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- **IMAMURA, Yoshihide**
Kobe-shi, Hyogo 650-8670 (JP)
- **MIKAMI, Kohei**
Kobe-shi, Hyogo 650-8670 (JP)
- **IWASAKI, Hayato**
Kobe-shi, Hyogo 650-8670 (JP)
- **HIRAKAWA, Takeo**
Kobe-shi, Hyogo 650-8670 (JP)

(71) Applicant: **Kawasaki Jukogyo Kabushiki Kaisha**
Kobe-shi, Hyogo 650-8670 (JP)

(74) Representative: **Dehns**
St. Brides House
10 Salisbury Square
London EC4Y 8JD (GB)

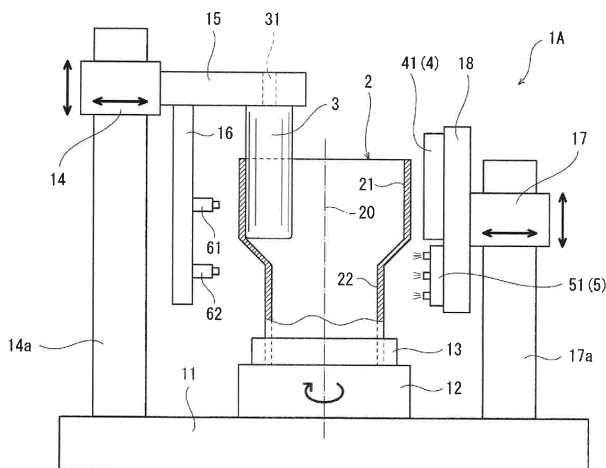
(72) Inventors:
• **IKAWA, Ken**
Kobe-shi, Hyogo 650-8670 (JP)

(54) TUBE DIAMETER EXPANDING METHOD AND MOLDING APPARATUS

(57) A tube diameter expanding method includes: rotating a tube having one end fixed to a turntable about a center axis of the tube; inserting a rod-like roller which extends in an axial direction of the tube into the tube from another end of the tube, and bringing the rod-like roller into contact with a forming region extending from the other end to a predetermined position of the tube; heating the forming region of the tube; cooling at least a section

located near the forming region and within a non-forming region extending from the predetermined position to the one end of the tube; and moving the rod-like roller in a state of contacting the forming region of the tube, in a direction from the one end of the tube toward the other end of the tube and outward in a radial direction of the tube.

Fig. 1



Description

Technical Field

[0001] The present invention relates to a tube diameter expanding method and a forming apparatus for implementing the same.

Background Art

[0002] Conventionally, a method of partially expanding a tube in diameter by spinning forming is known. For example, PTL 1 discloses a tube diameter expanding method using a pair of disk rollers.

[0003] Specifically, in the diameter expanding method disclosed in PTL 1, a tube having one end thereof fixed to a turntable is rotated about a center axis of the tube in a state where the tube is sandwiched between a first roller disposed in the tube and a second roller disposed outside the tube. Then, the first roller and the second roller are moved in a direction from one end toward the other end of the tube and outward in a radial direction of the tube. As a result, the first roller presses the tube, and a section extending from the pressed position to the other end is expanded in diameter. The second roller plays a role of enhancing formability of the diameter-expanded section.

Citation List

Patent Literature

[0004] PTL 1: JP 2000-246353 A

Summary of Invention

Technical Problem

[0005] Incidentally, in a case where a tube is expanded in diameter by moving a disk roller disposed inside the tube in the radial direction and the axial direction of the tube, a section of the tube which is located at the other-end side of the disk roller tries to maintain the original diameter as illustrated in Fig. 7. Therefore, thickness reduction (so-called necking) occurs due to tension at a section of the tube which is located at the one-end side of the disk roller. In order to suppress occurrence necking as described above, it is desirable to use a rod-like roller extending in the axial direction of the tube in lieu of the disk roller.

[0006] However, in the case of using a rod-like roller, it is necessary to press a wide range of a forming region which is a region of the tube whose diameter is to be expanded. Therefore, it is necessary to push the rod-like roller outward in the radial direction with great force. In contrast, if the forming region of the tube is heated, pushing force of the rod-like roller can be reduced.

[0007] However, in a case where the forming region of

the tube is heated, a large amount of heat is given to the forming region, and the heat amount is also transmitted to a non-forming region of the tube which is located at the one-end side of the forming region. Therefore, when the rod-like roller is pressed against the forming region, the non-forming region also deforms.

[0008] In view of the above, an object of the present invention is to suppress deformation of a non-forming region of a heated tube when a rod-like roller is pressed against a heated forming region of the tube.

Solution to Problem

[0009] In order to solve the above-described problem, the present invention provides a tube diameter expanding method including: a step for rotating a tube having one end fixed to a turntable about a center axis of the tube; a step for inserting a rod-like roller extending in an axial direction of the tube into the tube from the other end of the tube, and bringing the rod-like roller into contact with a forming region extending from the other end to a predetermined position of the tube; a step for heating the forming region of the tube; a step for cooling at least a section located near the forming region and within a non-forming region extending from the predetermined position to the one end of the tube; and a step for moving the rod-like roller in a state of contacting the forming region of the tube, in a direction from the one end of the tube toward the other end of the tube and outward in a radial direction of the tube.

[0010] According to the above configuration, the rod-like roller is pressed against the heated forming region of the tube. Therefore, it is possible to expand the forming region in diameter with a relatively small pushing force while suppressing occurrence of necking. In addition, since at least the section located near the forming region and within the non-forming region of the tube is cooled, it is possible to suppress deformation of the non-forming region when the rod-like roller is pressed against the heated forming region.

[0011] The forming region of the tube may be heated from outside of the tube. According to this configuration, it is possible to further suppress protrusion of an inner peripheral surface of the tube which may be caused by pressing of the rod-like roller as compared to a case where the forming region is heated from inside of the tube.

[0012] The forming region of the tube may be heated by induction heating. In a case where a burner is used to heat the forming region of the tube, a temperature gradient between the forming region and the non-forming region becomes gentle. In contrast, in a case where the forming region is heated by induction heating, the temperature gradient between the forming region and the non-forming region becomes steep. Therefore, if the forming region is heated by induction heating, deformation of the non-forming region can be more effectively suppressed. In other words, it is possible to accurately

form a tapered portion in the non-forming region indicating a track of the rod-like roller.

[0013] The forming region of the tube may be heated by using a heater including a heating head that faces an inner peripheral surface or an outer peripheral surface of the tube. When the rod-like roller in a state of contacting the forming region of the tube is moved in the direction from the one end toward the other end of the tube and outward in the radial direction of the tube, the heating head may be moved in the radial direction of the tube in synchronization with movement of the rod-like roller. According to this configuration, it is possible to keep a distance between the forming region of the tube and the heating head substantially constant, and it is possible to expand the forming region in diameter while stably heating the forming region.

[0014] The non-forming region of the tube may be cooled by using a cooler including a cooling head that supplies cooler agent to the outer peripheral surface of the tube. When the rod-like roller in a state of contacting the forming region of the tube is moved in the direction from the one end toward the other end of the tube and outward in the radial direction of the tube, the cooling head may be moved in the axial direction and the radial direction of the tube in synchronization with movement of the rod-like roller. According to this configuration, a positional relationship between a tip of the rod-like roller and the cooling head is unchanged even if the forming region gradually narrows as the rod-like roller moves in the axial direction of the tube. Therefore, it is possible to continuously cool at least the section located near the forming region and within the non-forming region.

[0015] In a state where an auxiliary roller supports at least the other end of the tube from outside in the radial direction, the rod-like roller in a state of contacting the forming region of the tube may be moved in the direction from the one end toward the other end of the tube and outward in the radial direction of the tube. According to this configuration, deflection of the tube during forming can be prevented.

[0016] The tip of the rod-like roller may be flat. According to this configuration, it is possible to further suppress interference between the rod-like roller and the tapered portion in the non-forming region indicating the track of the rod-like roller as compared to a case where the tip of the rod-like roller is semi-spherical. Therefore, it is possible to accurately expand the forming region of the tube in diameter.

[0017] For example, the tube may have a thickness of 8 mm or more.

[0018] In addition, the present invention provides a forming apparatus including: a turntable to which one end of a tube is fixed; a rod-like roller which extends in an axial direction of the tube, the rod-like roller being inserted into the tube from the other end of the tube and being brought into contact with a forming region extending from the other end of the tube to a predetermined position; a heater which heats the forming region of the tube; a cool-

er which cools at least a section located near the forming region and within a non-forming region extending from the predetermined position to the one end of the tube; and a roller moving device which moves the rod-like roller in the axial direction and a radial direction of the tube. By using this forming apparatus, it is possible to implement the tube diameter expanding method described above.

Advantageous Effects of Invention

[0019] According to the present invention, it is possible to suppress deformation of the non-forming region of the heated tube when the rod-like roller is pressed against the heated forming region of the tube.

Brief Description of Drawings

[0020]

Fig. 1 is a schematic configuration diagram of a forming apparatus that implements a tube diameter expanding method according to Embodiment 1 of the present invention.

Fig. 2 is a diagram illustrating a positional relationship between a tube and a rod-like roller before forming is started.

Fig. 3 is a diagram illustrating a positional relationship between the tube and the rod-like roller during forming.

Fig. 4 is a cross-sectional view taken along line IV-IV in Fig. 2.

Fig. 5A is a front view of a heating head used in Embodiment 1, Fig. 5B is a front view of a heating head of a modification, and Fig. 5C is a front view of a heating head of another modification.

Fig. 6 is a schematic configuration diagram of a forming apparatus that implements a tube diameter expanding method according to Embodiment 2 of the present invention.

Fig. 7 is a diagram for describing necking occurring when a disk roller is used.

Description of Embodiments

Embodiment 1

[0021] First, a tube diameter expanding method according to Embodiment 1 of the present invention will be described. The diameter expanding method according to the present embodiment is implemented by a forming apparatus 1A illustrated in Fig. 1.

[0022] The forming apparatus 1A partially expands a tube 2 in diameter by spinning forming. The material constituting the tube 2 is not particularly limited; however, the diameter expanding method according to the present embodiment is particularly useful for the tube 2 made of metal having high deformation resistance. Examples of the metal having high deformation resistance include a

worked material which is difficult to plastically deform such as stainless steel or a titanium alloy. Even if the tube 2 is not made of the worked material which is difficult to plastically deform but is made of soft steel or an aluminum alloy having a thickness of 8 mm or more, deformation resistance becomes high.

[0023] Specifically, the forming apparatus 1A includes a base 11 and a turntable 12 rotatably supported by the base 11. The turntable 12 is rotated by a motor, not illustrated. In the present embodiment, an axial direction of the turntable 12 is a vertical direction; however, the axial direction of the turntable 12 may be another direction such as a horizontal direction.

[0024] A lower end (one end) of the tube 2 is fixed to the turntable 12 such that a center axis 20 of the tube 2 and a rotation center of the turntable 12 are aligned. To be specific, the tube 2 is rotated about the center axis 20. In the present embodiment, the lower end of the tube 2 is fixed to the turntable 12 by a chuck 13 provided on the turntable 12. However, the method of fixing the lower end of the tube 2 to the turntable 12 is not limited to this. For example, in lieu of the chuck 13, a tubular body fitted with the tube 2 may be provided on the turntable 12, and the lower end of the tube 2 may be fixed to the tubular body with a bolt.

[0025] Further, the forming apparatus 1A includes a rod-like roller 3 that presses the tube 2 from inside, a heater 4 that heats the tube 2 from outside, and a cooler 5 that cools the tube 2 from outside.

[0026] The rod-like roller 3 extends in the axial direction of the tube 2 and has a cylindrical shape. The rod-like roller 3 is inserted into the tube 2 from an upper end (the other end) of the tube 2 and is brought into contact with a forming region 21 extending from the upper end to a predetermined position of the tube 2. In the present embodiment, a tip of the rod-like roller 3 is flat and parallel to a plane orthogonal to the axial direction of the tube 2. Therefore, a peripheral surface of the rod-like roller 3 is connected to a tip surface of the rod-like roller 3 via a curved portion of the rod-like roller 3, the curved portion having a small curvature radius.

[0027] The axial direction of the rod-like roller 3 is not necessarily required to be perfectly parallel to the axial direction of the tube 2 but may be substantially parallel (for example, an angular difference between the axial directions is within ± 10 degrees). In addition, the peripheral surface of the rod-like roller 3 may have a tubular shape parallel to the axial direction of the tube 2, or may be a tapered shape tapering upward or downward. Further, the peripheral surface of the rod-like roller 3 is not necessarily smooth and may have small unevenness.

[0028] The rod-like roller 3 is provided with a shaft 31 that projects upward from an upper-end surface of the rod-like roller 3. The shaft 31 is rotatably supported by an arm 15. To be specific, the rod-like roller 3 rotates following rotation of the tube 2 when the rod-like roller 3 contacts the forming region 21 of the tube 2.

[0029] The arm 15 is connected to a first moving device

14 attached to a post 14a rising from the base 11. The first moving device 14 functions as a roller moving device that moves the rod-like roller 3 in the axial direction and a radial direction of the tube 2 via the arm 15. In the present embodiment, the first moving device 14 includes a pair of linear actuators whose axial directions are orthogonal to each other. Each linear actuator may be an electric/hydraulic/pneumatic cylinder, a ball screw mechanism, or a rack-and-pinion mechanism. However, the first moving device 14 may be a robot arm.

[0030] The heater 4 heats the forming region 21 of the tube 2. In the present embodiment, the heater 4 heats the forming region 21 of the tube 2 by induction heating. Specifically, as illustrated in Fig. 2, the heater 4 includes a heating head 41 facing an outer peripheral surface of the tube 2, a plurality of coils 42 embedded in the heating head 41, and an AC power supply circuit 43 applying an AC voltage to the coils 42. It is desirable that a frequency of the AC voltage is a high frequency in a range from 5 k to 400 kHz. To be specific, induction heating is desirably high-frequency induction heating.

[0031] In the present embodiment, as illustrated in Fig. 4, an angle between the heating head 41 and the rod-like roller 3 in a circumferential direction of the tube 2 is 180 degrees. However, the angle between the heating head 41 and the rod-like roller 3 in the circumferential direction of the tube 2 may be another angle such as 90 degrees. In addition, in the present embodiment, as illustrated in Figs. 4 and 5A, each coil 42 has an oval shape long in the circumferential direction of the tube 2. However, as illustrated in Fig. 5B, each of the coils 42 may have an oval shape long in the axial direction of the tube 2. Alternatively, as illustrated in Fig. 5C, only one coil 42 may be provided so as to form a polygon (for example, a triangle). Note that a plurality of heating heads 41 may be provided side by side in the circumferential direction of the tube 2.

[0032] Returning to Fig. 2, the cooler 5 cools at least a section (i.e., an upper portion) located near the forming region 21 and within a non-forming region 22 (i.e., the region other than the forming region 21 of the tube 2) extending from the predetermined position described above to the lower end of the tube 2. In the present embodiment, the cooler 5 cools the non-forming region 22 of the tube 2 by heat transfer to cooler agent. Specifically, the cooler 5 includes a cooling head 51 that supplies cooler agent to the outer peripheral surface of the tube 2, and a delivery device 52 which delivers cooler agent to the cooling head 51 and whose revolution speed can be changed. For example, in a case where the cooler agent is a gas (for example, air or inert gas), the delivery device 52 may be a compressor or a fan. Alternatively, in a case where the cooler agent is liquid (for example, water or oil), the delivery device 52 may be a pump.

[0033] A heating temperature of the forming region 21 by the heater 4 is desirably not lower than one third of a melting point of the material constituting the tube 2, and more desirably not lower than one half of the melting

point. It is desirable that a cooling temperature of the upper portion of the non-forming region 22 by the cooler 5 is set so that the upper portion of the non-forming region 22 is not deformed when the rod-like roller is pressed against the forming region 21.

[0034] In particular, it is desirable that the heater 4 heats entirety of the forming region 21 to approximately an identical temperature. In addition, in a case where the heating temperature of the forming region 21 by the heater 4 is not lower than one half of the melting point of the material constituting the tube 2, the cooler 5 desirably cools at least the upper portion of the non-forming region 22 such that the temperature is lowered to a temperature not higher than one quarter of the melting point of the material constituting the tube 2 in a minimal range extending from the upper end of the non-forming region 22 to a position slightly away from the upper end in the non-forming region 22. For example, the minimal range is substantially equal to the height of the curved portion of the rod-like roller 3.

[0035] In the present embodiment, the heating head 41 of the heater 4 and the cooling head 51 of the cooler 5 are attached to a holding plate 18. The holding plate 18 is connected to a second moving device 17 attached to a post 17a rising from the base 11. The second moving device 17 functions as a heating-head moving device that moves the heating head 41 in the axial direction and the radial direction of the tube 2 via the holding plate 18 and also functions as a cooling-head moving device that moves the cooling head 51 in the axial direction and the radial direction of the tube 2 via the holding plate 18. In the present embodiment, the second moving device 17 includes a pair of linear actuators whose axial directions are orthogonal to each other. Each linear actuator may be an electric/hydraulic/pneumatic cylinder, a ball screw mechanism, or a rack-and-pinion mechanism. However, the second moving device 17 may be a robot arm.

[0036] However, the heating head 41 may be attached to the arm 15, and the first moving device 14 may function as the heating-head moving device. Alternatively, the cooling head 51 may be attached to the arm 15, and the first moving device 14 may function as the cooling-head moving device. Furthermore, in lieu of the second moving device 17, a moving device exclusive for the heating head 41 and a moving device exclusive for the cooling head 51 may be separately provided.

[0037] The AC power supply circuit 43 of the heater 4 and the delivery device 52 of the cooler 5 are controlled by a control device 6. For example, the control device 6 may be a sequencer (registered trademark), or may be a computer including a CPU and memories such as a ROM and a RAM.

[0038] The control device 6 is connected to a first temperature sensor 61 and a second temperature sensor 62. The first temperature sensor 61 detects the temperature of the forming region 21 of the tube 2. The second temperature sensor 62 detects the temperature of the upper portion of the non-forming region 22 of the tube 2.

For example, each of the first temperature sensor 61 and the second temperature sensor is a radiation thermometer that detects temperature according to infrared light or visible light.

[0039] In the present embodiment, the first temperature sensor 61 and the second temperature sensor 62 are attached to a bracket 16 suspended from the arm 15. To be specific, the first temperature sensor 61 and the second temperature sensor 62 move together with the rod-like roller 3. However, the first temperature sensor 61 and the second temperature sensor 62 may be attached to the holding plate 18. Alternatively, the first temperature sensor 61 and the second temperature sensor 62 may be moved by a moving device other than the first moving device 14 and the second moving device 17, or may be fixed in a fixed position.

[0040] The control device 6 controls output from the heater 4 and the cooler 5. Specifically, the control device 6 controls the AC power supply circuit 43 of the heater 4 according to the temperature detected by the first temperature sensor 61, and controls the delivery device 52 of the cooler 5 according to the temperature detected by the second temperature sensor 62. However, in lieu of the delivery device 52 whose revolution speed can be changed, a delivery device whose revolution speed is constant and a flow control valve provided in a flow path from the delivery device to the cooling head may be used, and the flow control valve may be controlled by the control device 6.

[0041] Next, referring to Figs. 1 to 3, operation of the forming apparatus 1A for partially expanding the tube 2 in diameter will be described.

[0042] First, the first moving device 14 inserts the rod-like roller 3 into the tube 2 from the upper end of the tube 2 and brings the rod-like roller 3 into contact with the forming region 21 of the tube 2 (see Fig. 2). Then, the turntable 12 rotates the tube 2 about the center axis 20. However, rotation of the tube 2 may be started before the rod-like roller 3 is inserted into the tube 2.

[0043] Next, the heater 4 heats the forming region 21, and the cooler 5 cools at least the upper portion of the non-forming region 22. When both the forming region 21 and the non-forming region 22 reach desired temperatures, the first moving device 14 moves the rod-like roller 3 in a state of contacting the forming region 21 of the tube 2, in a direction from the lower end toward the upper end of the tube 2 (i.e., upward) and outward in the radial direction of the tube 2. At this time, the second moving device 17 moves the heating head 41 and the cooling head 51 in the axial direction and the radial direction of the tube 2 in synchronization with movement of the rod-like roller 3. Here, "synchronization" means that, in each of the axial direction and the radial direction of the tube 2, a movement amount of the heating head 41 and the cooling head 51 is identical to a movement amount of the rod-like roller 3. For example, assume that movement of the rod-like roller 3 in the axial direction of the tube 2 and movement of the rod-like roller 3 in the radial direction

of the tube 2 are separately and intermittently performed, as will be described later. In that case, when the rod-like roller 3 is moved in the axial direction of the tube 2, the heating head 41 and the cooling head 51 are moved only in the axial direction of the tube 2 by the amount identical to the movement amount of the rod-like roller 3. When the rod-like roller 3 is moved in the radial direction of the tube 2, the heating head 41 and the cooling head 51 are moved only in the radial direction of the tube 2 by the amount identical to the movement amount of the rod-like roller 3.

[0044] While the heating head 41 and the cooling head 51 are moved in the axial direction and the radial direction of the tube 2, the control device 6 controls the AC power supply circuit 43 of the heater 4 so that the temperature detected by the first temperature sensor 61 becomes a desired temperature and controls the delivery device 52 of the cooler 5 so that the temperature detected by the second temperature sensor 62 becomes a desired temperature.

[0045] As the rod-like roller 3 moves upward, the forming region 21 gradually narrows and the non-forming region 22 gradually widens (see Fig. 3) accordingly. In other words, as the rod-like roller 3 moves upward and radially outward, the section which is the lower end of the forming region 21 becomes a tapered portion expanded in diameter (i.e., the tapered portion indicates a track of the rod-like roller 3), and the tapered portion becomes part of the non-forming region 22.

[0046] Each of movement of the rod-like roller 3 in the axial direction of the tube 2 and movement of the rod-like roller 3 in the radial direction of the tube 2 may be performed continuously or the movements may be performed separately and intermittently. In addition, the movement amount of the rod-like roller 3 in the axial direction of the tube 2 may be far greater (the angle of the tapered portion in the non-forming region 22 is small), or may be far smaller (the angle of the tapered portion in the non-forming region 22 is large) than the movement amount of the rod-like roller 3 in the radial direction of the tube 2.

[0047] Movement of the rod-like roller 3 upward and outward in the radial direction of the tube 2 is terminated when the forming region 21 is expanded in diameter by a desired amount as illustrated in Fig. 3. Therefore, it is possible to expand the tube 2 in diameter such that the tapered portion exists between a small-diameter tubular portion and a large-diameter tubular portion, in other words, the tube 2 has one stepped portion. Then, after once the rod-like roller 3 is removed from the tube 2 and moved slightly upward, the above-described operation is repeated. Thus, the tube 2 can be expanded in diameter such that the tube 2 has a plurality of stepped portions. However, the rod-like roller 3 may be moved upward to the upper end of the tube 2 in order to expand the tube 2 in diameter such that the tube 2 only has the small-diameter tubular portion and the tapered portion.

[0048] As described above, according to the tube di-

ameter expanding method of the present embodiment, the rod-like roller 3 is pressed against the heated forming region 21 of the tube 2. Therefore, it is possible to expand the forming region 21 in diameter with a relatively small pushing force while suppressing occurrence of necking. In addition, since at least the upper portion of the non-forming region 22 of the tube 2 is cooled, it is possible to suppress deformation of the non-forming region 22 when the rod-like roller 3 is pressed against the heated forming region 21.

[0049] In addition, in the present embodiment, since the heating head 41 is moved in the radial direction of the tube 2 in synchronization with movement of the rod-like roller 3 in the radial direction of the tube 2, the distance between the forming region 21 of the tube 2 and the heating head 41 can be kept approximately constant. Therefore, it is possible to expand the forming region 21 in diameter while stably heating the forming region 21. In particular, in the present embodiment, the heating head 41 is also moved in the axial direction of the tube 2 in synchronization with movement of the rod-like roller 3 in the axial direction of the tube 2. Therefore, it is possible to keep positional relationship between the tip of the rod-like roller 3 and the heating head 41 unchanged even if the forming region 21 gradually narrows as the rod-like roller 3 moves in the axial direction of the tube 2.

[0050] Further, in the present embodiment, the cooling head 51 is moved in synchronization with movement of the rod-like roller 3. Therefore, it is possible to keep positional relationship between the tip of the rod-like roller 3 and the cooling head 51 unchanged even if the forming region 21 gradually narrows as the rod-like roller 3 moves in the axial direction of the tube 2. Therefore, at least the upper portion of the non-forming region 22 can be continuously cooled.

Embodiment 2

[0051] Next, a tube diameter expanding method according to Embodiment 2 of the present invention will be described. In the present embodiment, a forming apparatus 1B illustrated in Fig. 6 implements the tube diameter expanding method. In the present embodiment, an angle between a heating head 41 and a rod-like roller 3 in a circumferential direction of a tube 2 is 90 degrees. To be specific, the rod-like roller 3 is moved in an up-down direction and a direction orthogonal to the paper surface of Fig. 6 by a first moving device 14 (not illustrated in Fig. 6). Further, in the present embodiment, the forming apparatus 1B includes an auxiliary roller 7. The other configuration of the forming apparatus 1B is identical to that of the forming apparatus 1A of Embodiment 1.

[0052] The auxiliary roller 7 extends in an axial direction of the tube 2 and has a cylindrical shape with a semi-spherical tip. In the present embodiment, an angle between the rod-like roller 3 and the auxiliary roller 7 in the circumferential direction of the tube 2 is 90 degrees. However, the angle between the rod-like roller 3 and the aux-

iliary roller 7 in the circumferential direction of the tube 2 may be another angle such as 180 degrees.

[0053] At least during forming, the auxiliary roller 7 comes into contact with at least an upper portion (section including an upper end of the tube 2) of a forming region 21 from outside the tube 2. In the present embodiment, a length of the auxiliary roller 7 is shorter than a length of the rod-like roller 3 and comes into contact with only the upper portion of the forming region 21. However, the length of the auxiliary roller 7 may be equal to or longer than that of the rod-like roller 3, and the auxiliary roller 7 may be brought into contact with entirety of the forming region 21.

[0054] The auxiliary roller 7 is provided with a shaft 71 that projects upward from an upper-end surface of the auxiliary roller 7. The shaft 71 is rotatably supported by an arm 81. To be specific, the auxiliary roller 7 rotates following rotation of the tube 2 when the auxiliary roller 7 contacts the upper portion of the forming region 21 of the tube 2.

[0055] The arm 81 is connected to a linear actuator 82 attached to a post 83 rising from a base 11. The linear actuator 82 moves the auxiliary roller 7 in a radial direction of the tube 2 via the arm 81. For example, the linear actuator 82 may be an electric/hydraulic/pneumatic cylinder, a ball screw mechanism, or a rack-and-pinion mechanism.

[0056] In the present embodiment, the linear actuator 82 is controlled by a control device 6 so that the auxiliary roller 7 is always pressed against the tube 2 with a constant pressing force. To be specific, when the first moving device 14 moves the rod-like roller 3 in a state of contacting the forming region 21 of the tube 2, upward and radially outward, the auxiliary roller 7 supports at least the upper end of the tube 2 from outside in the radial direction. In other words, while at least the upper end of the tube 2 is supported by the auxiliary roller 7, the rod-like roller 3 is pressed against the forming region 21. Note that a thickness of the forming region 21 becomes thinner as the diameter expands. Therefore, a moving speed of the auxiliary roller 7 in the radial direction of the tube 2 is slower than a moving speed of the rod-like roller 3 in the radial direction of the tube 2.

[0057] Also in the present embodiment, similar effects as in Embodiment 1 can be obtained. In addition, in the present embodiment, due to action of the auxiliary roller 7, deflection of the tube 2 during forming can be prevented.

Other Embodiments

[0058] The present invention is not limited to the above-described Embodiments 1 and 2, and various modifications are possible without departing from the subject matter of the present invention.

[0059] For example, a heater 4 may be disposed such that a heating head 41 faces an inner peripheral surface of a tube 2, and a forming region 21 may be heated from

inside of the tube 2. However, if the forming region 21 is heated from outside of the tube 2, it is possible to further suppress protrusion of the inner peripheral surface of the tube 2 which may be caused by pressing of a rod-like roller 3 as compared to a case where the forming region 21 is heated from inside of the tube 2. Similarly, a cooler 5 may also be disposed such that a cooling head 51 supplies cooler agent to the inner peripheral surface of the tube 2, and may cool at least an upper portion of a non-forming region 22 from inside of the tube 2.

[0060] In addition, the heater 4 does not necessarily heat the forming region 21 of the tube 2 by induction heating. For example, as the heater 4, a burner emitting a flame from a nozzle (heating head) may be used. However, in a case where the burner is used to heat the forming region 21 of the tube 2, a temperature gradient between the forming region 21 and the non-forming region 22 becomes gentle. In contrast, in a case where the forming region 21 is heated by induction heating, the temperature gradient between the forming region 21 and the non-forming region 22 becomes steep. Therefore, if the forming region 21 is heated by induction heating, deformation of the non-forming region 22 can be more effectively suppressed. In other words, it is possible to accurately form a tapered portion in the non-forming region 22 indicating a track of the rod-like roller 3.

[0061] In addition, a second moving device 17 may not have the function of moving the heating head 41 and the cooling head 51 in the axial direction of the tube 2, and may only have the function of moving the heating head 41 and the cooling head 51 in the radial direction of the tube 2. To be specific, when a first moving device 14 moves the rod-like roller 3 in a state of contacting the forming region 21 of the tube 2, upward and outward in the radial direction of the tube 2, the second moving device 17 may move the heating head 41 and the cooling head 51 in the radial direction of the tube 2 in synchronization with only movement of the rod-like roller 3 in the radial direction of the tube 2.

[0062] In addition, in a case where a diameter expansion amount of the tube 2 is small, either one or both of the heating head 41 and the cooling head 51 may be fixed in a fixed position. Alternatively, even in a case where the diameter expansion amount of the tube 2 is large, the cooling head 51 may be fixed at a fixed position and a supply amount of cooler agent to be supplied to the inner peripheral surface or an outer peripheral surface of the tube 2 may be controlled according to a second temperature sensor 62.

[0063] The cooler 5 does not necessarily have to cool at least the upper portion of the non-forming region 22 of the tube 2 by heat transfer to cooler agent. For example, the cooler 5 may be configured to cool at least the upper portion of the non-forming region 22 by contacting a heat radiator that deforms according to forming of the tube 2.

[0064] A tip of the rod-like roller 3 may be semi-spherical. However, if the tip of the rod-like roller 3 is flat, it is

possible to further suppress interference between the rod-like roller 3 and a tapered portion indicating the track of the rod-like roller 3 in the non-forming region 22 as compared to a case where the tip of the rod-like roller 3 is semi-spherical. Therefore, it is possible to accurately expand the forming region 21 of the tube 2 in diameter.

[0065] In addition, heating of the forming region 21 of the tube 2, cooling of at least the upper portion of the non-forming region 22 of the tube 2, and pressing of the rod-like roller 3 against the forming region 21 are not necessarily performed simultaneously. For example, firstly, the forming region 21 of the tube 2 may be heated, and then heating of the forming region 21 of the tube 2 may be stopped to cool the non-forming region 22. Thereafter, cooling of the non-forming region 22 may be stopped and the rod-like roller 3 may be pressed against the forming region 21.

Reference Signs List

[0066]

1A, 1B	forming apparatus
14	first moving device (roller moving device)
17	second moving device (heating-head moving device, cooling-head moving device)
2	tube
20	center axis
21	forming region
22	non-forming region
3	rod-like roller
4	heater
41	heating head
5	cooler
51	cooling head
6	control device
61	first temperature sensor
62	second temperature sensor
7	auxiliary roller

Claims

1. A tube diameter expanding method comprising:

rotating a tube having one end fixed to a turntable about a center axis of the tube;
 inserting a rod-like roller which extends in an axial direction of the tube into the tube from another end of the tube, and bringing the rod-like roller into contact with a forming region extending from the other end to a predetermined position of the tube;
 heating the forming region of the tube;
 cooling at least a section located near the forming region and within a non-forming region extending from the predetermined position to the one end of the tube; and

moving the rod-like roller in a state of contacting the forming region of the tube, in a direction from the one end of the tube toward the other end of the tube and outward in a radial direction of the tube.

2. The tube diameter expanding method according to claim 1, wherein the forming region of the tube is heated from outside of the tube.

3. The tube diameter expanding method according to claim 1 or 2, wherein the forming region of the tube is heated by induction heating.

4. The tube diameter expanding method according to any one of claims 1 to 3, wherein, the forming region of the tube is heated by using a heater which includes a heating head that faces an inner peripheral surface or an outer peripheral surface of the tube, and when the rod-like roller in a state of contacting the forming region of the tube is moved in the direction from the one end toward the other end of the tube and outward in the radial direction of the tube, the heating head is moved in the radial direction of the tube in synchronization with movement of the rod-like roller.

5. The tube diameter expanding method according to any one of claims 1 to 4, wherein the non-forming region of the tube is cooled by using a cooler which includes a cooling head that supplies cooler agent to an outer peripheral surface of the tube, and when the rod-like roller in a state of contacting the forming region of the tube is moved in the direction from the one end toward the other end of the tube and outward in the radial direction of the tube, the cooling head is moved in the axial direction and the radial direction of the tube in synchronization with movement of the rod-like roller.

6. The tube diameter expanding method according to any one of claims 1 to 5, wherein in a state where an auxiliary roller supports at least the other end of the tube from outside in the radial direction, the rod-like roller in a state of contacting the forming region of the tube is moved in the direction from the one end toward the other end of the tube and outward in the radial direction of the tube.

7. The tube diameter expanding method according to any one of claims 1 to 6, wherein a tip of the rod-like roller is flat.

8. The tube diameter expanding method according to any one of claims 1 to 7, wherein the tube has a thickness of not less than 8 mm.

9. A forming apparatus comprising:

a turntable to which one end of a tube is fixed;
 a rod-like roller which extends in an axial direction of the tube, the rod-like roller being inserted 5
 into the tube from another end of the tube and being brought into contact with a forming region extending from the other end to a predetermined position of the tube;
 a heater which heats the forming region of the tube; 10
 a cooler which cools at least a section located near the forming region and within a non-forming region extending from the predetermined position to the one end of the tube; and 15
 a roller moving device which moves the rod-like roller in the axial direction and a radial direction of the tube.

10. The forming apparatus according to claim 9, further comprising: 20

a first temperature sensor which detects temperature of the forming region of the tube;
 a second temperature sensor which detects 25
 temperature of the section located near the forming region and within the non-forming region of the tube; and
 a control device which controls the heater according to temperature detected by the first temperature sensor and controls the cooler according to temperature detected by the second temperature sensor. 30

11. The forming apparatus according to claim 9 or 10, wherein the heater heats the forming region by induction heating. 35

12. The forming apparatus according to any one of claims 9 to 11, wherein the heater includes a heating head which faces an inner peripheral surface or an outer peripheral surface of the tube, 40
 the forming apparatus further comprising a heating-head moving device which moves the heating head in the radial direction of the tube in synchronization with movement of the rod-like roller, when the roller moving device moves the rod-like roller in a state of contacting the forming region of the tube, in a direction from the one end toward the other end of the tube and outward in the radial direction of the tube. 45 50

13. The forming apparatus according to any one of claims 9 to 12, wherein the cooler includes a cooling head which supplies cooler agent to an outer peripheral surface of the tube, 55
 the forming apparatus further comprising a cooling-head moving device which moves the cooling head in the axial direction and the radial direction of the

tube in synchronization with movement of the rod-like roller, when the roller moving device moves the rod-like roller in a state of contacting the forming region of the tube, in a direction from the one end toward the other end of the tube and outward in the radial direction of the tube.

14. The forming apparatus according to any one of claims 9 to 13, further comprising an auxiliary roller which supports at least the other end of the tube from outside in the radial direction of the tube, when the roller moving device moves the rod-like roller in a state of contacting the forming region of the tube, in a direction from the one end toward the other end of the tube and outward in the radial direction of the tube.

15. The forming apparatus according to any one of claims 9 to 14, wherein a tip of the rod-like roller is flat.

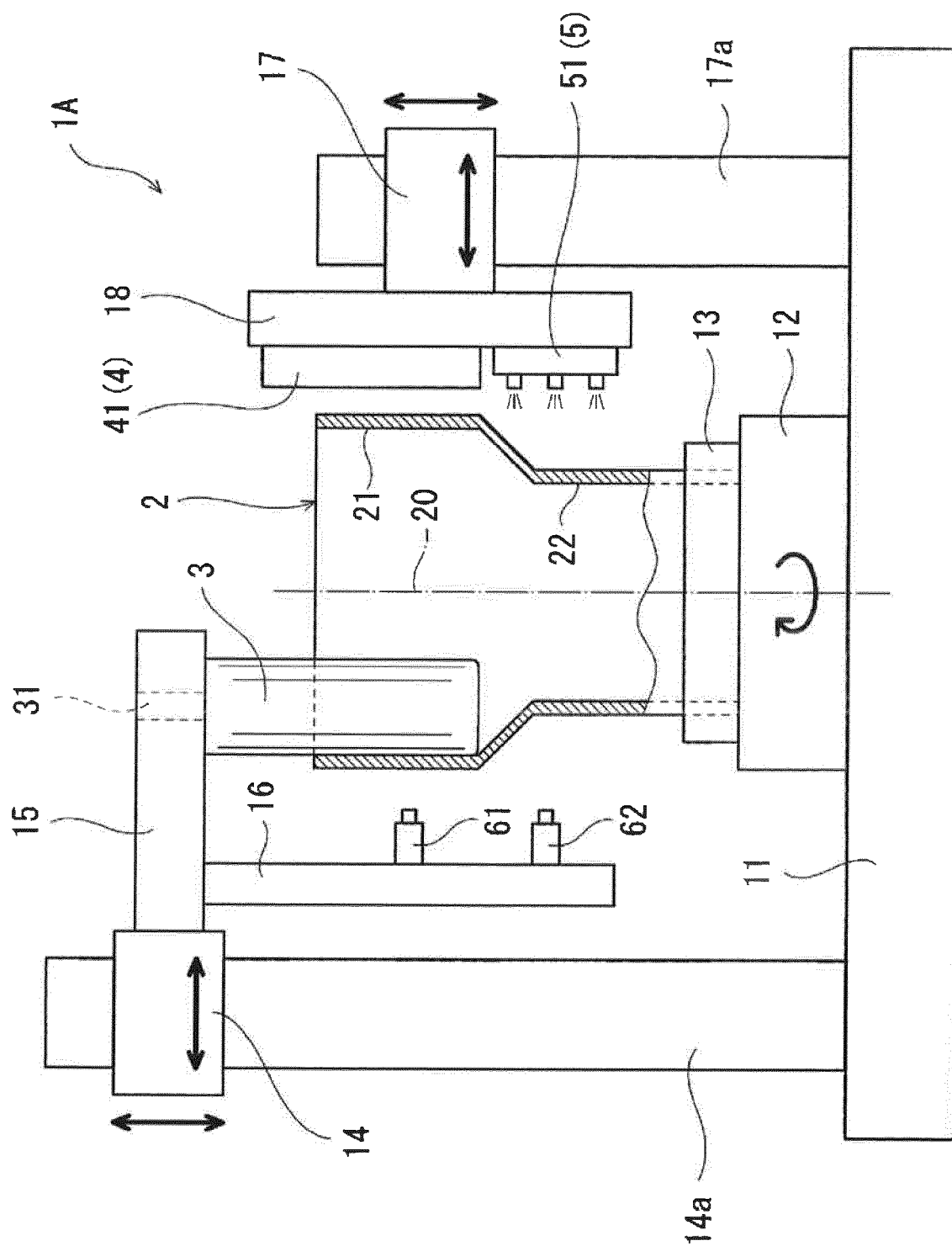
[illegible]

Fig. 2

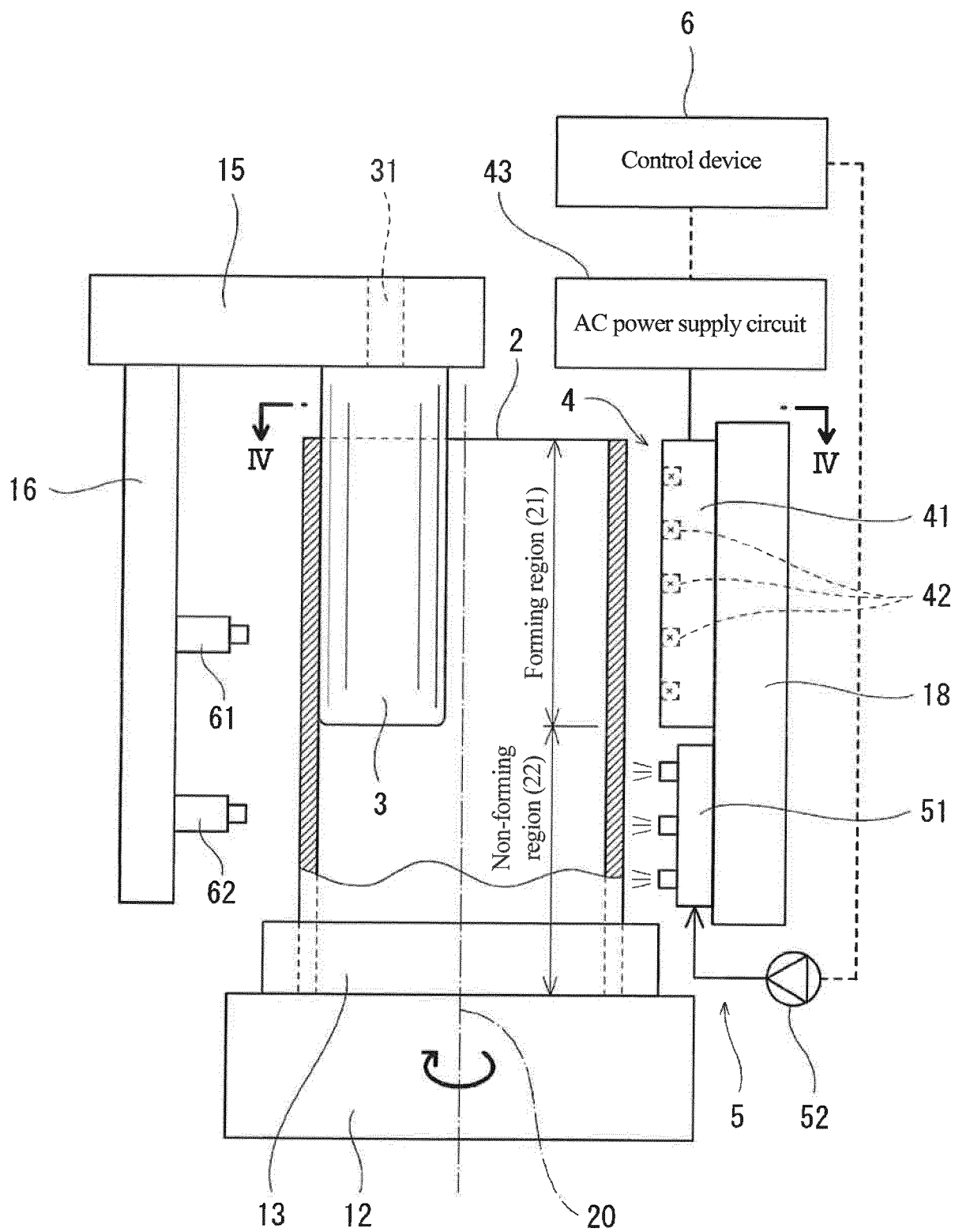


Fig. 3

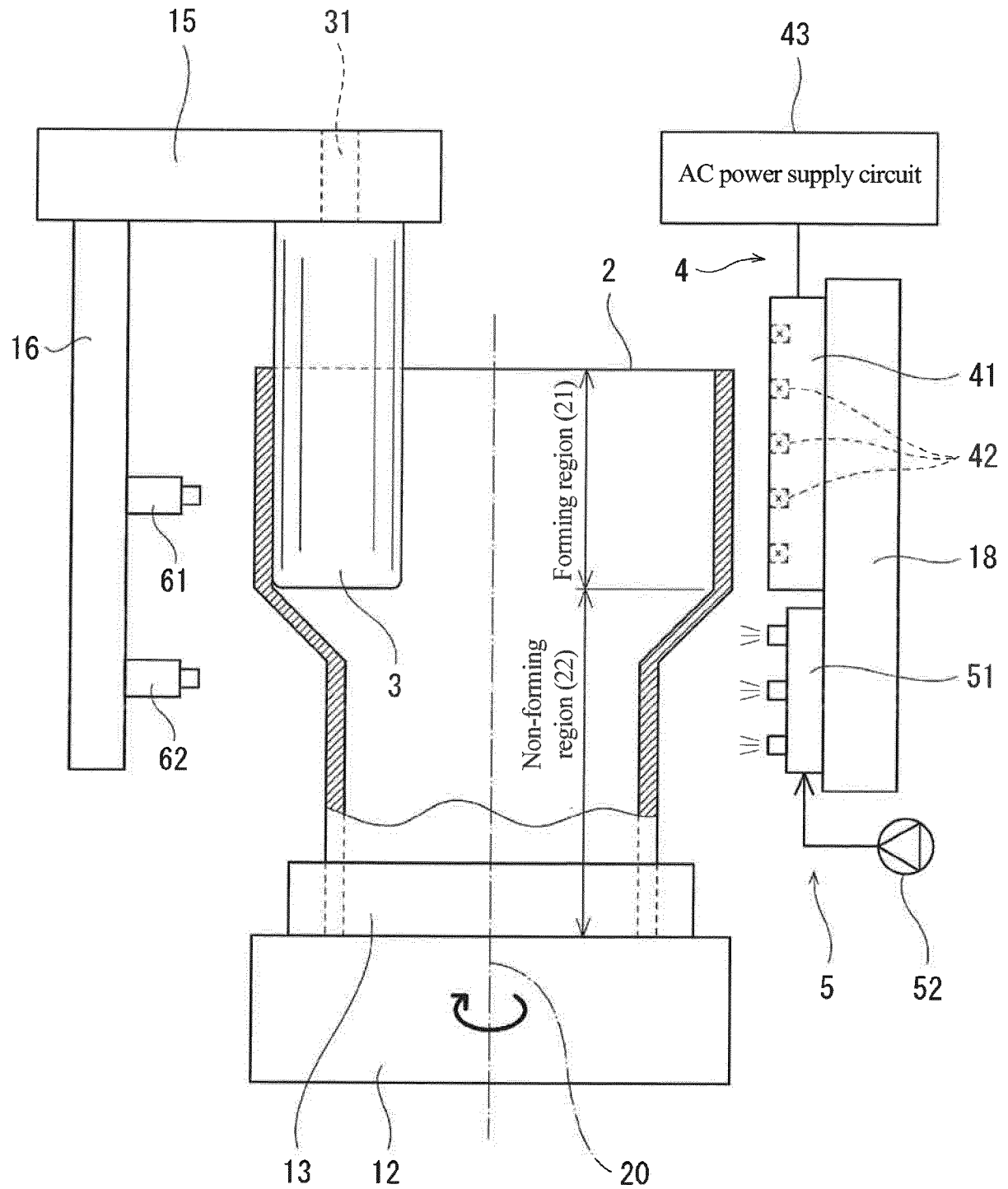


Fig. 4

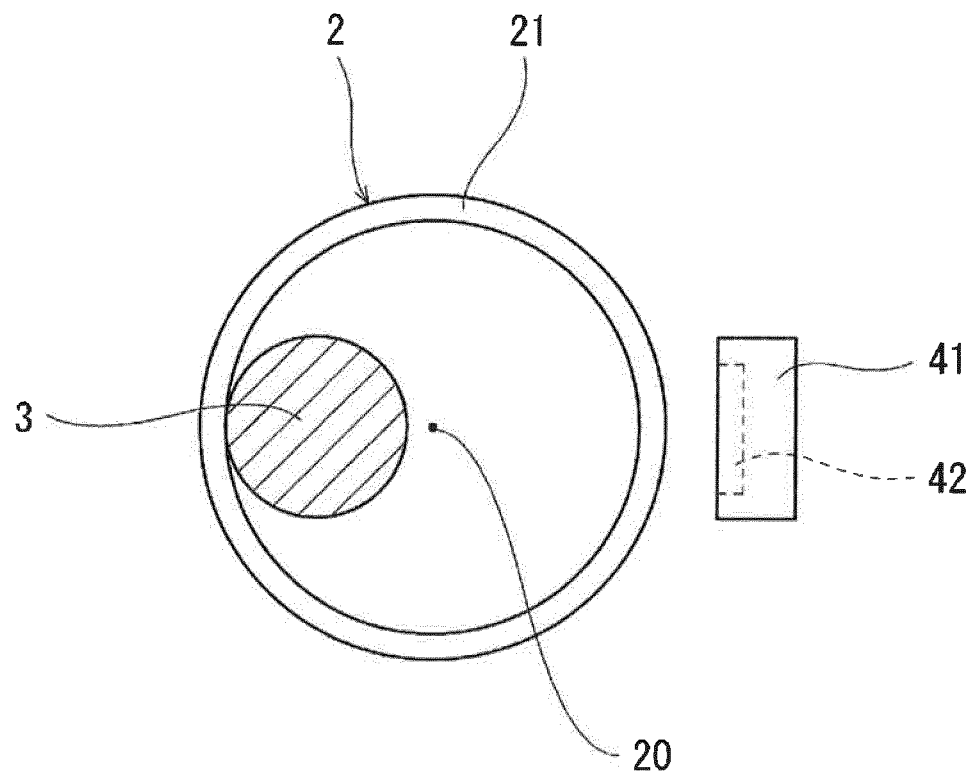


Fig. 5A

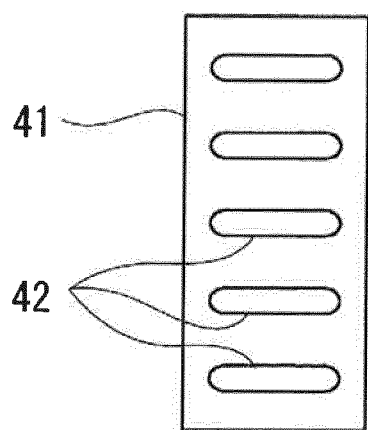


Fig. 5B

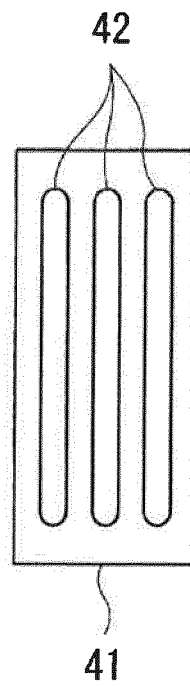
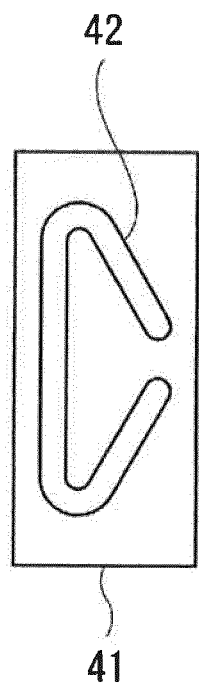


Fig. 5C



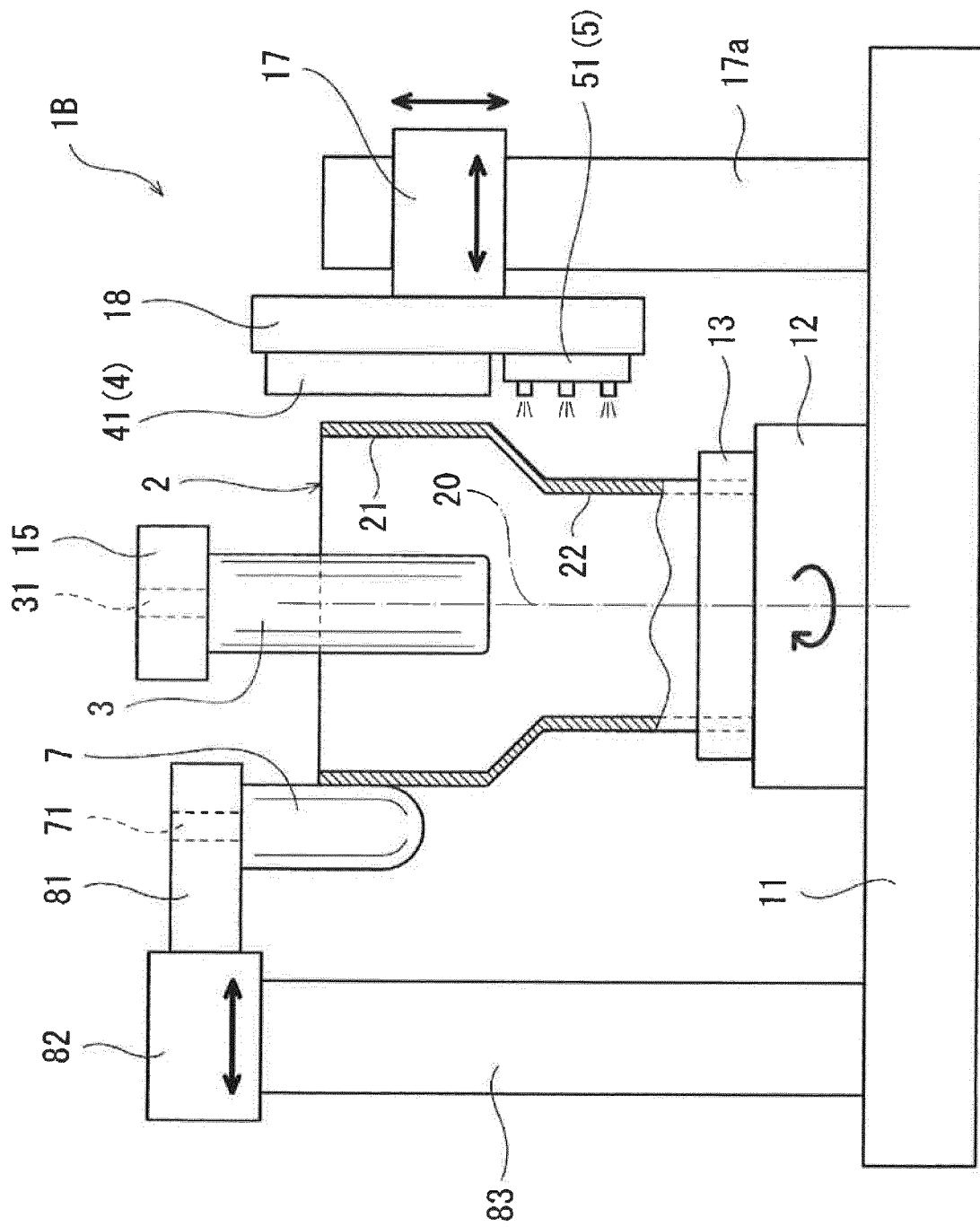
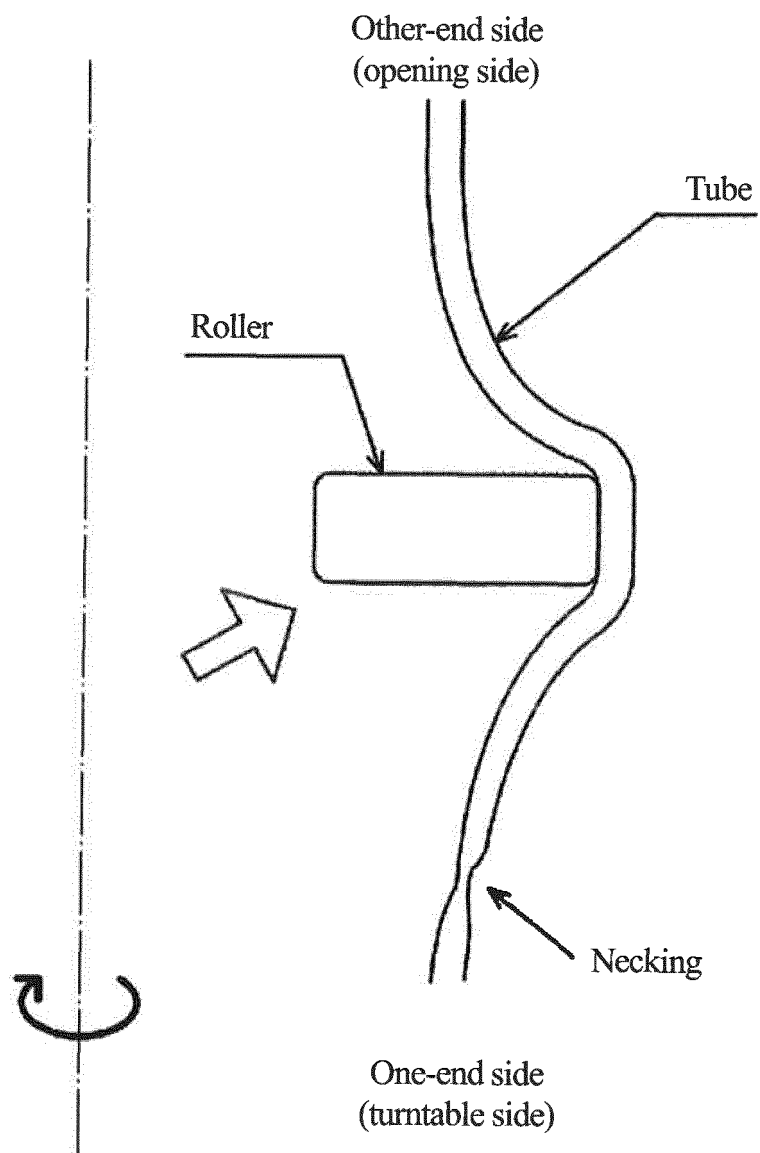


Fig. 6

Fig. 7



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/001438

A. CLASSIFICATION OF SUBJECT MATTER

B21D41/02(2006.01)i, B21C37/18(2006.01)i, B21D22/14(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B21D41/02, B21C37/18, B21D22/14

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016

Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

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 11-732 A (Hitachi, Ltd.), 06 January 1999 (06.01.1999), paragraphs [0042] to [0043]; fig. 4 (Family: none)	1-15
A	JP 29-8663 B1 (Sumitomo Metal Industries, Ltd.), 28 December 1954 (28.12.1954), (Family: none)	1-15
A	JP 2016-13567 A (Kawasaki Heavy Industries, Ltd.), 28 January 2016 (28.01.2016), & WO 2016/002164 A1	1-15

☒ Further documents are listed in the continuation of Box C.
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Date of the actual completion of the international search
03 June 2016 (03.06.16)Date of mailing of the international search report
14 June 2016 (14.06.16)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/001438

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0081700 A1 (AIR PRODUCTS AND CHEMICALS, INC.), 22 June 1983 (22.06.1983), (Family: none)	1-15

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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