from accumulation of heat to the die caused by repeated forming may be suppressed.

[0067] According to this forming method, it is possible to obtain the operation and effects having the same meaning as that of the above-described forming device 1.

[0068] The present invention is not limited to the above-described embodiment.

[0069] The pattern of the flow path of the cooling medium formed in the die is not limited to the above-described embodiment and may be appropriately changed as long as the pattern can satisfactorily cool the die.

[0070] The control mode of the cooling capacity by the control unit is not limited to that shown in the above-described embodiment. For example, a control pattern as shown in Figs. 9A and 9B may be adopted. In addition, in Figs. 9A and 9B, only the graph La showing the change mode of the minimum value and the graph Lb showing the change mode of the maximum value are shown, and the graph of the temperature change is omitted. The graph of the temperature change has such a shape that a wave is drawn within the range of the graphs La or Lb.

[0071] In Fig. 9A, the control unit 8 adjusts such that the cooling capacity becomes extremely high. The flow rate of the graph FG3 is higher than that of the graph TG1 shown in Fig. 8A. In this case, the amount of heat removed from the dies 11 and 12 by the cooling unit 7 in single forming is larger than the amount of heat input from the metal material to the dies 11 and 12. In the control pattern of Figs. 8A and 8B, the dies 11 and 12 are brought into the stable state at a high temperature, but in the control pattern of Figs. 9A and 9B, the dies 11 and 12 are brought into the stable state at a low temperature.

[0072] In Fig. 9B, the control unit 8 adjusts the cooling capacity so as to lower the temperature to allow the temperature rise of the dies 11 and 12 when the temperature rises to a predetermined temperature. As shown in the graph FG4, at the forming start stage, the control unit 8 allows the temperature rise of the dies 11 and 12 to some extent by suppressing the flow rate of the cooling medium to a low value. When the control unit 8 identifies that the temperatures of the dies 11 and 12 have reached a predetermined temperature on the basis of the detection result of the temperature sensor 100, the control unit 8 temporarily increases the flow rate of the cooling medium. Accordingly, the control unit 8 lowers the temperature of the dies 11 and 12 by increasing the amount of heat removed by the cooling unit 7 rather than the amount of heat input to the dies 11 and 12. When the control unit 8 identifies that the temperatures of the dies 11 and 12 have returned to about an initial stage on the basis of the detection result of the temperature sensor 100, the control unit 8 returns the flow rate of the cooling medium. Here, the control unit 8 sets the temperature range W of the dies 11 and 12 to such an extent that the quality of the formed product does not change excessively. Accordingly, the control unit 8 allows the pattern of temperature change of the dies 11 and 12 to fluctuate, but sup-

presses the width of the fluctuation, thereby suppressing the variations of the quality of the formed product.

[0073] As described above, the cooling unit 7 makes the amount of heat removed from the dies 11 and 12 larger than the amount of heat input to the dies 11 and 12 from the metal material. In this case, the cooling unit 7 can suppress the temperature rise of the dies 11 and 12 or lower the temperature of the dies 11 and 12 that have risen. Accordingly, in a case where the repeated forming is performed, a change in hardenability resulting from the temperature of the dies 11 and 12 becoming excessively high can be suppressed. From the above, the forming device can improve the stability of the quality of the formed product in a case where the repeated forming is performed.

[0074] A forming method according to a modification example is a forming method of forming a heated metal material. The forming method includes a forming process of performing quench forming by bringing the metal material into contact with a die, and a cooling process of cooling the die. In the cooling process, an amount of heat removed from the die is made larger than an amount of input heat from the metal material to the die.

[0075] According to this forming method, it is possible to obtain the operation and effects having the same meaning as that of the forming device 1 according to the above-described modification example.

[0076] Additionally, a die 110 as shown in Figs. 10A and 10B may be adopted. The die 110 shown in Figs. 10A and 10B includes a lower die 111, an upper die 112, and an insert die 113. The insert die 113 is connected to the upper die 112 via a damper 135. The lower die 111, the upper die 112, and the insert die 113 have flow paths 131, 132, and 133 through which the cooling medium is made to flow. The insert die 113 has a protrusion portion 113a for forming a complicated shape. According to such a die 110, as shown in Fig. 10A, when the upper die 112 is lowered and closed, the insert die 113 is first brought into a state of being close to the metal pipe material 300. Accordingly, when a high-pressure fluid is supplied to the metal pipe material 300, the shape corresponding to the insert die 113 is first formed. Then, when the upper die 112 is lowered, as shown in Fig. 10B, the lower die 111, the upper die 112, and the insert die 113 form a final formed product 301 with a flange.

[0077] As described above, in a case where a complicated part having an irregular shape is formed, it is desired to start forming in a state in which the temperature is as high as possible. Therefore, by using the insert die 113 as described above, a die contact portion in the irregular shape can be suppressed to a minimum necessary part. Therefore, expansion forming can be performed before the temperature of the metal pipe material 300 drops. Here, in the insert die structure as described above, it is considered that there is almost no heat transfer in a sliding portion between the upper die 112 and the insert die 113. Therefore, the upper die 112 and the insert die 113 need to be individually cooled independently of

each other. In this case, when the die temperatures are different from each other, the formed product 301 becomes a factor of having an internal strain, which affects the forming accuracy. Therefore, it is necessary to adjust the die temperatures by controlling the cooling medium flowing through the flow paths 131, 132, and 133 such that the die temperature differences among the lower die 111, the upper die 112, and the insert die 113 are as small as possible.

Reference Signs List

[0078]

15	1	Forming device
	7	Cooling unit
	8	Control unit
	11, 12	Die
	40, 300	Metal pipe material (metal material)
20	100	Temperature sensor
	111	Lower die (die)
	112	Upper die (die)
	113	Insert die (die)
	131, 132, 133	Flow path (cooling unit)

Claims

1. A forming device that forms a heated metal material, the forming device comprising:
 - a die that performs quench forming by coming into contact with the metal material; and
 - a cooling unit that cools the die, wherein the cooling unit suppresses deterioration in hardenability to the metal material resulting from accumulation of heat to the die caused by repeated forming.
2. The forming device according to claim 1, wherein the cooling unit makes a temperature of the die fall within a predetermined range.
3. The forming device according to claim 1 or 2, wherein the cooling unit increases a cooling capacity as the number of times of forming of the die increases.
4. The forming device according to any one of claims 1 to 3, wherein the cooling unit increases a cooling capacity as a forming time of the die becomes longer.
5. The forming device according to any one of claims 1 to 4, comprising:
 - a temperature sensor that detects a temperature of the die,

wherein the cooling unit adjusts a cooling capacity on the basis of a detection result of the temperature sensor.

6. A forming device that forms a heated metal material, the forming device comprising: 5

a die that performs quench forming by coming into contact with the metal material; and
a cooling unit that cools the die, 10
wherein the cooling unit makes an amount of heat removed from the die larger than an amount of input heat from the metal material to the die.

7. A forming method of forming a heated metal material, the forming method comprising: 15

a forming process of performing quench forming by bringing the metal material into contact with a die; and 20
a cooling process of cooling the die,
wherein in the cooling process, deterioration of hardenability to the metal material resulting from accumulation of heat to the die caused by repeated forming is suppressed. 25

8. A forming method of forming a heated metal material, the forming method comprising:

a forming process of performing quench forming by bringing the metal material into contact with a die; and 30
a cooling process of cooling the die,
wherein in the cooling process, an amount of heat removed from the die is made larger than an amount of input heat from the metal material to the die. 35

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FIG. 1

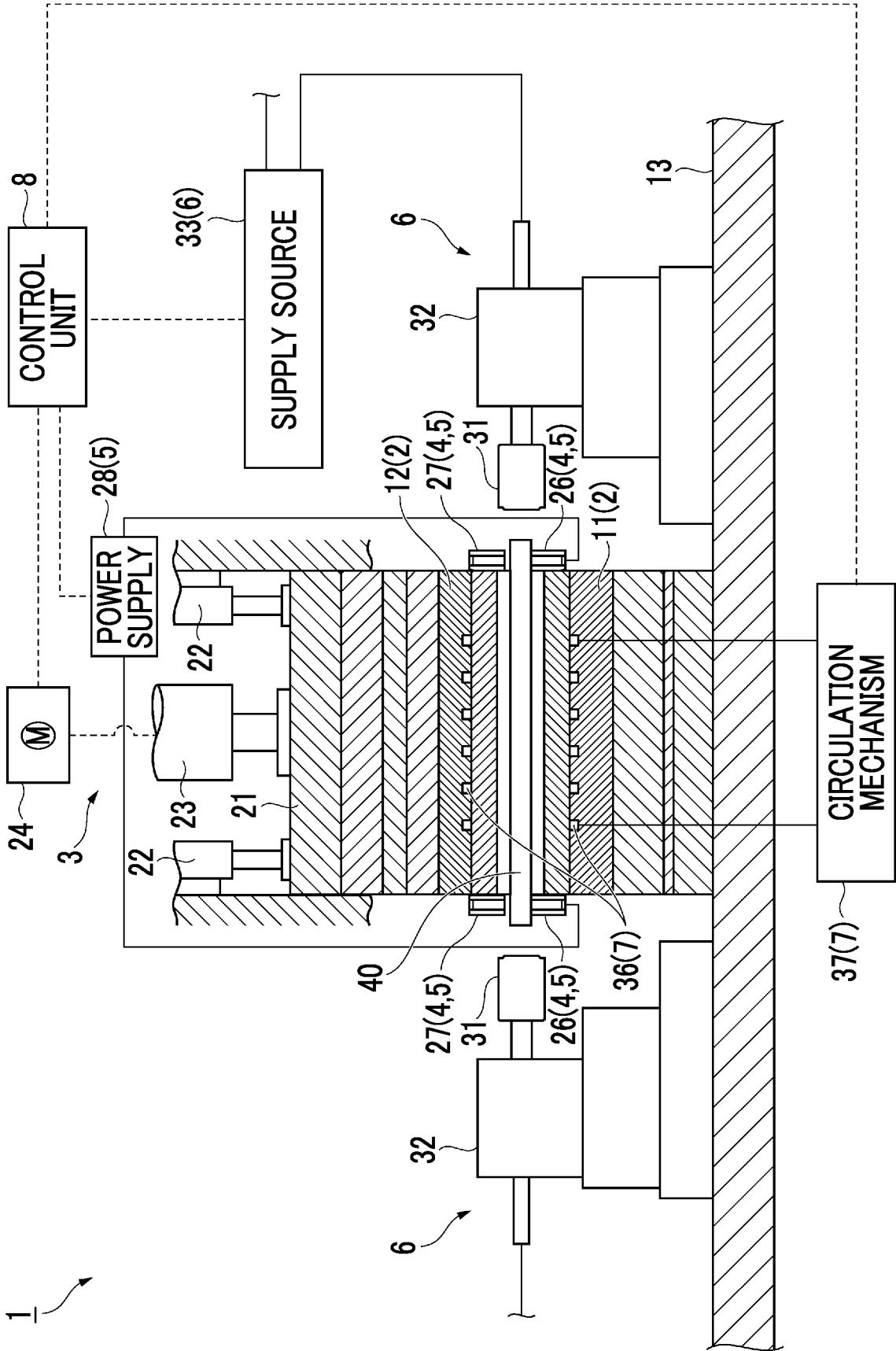


FIG. 2A

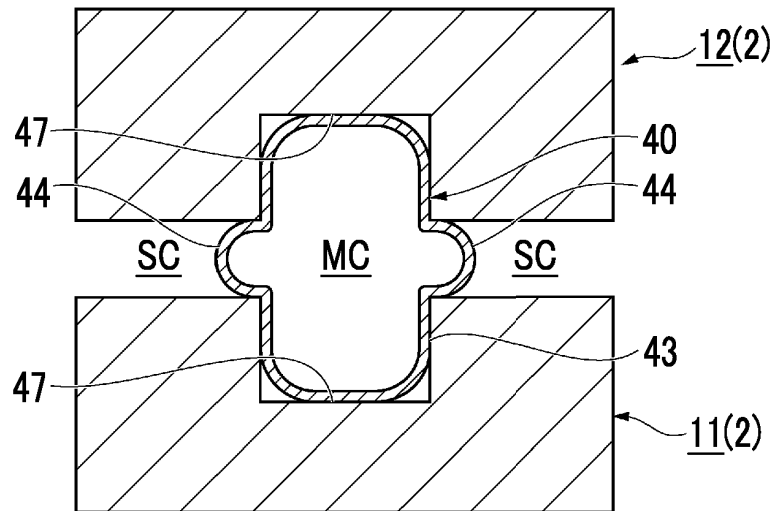


FIG. 2B

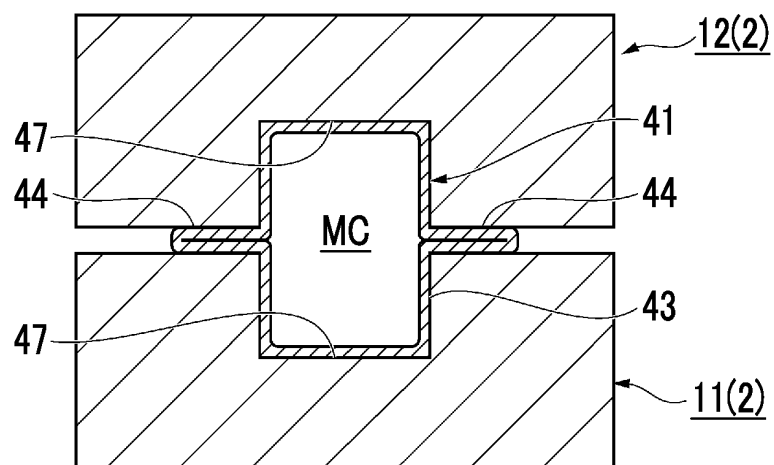


FIG. 3

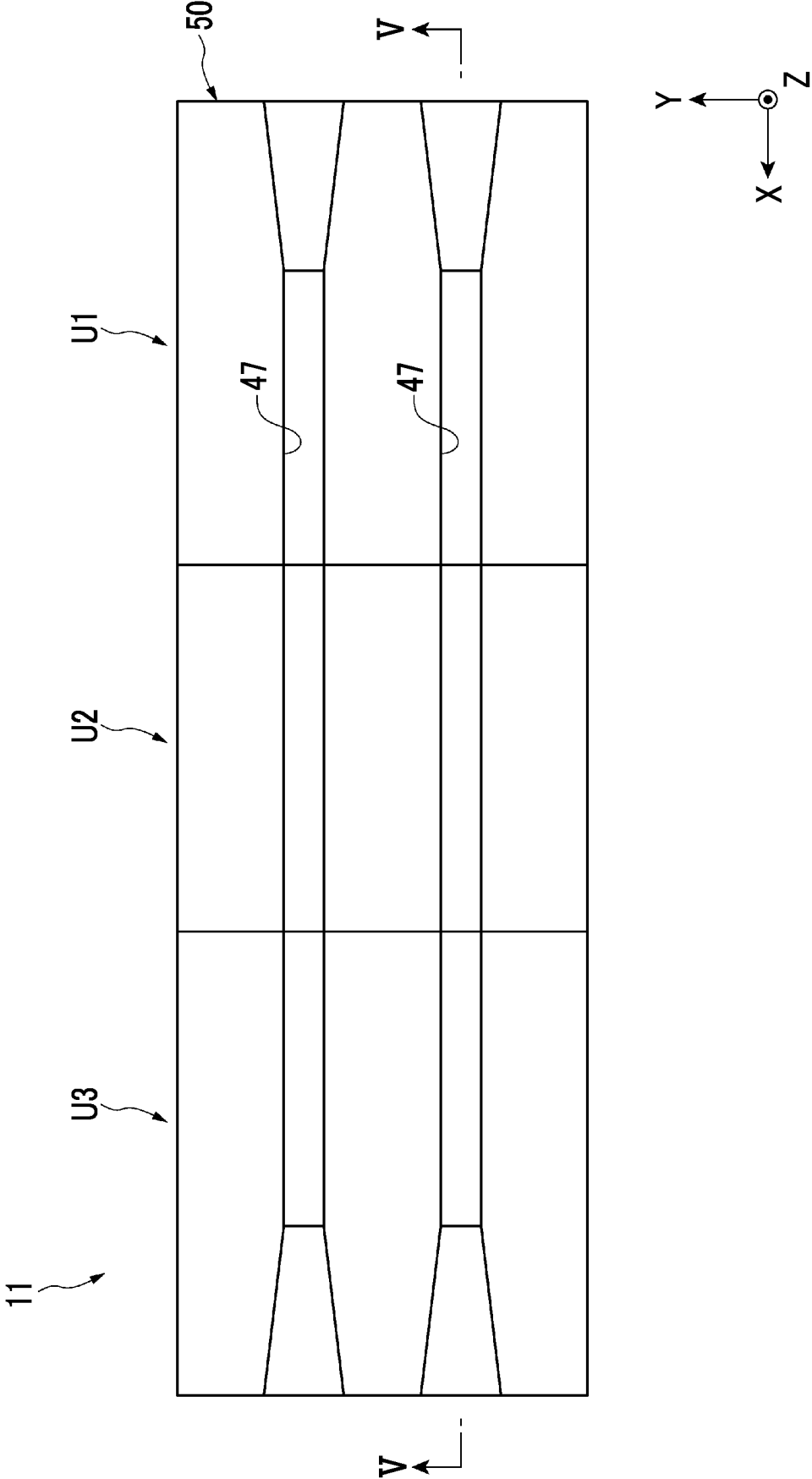


FIG. 4

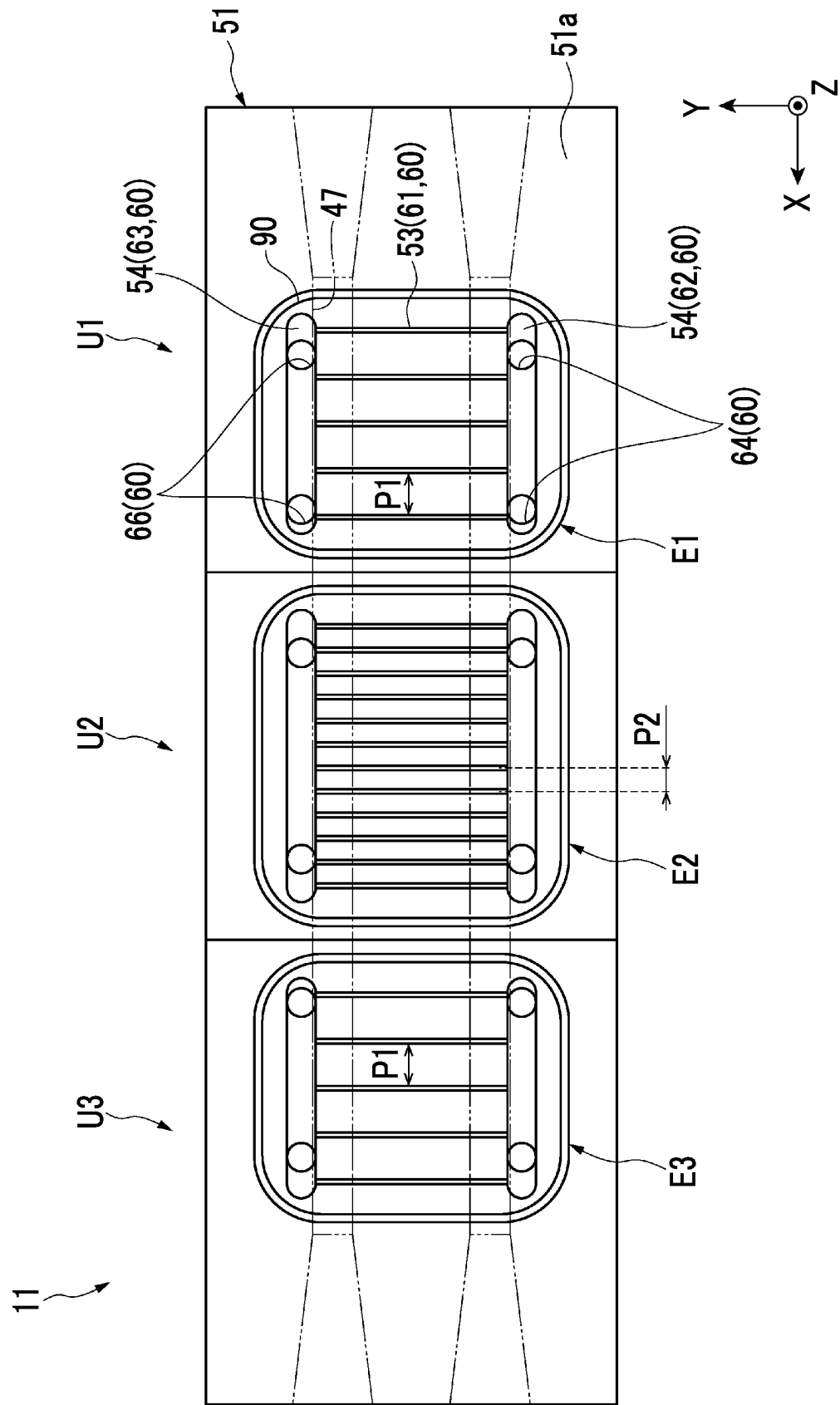


FIG. 5

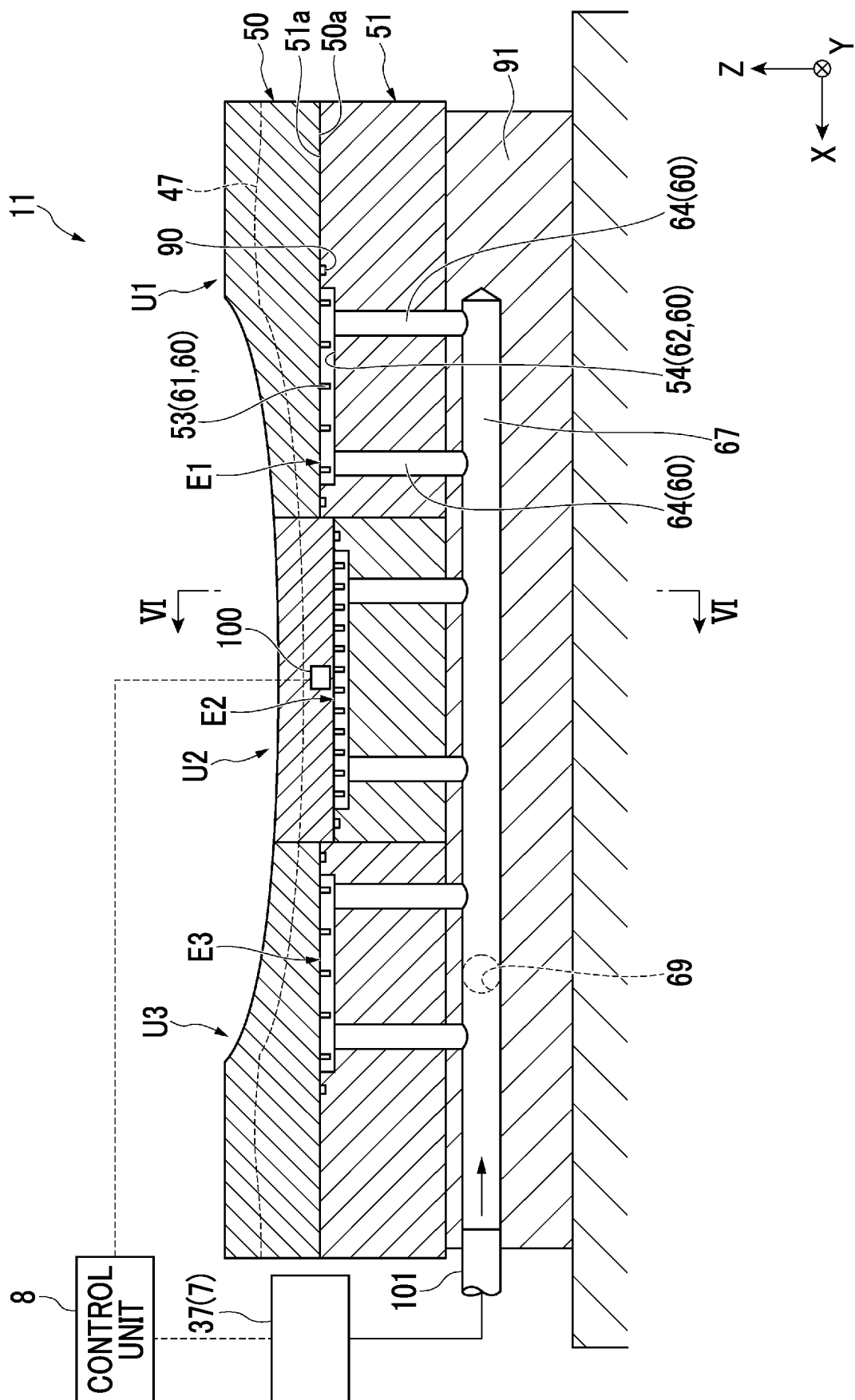


FIG. 6

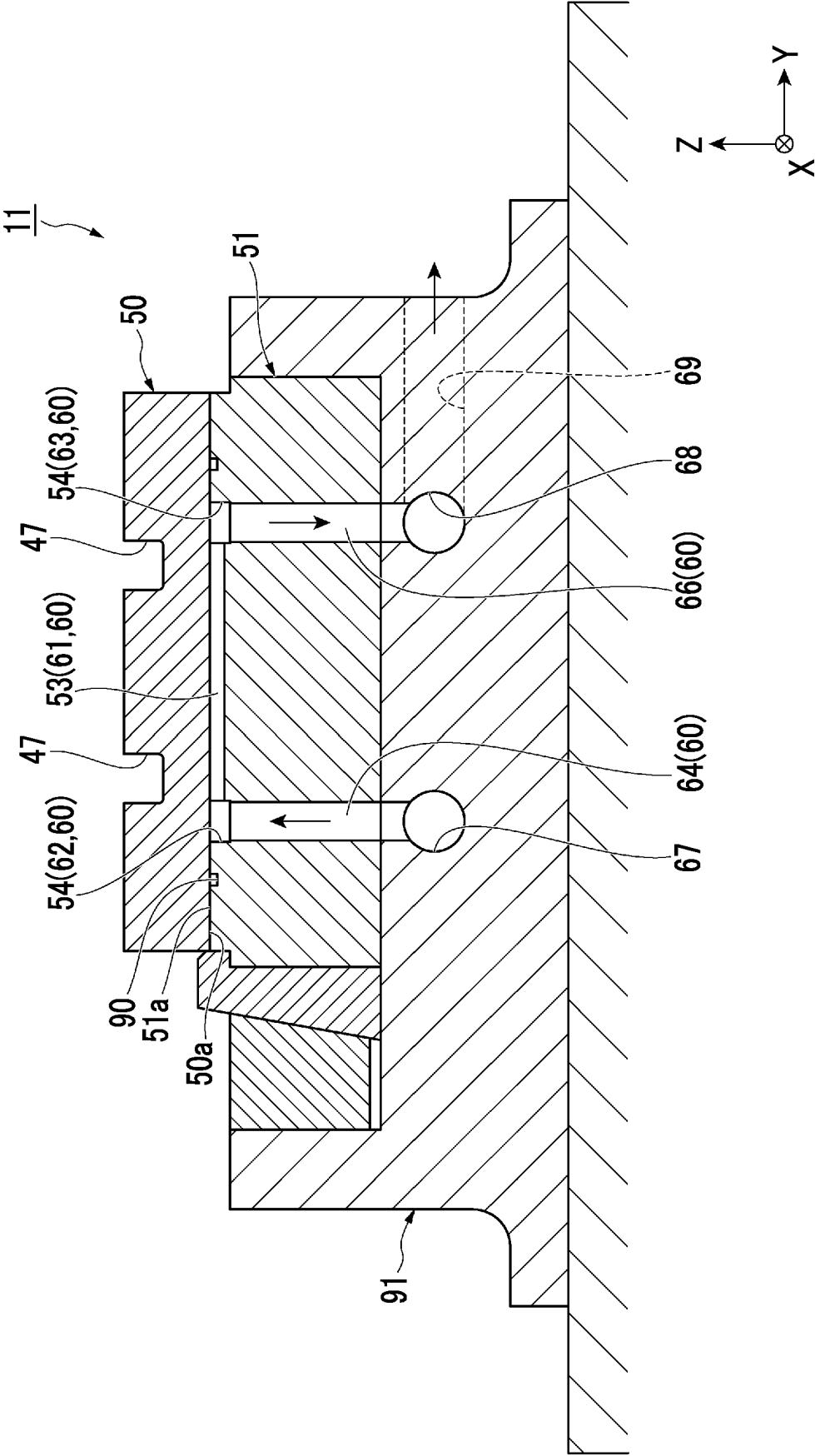


FIG. 7A

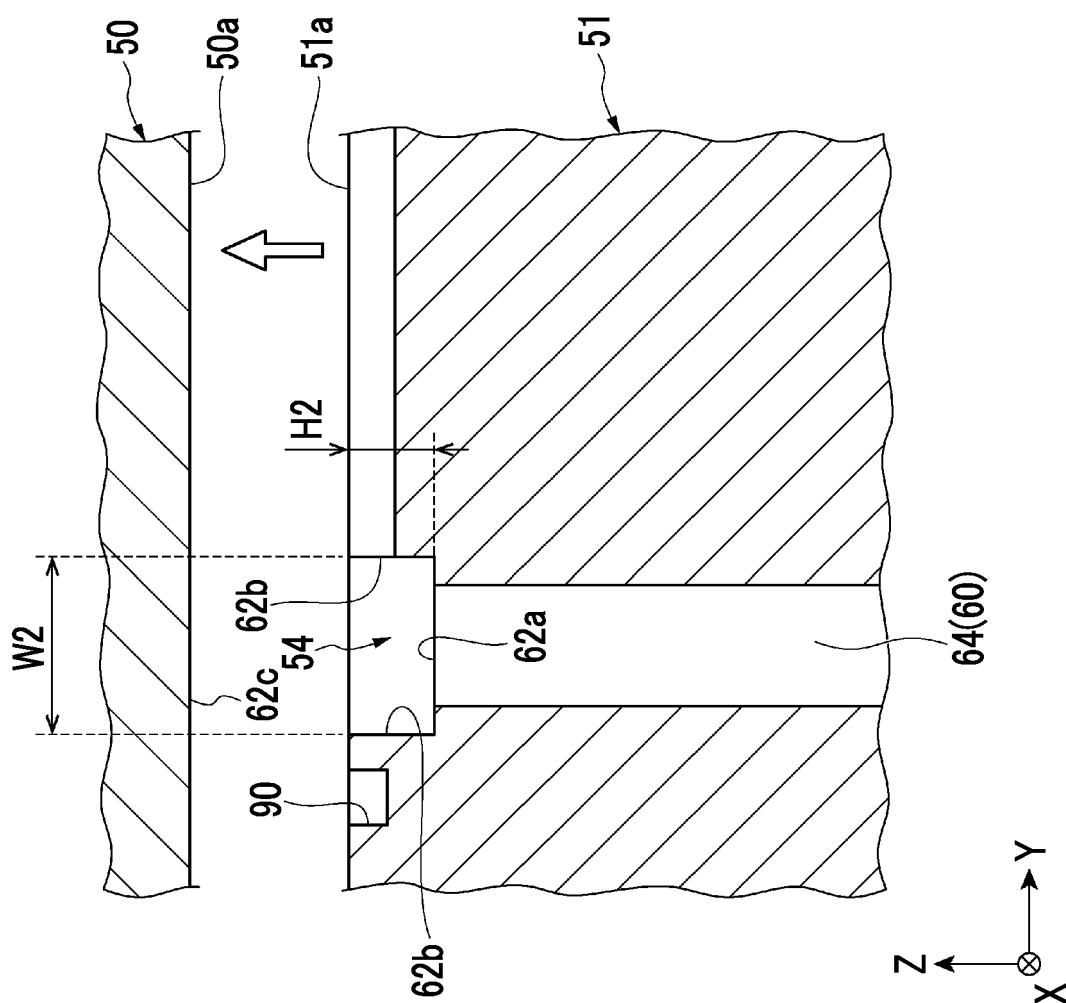


FIG. 7B

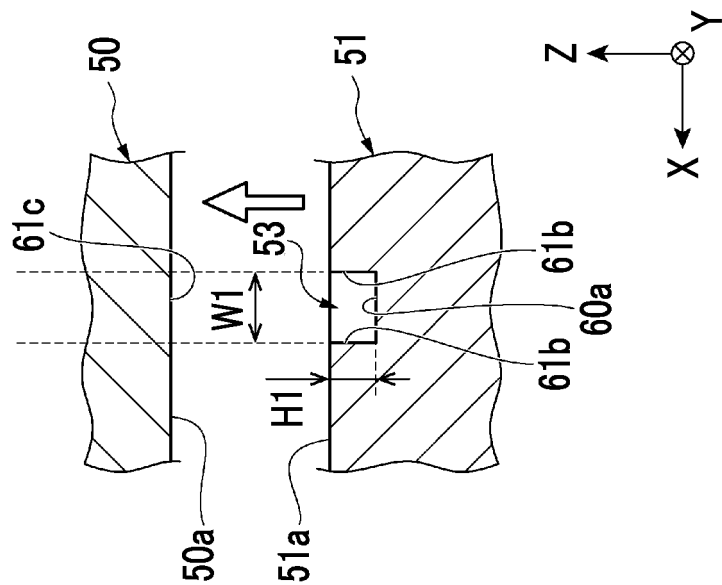


FIG. 8A

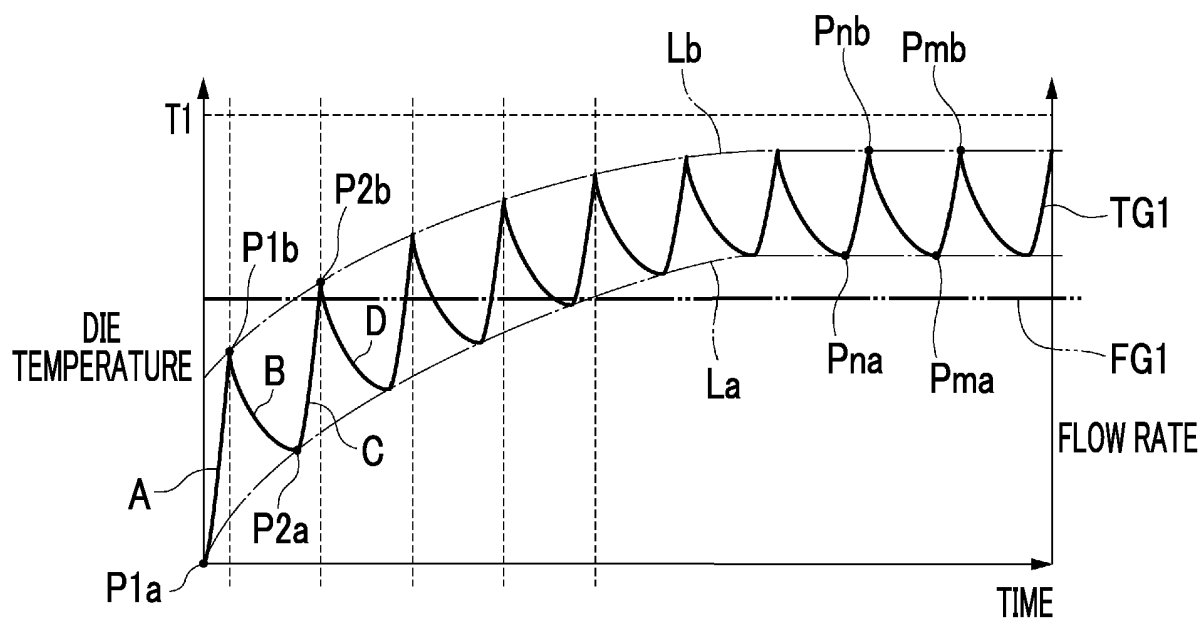


FIG. 8B

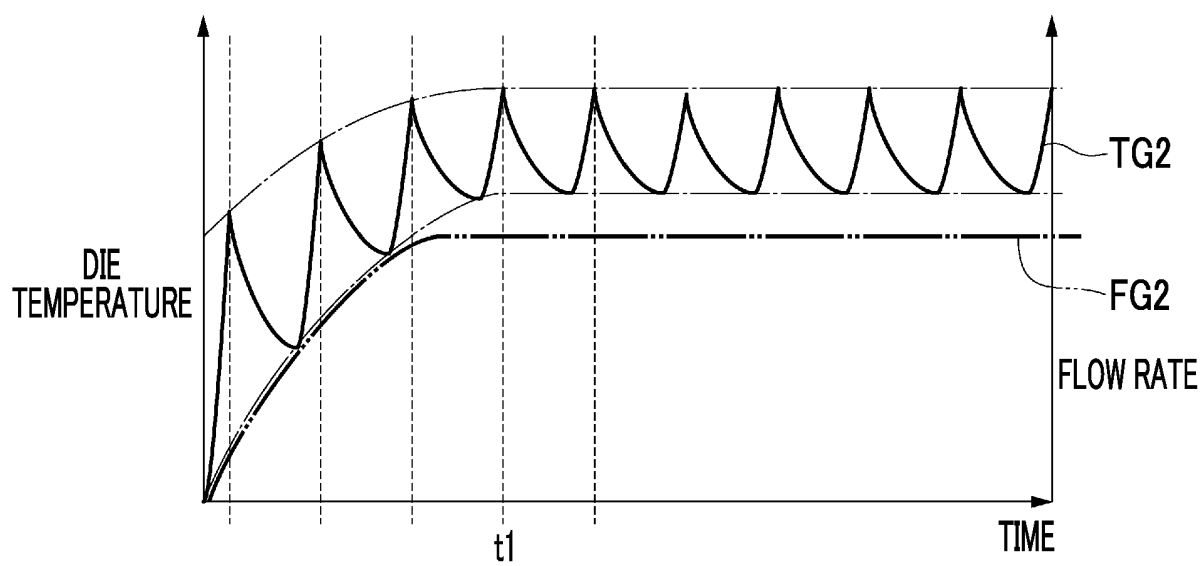


FIG. 9A

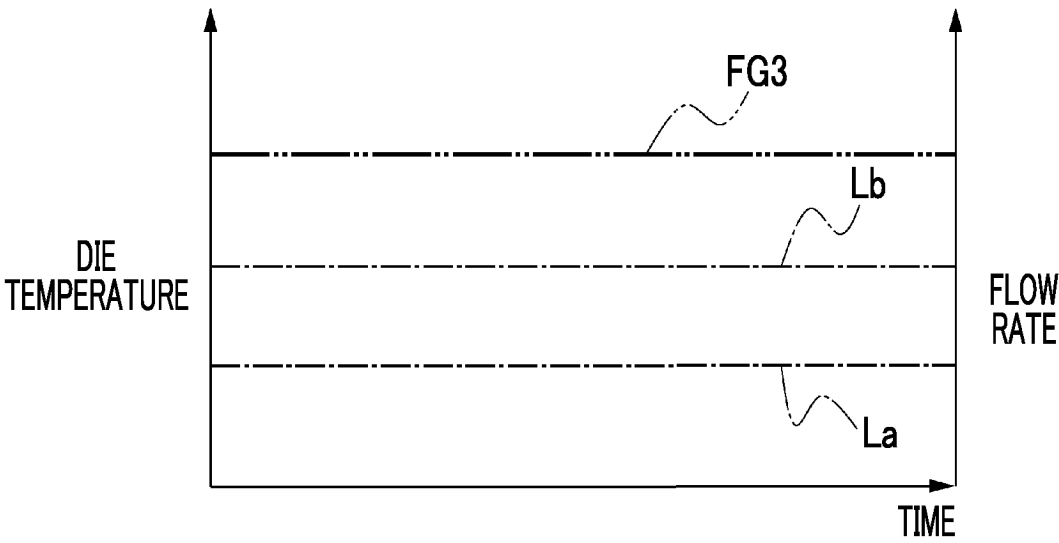


FIG. 9B

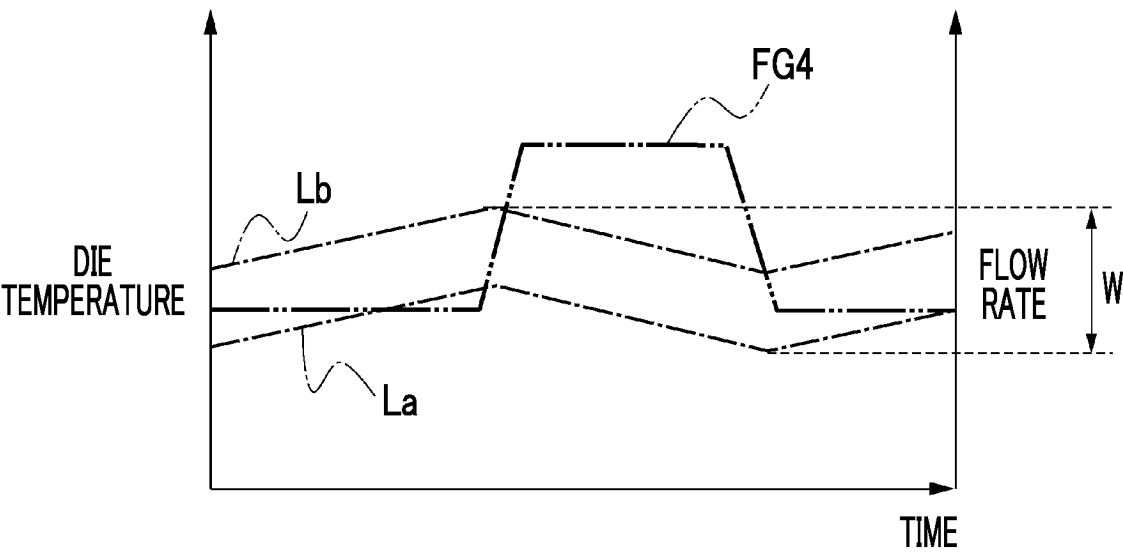


FIG. 10A

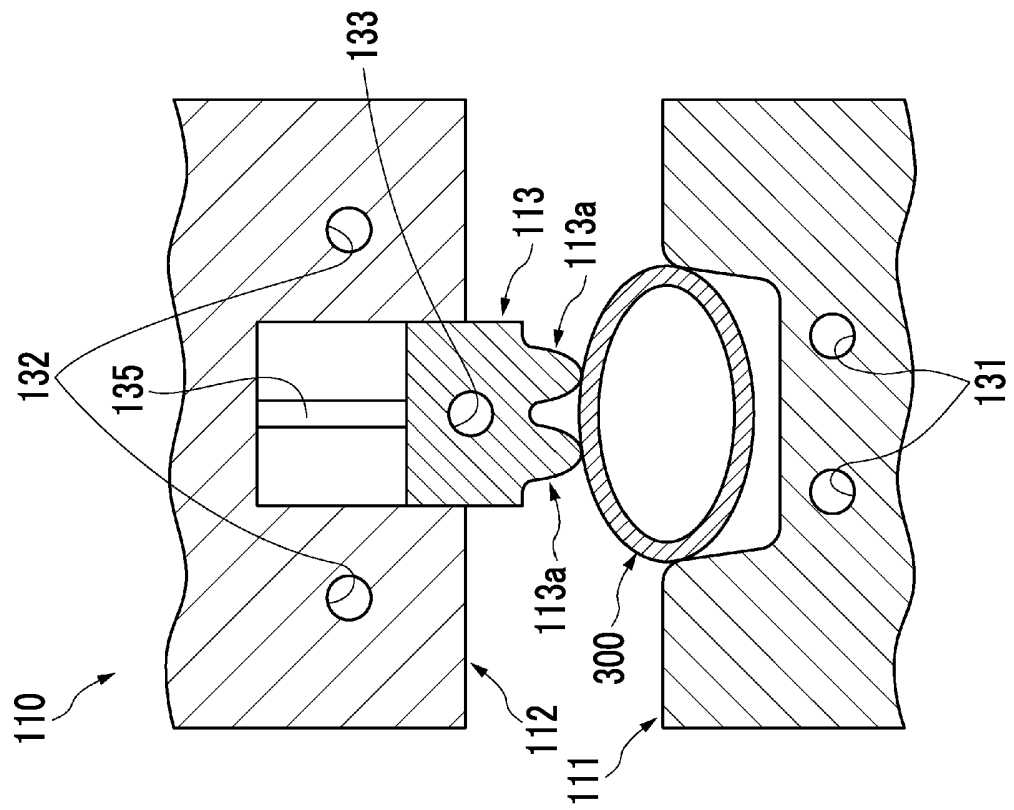
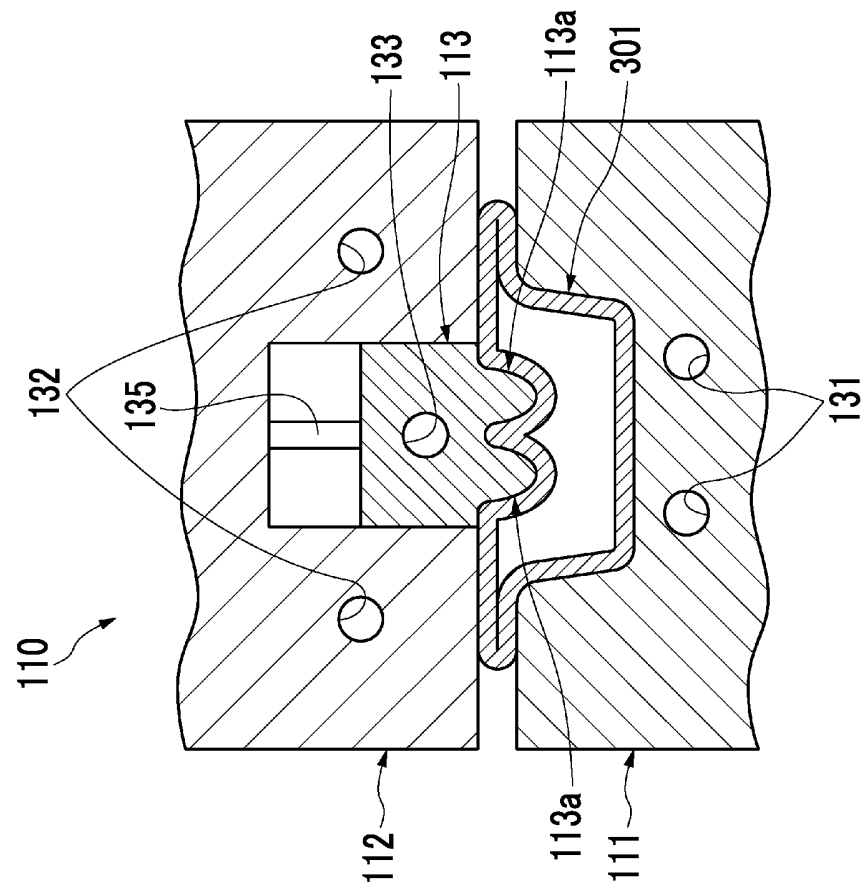


FIG. 10B



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/000860

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. B21D26/033 (2011.01) i, B21D22/20 (2006.01) i, B21D24/00 (2006.01) i, B21D37/16 (2006.01) i

FI: B21D26/033, B21D37/16, B21D24/00M, B21D22/20H

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)

Int.Cl. B21D26/033, B21D22/20, B21D24/00, B21D37/16

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

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2021

Registered utility model specifications of Japan 1996-2021

Published registered utility model applications of Japan 1994-2021

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.
X	JP 6378960 B2 (KEYLEX CORP.) 22 August 2018 (2018-08-22), paragraphs [0005], [0015]-[0019], [0055]-[0060], [0066], [0069], fig. 5, 6	1-8
A	JP 2002-282951 A (TOYOTA MOTOR CORPORATION) 02 October 2002 (2002-10-02), paragraph [0016]	1-8



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

09 February 2021

Date of mailing of the international search report

02 March 2021

Name and mailing address of the ISA/

Japan Patent Office

3-4-3, Kasumigaseki, Chiyoda-ku,

Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No. PCT/JP2021/000860
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JP 6378960 B2	22 August 2018	(Family: none)
JP 2002-282951 A	02 October 2002	(Family: none)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2009220141 A [0003]