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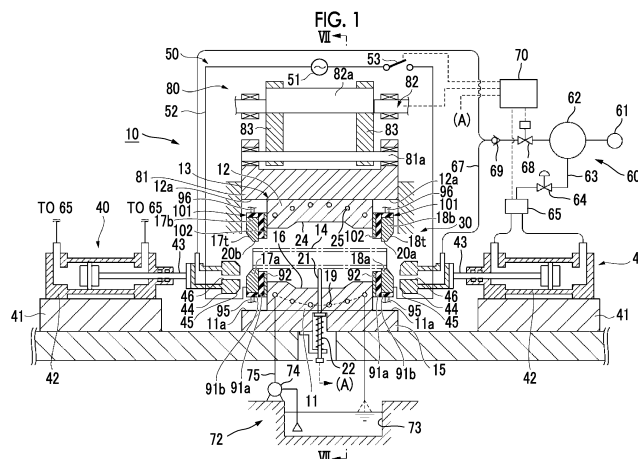
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(54) **MOLDING APPARATUS AND MOLDING METHOD**

(57) A forming apparatus (forming apparatus 10) is a forming apparatus that expands a metal pipe material (metal pipe material 14) and forms a metal pipe (metal pipe 100), the apparatus including: electrodes (electrodes 17 and 18) that hold the metal pipe material and supplies electric power to the metal pipe material to heat the metal pipe material; a forming die (forming die 30)

that quenches and forms the expanded metal pipe; and members (first insulating materials 91a and 101a, and sliding materials 92 and 102) disposed between the electrodes and the forming die, in which a region where quenching is not performed in the metal pipe is adjusted by adjusting a length of the members.



Description

Technical Field

[0001] The present disclosure relates to a forming apparatus and a forming method.

Background Art

[0002] In the related art, there is known a forming apparatus in which a metal pipe material is expanded and a metal pipe is formed by a forming die. For example, the forming apparatus disclosed in PTL 1 includes an electrode, an insulating material, a sliding material, and a forming die. In this forming apparatus, the metal pipe material held by the electrode, the insulating material, and the sliding material is energized and heated by the electric power supplied from the electrode, the metal pipe material disposed in the forming die in a state where the forming die is open is expanded, and accordingly, the metal pipe is formed.

Citation List

Patent Literature

[0003] [PTL 1] Japanese Unexamined Patent Publication No. 2016-190248

Summary of Invention

Technical Problem

[0004] There is a case where the metal pipe formed by the forming apparatus as described above is joined to another member. In this case, by forming a bolt hole at the end portion of the metal pipe or by welding the end portion of the metal pipe to another member, the metal pipe is connected to the other member. At this time, when the hardness of the end portion of the metal pipe is extremely high, it becomes difficult to drill or weld the end portion. Meanwhile, the center portion or the like of the metal pipe in order to ensure the stiffness of the metal pipe, sufficient hardness is required depending on the place.

[0005] Therefore, an object of the present disclosure is to provide a forming apparatus and a forming method capable of forming a metal pipe capable of adjusting a place having a low hardness and a place having a high hardness.

Solution to Problem

[0006] According to an aspect of the invention, there is provided a forming apparatus that expands a metal pipe material and forms a metal pipe, the apparatus including: an electrode that holds the metal pipe material, and supplies electric power to the metal pipe material to

heat the metal pipe material; a forming die that quenches and forms the expanded metal pipe; and a member disposed between the electrode and the forming die, in which a region where quenching is not performed in the metal pipe is adjusted by adjusting a length of the member.

[0007] In this aspect, the member is disposed between the electrode and the forming die. When forming the metal pipe material, the place corresponding to the forming die in the metal pipe material is quenched and formed by the forming die after being heated to a high temperature, and thus, the hardness is increased. Meanwhile, the place corresponding to the member in the metal pipe material is a place where quenching is not performed. Here, by adjusting the length of the member, the region where quenching is not performed in the metal pipe is adjusted. Therefore, the place where the hardness is low and the place where the hardness is high can be adjusted.

[0008] The member may be an insulating material and a sliding material arranged in order from an electrode side, and a sum of a thickness of the insulating material and a thickness of the sliding material in an array direction of the insulating material and the sliding material may be greater than a contact length between the electrode and the metal pipe material in a longitudinal direction of the metal pipe material. Of the metal pipe material, the portion held by the insulating material and the sliding material has a low cooling speed and is unlikely to be quenched, and thus, by providing the relatively thick insulating material and the sliding material, it is possible to increase the region having low hardness formed at the end portion of the metal pipe.

[0009] According to another aspect of the invention, there is provided a forming method for expanding a metal pipe material and forming a metal pipe, the method including: a step of heating the metal pipe material; and a step of forming the metal pipe material expanded by using a forming die, in which in the heating step, a member of which a length is adjusted is disposed between the electrode and the forming die, and a region where quenching is not performed in the metal pipe is adjusted.

[0010] In this aspect, it is possible to obtain the actions and effects similar to those of the above-described forming apparatus.

Advantageous Effects of Invention

[0011] According to an aspect of the present disclosure, the place where the hardness is low and the place where the hardness is high can be adjusted.

Brief Description of Drawings

[0012]

Fig. 1 is a schematic configuration view showing a forming apparatus according to an embodiment.

Fig. 2 is an enlarged perspective view showing a periphery of an electrode.

Fig. 3 is a sectional view taken along line III-III shown in Fig. 2.

Fig. 4 is a front view of the electrode.

Figs. 5A and 5B are enlarged views of the periphery of the electrode, Fig. 5A is a sectional view showing a state where the electrode holds a metal pipe material, and Fig. 5B is a view showing a state where a gas is supplied to the metal pipe material.

Figs. 6A and 6B are views showing a manufacturing step of a metal pipe, Fig. 6A is a view showing a state where the metal pipe material is disposed in a die, and Fig. 6B is a view showing a state where an end portion of the metal pipe material is heated.

Fig. 7 is a view showing a state where blow forming is performed.

Figs. 8A and 8B are sectional views of a forming die.

Fig. 8A is a view before blow forming, and Fig. 8B is a view after blow forming.

Fig. 9 is a view showing an example of the metal pipe which is a finished product.

Fig. 10 is a graph showing hardness distribution of the metal pipe according to an example.

Description of Embodiments

[0013] Hereinafter, preferred embodiments of a forming apparatus according to the present disclosure will be described with reference to the drawings. In addition, in each drawing, the same reference numerals are assigned to the same portions or the corresponding portions, and repeated descriptions thereof are omitted.

<Configuration of forming apparatus>

[0014] Fig. 1 is a schematic configuration view of a forming apparatus according to an embodiment. As shown in Fig. 1, a forming apparatus 10 for forming a metal pipe includes a forming die 13 including an upper die 12 and a lower die 11, a drive mechanism 80 which moves at least one of the upper die 12 and the lower die 11, a pipe holding mechanism 30 which holds a metal pipe material 14 disposed between the upper die 12 and the lower die 11, a power supply portion 50 which supplies electric power for heating the metal pipe material 14 held by the pipe holding mechanism 30, a gas supply portion 60 which supplies a high-pressure gas (gas) into the metal pipe material 14 which is held between the upper die 12 and the lower die 11 and is heated, a pair of gas supply mechanism 40 for supplying the gas from the gas supply portion 60 into the metal pipe material 14 held by the pipe holding mechanism 30, a water circulation mechanism 72 which forcibly water-cools the forming die 13, and a controller 70 which controls driving of the drive mechanism 80, driving of the pipe holding mechanism 30, driving of a power supply portion 50, and gas supply of the gas supply portion 60.

[0015] In the following description, the pipe related to the finished product will be referred to as a metal pipe 100 (refer to Fig. 9), and the pipe in the middle of completion will be referred to as a metal pipe material 14.

5 The metal pipe material 14 is a long steel material having a hollow tubular shape, and has a pair of end portions 14a and 14b positioned on both end sides thereof and a center portion 14c positioned between the pair of end portions 14a and 14b. (refer to Fig. 6A). As will be described later, as the metal pipe material 14 is formed, the pair of end portions 14a and 14b of the metal pipe material 14 are a pair of end portions 100a and 100b of the metal pipe 100, and the center portion 14c of the metal pipe material 14 is a center portion 100c of the metal pipe 100.

10 **[0016]** As illustrated in Fig. 1, the lower die 11, which is one part of the forming die 13, is fixed to a base stage 15. The lower die 11 is configured with a large steel block and includes a rectangular cavity (recessed portion) 16 on the upper surface of the lower die 11, for example. A cooling water passage 19 is formed in the lower die 11, and the lower die 11 includes a thermocouple 21 which is inserted from below at an approximately center. The thermocouple 21 is supported to be movable upward or downward by a spring 22.

25 **[0017]** Furthermore, the spaces 11a are formed in the vicinity of left and right ends (left and right ends in Fig. 1) of the lower die 11, and in the spaces 11a, the lower electrodes 17a and 18a, which are movable portions of the pipe holding mechanism 30, are disposed to be capable of advancing and retreating upward and downward. In addition, the metal pipe material 14 is placed on the lower electrodes 17a and 18a, and accordingly, the lower electrodes 17a and 18a come into contact with the metal pipe material 14 disposed between the upper die 12 and the lower die 11. Accordingly, the lower electrodes 17a and 18a are electrically connected to the metal pipe material 14.

30 **[0018]** The upper die 12, which is the other part of the forming die 13, is fixed to a slide 81 (which will be described later) that configures the drive mechanism 80. The upper die 12 is configured with a large steel block, a cooling water passage 25 is formed in the upper die 12, and the upper die 12 includes a rectangular cavity (recessed portion) 24 on the lower surface of the upper die 12, for example. The cavity 24 is provided at a position facing the cavity 16 of the lower die 11.

35 **[0019]** Similar to the lower die 11, spaces 12a are formed in the vicinity of left and right ends (left and right ends in Fig. 1) of the upper die 12, and upper electrodes 17b and 18b or the like, which are movable portions of the pipe holding mechanism 30 and will be described later, are disposed in the spaces 12a to be capable of advancing and retreating upward and downward. In addition, in a state where the metal pipe material 14 is placed on the lower electrodes 17a and 18a, the upper electrodes 17b and 18b move downward, and accordingly, the upper electrodes 17b and 18b come into contact with the metal pipe material 14 disposed between the

upper die 12 and the lower die 11. Accordingly, the upper electrodes 17b and 18b are electrically connected to the metal pipe material 14. Hereinafter, in a case where it is not necessary to particularly distinguish the lower electrodes 17a and 18a from the upper electrodes 17b and 18b, these are collectively referred to as electrodes 17 and 18.

[0020] Fig. 2 is an enlarged perspective view showing the vicinity of the electrode 18, and Fig. 3 is a sectional view taken along line III-III shown in Fig. 2.

[0021] As shown in Figs. 2 and 3, between the lower electrode 18a and the lower die 11, a first insulating material 91a and a sliding material 92 are arranged in order from the lower electrode 18a side. In other words, the first insulating material 91a is provided between the lower electrode 18a and the lower die 11, and the sliding material 92 is provided between the first insulating material 91a and the lower die 11. Between the upper electrode 18b and the upper die 12, a first insulating material 101a and a sliding material 102 are arranged in order from the upper electrode 18b side. In other words, the first insulating material 101a is provided between the upper electrode 18b and the upper die 12, and the sliding material 102 is provided between the first insulating material 101a and the upper die 12.

[0022] The first insulating materials 91a and 101a are plate materials made of a material having heat resistance and insulation properties, and have a function of preventing energization between the electrode 18 and the forming die 13. As the first insulating materials 91a and 101a, for example, a ceramic plate made of alumina is used. The first insulating material 91a has a thickness d1 in the array direction of the first insulating material 91a and the sliding material 92, and the first insulating material 101a has a thickness d1 in the array direction of the first insulating material 101a and the sliding material 102.

[0023] The sliding materials 92 and 102 are plate materials made of a heat-resistant material. As the sliding materials 92 and 102, for example, an alloy plate made of lead bronze, gunmetal, brass, phosphor bronze or white metal is used. The sliding material 92 has a thickness d2 in the array direction of the first insulating material 91a and the sliding material 92, and the sliding material 102 has a thickness d2 in the array direction of the first insulating material 101a and the sliding material 102.

[0024] A second insulating material 91b is fixed to the lower surface of the lower electrode 18a. An advancing and retreating rod 95 is connected to the second insulating material 91b, and an actuator is connected to the advancing and retreating rod 95 (refer to Fig. 1). The actuator is for moving the lower electrodes 17a and 18a or the like upward or downward and a fixation portion of the actuator is held on the base stage 15 side together with the lower die 11.

[0025] As shown in Fig. 3, the first insulating material 91a and the sliding material 92 are fixed to each other by fixing means 93 having a bolt 93a and a female screw member 93b. Specifically, the bolt 93a that penetrates

the sliding material 92 and enters the opening portion of the first insulating material 91a is screwed into the female screw member 93b embedded in the opening portion of the first insulating material 91a, and accordingly, the first insulating material 91a and the sliding material 92 are fastened and fixed to each other. The lower electrode 18a and the first insulating material 91a are fixed to each other by the fixing means 94. The second insulating material 91b is fixed to the lower surface of the lower electrode 18a and the first insulating material 91a.

[0026] Similarly, a second insulating material 101b is attached to the upper surface of the upper electrode 18b. An advancing and retreating rod 96 is connected to the second insulating material 101b, and an actuator is connected to the advancing and retreating rod 96. The actuator is for moving the upper electrodes 17b and 18b or the like upward or downward and a fixation portion of the actuator is held on the slide 81 side of the drive mechanism 80 together with the upper die 12.

[0027] The first insulating material 101a and the sliding material 102 are fixed to each other by the fixing means 93 having the bolt 93a and the female screw member 93b. Specifically, the bolt 93a that penetrates the sliding material 102 and enters the opening portion of the first insulating material 101a is screwed into the female screw member 93b embedded in the opening portion of the first insulating material 101a, and accordingly, the first insulating material 101a and the sliding material 102 are fastened and fixed to each other. The upper electrode 18b and the first insulating material 101a are fixed to each other by the fixing means 94. The second insulating material 101b is fixed to the upper surface of the upper electrode 18b and the first insulating material 101a.

[0028] Fig. 4 is a front view of the electrodes 17 and 18. As shown in Fig. 4, a semi-arc-shaped concave groove 20a corresponding to the shape of the outer peripheral surface of the metal pipe material 14 is formed on each of the surfaces of the lower electrode 18a and the upper electrode 18b that face each other, and the metal pipe material 14 can be placed so as to be exactly fitted into portions of the concave grooves 20a. Further, semi-arc-shaped concave grooves are also formed on each of the surface where the first insulating material 91a and the first insulating material 101a face each other and the surface where the sliding material 92 and the sliding material 102 face each other. These concave grooves have a diameter greater than the diameter of the concave groove 20a. Therefore, when the metal pipe material 14 is held between the upper electrode 18b and the lower electrode 18a, the first insulating materials 91a and 101a and the sliding materials 92 and 102 are not in contact with the metal pipe material 14. In addition, on the front surface (surface facing the outside of the die) of the electrode 18, a tapered concave surface 18t which is recessed with peripheries thereof inclined to form a tapered shape toward the concave groove 20a, is formed (also refer to Figs. 5A and 5B). Accordingly, when the metal pipe material 14 is sandwiched in the up-down direction

at the right part of the pipe holding mechanism 30, the electrodes 18 can exactly surround and hold the outer periphery of the end portion 14a of the metal pipe material 14 so as to come into close contact with the entire periphery.

[0029] As shown in Fig. 4, a refrigerant flow path 26 for circulating the cooling medium R is formed inside the lower electrode 18a. A pipe 28 is connected to the refrigerant flow path 26, and a refrigerant supply device 32 is connected to the pipe 28. The refrigerant supply device 32 supplies the cooling medium R to the refrigerant flow path 26 through the pipe 28, and recovers the cooling medium R that has exchanged heat with the lower electrode 18a from the refrigerant flow path 26. Similarly, a refrigerant flow path 27 for circulating the cooling medium R is formed inside the upper electrode 18b. A pipe 29 is connected to the refrigerant flow path 27, and a refrigerant supply device 31 is connected to the pipe 29. The refrigerant supply device 31 supplies the cooling medium R to the refrigerant flow path 27 through the pipe 29, and recovers the cooling medium R that has exchanged heat with the upper electrode 18b from the refrigerant flow path 27.

[0030] In one embodiment, the controller 70 may be connected to the refrigerant supply devices 31 and 32, and the flow rate of the cooling medium R supplied from the refrigerant supply devices 31 and 32 to the refrigerant flow paths 26 and 27 may be controlled in accordance with the control signal from the controller 70.

[0031] In this manner, as the cooling medium R circulates in the refrigerant flow paths 26 and 27, the heat of the electrode 18 is taken away by the cooling medium R, and the electrode 18 is cooled. As the cooling medium R, for example, cooling water is used. The cooling medium R is not limited to a liquid, and the electrode 18 may be cooled by using phase change cooling using heat of vaporization or gas cooling using gas.

[0032] The left part of the pipe holding mechanism 30 has the same configuration as that of the right part of the above-described pipe holding mechanism 30. In other words, the left part of the pipe holding mechanism 30 includes the lower electrode 17a and the upper electrode 17b that face each other in the up-down direction, the first insulating materials 91a and 101a that face each other in the up-down direction, and the sliding materials 92 and 102 that face each other in the up-down direction. More specifically, the first insulating material 91a is provided between the lower electrode 17a and the lower die 11, and the sliding material 92 is provided between the first insulating material 91a and the lower die 11. The advancing and retreating rod 95 is connected to the second insulating material 91b, and the actuator for moving the lower electrode 17a upward and downward is connected to the advancing and retreating rod 95. Further, the first insulating material 101a is provided between the upper electrode 17b and the upper die 12, and the sliding material 102 is provided between the first insulating material 101a and the upper die 12. The advancing and re-

treating rod 96 is connected to the second insulating material 101b, and the actuator for moving the upper electrode 17b upward and downward is connected to the advancing and retreating rod 96.

[0033] As shown in Fig. 4, at the left part of the pipe holding mechanism 30, a semi-arc-shaped concave groove 20b corresponding to the shape of the outer peripheral surface of the metal pipe material 14 is formed on each of the surfaces of the lower electrode 17a and the upper electrode 17b that face each other, and the metal pipe material 14 can be placed so as to be exactly fitted into portions of the concave grooves 20b. Further, semi-arc-shaped concave grooves are also formed on the surface where the first insulating material 91a and the first insulating material 101a face each other and the surface where the sliding material 92 and the sliding material 102 face each other. These concave grooves have a diameter greater than the diameter of the concave groove 20b. Therefore, when the metal pipe material 14 is held between the upper electrode 17b and the lower electrode 17a, the first insulating materials 91a and 101a and the sliding materials 92 and 102 are not in contact with the metal pipe material 14. In addition, on the front surface (surface facing the outside of the die) of the electrode 17, a tapered concave surface 17t which is recessed with peripheries thereof inclined to form a tapered shape toward the concave groove 20b, is formed. Accordingly, when the metal pipe material 14 is sandwiched in the up-down direction at the right part of the pipe holding mechanism 30, the electrodes 17 can exactly surround and hold the outer periphery of the end portion 14b of the metal pipe material 14 so as to come into close contact with the entire periphery.

[0034] Similar to the lower electrode 18a and the upper electrode 18b, the lower electrode 17a and the upper electrode 18b are formed with refrigerant flow paths 26 and 27, respectively. Refrigerant supply devices 31 and 32 are connected to the refrigerant flow path 26 and 27 through the pipes 28 and 29, respectively. The refrigerant supply devices 31 and 32 circulate and supply the cooling medium R to the refrigerant flow paths 26 and 27. As the cooling medium R circulates in the refrigerant flow paths 26 and 27, the heat of the lower electrode 17a and the upper electrode 17b is taken away by the cooling medium R, and the electrode 17 is cooled.

[0035] Fig. 5A is a view showing a state where the electrode 18 holds the metal pipe material 14. Here, as shown in Fig. 5A, when the contact length of the electrode 18 and the metal pipe material 14 held on the electrode 18 in the longitudinal direction of the metal pipe material 14 is L, a sum D of the thickness d1 of the first insulating material 91a and the thickness d2 of the sliding material 92 is set to be greater than the contact length L. Similarly, when the contact length of the electrode 17 and the metal pipe material 14 held on the electrode 17 in the longitudinal direction of the metal pipe material 14 is L, the sum D of the thickness d1 of the first insulating material 91a and the thickness d2 of the sliding material 92 is set to

be greater than the contact length L. By making the sum D of the thicknesses greater than the contact length L, it is possible to increase the region having low hardness formed at the end portions 100a and 100b of the metal pipe 100.

[0036] However, in the above-described example, the sum D of the thickness d1 of the first insulating materials 91a and 101a and the thickness d2 of the sliding materials 92 and 102 is set to be greater than the contact length L between the electrodes 17 and 18 and the metal pipe material 14, but the sum D of the thicknesses may be the contact length L or less. By increasing the sum D of the thicknesses, the length of the uncured portion formed on the end portion side of the metal pipe 100 can be adjusted. In other words, by adjusting the sum D, the region where quenching is not performed in the metal pipe 100 is adjusted. Therefore, the sum D of the thickness d1 of the first insulating materials 91a and 101a and the thickness d2 of the sliding materials 92 and 102 may be appropriately adjusted according to the required length of the uncured portion.

[0037] Fig. 1 will be referred to. Returning to Fig. 1, the drive mechanism 80 includes the slide 81 which moves the upper die 12 such that the upper die 12 and the lower die 11 are combined to each other, a shaft 82 which generates a driving force for moving the slide 81, and a connecting rod 83 for transmitting the driving force generated by the shaft 82 to the slide 81. The shaft 82 extends in the left-right direction above the slide 81, is supported to be rotatable, and includes an eccentric crank 82a which protrudes from left and right ends at a position separated from the axial center of the shaft 82 and extends in the left-right direction. The eccentric crank 82a and a rotary shaft 81a which is provided above the slide 81 and extends in the left-right direction are connected to each other by the connecting rod 83. In a case of the drive mechanism 80, the upward and downward movement of the slide 81 can be controlled by the controller 70 that controls rotation of the shaft 82 such that the height of the eccentric crank 82a in the up-down direction is changed and the positional change of the eccentric crank 82a is transmitted to the slide 81 through the connecting rod 83. Here, oscillation (rotary motion) of the connecting rod 83 generated when the positional change of the eccentric crank 82a is transmitted to the slide 81 is absorbed by the rotary shaft 81a. Note that, the shaft 82 is rotated or stopped in accordance with the driving of a motor or the like controlled by the controller 70, for example.

[0038] The power supply portion 50 includes a power source 51, a busbar 52 connected to the electrodes 17 and 18 below the power source 51, and a switch 53 provided on the busbar 52. The power supply portion 50 supplies electric power for energizing and heating the metal pipe material 14 to the electrodes 17 and 18. Specifically, the power supply portion 50 is controlled by a control signal from the controller 70 so that the metal pipe material 14 is heated until reaching quenching temperature (equal to or higher than an AC3 transformation point

temperature). The power supply portion 50 configures a heating unit that heats the metal pipe material 14 together with the electrodes 17 and 18.

[0039] Each of the pair of gas supply mechanisms 40 includes a cylinder unit 42, a cylinder rod 43 which advances and retreats in accordance with an operation of the cylinder unit 42, and a seal member 44 connected to a tip of the cylinder rod 43 on the pipe holding mechanism 30 side. The cylinder unit 42 is supported on a block 41. At the tip of the seal member 44, the tapered surface 45 is formed to be tapered, and the tip is configured to have a shape that can be exactly fitted to and in contact with the tapered concave surfaces 17t and 18t of the electrodes 17 and 18 (refer to Fig. 5B). The seal member 44 is connected to the cylinder unit 42 through the cylinder rod 43, and can advance and retreat in accordance with the operation of the cylinder unit 42. The cylinder unit 42 is placed and fixed on the base stage 15 through the block 41. The seal member 44 is formed with a gas passage 46 through which the high-pressure gas supplied from the gas supply portion 60 flows. The gas passage 46 opens at the tip of the seal member 44, and the gas flowing through the gas passage 46 is injected from the opening.

[0040] The gas supply portion 60 includes a gas source 61, an accumulator 62 in which the gas supplied by the gas source 61 is collected, a first tube 63 which extends from the accumulator 62 to the cylinder unit 42 of the gas supply mechanism 40, a pressure control valve 64 and a switching valve 65 which are interposed in the first tube 63, a second tube 67 which connects the accumulator 62 and the gas passage 46 to each other, and a pressure control valve 68 and a check valve 69 which are interposed in the second tube 67. The pressure control valve 64 supplies high-pressure gas, which is for pressing the metal pipe material 14 of the seal member 44, to the cylinder unit 42. The check valve 69 prevents the high-pressure gas from backflowing in the second tube 67.

[0041] The pressure control valve 68 supplies the gas passage 46 with a gas having an operation pressure for expanding the metal pipe material 14. The controller 70 is connected to the pressure control valve 68, and the controller 70 can control the opening degree of the pressure control valve 68 of the gas supply portion 60 such that a gas having a desired operation pressure is supplied into the metal pipe material 14.

[0042] With the information transmitted from (A) shown in Fig. 1, the controller 70 acquires temperature information from the thermocouple 21 and controls the drive mechanism 80 and the power supply portion 55. The water circulation mechanism 72 includes a water tank 73 which collects water, a water pump 74 which pumps up the water collected in the water tank 73, pressurizes the water, and sends the water to the cooling water passage 19 of the lower die 11 and the cooling water passage 25 of the upper die 12, and a pipe 75. Although omitted, a cooling tower for lowering the water temperature and a filter for purifying the water may be interposed in the pipe

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<Metal Pipe Forming method Using forming apparatus>

[0043] Next, a metal pipe forming method using the forming apparatus 10 will be described. Figs. 6A and 6B show a process from the pipe loading step of loading a metal pipe material 14 as the material to the energizing and heating step of energizing and heating the metal pipe material 14. First, the quenchable steel type cylindrical metal pipe material 14 is prepared. As shown in Fig. 6A, the metal pipe material 14 is placed (loaded) on the electrodes 17 and 18 provided on the lower die 11 side by using a robot arm or the like. Since the concave grooves 20a and 20b are formed on the electrodes 17 and 18, the metal pipe material 14 is positioned by the concave grooves 20a and 20b.

[0044] Next, the controller 70 controls the drive mechanism 80 and the pipe holding mechanism 30 such that the end portions 14a and 14b of the metal pipe material 14 are held by the pipe holding mechanism 30. Specifically, as shown in Fig. 6B, the actuator (not shown) capable of making the pipe holding mechanism 30 advance and retreat is operated, and the advancing and retreating rods 95 and 96 are moved upward and downward, respectively. During this upward and downward movement, the sliding material 92 and the sliding material 102 slide with respect to the lower die 11 and the upper die 12, respectively. Further, due to this upward and downward movement, the end portions 14a and 14b of the metal pipe material 14 are sandwiched in the up-down direction by the pipe holding mechanism 30. The sandwiching is performed in an aspect in which the concave grooves 20a and 20b formed on the electrodes 17 and 18 and the concave grooves formed on the first insulating materials 91a and 101a and the sliding materials 92 and 102 are present such that the electrodes 17 and 18 come into close contact with the vicinity of the both end portions of the metal pipe material 14 over the entire periphery. The present disclosure is not limited to a configuration in which the electrodes 17 and 18 come into close contact over the entire periphery of the metal pipe material 14, and the electrodes 17 and 18 may be in contact with a part of the metal pipe material 14 in the peripheral direction.

[0045] Next, the controller 70 controls the power supply portion 50 so as to heat the metal pipe material 14. Specifically, when the switch 53 is turned on by the control signal from the controller 70, the electric power from the power source 51 is supplied to the electrodes 17 and 18 through the busbar 52. The power supplied to the electrodes 17 and 18 is transmitted to the metal pipe material 14, and due to the resistance present in the metal pipe material 14, the metal pipe material 14 itself generates heat (Joule heat).

[0046] Here, since the current has the property of selectively flowing through a portion having a low resistance, as shown in Fig. 5A, a current C supplied from the

electrode 18 does not evenly flow over the entire length of the metal pipe material 14, and mainly flows into the metal pipe material 14 from the vicinity of the boundary between the electrode 18 and the first insulating materials 91a and 101a. In other words, at the boundary surface between the electrodes 18a and 18b and the metal pipe material 14, the region on the first insulating material 91a and 101a side is a region in which a larger current flows than in the region on the end portion 14a side. Therefore, when energizing and heating the metal pipe material 14, at the end portions 14a and 14b of the metal pipe material 14, the flow of current smaller than that at the center portion 14c of the metal pipe material 14. In Fig. 5A, only the main flow of the current C is indicated by an arrow, but the current also flows in the vicinity of the end portion 14a. Accordingly, the metal pipe material 14 has temperature distribution in which the temperatures of the end portions 14a and 14b are lower than the temperature of the center portion 14c of the metal pipe material 14. More specifically, the metal pipe material 14 is heated such that the temperature of the end portion 14a becomes lower than the quenching temperature of the metal pipe material 14, and the temperature of the center portion 14c becomes higher than the quenching temperature of the metal pipe material 14.

[0047] In particular, since the electrodes 17 and 18 are managed to a low temperature by the cooling medium R that flows through the refrigerant flow path 26, the temperature rise of the end portions 14a and 14b of the metal pipe material 14 is suppressed. Meanwhile, the temperature of the center portion 14c of the metal pipe material 14 is constantly measured by the thermocouple 21, and the electric power supplied to the electrodes 17 and 18 is controlled based on the measurement result.

[0048] Next, as shown in Fig. 7, the controller 70 controls the drive mechanism 80 such that the forming die 13 is closed with respect to the heated metal pipe material 14. Accordingly, the cavity 16 of the lower die 11 and the cavity 24 of the upper die 12 are combined with each other such that the metal pipe material 14 is disposed in a cavity portion MC between the lower die 11 and the upper die 12 and is sealed. At the time of closing the die, the sliding material 92 slides with respect to the lower die 11 and the sliding material 102 slides with respect to the upper die 12.

[0049] Thereafter, by operating the cylinder unit 42 of the gas supply mechanism 40, the seal member 44 advances such that both ends of the metal pipe material 14 are sealed (also refer to Fig. 5B). After the sealing is completed, the pressure control valve 68 is opened to blow the high-pressure gas from the accumulator 62 into the metal pipe material 14 through the gas passage 46.

[0050] The center portion 14c of the metal pipe material 14 is heated to a high temperature (approximately 950°C) and softened, and accordingly, the gas supplied into the metal pipe material 14 thermally expands. Therefore, for example, compressed air may be used as the gas to be supplied such that the center portion 14c of the metal

pipe material 14 can be easily expanded by compressed air obtained by thermally expanding the metal pipe material 14 of 950°C. Accordingly, as shown in Figs. 8A and 8B, the center portion 14c of the metal pipe material 14 disposed in the cavity portion MC of the forming die 13 is formed so as to follow the shape of the cavity portion MC.

[0051] An outer peripheral surface of the blow-formed and expanded center portion 14c of the metal pipe material 14 comes into contact with the cavity 16 of the lower die 11 and the cavity 24 of the upper die 12 and rapidly cooled (since the upper die 12 and the lower die 11 have a large heat capacity and are managed to a low temperature, when the metal pipe material 14 comes into contact with the upper die 12 and the lower die 11, the heat of the pipe surface is taken to the die side at once), and thus, quenching is performed. The above-described cooling method is referred to as die contact cooling or die cooling. Immediately after being rapidly cooled, austenite transforms into martensite (hereinafter, transformation from austenite to martensite is referred to as martensitic transformation). The cooling speed is set to be low in a second half of the cooling, and thus, martensite transforms into another structure (such as troostite, sorbite, or the like) due to recuperation. Therefore, it is not necessary to separately perform tempering treatment. In the present embodiment, the cooling may be performed by supplying a cooling medium into, for example, the cavity 24, instead of or in addition to the die cooling. For example, cooling may be performed by bringing the metal pipe material 14 into contact with the dies (the upper die 12 and the lower die 11) until a temperature at which the martensitic transformation starts is reached, and the dies may be opened thereafter with a cooling medium (cooling gas) blown onto the metal pipe material 14 such that martensitic transformation occurs.

[0052] Meanwhile, when energizing and heating the metal pipe material 14, the end portions 14a and 14b of the metal pipe material 14 are heated so as to have a temperature lower than the quenching temperature, and thus, the end portion 14a is not quenched. In particular, since the electrodes 17 and 18 are managed to a low temperature by the cooling medium R that flows through the refrigerant flow path 26, the temperature rise of the end portions 14a and 14b of the metal pipe material 14 is suppressed during the energization and heating, and quenching the end portions 14a and 14b of the metal pipe material 14 is suppressed. The portion held between the first insulating materials 91a and 101a and the sliding materials 92 and 102 of the metal pipe material 14 is not in contact with the forming die 13, and thus, as compared to the center portion 14c of the metal pipe material 14, the cooling speed decreases. Therefore, the portion of the metal pipe material 14 is less likely to be quenched. From the above, of the metal pipe, the regions corresponding to the electrodes 17 and 18, the insulating materials 91a and 101a, and the sliding materials 92 and 102 at the time of forming are regions where quenching

is not performed.

[0053] As described above, the metal pipe 100 having an approximately rectangular main body is obtained by performing cooling after the blow forming with respect to the metal pipe material 14 and by performing die opening. At the time of closing the die, the sliding material 92 slides with respect to the lower die 11 and the sliding material 102 slides with respect to the upper die 12.

[0054] Fig. 9 is a view showing the metal pipe 100 which is a finished product. As shown in Fig. 9, the metal pipe 100, which is a forming product, has the pair of end portions 100a and 100b and the center portion 100c. The pair of end portions 100a and 100b are formed by forming the pair of end portions 14a and 14b of the metal pipe material 14, and the center portion 100c is formed by forming the center portion 14c of the metal pipe material 14. As described above, since the pair of end portions 100a and 100b are not quenched, the pair of end portions 100a and 100b are uncured portions having relatively low hardness. On the other hand, since the center portion 100c is quenched, the center portion 100c is a cured portion having a hardness higher than that of the end portions 100a and 100b. Therefore, by forming the metal pipe material 14 using the forming apparatus 10, it is possible to form the metal pipe 100 having a low hardness at the pair of end portions 100a and 100b and a high hardness at the center portion 100c.

[0055] In one embodiment, by controlling the temperature distribution of the metal pipe material 14 at the time of forming, the temperatures of the electrodes 17 and 18, the temperature of the forming die 13, and the like, the metal pipe 100 having a Vickers hardness of less than 300 HV at the pair of end portions 100a and 100b and having a Vickers hardness of 300 HV or greater at the center portion 100c may be formed. By setting the Vickers hardness of the pair of end portions 100a and 100b to be less than 300 HV, it is possible to perform processing such as drilling and welding on the pair of end portions 100a and 100b.

[0056] According to the forming apparatus 10, when the forming die 13 is moved by the drive mechanism 80, the sliding materials 92 and 102 are interposed respectively between the lower die 11 and the first insulating material 91a and between the upper die 12 and the first insulating material 101a, respectively, and thus, the forming die 13 and the first insulating materials 91a and 101a do not come into contact with each other. Therefore, the abrasion of the first insulating materials 91a and 101a can be suppressed.

[0057] Above, the forming apparatus 10 is the forming apparatus 10 that expands the metal pipe material 14 and forms the metal pipe 100, the apparatus including: the electrodes 17 and 18 that hold the metal pipe material 14, supplies electric power to the metal pipe material 14, and heats the metal pipe material 14; the forming die 13 that quenches and forms the expanded metal pipe 100; and the sliding materials 92 and 102 and the insulating materials 91a, 91b, 101a, and 101b disposed between

the electrodes 17 and 18 and the forming die 13, in which a region where quenching is not performed in the metal pipe 100 is adjusted by adjusting a length of the sliding materials 92 and 102 and the insulating materials 91a, 91b, 101a, and 101b.

[0058] In this aspect, the sliding materials 92 and 102 and the insulating materials 91a, 91b, 101a, and 101b are disposed between the electrodes 17 and 18 and the forming die 13. When forming the metal pipe material 14, the place corresponding to the forming die 13 in the metal pipe material 14 is quenched and formed by the forming die 13 after being heated to a high temperature, and thus, the hardness is increased. Meanwhile, the places corresponding to the sliding materials 92 and 102 and the insulating materials 91a, 91b, 101a, and 101b in the metal pipe material 14 are places where quenching is not performed. Here, by adjusting the length of the sliding materials 92 and 102 and the insulating materials 91a, 91b, 101a, and 101b, the region where quenching is not performed in the metal pipe 100 is adjusted. Therefore, the place where the hardness is low and the place where the hardness is high can be adjusted.

[0059] The forming method is the forming method for expanding the metal pipe material 14 and forming the metal pipe 100, the method including: a step of heating the metal pipe material 14; and a step of forming the metal pipe material 14 expanded by using the forming die 13, in which, in the heating step, the sliding materials 92 and 102 and the insulating materials 91a, 91b, 101a, and 101b, of which the lengths are adjusted, are disposed between the electrodes 17 and 18 and the forming die 13, and a region where quenching is not performed in the metal pipe 100 is adjusted.

[0060] In this aspect, it is possible to obtain the actions and effects similar to those of the above-described forming apparatus.

[0061] Hereinafter, the present disclosure will be described more specifically based on Examples, but the present disclosure is not limited to the following Examples.

[0062] Fig. 10 is a graph showing hardness distribution of the metal pipe according to an example. The metal pipe is obtained by forming the metal pipe material using the above-described forming apparatus 10.

[0063] The metal pipe according to the example formed in this manner has the hardness distribution shown in Fig. 10. Specifically, the metal pipe according to the example has a Vickers hardness of less than 300 HV within a distance of 0 mm to 55 mm from one end, and has a Vickers hardness of approximately 500 HV within a distance of 65 mm to 150 mm from one end. From this example, by forming the metal pipe material using the forming apparatus 10, it is confirmed that it is possible to form the metal pipe having a low hardness at the end portion and a high hardness at the center portion.

[0064] Although the forming apparatus 10 according to various embodiments has been described above, various modifications can be configured without being lim-

ited to the above-described embodiment without changing the concept of the disclosure.

[0065] In the above-described embodiment, the sum of the thickness of the first insulating material 91a and the thickness of the sliding material 92 is set to be the same as the sum of the thickness of the first insulating material 101a and the thickness of the sliding material 102. However, the sum of these thicknesses may be different from each other. In this case, the length of the uncured portion can be made different between the upper side and the lower side of the metal pipe 100.

[0066] In the above-described embodiment, the first insulating materials 91a and 101a and the sliding materials 92 and 102 are configured as members independent of each other, but the sliding materials 92 and 102 are respectively sprayed to the first insulating materials 91a and 101a, and accordingly, the first insulating materials 91a and 101a and the sliding materials 92 and 102 may be integrally formed. In this case, since the first insulating materials 91a and 101a and the sliding materials 92 and 102 can be fixed without using the fixing means 93, the number of components can be reduced and the cost can be reduced.

[0067] In the above-described embodiment, the sliding materials 92 and 102 are fixed to the first insulating materials 91a and 101a sides, respectively, but the sliding material 92 may be fixed to the lower die 11 and the sliding material 102 may be fixed to the upper die 12, respectively. Even in this case, since the forming die 13 and the first insulating materials 91a and 101a do not come into contact with each other, abrasion of the first insulating materials 91a and 101a can be suppressed.

[0068] The drive mechanism 80 according to the above-described embodiments moves only the upper die 12, but in addition to or instead of the upper die 12, or the lower die 11 may be moved. In a case where the lower die 11 moves, the lower die 11 is not fixed to the base stage 15, but is attached to, for example, the slide 81 of the drive mechanism 80.

[0069] The metal pipe 100 according to the above-described embodiment may have one or more flange portions. In this case, when the upper die 12 and the lower die 11 are fitted to each other, one or more sub-cavity portions that communicate with the cavity portion MC are formed in the forming die 13.

[0070] The drive mechanism 80 according to the above-described embodiment, for example, a pressure cylinder, a guide cylinder, and a servo motor may be used instead of the shaft 82. In this case, the slide 81 is suspended by the pressure cylinder and is guided to prevent lateral oscillation by the guide cylinder. The servomotor functions as a fluid supply unit that supplies the fluid (operating oil in a case of adopting a hydraulic cylinder as a pressure cylinder), which drives the pressure cylinder, to the pressure cylinder.

[0071] There is a case where the metal pipe formed by the forming apparatus is joined to another member. In this case, by forming a bolt hole at the end portion of

the metal pipe or by welding the end portion of the metal pipe to another member, the metal pipe is connected to the other member. At this time, when the hardness of the end portion of the metal pipe is extremely high, it becomes difficult to drill or weld the end portion. Meanwhile,

[0072] Therefore, in one aspect, it is required to provide a forming apparatus and a forming method capable of forming a metal pipe having a low hardness at the end portion and a high hardness at the center portion.

[0073] In one aspect, a forming apparatus expands the metal pipe material to form a metal pipe. The forming apparatus includes an electrode that holds the end portion of the metal pipe material, supplies the electric power to the metal pipe material, and heats the metal pipe material, a gas supply portion that supplies the gas into the heated metal pipe material and expands the heated metal pipe material, and the forming die that forms the expanded metal pipe. This electrode heats the metal pipe material such that the temperature of the end portion of the metal pipe material to the temperature lower than that at the center portion of the metal pipe material.

[0074] In this aspect, the metal pipe material is heated such that the temperature of the end portion of the metal pipe material to the temperature lower than that at the center portion of the metal pipe material. When the temperature rise at the end portion of the metal pipe material is suppressed during forming of the metal pipe material, the end portion of the metal pipe material is less likely to be quenched, and thus, the increase in hardness is suppressed. Meanwhile, since the center portion of the metal pipe is heated to a high temperature, then, quenching is performed by performing cooling after this, and the hardness is increased. Therefore, according to the forming apparatus of the above-described aspect, it is possible to form a metal pipe having a low hardness at the end portion and a high hardness at the center portion.

[0075] The electrode may be formed with a refrigerant flow path through which the cooling medium flows. By allowing the cooling medium to flow through the refrigerant flow path, it is possible to suppress a temperature rise at the end portion of the metal pipe material when electric power is supplied from the electrodes. Accordingly, the end portion of the metal pipe material which is held in the electrode is less likely to be quenched, and the metal pipe having a low hardness at the end portion can be more reliably formed.

[0076] The insulating material and the sliding material may be arranged in order from the electrode side between the electrode and the forming die, and a sum of a thickness of the insulating material and a thickness of the sliding material in an array direction of the insulating material and the sliding material may be greater than a contact length between the electrode and the metal pipe material in the longitudinal direction of the metal pipe material. Of the metal pipe material, the portion held by

the insulating material and the sliding material has a low cooling speed and is unlikely to be quenched, and thus, by providing the relatively thick insulating material and the sliding material, it is possible to increase the region having low hardness formed at the end portion of the metal pipe.

[0077] According to the aspect, it is possible to form a metal pipe having a low hardness at the end portion and a high hardness at the center portion.

Reference Signs List

[0078]

- 10 forming apparatus
- 11 lower die
- 12 upper die
- 13 forming die
- 14 metal pipe material
- 14a, 14b end portion
- 14c center portion
- 17, 18 electrode
- 26, 27 refrigerant flow path
- 30 pipe holding mechanism
- 31, 32 refrigerant supply device
- 40 gas supply mechanism
- 50 power supply portion
- 60 gas supply portion
- 70 controller
- 91a, 101a first insulating material (member)
- 91b, 101b second insulating material (member)
- 92, 102 sliding material (member)
- 100 metal pipe
- 100a, 100b end portion
- 100c center portion
- D sum of thicknesses
- L contact length
- MC cavity portion
- R cooling medium

Claims

1. A forming apparatus that expands a metal pipe material and forms a metal pipe, the apparatus comprising:

an electrode that holds the metal pipe material, and supplies electric power to the metal pipe material to heat the metal pipe material;
a forming die that quenches and forms the expanded metal pipe; and
a member disposed between the electrode and the forming die, wherein
a region where quenching is not performed in the metal pipe is adjusted by adjusting a length of the member.

2. The forming apparatus according to the claim 1, wherein

the member is an insulating material and a sliding material arranged in order from an electrode side, and
a sum of a thickness of the insulating material and a thickness of the sliding material in an array direction of the insulating material and the sliding material is greater than a contact length between the electrode and the metal pipe material in a longitudinal direction of the metal pipe material.

3. A forming method for expanding a metal pipe material and forming a metal pipe, the method comprising:

a step of heating the metal pipe material; and
a step of forming the metal pipe material expanded by using a forming die, wherein
in the heating step, a member of which a length is adjusted is disposed between the electrode and the forming die, and a region where quenching is not performed in the metal pipe is adjusted.

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FIG. 1
VII

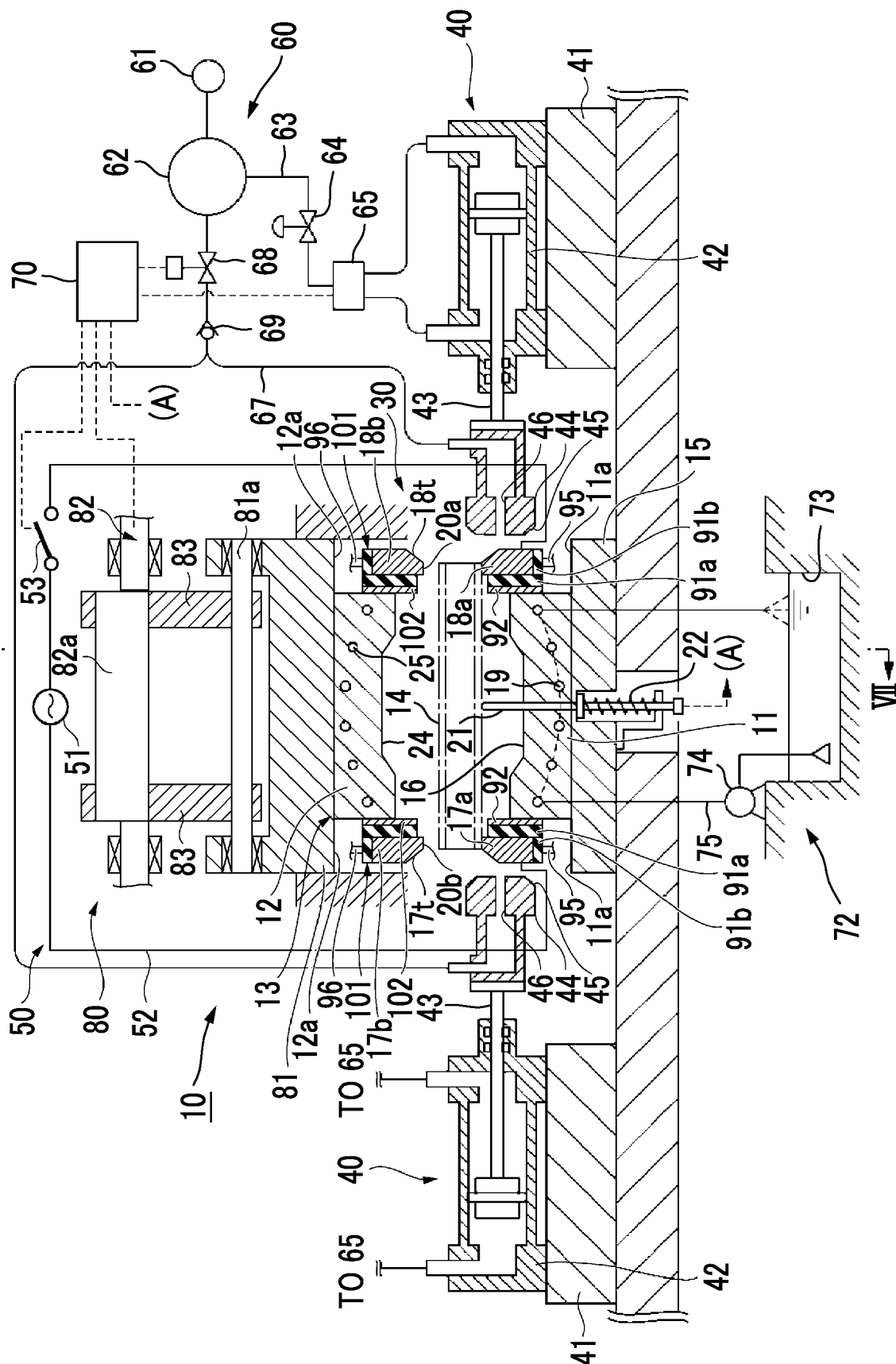


FIG. 2

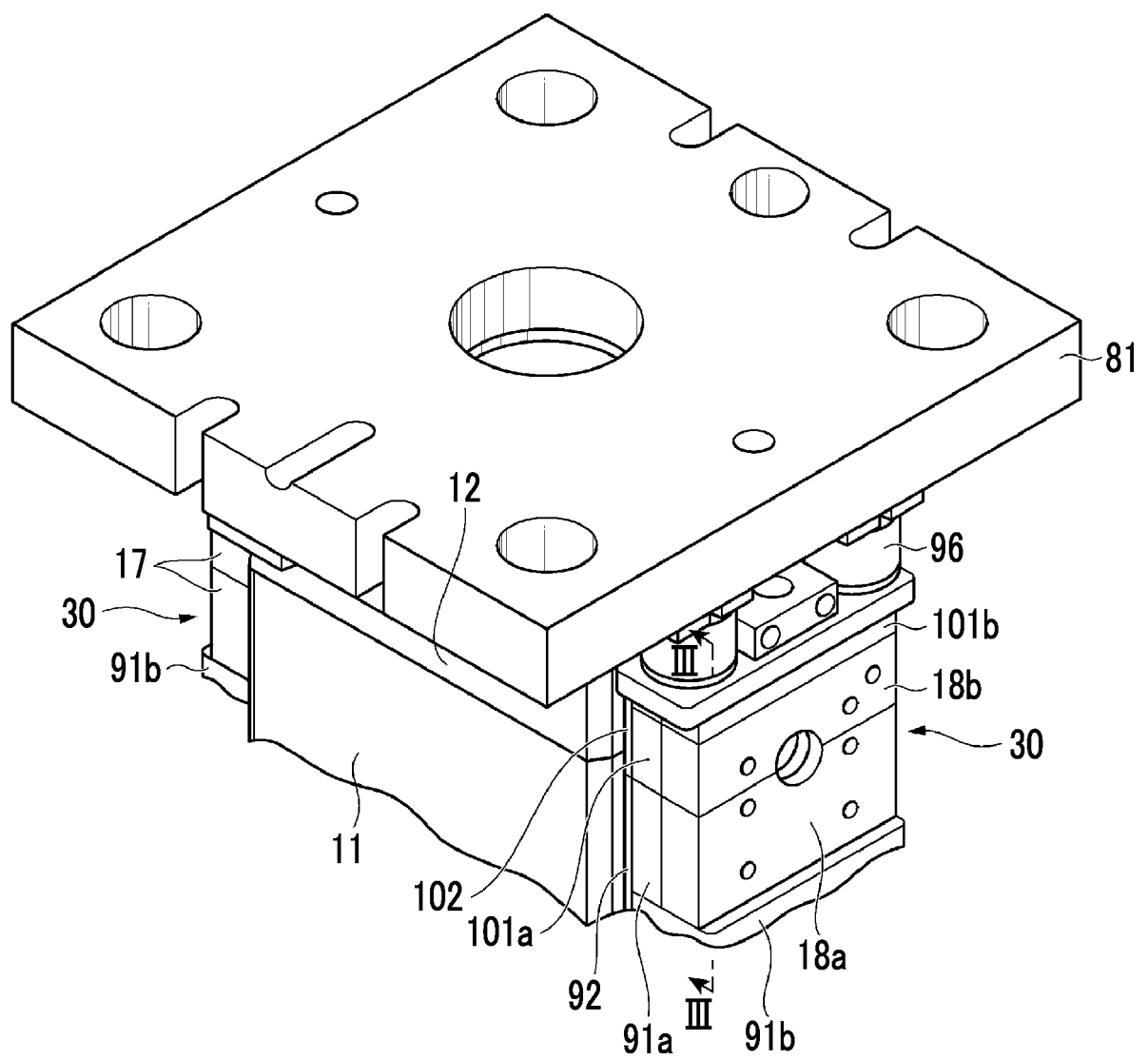


FIG. 3

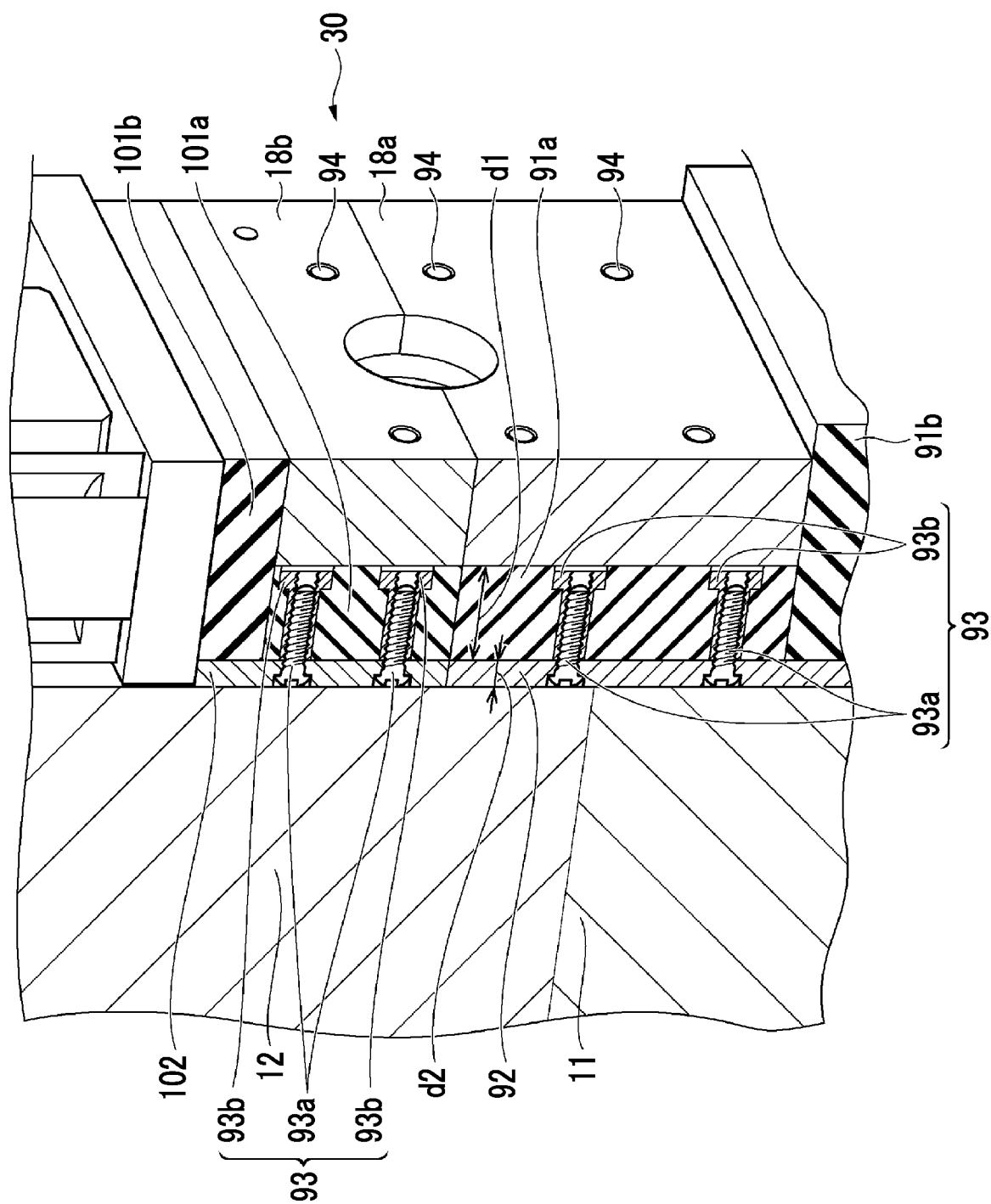


FIG. 4

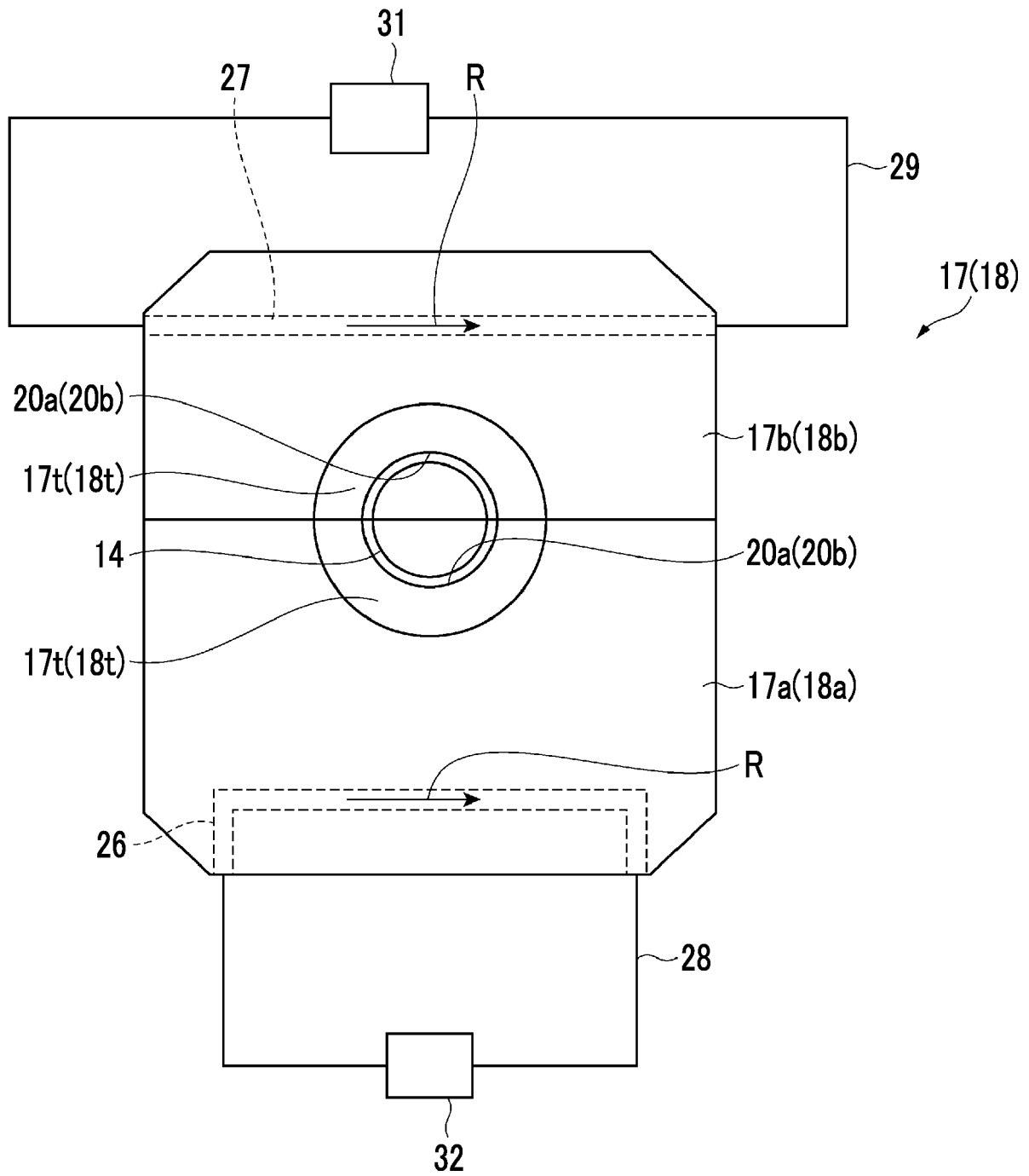


FIG. 5A

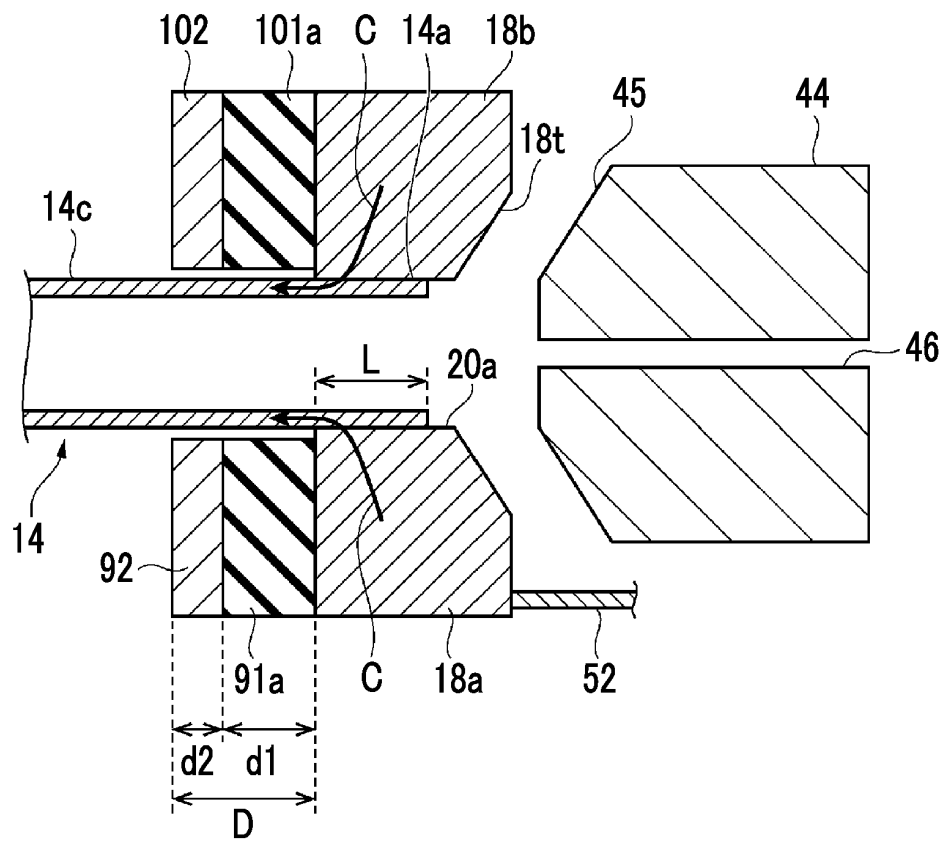
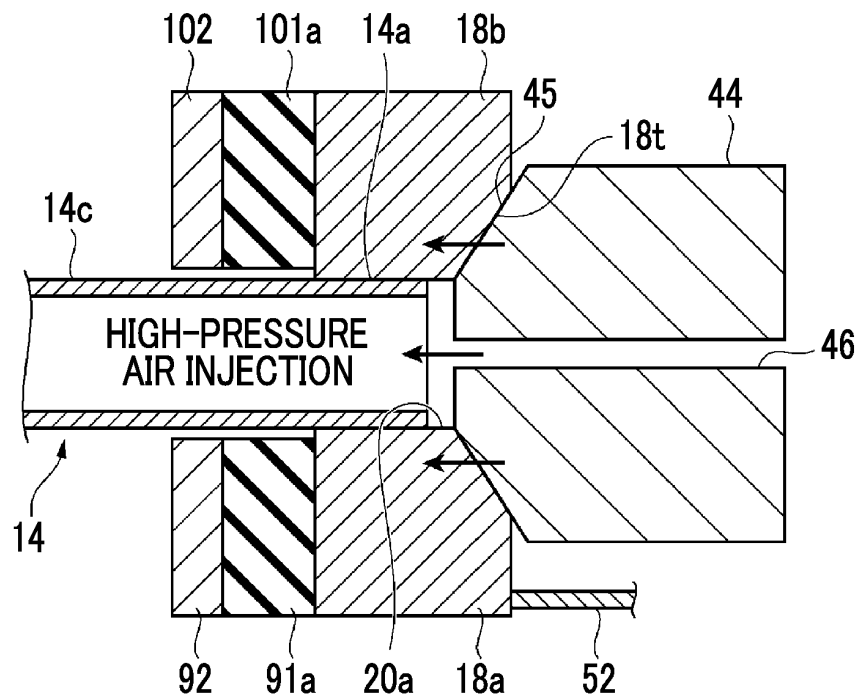


FIG. 5B



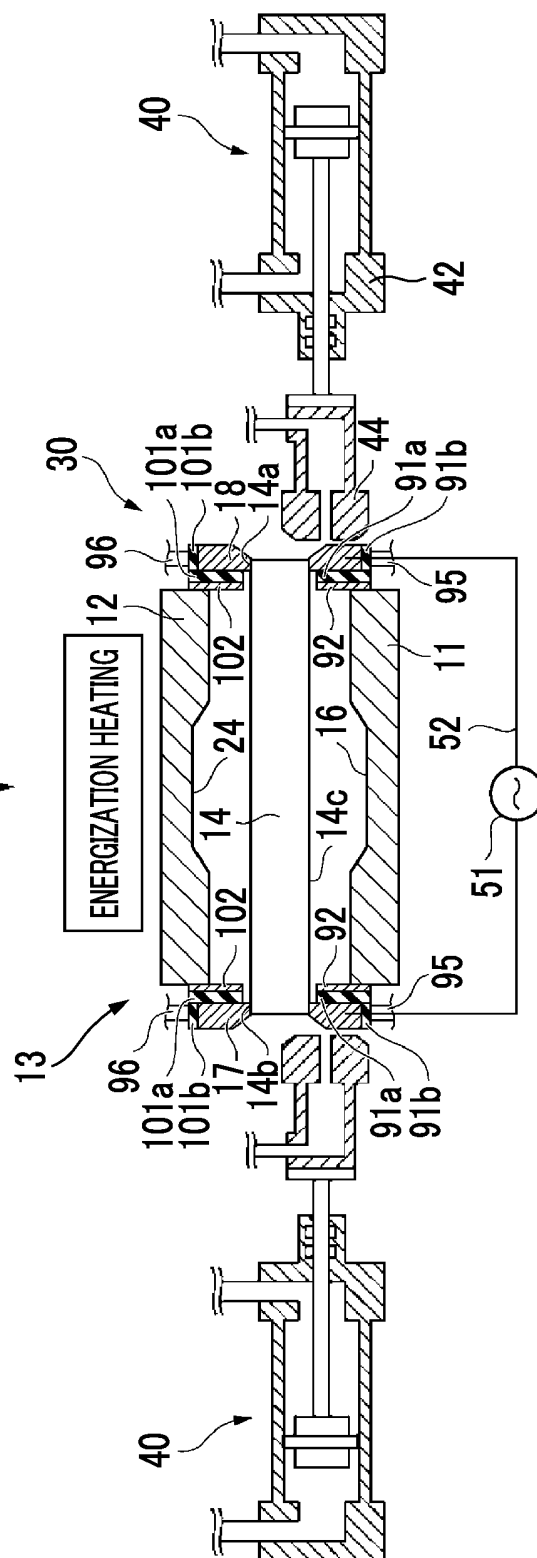
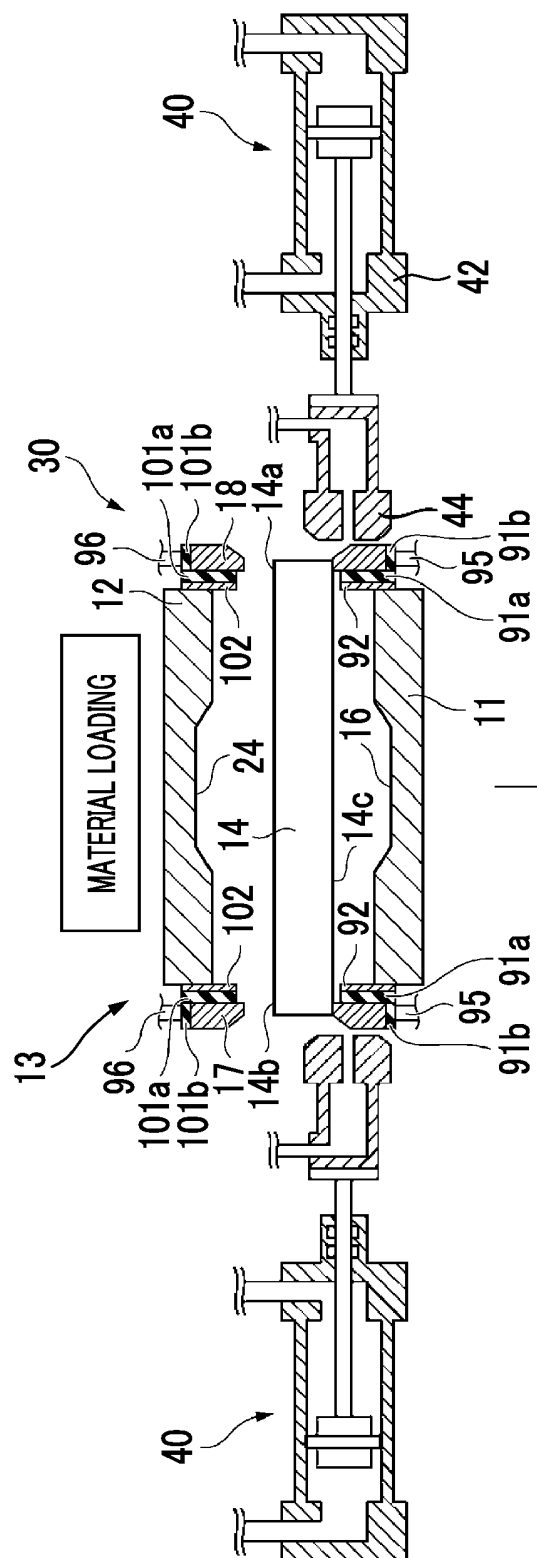


FIG. 7

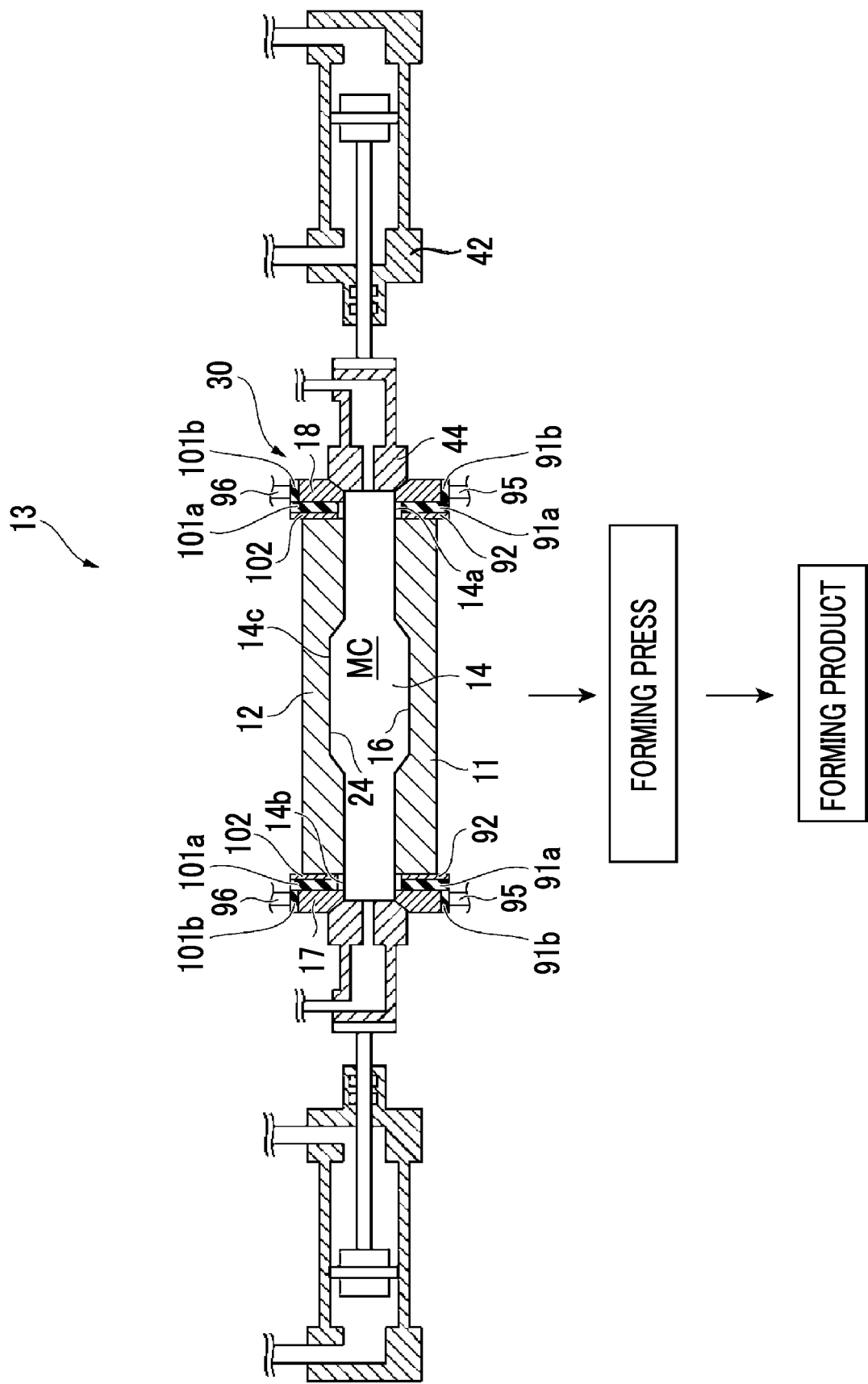


FIG. 8A

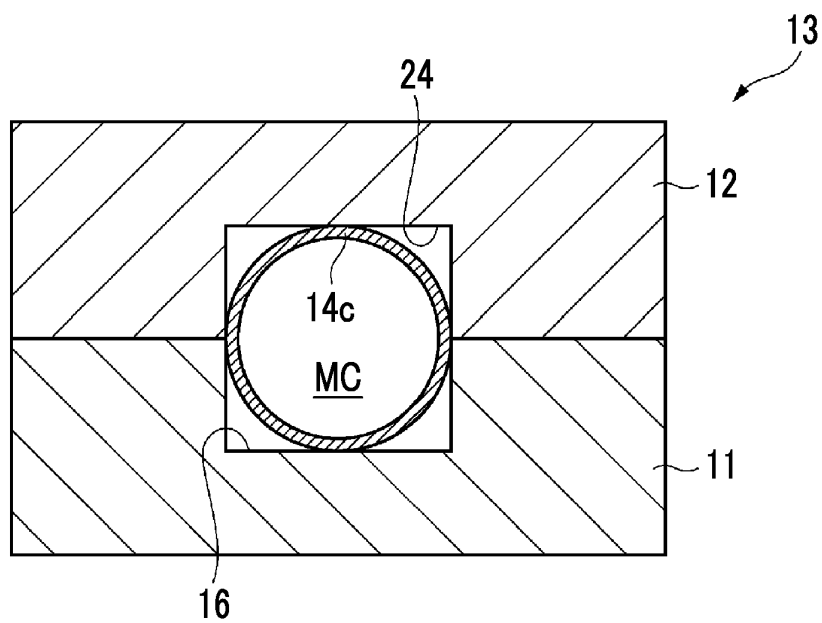


FIG. 8B

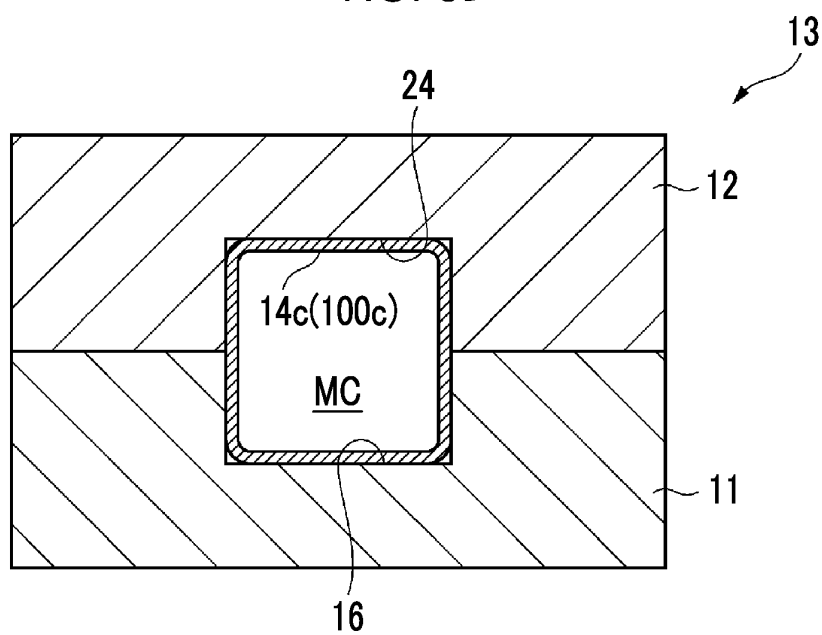


FIG. 9

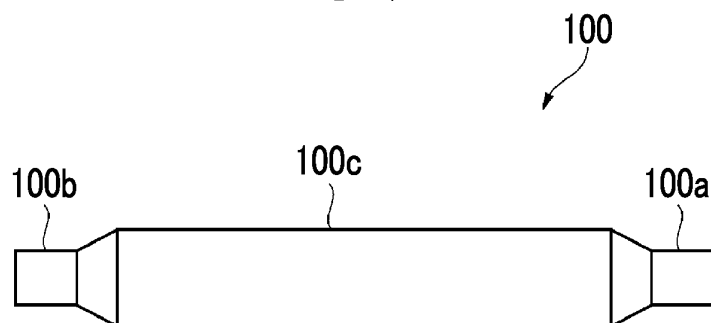
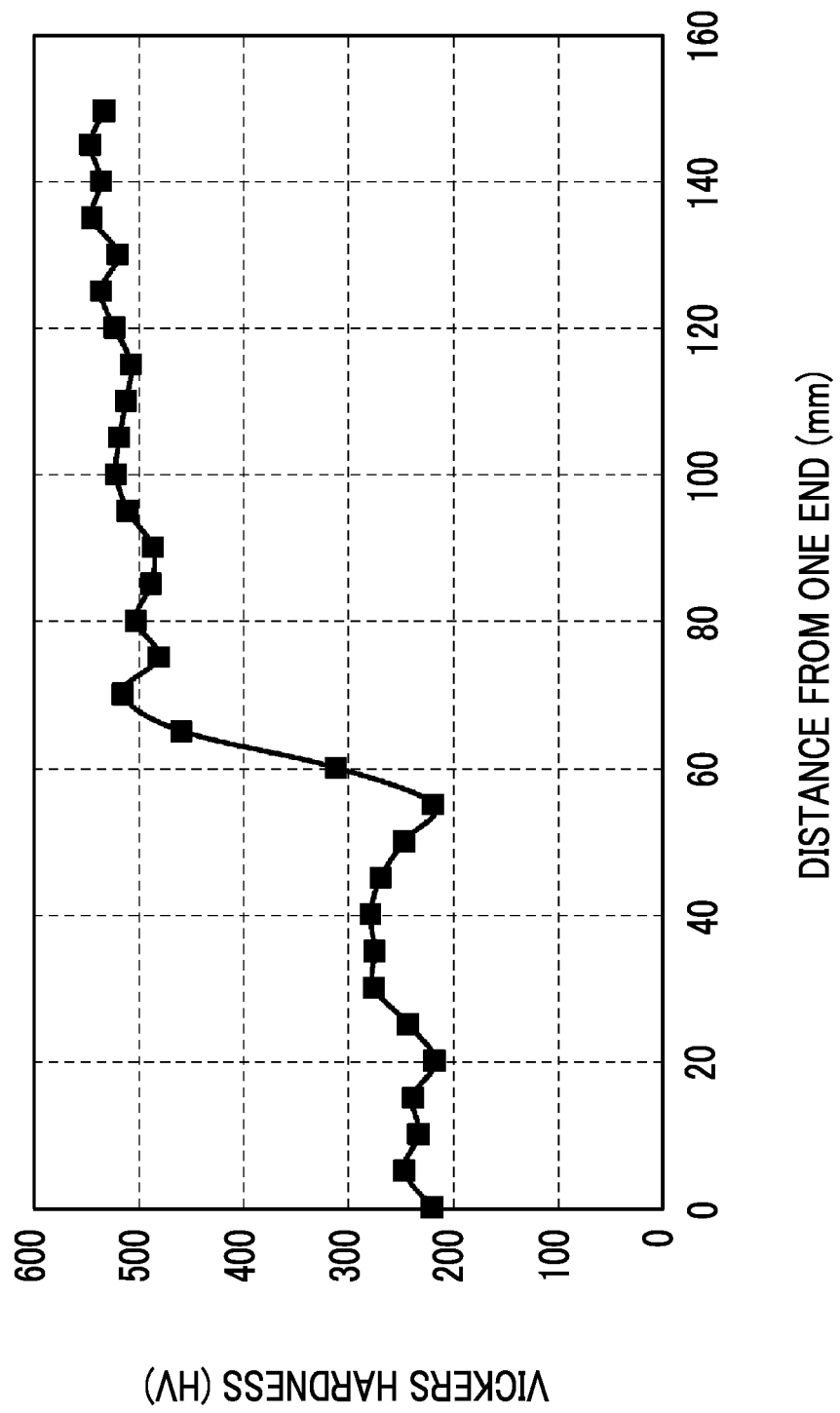


FIG. 10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/008691

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. B21D37/16(2006.01)i, B21D51/10(2006.01)i, B21D26/033(2011.01)i
 FI: B21D26/033, B21D37/16, B21D51/10

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. B21D37/00, 37/16, B21D51/10, B21D22/00-26/14

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 1971-2020

Registered utility model specifications of Japan 1996-2020

Published registered utility model applications of Japan 1994-2020

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 2015-221445 A (SUMITOMO HEAVY INDUSTRIES, LTD.) 10 December 2015, paragraphs [0017]-[0060], fig. 1-16	1-3
A	US 6613164 B2 (DYKSTRA, William C.) 02 September 2003, description, column 8, line 60 to column 20, line 61, fig. 1-29	1-3
A	US 2007/0101786 A1 (YANG, Wuhua) 10 May 2007, paragraphs [0009]-[0026], fig. 1, 2	1-3



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"I"

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

"X"

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

"Y"

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

"&"

document member of the same patent family

Date of the actual completion of the international search

25.03.2020

Date of mailing of the international search report

07.04.2020

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 Japan Patent Office
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/JP2020/008691

Patent Documents referred to in the Report	Publication Date	Patent Family	Publication Date
JP 2015-221445 A	10.12.2015	US 2017/0066028 A1 paragraphs [0024]- [0089], fig. 1-16 WO 2015/178419 A1 EP 3147043 A1 KR 10-2017-0003987 A CN 106457346 A WO 2001/023116 A1 description, page 12, line 5 to page 29, line 11, fig. 1-29 EP 1704936 A2 (Family: none)	
US 6613164 B2	02.09.2003		
US 2007/0101786 A1	10.05.2007		

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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