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- **YOSHITOME, Takahiro**  
Kawasaki-shi  
Kanagawa 210-0821 (JP)
- **KAYANO, Hotaka**  
Kawasaki-shi  
Kanagawa 210-0821 (JP)
- **NISHIMOTO, Yuzo**  
Kawasaki-shi  
Kanagawa 210-0821 (JP)

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(71) Applicant: **Dai-Ichi High Frequency Co., Ltd.**  
**Chuo-ku**  
**Tokyo 103-0002 (JP)**

(74) Representative: **Jones, Keith William et al**  
**Murgitroyd & Company**  
**Scotland House**  
**165-169 Scotland Street**  
**Glasgow**  
**G5 8PL (GB)**

(72) Inventors:  
• **KISHIHARA, Shigeki**  
Kawasaki-shi  
Kanagawa 210-0821 (JP)

(54) **METALLIC PIPE BENDING APPARATUS, AND METHOD FOR MANUFACTURING A METALLIC PIPE HAVING A BENT PORTION**

(57) A metal pipe bending apparatus comprises heating means for fully circumferentially heating a portion of a metal pipe which is an object for a bending process, propulsion means for propulsively driving the metal pipe toward the heating means in an axial direction of pipe, guiding means including a cramp arm for cramping the metal pipe and configured for pivotal movement about a pivot shaft, for cramping a point in front of a region of the metal pipe heated by the heating means with the cramp arm, revolving the cramp point about the pivot shaft in association with the metal pipe propulsively driven by the propulsion means, and thereby applying a bending moment to the metal pipe, and compression means for causing a compression force to act on the metal pipe by ap-

plying a draw-back force to the metal pipe through the cramp arm with the pivot shaft serving as a fulcrum, where the draw-back force includes a force in a direction opposite to a direction in which the metal pipe is propulsively driven by the propulsion means. The compression means is disposed such that a distance from a point at which the draw-back force is applied to the pivot shaft is larger than a distance from a point at which the metal pipe is cramped by the cramp arm to the pivot shaft. The amount of reduced thickness can be further restrained without requiring an increase in compression driving force in a metal pipe bending process.

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**Description**

## TECHNICAL FIELD

5 **[0001]** The present invention relates to a metal pipe bending apparatus, and a method of manufacturing a metal pipe having a bent portion, and more particularly, to technologies for bending a metal pipe while preventing a reduced thickness of the metal pipe (reduction in thickness).

## BACKGROUND ART

10 **[0002]** In industrial facilities such as plants, factories, electric power generating stations and the like, metal pipes are nowadays widely used as pipes for carrying therethrough fluids such as petrol, gases, a variety of liquids, and the like, or as frame structure materials of civil constructions such as bridges, roofs of stadiums, and the like. While these metal pipes have been previously standardized and made into predetermined shapes (straight pipes and deformed pipes (elbow, bend, and the like)) before they are used, straight pipes may be bent conforming to applications of construction to produce intended pipes (hereinafter referred to as the "bent pipe"). Such bent pipes have been widely used because they can flexibly accommodate requests for a variety of curvatures and pipe line shapes.

15 **[0003]** On the other hand, when a bent pipe is manufactured, simply bending a straight pipe, i.e., a raw material would result in a reduced thickness of the pipe (pipe thickness) on the outer peripheral side of a bent portion, possibly failing to meet required strength and specifications for the pipe. To solve this problem, a variety of proposals have been made in relation to so-called compression bending for preventing a reduction in pipe thickness (reduced thickness) by not only simply bending a straight pipe (see, for example, JP-B-54-28156) but also bending the straight pipe while applying a compression force to the straight pipe in the axial direction of the pipe (see, for example, JP-B-2-47287).

## 25 DISCLOSURE OF THE INVENTION

**[0004]** In recent years, in pipe lines of a variety of plants for petrol, gas, chemical, power generation and the like, there is a tendency of reducing pipe diameters (outer diameters) as much as possible to increase flow rates for carrying out high-pressure transportation, in order to reduce the scale and cost of an entire plant. For this reason, requests have been increasingly made to employ high-strength materials which can bear high pipe inner pressures and to maintain the pipe thickness, even after bending, equal to the thickness of base pipes (bringing a reduction in thickness closer to zero).

30 **[0005]** On the other hand, the radius of curvature of a bent pipe is often required to have the same dimensions as standardized commercially available elbows and the like because of the ease of works. However, from the fact that the radii of curvature of these elbows are small in general, and that a smaller radius of curvature results in a larger reduction in pipe thickness in the outer periphery of the pipe during a bending process, it is practically not easy to respond to the request for bringing a reduction in thickness of bent pipes closer to zero. Also, with the progress of technologies for manufacturing straight pipes which serve as a base material of bent pipes, straight pipes are now manufactured with numerical values close to minima of manufacturing tolerances, so that even a slight reduction in thickness of a pipe, if experienced during a bending process, would result in a failure of ensuring a pipe thickness required for the pipe.

35 **[0006]** On the other hand, a reduction in thickness can be restrained by employing the aforementioned compression bending for preventing the reduction in thickness, provided that an increased compression force is applied in this event in the axial direction of the pipe. However, in the present situation, the accomplishment of an increased compression force would introduce an increase in power of a compression driving unit, as well as an increase in scale of a mechanism for supporting the compression driving unit and hence an overall bending machine. Accordingly, the aforementioned request cannot be sufficiently responded simply by increasing a compression force. Giving an example, when a steel pipe of 12B/sch80 (17.4 mm thick) is bent with 1.5 DR (bending radius: 478 mm), a bending process which applies a normal compression force involves driving the steel pipe with approximately 60 tons of propulsive driving force and results in a thickness reduction percentage of 12.5 %, whereas approximately 180 tons (approximately three times) of propulsive driving force is even required for reducing the thickness reduction percentage to 0 %.

40 **[0007]** It is therefore an object of the present invention to more reduce the amount of reduced thickness without introducing an increase in compression driving force in a metal pipe compression bending process.

45 **[0008]** To solve the problem and achieve the object, a metal pipe bending apparatus according to the present invention comprises heating means for fully circumferentially heating a portion of a metal pipe which is an object for a bending process, propulsion means for propulsively driving the metal pipe toward the heating means in an axial direction of pipe, guiding means including a cramp arm for cramping the metal pipe and configured for pivotal movement about a pivot shaft, for cramping a point in front of a region of the metal pipe heated by the heating means with the cramp arm, revolving the cramp point about the pivot shaft in association with the metal pipe propulsively driven by the propulsion means,

and thereby applying a bending moment to the metal pipe, and a compression means for causing a compression force to act on the metal pipe by applying a draw-back force to the metal pipe through the cramp arm with the pivot shaft serving as a fulcrum, where the draw-back force includes a force in a direction opposite to a direction in which the metal pipe is propulsively driven by the propulsion means. The compression means is disposed such that the distance from a point at which the draw-back force is applied to the pivot shaft is larger than the distance from a point at which the metal pipe is cramped by the cramp arm to the pivot shaft.

**[0009]** In the bending apparatus of the present invention, a metal pipe is propulsively driven while a portion of the metal pipe is fully circumferentially heated by the heating means, and simultaneously, the metal pipe is guided by the guiding means, after the metal pipe has passed through the heating means, such that the metal pipe is curved to appear as an arc. Specifically, when the direction in which the metal pipe is propulsively driven is defined as "forward" (in the present application, the "front" refers to a forward direction with respect to the direction in which the metal pipe is propulsively driven, while the "back" refers to a backward direction opposite to that), a point in front of the heated region is cramped by the cramp arm. This cramp arm is disposed for pivotal movement about the pivot shaft, and therefore makes a pivotal movement together with the metal pipe propulsively driven by the propulsion means, such that the cramped point of the metal pipe revolves about the pivot shaft to apply a bending moment to the heated region of the metal pipe to cause the metal pipe to continuously plastically deform, with the result that the metal pipe can be curved to appear as an arc.

**[0010]** On the other hand, a reduced thickness (reduction in thickness) is prevented on the outer peripheral side of the pipe by applying a compression force in the axial direction of the pipe in addition to the aforementioned bending moment. This compression force is produced by applying the metal pipe with a draw-back force, which is a force in the direction opposite to the direction in which the pipe is propulsively driven, through the cramp arm with the pivot shaft serving as a fulcrum. In the present invention, the distance from a position at which the draw-back force is applied to the pivot shaft is made larger than the distance from the point at which the metal pipe is cramped by the cramp arm to the pivot shaft. In this way, a large compression force can be applied to act on the metal pipe with a smaller draw-back force, as compared with before, to reduce the amount of reduced thickness during the bending process.

**[0011]** For "making the distance from a position at which the draw-back force is applied to the pivot shaft larger than the distance from the point at which the metal pipe is cramped by the cramp arm to the pivot shaft," as described above, in one example, the compression means may be disposed outside of the point of the metal pipe heated by the heating means, as viewed from the pivot shaft side (i.e., the point at which the metal pipe is cramped by the cramp arm in an initial state before the bending process).

**[0012]** Specific components of the compression means may include a pinion fixed to the cramp arm for pivotal movement together with the cramp arm, a rack in mesh with the pinion, and braking means for braking a movement of the rack driven in association with the pivotal movement of the cramp arm and pinion to thereby generate the compression force.

**[0013]** In the present invention, however, the components of the compression means are not limited to a mechanism comprised of a pinion and a rack as described above, but may employ, for example, a wire and a gear, a cylinder, and a variety of other driving/transmission mechanisms. Likewise, as to the propulsion means, its structure is not a particular concern as long as it comprises a mechanism capable of propulsively driving a metal pipe.

**[0014]** The bending apparatus of the present invention may further comprise a movable base including rear cramping means for cramping a rear portion of the metal pipe to transmit a propulsive driving force to the metal pipe, where the movable base is configured for traveling toward the heating means. The propulsion means may include a propulsive driving means having one end engaged to the movable base and the other end engaged to the pivot shaft, the propulsive driving means configured to corrupt or extend to propulsively drive the metal pipe through the movable base, and the compression means may include compression driving means having one end engaged to the movable base and the other end engaged to the pivot shaft, the compression driving means configured to corrupt or extend to apply a compression force to the metal pipe.

**[0015]** In the structure of the apparatus as described above, a rear portion of the metal pipe is cramped by the rear cramping means, and the movable base provided with the rear cramping means is transported by the propulsive driving means, thereby propulsively driving the metal pipe. The propulsive driving means has one end engaged to the movable base and the other end engaged to the pivot shaft, respectively, and corrupts (for example, by shortening the distance between the movable base and the pivot shaft (drawing the movable base or pivot shaft nearer)) or extends (for example, by pushing the movable base from the back to drive the same forward) to bring the movable base and pivot shaft closer to each other. In this way, the movable base is moved ahead relative to the pivot shaft to propulsively drive the metal pipe.

**[0016]** Similarly, the compression driving means also has one end engaged to the movable base and the other end engaged to the pivot shaft, respectively, and corrupts (for example, by shortening the distance between the movable base and the pivot shaft (drawing the movable base or pivot shaft nearer)) or extends (for example, by pushing the movable base from the back to drive the same forward) to generate the draw-back force which causes a compression force to act on the metal pipe.

**[0017]** Further, in the structure of the apparatus including the movable base as described above, when the compression means (compression driving means) is disposed outside of the point at which the metal pipe is cramped by the cramp arm, as viewed from the pivot shaft side, as described above, the propulsion means for propulsively driving the metal pipe, which is an object intended for the bending process, and the compression means for applying a compression force are coupled to each other through the movable base across the metal pipe, and they are arranged in a balanced state like a see-saw. Consequently, a counterforce of the propulsive driving force for propulsively driving the metal pipe is canceled by a counterforce of the compression force for preventing a reduced thickness. As compared with a structure of an apparatus which relies fully on components external to the apparatus for supporting these counterforces, the bending apparatus of the present invention requires only a simple supporting structure, and can be reduced in size as a whole. This aspect will be described later in greater detail with reference to Figs. 1A - 2.

**[0018]** Also, a method of manufacturing a metal pipe including a bent portion, according to the present invention, fully circumferentially heats a portion of the metal pipe, and applies the heated portion with a bending moment and a compression force in an axial direction of the pipe to plastically deform at least part of the metal pipe into a curved state. The method includes cramping a position of the metal pipe near the heated portion thereof, and cramping the metal pipe with a cramp arm configured for pivotal movement about a pivot shaft spaced apart from the cramping point by a certain distance, propulsively driving the metal pipe in the axial direction of the pipe to cause a pivotal movement of the point of the metal pipe cramped by the cramp arm to guide the metal pipe such that at least part thereof is curved to appear as an arc, and applying a compression force to the metal pipe at a position spaced apart from the pivot shaft by a distance larger than a distance from the point of the metal pipe cramped by the cramp arm to the pivot shaft, by applying the metal pipe with a draw-back force in a direction opposite to the direction in which the metal pipe is propulsively driven through the cramp arm with the pivot shaft serving as a fulcrum.

**[0019]** The manufacturing method according to the present invention as described above can also generate a larger compression force acting on the metal pipe with a smaller force (draw-back force) as compared with before, to restrain a reduction in thickness of the pipe during a bending process, in a manner similar to the aforementioned bending apparatus according to the present invention.

**[0020]** In the manufacturing method of the present invention, as a specific aspect of the method, the draw-back force can also be applied outside of a point at which the metal pipe is heated by the heating means (i.e., the point at which the metal pipe is cramped by the cramp arm in the initial state before the bending process), as viewed from the pivot shaft side.

**[0021]** Also, in the foregoing method, a rear portion of the metal pipe may be cramped by a movable base for cramping the rear portion of the metal pipe and configured for traveling toward the heated position of the metal pipe, while the metal pipe is propulsively driven by driving means having one end engaged to the movable base and the other end engaged to the pivot shaft and configured for contraction and extension, and a compression force may be simultaneously applied to the metal pipe by driving means having one end engaged to the movable base and the other end engaged to the pivot shaft and configured for contraction and extension.

**[0022]** In the present invention, a metal pipe which is an object intended for the bending process is not particularly limited in material or dimensions (outer diameter, inner diameter, thickness). For example, pipes made of materials mainly containing steel (for example, steel pipes, stainless steel pipes, special steel pipes and the like) can be intended for the bending by the present invention, but pipes may mainly contain another material or may be made of metal alloys. Further, in the present invention, a portion of a pipe to be bent (curved pipe portion) may be part of the pipe or the entirety of the pipe.

**[0023]** According to the present invention, the amount of reduced thickness can be further restrained without requiring an increase in compression driving force in a compression bending process for metal pipes.

## BRIEF DESCRIPTION OF THE DRAWINGS

### [0024]

[Fig. 1A]

A conceptual diagram showing the structure of an apparatus (in an initial state before a process is started) according to an embodiment of the present invention.

[Fig. 1B]

A conceptual diagram showing the structure of the apparatus (during the process) of the apparatus according to an embodiment of the present invention.

[Fig. 2]

A conceptual diagram for describing operations in the structure of the apparatus (in a state after time  $t_1$  elapsed from the start of the process).

[Fig. 3A]

A diagram showing a bending apparatus according to a first example of the present invention (in an initial state before a process is started).

[Fig. 3B]

A diagram showing the bending apparatus according to the first example (in a state during the process).

[Fig. 4]

A diagram showing a bending apparatus according to a second example of the present invention.

[Fig. 5]

A diagram showing a bending apparatus according to a third example of the present invention.

## BEST MODE FOR CARRYING OUT THE INVENTION

**[0025]** In the following, an embodiment and exemplary implementations will be described with reference to the drawings. First described is the principles of an apparatus according to an embodiment, followed by a description of exemplary configurations of the apparatus which are further embodied as exemplary implementations. In the respective figures, the same reference numerals indicate the same or similar components.

### [Principles of Apparatus]

**[0026]** Fig. 1A and Fig. 1B are conceptual diagrams showing the structure of an apparatus according to an embodiment of the present invention, and Fig. 2 shows the operation of the apparatus. As shown in Fig. 1, the apparatus of this embodiment comprises a heating coil 11 for fully circumferentially heating a metal pipe 1 which is intended for bending; a power supply unit 12 for supplying a current to this heating coil 11; a crank arm 21 having a cramp member 22 for cramping the metal pipe at a position in front of the heating coil 11 and configured for pivotal movement about a pivot shaft A defined at a position spaced apart from the heating coil 11 by a certain distance R1; a movable base (hereinafter simply referred to as the "base") 51 having a cramp member 52 for cramping a rear portion of the metal pipe and configured for forward movement toward the heating coil 11; a propulsive driving unit (propulsive driving means) 31 for driving the base 51 to travel toward the pivot shaft A; compression driving unit 41 for applying a compression force to the metal pipe 1; and a guide wheel 42 coupled to the crank arm 21 to rotate together with this about the pivot shaft A.

**[0027]** The pivot shaft A is fixed (for example, to a construction or a floor) so as not to move about, and the propulsive driving unit 31 comes into engagement with the pivot shaft A and base 51, and draws the base 51 toward the pivot shaft A to cause the base 51 to travel, thereby forcing the metal pipe 1 fixed to (cramped on) the base 51 to travel forward toward the heating coil 11. Also, since a leading end of the metal pipe 1 is fixed to (cramped on) the crank arm 21 by way of the cramp member 22, the crank arm 21 makes a pivotal movement, associated with the traveling metal pipe 1, causing the cramping point of the metal pipe 1 to revolve about the pivot shaft A. In this way, the metal pipe 1 is guided by the crank arm 21, a portion of the metal pipe 1 heated by the heating coil 11 undergoes continuous plastic deformation which causes the portion to curve, so that the metal pipe 1 is curved in the shape of an arc which has a radius equal to the distance R1 between the pivot shaft A and the point of the metal pipe 1 cramped by the crank arm 21 (cramp member 22) (see Fig. 1B).

**[0028]** Also, in this event, the metal pipe 1 is simultaneously applied with a compression force by the compression driving unit 41. Specifically, the compression driving unit 41 has one end engaged to the base 51, and the other end engaged to the outer periphery (point B) of the guide wheel 42, and is driven to draw both parties 51, B toward each other so that the distance therebetween is shortened. The guide wheel 42 rotates to the accompaniment of the rotation of the crank arm 21 resulting from the driven metal pipe 1, and winds up a coupling member 45 (for example, a chain, a wire, a rack, a rod, and the like. The specific configuration will be described later) of the compression driving unit 41 to the guide wheel 42 or drives the coupling member 45 forward (in the direction in which the metal pipe 1 is propulsively driven), where the compression driving unit 41 generates a force against the winding or propulsive driving (draw-back force or braking force). This draw-back force acts on the metal pipe 1 as a compression force in the axial direction of the pipe through the guide wheel 42 and crank arm 21 to restrain a reduction in thickness of an outer peripheral portion of the pipe.

**[0029]** Also, in the structure of the apparatus described above, the compression driving unit 41 for generating the draw-back force is disposed outside of the metal pipe 1, as viewed from the pivot shaft A, so that a distance R2 from the pivot shaft A, which serves as a fulcrum, to the point (power point) B at which the draw-back force is applied, is larger than the distance R1 from the pivot shaft A to the cramping point (cramp member 22), at which metal pipe 1 is cramped by the crank arm 21, i.e., a point of action at which the compression force acts. Accordingly, from the principle of leverage, where the pivot shaft A serves as a fulcrum, a large compression force can be applied to the metal pipe 1 even with a small draw-back force. The structure of the present apparatus can further be characterized as described below.

## [Operation of Apparatus]

**[0030]** As the propulsive driving unit 31 and compression driving unit 41 are activated to start a bending process, the base 51 travels forward toward the pivot shaft A, as described above, where this traveling speed is designated by  $V_1$ . Also, this traveling base 51 also drives forward the point P at which the metal pipe 1 is heated by the heating coil 11 (heating point), and the cramp arm 21 rotates to cause the heating point P to revolve about the pivot shaft A (see Fig. 1B). Notably, the heating coil 11 does not move, and the pipe portion heated by the heating coil 11 (heated site) is suddenly cooled down by a coolant, for example, water, compressed air or the like, immediately after the bending deformation. Thus, plastic working is continuously performed in sequence. Fig. 2 is a diagram showing displacements of respective points (pivot shaft A, heating point P, point B at which the draw-back force is applied, and base  $X_0$ ) of the apparatus along the axial direction of the pipe when a time  $t_1$  has elapsed from the start of the process. As shown in this figure, the base 51 moves from the initial position  $X_0$  toward the pivot shaft A by  $V_1 \cdot t_1$ .

**[0031]** Also, assuming that  $v$  represents the speed of the heating point P which goes forward to the accompaniment of the traveling base 51, this forwarding speed  $v$  is given by the following equation when the compressibility of the metal pipe 1 is designated by  $\beta$ . This forwarding speed  $v$  is equal to a process speed.

**[0032]**

$$v = V_1 \cdot (1 - \beta) \quad \dots \text{ (Equation 1)}$$

**[0033]** Also, in this event, the point B at which the compression driving unit 41 is in engagement with the guide wheel 42 (at which the draw-back force is applied) also goes forward, where the forwarding speed  $V_2$  is controlled by the compression driving unit, as represented by the following equation:

**[0034]**

$$V_2 = V_1 \cdot (1 - \beta) \cdot R_2 / R_1 \quad \dots \text{ (Equation 2)}$$

**[0035]** The following Equation 3 is derived from the above Equation 1 and Equation 2, and the displacements of the respective points A, P, B, associated with the revolution of the cramp arm 21, are balanced. For reference, in Figs. 1B and 2, the respective points  $X_1$ , P, B after the displacement ( $t=t_1$ ) are designated by  $X_1$ ,  $P_1$ ,  $B_1$ , respectively. The pivot shaft A is fixed and is therefore free of displacement. Also, while B-B<sub>1</sub> and P-P<sub>1</sub> actually appear to be arcuate, they are represented by straight lines in Fig. 2.

**[0036]**

$$V_2 / v = R_2 / R_1 \quad \dots \text{ (Equation 3)}$$

**[0037]** In the foregoing operation, the base 51 is driven forward at speed  $V_1$  by the action of a tension  $F_1$  resulting from a counterforce at the point A (pivot shaft) by the propulsive driving unit 31 (see Fig. 1A), and together with this, a rear portion of the metal pipe 1 is applied with the same thrust  $F_1$  as the tension  $F_1$ , and the outer periphery of the guide wheel 42 (leading end of the cramp arm 21) is applied with a draw-back force (braking force)  $F_2$ , resulting from a counterforce at the base 51 by the compression driving unit 41. The thrust  $F_1$  is also involved in a dynamic balance with the forwarding operation of the metal pipe at speed  $V_1$ , which includes, as loads, a bending deformation resistance  $f_b$  of the metal pipe 1, a compression deformation resistance  $f_p$  of the metal pipe 1, and even a dynamic friction force  $f_\mu$  associated with movements of respective components which form part of the bending apparatus, in addition to involvement in a static balance with the draw-back force  $F_2$ . Also, among these loads, the compression deformation resistance  $f_p$  is dynamically balanced with the compression force  $F_p$ .

**[0038]** Here, the aforementioned bending deformation resistance  $f_b$  and compression deformation resistance  $f_p$  are essential forces for working purposes. They can also be said to be forces which are unlikely to constitute factors of disturbing the bending operation. This is because they act axially on the metal pipe 1, and the deformation resistance presents a stable value which is substantially uniquely dominated by the temperature. On the contrary, the aforementioned dynamic friction force  $f_\mu$  associated with movements of the respective components of the apparatus eccentrically acts on the metal pipe 1, and is likely to disturb the bending operation because a dry friction or a boundary friction dominates under a low-speed operation such as bending, with associated fluctuations in irregular amplitude at all times. However, the structure of the present apparatus is advantageous in that the aforementioned eccentric force is mostly canceled

(reduced in a substantial amount even if not completely canceled) because it acts in a see-saw fashion across the metal pipe 1, and then a disturbance to the bending operation is eased.

**[0039]** Additionally, the structure of the present apparatus is also advantageous in that the propulsive driving unit 31 and compression driving unit 41 are disposed in a see-saw form across the metal pipe 1, as described above, and a propulsive driving force and a compression force are generated to act such that the metal pipe 1 is sandwiched by the base 51 and cramp arm 21, in a so-called "closed structure," so that any fixing point (base) is required except for that for fixing the pivot shaft A, and the apparatus can be reduced in size as a whole. In the following, a description will be given of more specific exemplary configurations of the apparatus according to the present invention.

#### [Exemplary Implementation 1]

**[0040]** Figs. 3A to 3B show a bending apparatus according to a first exemplary implementation of the present invention. As shown in these figures, this bending apparatus comprises a heating coil 11 for heating a metal pipe 1 which is intended for bending; a power supply unit 12 for supplying a high-frequency current to the heating coil 11; a cramp arm 21 configured for rotation together with the metal pipe 1 which has a leading end thereof cramped thereby; base 51 for traveling toward the heating coil 11 with a rear portion of the metal pipe 1 cramped thereby; a propulsive driving unit 31 for driving the base 51 to travel forward; a compression driving unit 41 for applying a compression force to the metal pipe 1; and a seat 10 fixed to a pivot shaft A for supporting the base 51 such that the base 51 can travel toward the pivot shaft A.

**[0041]** The cramp arm 21 comprises a front cramp member 22 for cramping the metal pipe 1 at a position immediately in front of that portion heated by the heating coil 11, and is configured for pivotal movement about the pivot shaft A. In this example, the heating coil 11 is configured to inductively heat the metal pipe 1 with a high-frequency current supplied thereto from the power supply unit 12, but the heating coil 11 is not limited to the inductive heating coil, but may employ another heating means such as a gas burner, by way of example.

**[0042]** The base 51 comprises a rear cramp member 52 for cramping a rear portion of the metal pipe 1, and is installed on the seat 10 fixed at the pivot shaft A such that the base 51 can linearly travel (in a straight line) toward the heating coil 11 and pivot shaft A. This base 51 (and hence the metal pipe 1 cramped thereby) is driven by the propulsive driving unit 31 to travel toward the heating coil 11 and pivot shaft A. The propulsive driving unit 31 can comprise cylinders (for example, hydraulic cylinders) 32 fixed to the seat 10, and applies a propulsive driving force to the base 51 by connecting piston rods 33 included in the cylinders 32 to the trailing end of the base 51.

**[0043]** In this regard, while the base 51 is propulsively driven by two cylinders 32 in this example, one or three or more of such cylinders may be provided. Also, the aforementioned front cramp member 22 and rear cramp member 52 may be implemented, for example, by collet-type chucks, but any other chuck or cramping mechanism may be employed as long as it is a mechanism capable of cramping the metal pipe 1.

**[0044]** On the other hand, the compression driving unit 41 can comprise a cylinder (for example, hydraulic cylinder) 43 fixed to the base 51, where a rack 45 is formed at a leading end of a piston rod 44 included in the cylinder 43, and a guide wheel 42 is formed with teeth on the outer periphery for coming into mesh with the rack 45. The guide wheel 42 comprises a pinion which has teeth formed along the outer periphery thereof such that they are in mesh with the rack 45, and is fixed to the cramp arm 21 so as to rotate about the pivot shaft A together with the cramp arm 21. Accordingly, as the metal pipe 1 is propulsively driven, the cramp arm 21 rotates, and the guide wheel 42 rotates together with the cramp arm 21, causing the rack 45 to travel forward (in the same direction as the metal pipe 1) (see Fig. 3B), but the cylinder 43, which forms part of the compression driving unit 41, generates a draw-back force which acts on the rack 45 in a direction opposite to that in which the rack 45 is travelling. In this way, a compression force can be axially applied to the metal pipe 1 through the pinion (guide wheel) 42, cramp arm 21, and front cramp member 22.

**[0045]** In this exemplary implementation, the compression driving unit 41 is disposed on the opposite side of the pivot shaft A across the metal pipe 1 (metal pipe portion before bending) in accordance with the present invention, such that a distance R2 from the pivot shaft A to the compression driving unit 41 (to a point at which the rack 45 comes into mesh with the pinion 42 and at which the draw-back force is applied) is larger than a distance R1 from the pivot shaft A to the cramped position of the metal pipe 1 (front cramp member 22) (or a distance from the pivot shaft A to a portion of the metal pipe 1 heated by the heating coil 11), thus making it possible to efficiently apply a compression force to the metal pipe 1 with a small draw-back force to restrain a reduction in thickness during the bending process.

#### [Exemplary Implementation 2]

**[0046]** Fig. 4 shows a bending apparatus according to a second exemplary implementation of the present invention. As shown in Fig. 4, this bending apparatus comprises, like the first exemplary implementation described above, a heating coil 11 for heating a metal pipe 1, a power supply unit 12, a cramp arm 21, a base 51, a propulsive driving unit 31 (a propulsive cylinder 32 and a piston rod 33), compression driving unit 41 (a compression cylinder 43, a piston rod 44,

and a rack 45), a guide wheel (pinion) 42, a pivot shaft A, and a seat 10, but differs from the first exemplary implementation in that the cylinder 32 of the propulsive driving unit 31 is fixed to the base 51, and a leading end of the piston rod 33 of the propulsive driving unit 31 is fixed to the pivot shaft A, such that the base 51 is drawn toward the pivot shaft A by drawing the piston rod 33 into the propulsive cylinder 32.

**[0047]** Also, the pivot shaft A and propulsive driving unit 31 are disposed on one side of the metal pipe 1 with respect to the direction in which the metal pipe 1 is propulsively driven, while the compression driving unit 41 is disposed on the other side across the metal pipe 1, whereby a distance R2 from the pivot shaft A to the compression driving unit 41 (at a point at which the rack 45 comes into mesh with the pinion 42 and at which a draw-back force is applied) is made larger than a distance R1 from the pivot shaft A to a cramped position of the metal pipe 1 (front cramp member 22), in a manner similar to the first exemplary implementation described above. Since the remaining configuration is similar to the first exemplary implementation, the same reference numerals are shown in the drawing, and repeated descriptions are omitted (this is applied to a third exemplary implementation as well).

#### [Third Exemplary Implementation]

**[0048]** Fig. 5 shows a bending apparatus according to a third exemplary implementation of the present invention. As shown in Fig. 5, this bending apparatus comprises, like the first exemplary implementation described above, a heating coil 11, a power supply unit 12, a cramp arm 21, a base 51, a propulsive driving unit 31 (a propulsive cylinder 32 and a piston rod 33), compression driving unit 41 (a compression cylinder 43, a piston rod 44, and a rack 45), a guide wheel (pinion) 42, a pivot shaft A, and a seat 10, but differs from the first exemplary implementation in that the compression driving unit 41 is disposed on the same side as the pivot shaft A, when based on a portion of the metal pipe 1 heated by the heating coil 11 (alternatively, a point at which the metal pipe 1 is cramped by the cramp arm 21 in an initial state (upon start of a bending process)).

**[0049]** Like the first exemplary implementation described above, this compression driving unit 41 comprises the compression cylinder 43, and the piston rod 44 which comprises the rack 45 at its leading end, but the compression cylinder 43 is not fixed to the seat 10 or pivot shaft A, but is fixed, for example, to a floor through a fixing anchor 46. The rack 45 is in mesh with the pinion (guide wheel) 42 which rotates about the pivot shaft A together with the cramp arm 21, and retracts backward as the metal pipe 1 (base 51) is propulsively driven, whereas the compression cylinder 43 generates a force (draw-back force/braking force) in a direction opposite to the rack 45 (forward), thereby applying a compression force to the metal pipe 1 in the axial direction of the pipe through the rack 45, pinion 42, and cramp arm 21.

**[0050]** Notably, in this exemplary implementation, a distance R2 from the pivot shaft A to the compression driving unit 41 (at a point at which the rack 45 comes into mesh with the pinion 42 and at which a draw-back force is applied) is made larger than a distance R1 from the pivot shaft A to a cramped position of the metal pipe 1 (front cramp member 22) (alternatively, the distance between the pivot shaft A and the portion of the metal pipe 1 heated by the heating coil 11).

**[0051]** While the embodiment and exemplary implementations of the present invention have been described above, it is apparent to those skilled in the art that the present invention is not limited to them, and can be modified in various manner without departing from the scope described in the claims.

**[0052]** For example, the rack and pinion are used in the foregoing exemplary implementations as a mechanism (compression driving unit, guide wheel) for applying a compression force to a metal pipe, a chain and a sprocket, or a wire and a winding drum, or another power transmission mechanism can be used as well. Also, the cramping means for cramping a metal pipe may comprise a variety of mechanisms other than the foregoing as long as it bears a bending moment applied to the metal pipe and does not make slip with respect to an axial force in the axial direction of the pipe (thrust in the longitudinal direction of the pipe). Further, as to other propulsive driving unit, cramp arm, movable base and the like, a variety of mechanisms and structures can be employed other than the examples shown in the drawings.

#### DESCRIPTION OF REFERENCE NUMERALS

##### [0053]

|    |                                         |
|----|-----------------------------------------|
| A  | Pivot shaft                             |
| 1  | Metal Pipe (Object for Bending Process) |
| 10 | Seat                                    |
| 11 | Heating Coil                            |
| 12 | Power Supply Unit                       |
| 21 | Cramp Arm                               |
| 22 | Front Cramp Member                      |
| 31 | Driving Unit                            |
| 32 | Propulsive Cylinder                     |

|        |                          |
|--------|--------------------------|
| 33, 44 | Piston Rods              |
| 41     | Compression Driving Unit |
| 42     | Guide Wheel (Pinion)     |
| 43     | Compression Cylinder     |
| 5      | 45 Rack                  |
| 46     | Fixed Anchor             |
| 51     | Movable Base             |
| 52     | Rear Cramp Member        |

## Claims

### 1. A metal pipe bending apparatus comprising:

heating means for fully circumferentially heating a portion of a metal pipe which is an object for a bending process;  
 propulsion means for propulsively driving said metal pipe toward said heating means in an axial direction of pipe;  
 guiding means including a cramp arm for cramping said metal pipe and configured for pivotal movement about a pivot shaft, said guiding means configured for cramping a point in front of a region of said metal pipe heated by said heating means with said cramp arm, revolving the cramp point about the pivot shaft in association with said metal pipe propulsively driven by said propulsion means, and thereby applying a bending moment to said metal pipe; and  
 a compression means for causing a compression force to act on said metal pipe by applying a draw-back force to said metal pipe through said cramp arm with the pivot shaft serving as a fulcrum, said draw-back force including a force in a direction opposite to a direction in which said metal pipe is propulsively driven by said propulsion means,  
 said metal pipe bending apparatus **characterized in that:**

said compression means is disposed such that a distance from a point at which the draw-back force is applied to the pivot shaft is larger than a distance from a point at which said metal pipe is cramped by said cramp arm to the pivot shaft.

### 2. A metal pipe bending apparatus according to claim 1, **characterized in that:**

said compression means is disposed outside of the point of said metal pipe heated by said heating means, as viewed from the pivot shaft side.

### 3. A metal pipe bending apparatus according to claim 1 or 2, wherein:

said compression means includes:

a pinion fixed to said cramp arm for pivotal movement together with said cramp arm;  
 a rack in mesh with said pinion; and  
 braking means for braking a movement of said rack driven in association with the pivotal movement of said cramp arm and pinion to thereby generate the compression force.

### 4. A metal pipe bending apparatus according to any of claims 1 to 3, further comprising:

a movable base including rear cramping means for cramping a rear portion of said metal pipe to transmit a propulsive driving force to said metal pipe, said movable base configured for traveling toward said heating means,

wherein said propulsion means includes a propulsive driving means having one end engaged to said movable base and the other end engaged to the pivot shaft, said propulsive driving means configured to corrupt or extend to propulsively drive said metal pipe through said movable base, and

said compression means includes compression driving means having one end engaged to said movable base and the other end engaged to the pivot shaft, said compression driving means configured to corrupt or extend to apply a compression force to said metal pipe.

5. A method of manufacturing a metal pipe including a bent portion, for fully circumferentially heating a portion of said metal pipe, and applying the heated portion with a bending moment and a compression force in an axial direction of the pipe to plastically deform at least part of said metal pipe into a curved state, said method **characterized by**:

5 cramping a position of said metal pipe near the heated portion thereof, and cramping said metal pipe with a cramp arm configured for pivotal movement about a pivot shaft spaced apart from the cramping point by a certain distance;

propulsively driving said metal pipe in the axial direction of the pipe to cause a pivotal movement of the point of said metal pipe cramped by said cramp arm to guide said metal pipe such that at least part thereof is curved to appear as an arc; and

10 applying a compression force to said metal pipe at a position spaced apart from the pivot shaft by a distance larger than a distance from the point of said metal pipe cramped by said cramp arm to the pivot shaft, by applying said metal pipe with a draw-back force in a direction opposite to the direction in which said metal pipe is propulsively driven through said cramp arm with the pivot shaft serving as a fulcrum.

- 15 6. A method of manufacturing a metal pipe including a bent portion according to claim 5, including:

applying said draw-back force outside of the portion of said metal pipe heated by said heating means, as viewed from the pivot shaft side.

- 20 7. A method of manufacturing a metal pipe including a bent portion according to claim 5 or 6, including:

cramping a rear portion of said metal pipe by a movable base for cramping the rear portion of said metal pipe and configured for traveling toward the heated position of said metal pipe, and propulsively driving said metal pipe by driving means, said driving means having one end engaged to said movable base and the other end engaged to the pivot shaft and configured for contraction and extension; and

25 simultaneously applying a compression force to said metal pipe by driving means, said driving means having one end engaged to said movable base and the other end engaged to the pivot shaft and configured for contraction and extension.

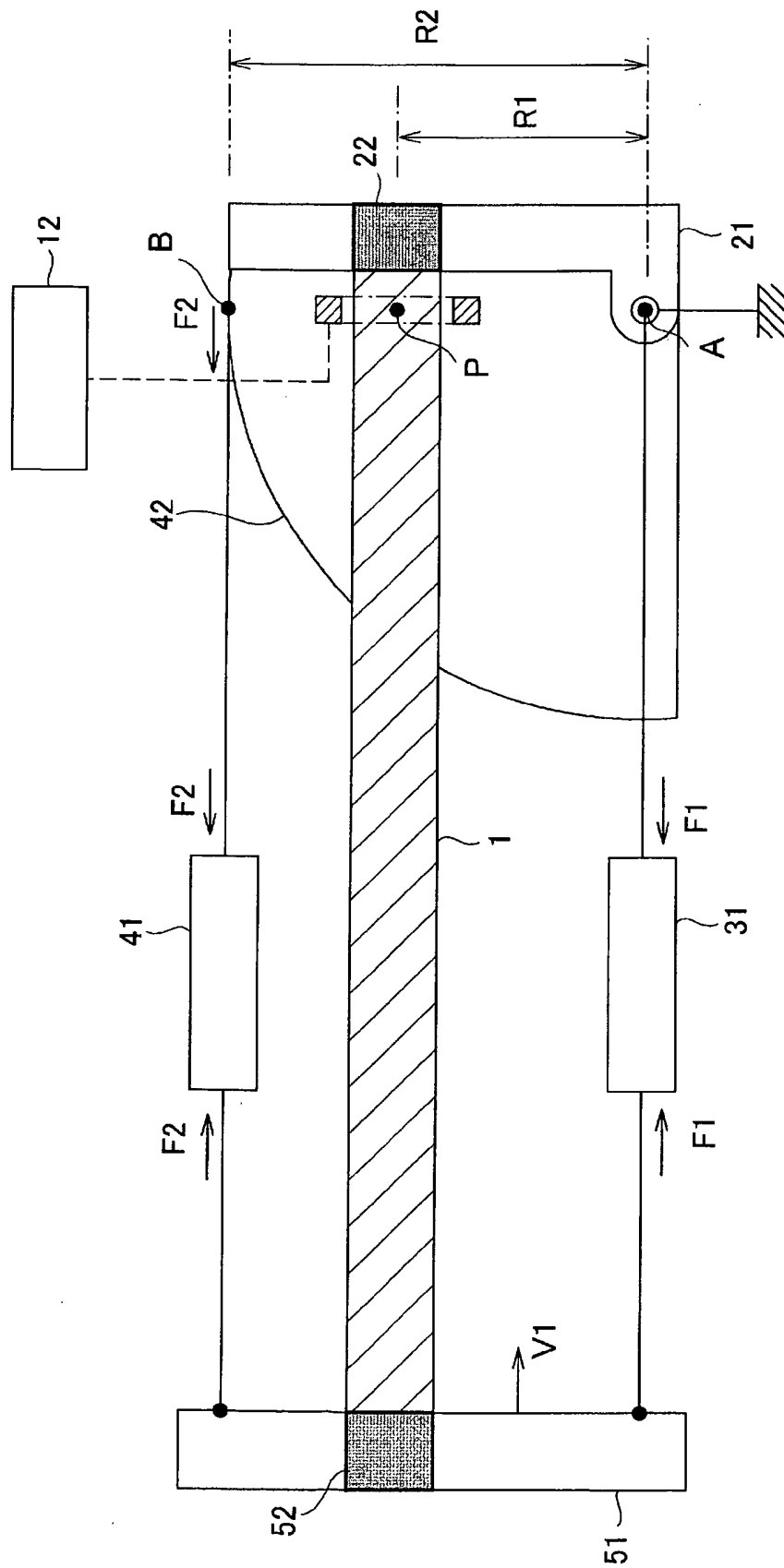
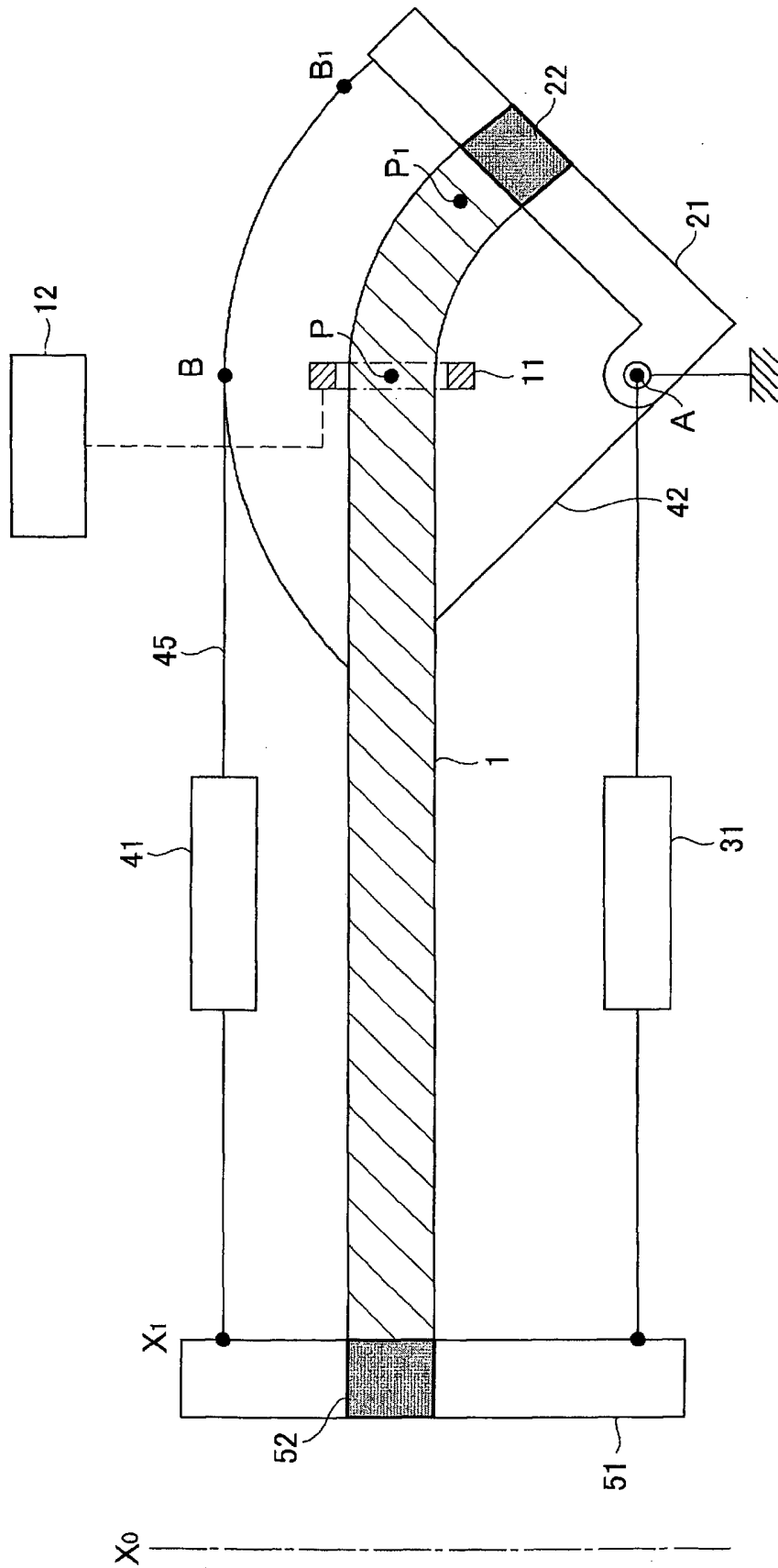


FIG. 1A



**FIG. 1B**

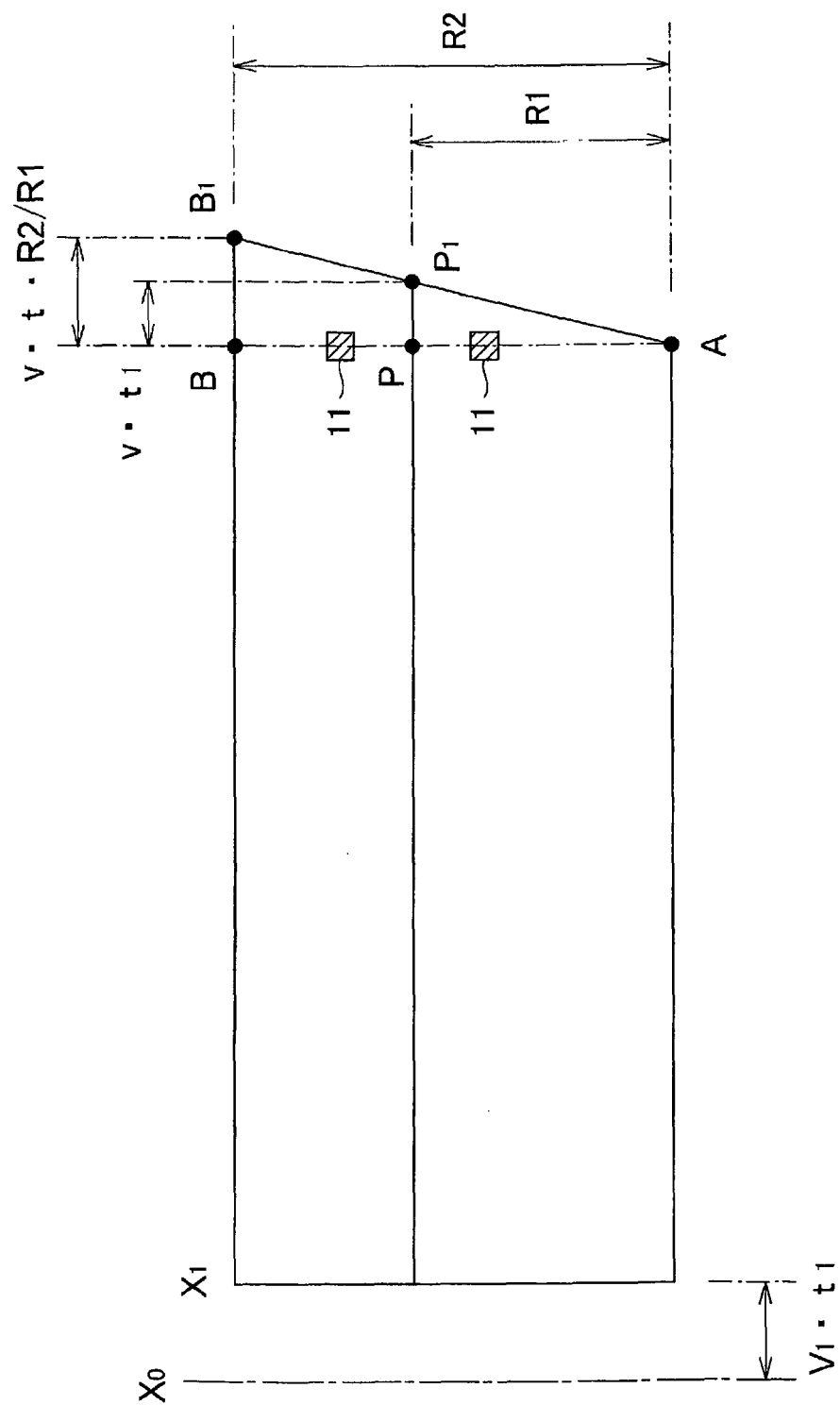


FIG. 2

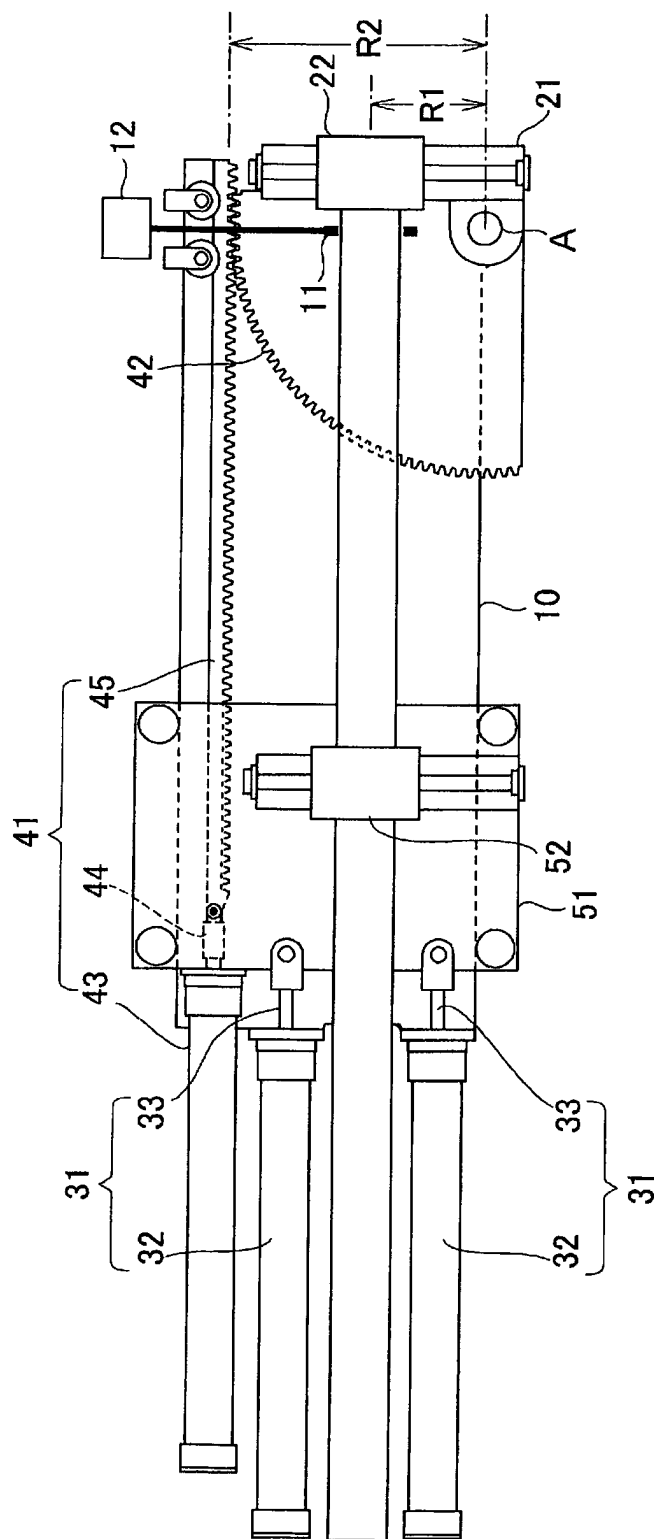


FIG. 3A

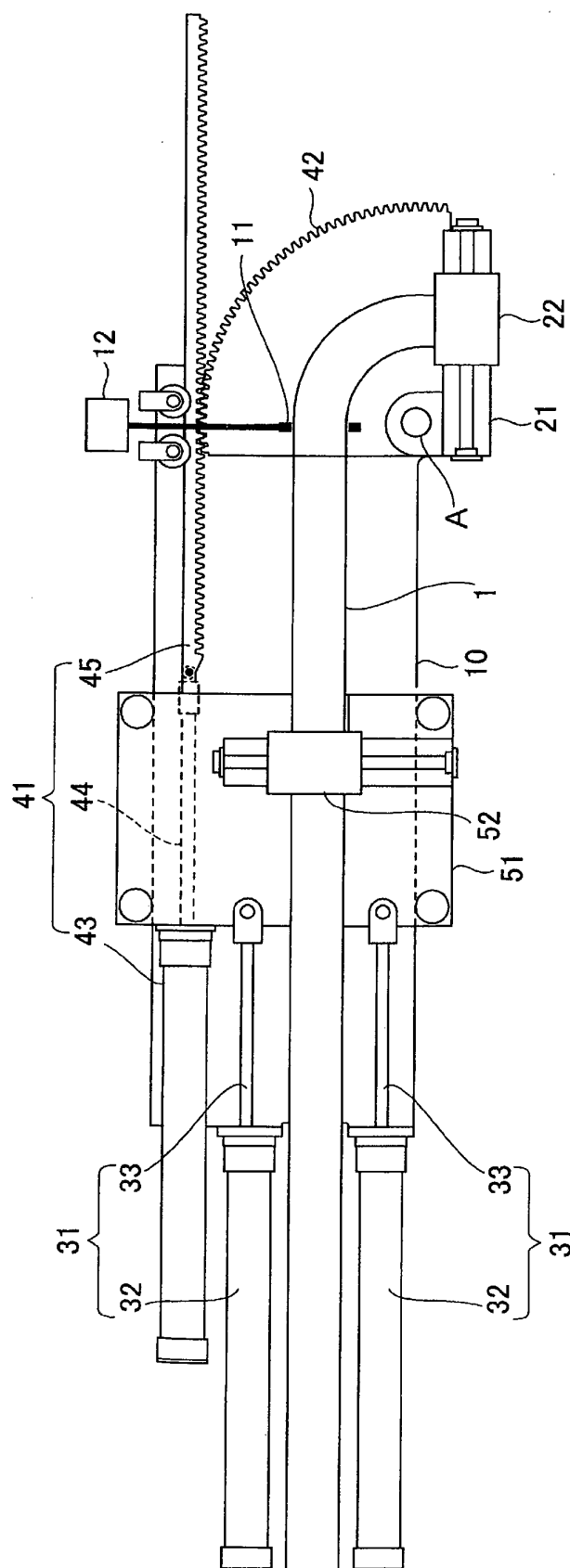


FIG. 3B

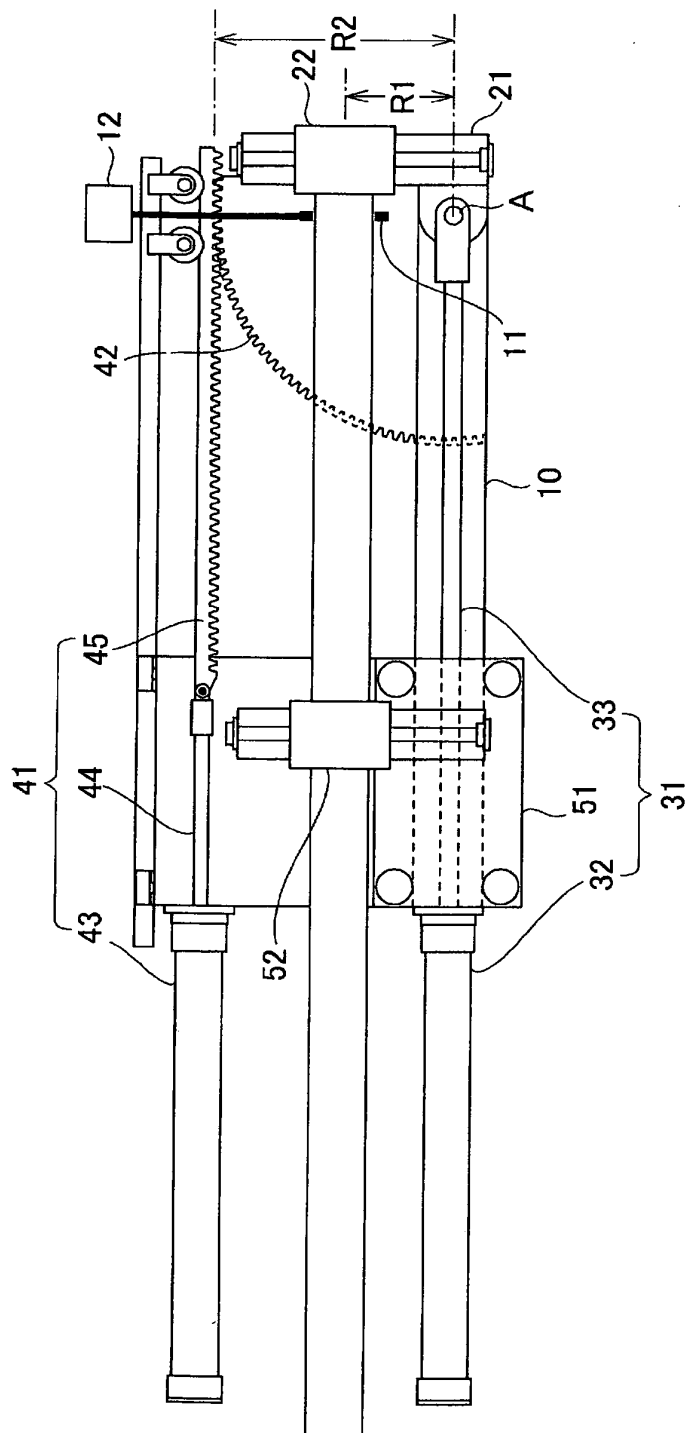


FIG. 4

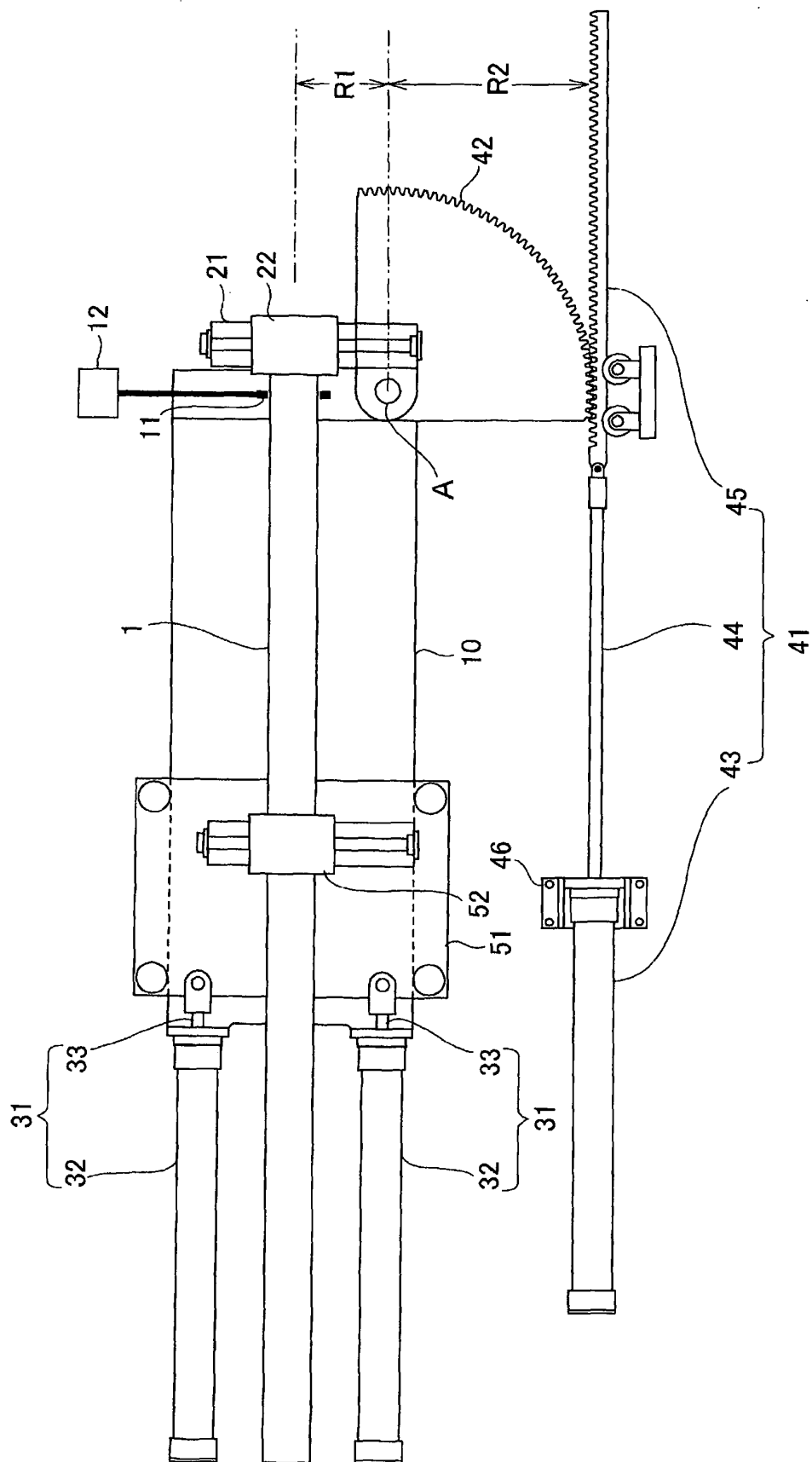


FIG. 5

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/061947

## A. CLASSIFICATION OF SUBJECT MATTER

**B21D7/16** (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)

**B21D7/16**

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 | 1996-2008 |
| Kokai Jitsuyo Shinan Koho | 1971-2008 | Toroku Jitsuyo Shinan Koho | 1994-2008 |

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

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                 | Relevant to claim No. |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X<br>Y    | JP 54-8154 A (Dai-Ichi High Frequency Co., Ltd.),<br>22 January, 1979 (22.01.79),<br>Figs. 1, 7<br>& US 4195506 A & GB 2000056 A<br>& DE 2825723 A | 1, 5<br>4, 7          |
| X         | JP 2004-223530 A (Dai-Ichi High Frequency Co., Ltd.),<br>12 August, 2004 (12.08.04),<br>Figs. 1, 2<br>& KR 10-2004-0067775 A                       | 1-3, 5-6              |

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

\* Special categories of cited documents:

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"&amp;" document member of the same patent family

Date of the actual completion of the international search  
01 September, 2008 (01.09.08)Date of mailing of the international search report  
09 September, 2008 (09.09.08)Name and mailing address of the ISA/  
Japanese Patent Office

Authorized officer

Facsimile No.

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/061947

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                        | Relevant to claim No. |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Y         | JP 2006-326667 A (Dai-Ichi High Frequency Co., Ltd.),<br>07 December, 2006 (07.12.06),<br>Fig. 3<br>& KR 10-2006-0124546 A & CN 1872441 A | 4, 7                  |

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- JP 54028156 B [0003]
- JP 2047287 B [0003]