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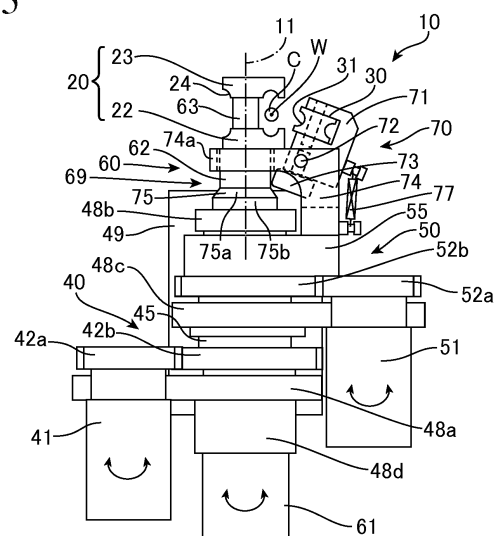
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(54) **PROCESSING UNIT AND PROCESSING DEVICE**

(57) There is provided a machining unit (10) that machines a rod-shaped member (W). The machining unit (10) includes: a first unit (23) including a first split die portion on an upper side, out of upper and lower split die portions that form a pair and include a bending channel that bends the rod-shaped member (W), and a first clamp portion on an upper side, out of upper and lower clamp portions that form a pair and hold the rod-shaped member inserted into the bending channel; a second unit (22) including a second split die portion on a lower side out of the upper and lower split die portions that form a pair and a second clamp portion on a lower side out of the upper and lower clamp portions that form a pair; a pressure unit (30) including a holding channel that holds the rod-shaped member in the bending channel from an outer circumferential side of the bending channel; and an opening-closing unit (69) that opens and closes the first unit (23), the second unit (22), and the pressure unit (30) in three different directions with respect to a setting center (C) that is a position of a center axis of the rod-shaped member (W) in a state where the rod-shaped member (W) is set the bending channel.

Fig. 3



Description

TECHNICAL FIELD

[0001] The present invention relates to a unit and apparatus that bend a rod-shaped member such as a metal pipe or a metal tube.

BACKGROUND ART

[0002] Japanese Laid-Open Patent Publication No. H11-138215 describes the provision of a pipe bender in which the configuration of the bending die and the clamping die is simplified and which is smaller than conventional pipe benders. In the pipe bender in the cited document, a bending die that is supported on an upper portion of rotating shaft is constructed of a split die capable of separating in the axial direction, with the respective pieces of the split die being formed so as to be integrated with halves of the clamping die. A pipe material to be bent is fed into a gap in the clamping die that has been separated together with the split die, and is pinched in the clamping die by closing the split die. After this, the bending die is rotated together with the rotating shaft to produce a configuration that bends along a guide of a concave channel formed in an outer circumference of the bending die.

[0003] Japanese Laid-Open Patent Publication No. 2003-305518 discloses the provision of a pipe bending unit of a pipe bending apparatus that is compact and is easy to control. The machining unit in the cited publication is a pipe bending unit of a pipe bending apparatus equipped with a bending roll, a clamp for fixing a pipe to the bending roll, a pressure unit for bending the pipe by moving along the bending roll while pressing the pipe onto the bending roll. In this pipe bending unit of a pipe bending apparatus, a fixed plate having pressure cams for supporting the clamp so as to contact and separate from the bending roll and determining the movement path of the pressure unit is installed, a rotary plate having clamping cams for supporting the pressure unit so as to contact and separate from the bending roll and moving the clamp is disposed, and the clamp and the pressure unit are operated by such cams.

DISCLOSURE OF THE INVENTION

[0004] There is demand for an apparatus capable of machining a rod-shaped member such as a pipe or a tube with greater efficiency.

[0005] One aspect of the present invention is a machining unit including: upper and lower split die portions that form a pair and include a bending channel for bending a rod-shaped member; upper and lower clamp portions that form a pair and hold the rod-shaped member inserted into the bending channel; and a pressure unit (pressure die) that includes a holding channel that holds the rod-shaped member in the bending channel from an

outer circumferential side of the bending channel. The machining unit includes: a first unit including a first split die portion on an upper side, out of the upper and lower split die portions that form a pair and a first clamp portion on an upper side, out of the upper and lower clamp portions that form a pair; a second unit including a second split die portion on a lower side out of the upper and lower split die portions that form a pair and a second clamp portion on a lower side out of the upper and lower clamp portions that form a pair; and an opening-closing unit that opens and closes the first unit, the second unit, and the pressure unit in three different directions relative to a setting center that is a position of a center axis of the rod-shaped member in a state where the rod-shaped member has been placed or set in the bending channel.

[0006] By opening the first unit, the second unit, and the pressure unit in three different directions, the first unit, the second unit, and the pressure unit will each move to a position where a certain distance is maintained from the setting center. This means that it is easy to access the setting center and it is possible to load and unload a work that is a rod-shaped member, such as a pipe or a tube, on a simple path, typically a linear path, to a position where the rod-shaped member is held for a bending process, that is, the "setting center". This means that it is possible to reduce the time required to set the rod-shaped member and to reduce the work time required by a bending process. In particular, when a plurality of bending processes are required to turn one rod-shaped member into a product, although the number of times the hold is switched will increase, it is possible, by reducing the time required to change the hold, to reduce the machining time (manufacturing time) including the bending processes.

[0007] It is desirable for the opening-closing unit to include a first opening-closing unit (balanced opening-closing unit) that opens and closes the first unit and the second unit in a uniformly (in a equivalently manner, in a balanced manner); and a second opening-closing unit that operates in concert with the first opening-closing unit and moves the pressure unit away from and toward the setting center. The second opening-closing unit may be a link unit that opens and closes the pressure unit in synchronization by using movement of the first opening-closing unit. The driving mechanism and control of the pressure unit can be simplified.

[0008] The second opening-closing unit may include: a skirt-shaped cylindrical cam that moves up and down in concert with the first opening-closing unit; and a cam follower that moves while contacting a circumferential surface of the skirt-shaped cylindrical cam and, in concert with the skirt-shaped cylindrical cam moving up and down and the first unit and the second unit opening and closing, moves the pressure unit relative to the bending channel so as to open and close the pressure unit. If the first and second units are closed when the skirt-shaped cylindrical cam moves upward, a skirt-shaped cylindrical cam that is narrow in the first and second directions (up-down di-

rections) is used. Since it is possible to receive the bending reaction force of the pressure unit using the skirt-shaped cylindrical cam, it is possible to omit a driving means and energy for keeping the pressure unit in the die closed state.

[0009] The first opening-closing unit may include: a first opening-closing shaft that moves the first unit up and down; a second opening-closing shaft that moves the second unit up and down; a left-hand and right-hand screw member that moves the first opening-closing shaft and the second opening-closing shaft up and down in opposite directions; and an opening-closing motor that rotates the left-hand and right-hand screw member. It is possible to provide a mechanism that opens and closes the first and second units and the pressure unit using a single opening-closing motor.

[0010] The second opening-closing unit may include: a holder that supports the pressure unit so as to swing relative to the first opening-closing shaft and the second opening-closing shaft; and a support portion that supports the holder so as to be capable of revolving relative to the first opening-closing shaft and the second opening-closing shaft. By supporting an arm that swings the pressure unit with a first opening-closing shaft and the second opening-closing shaft, it is possible to receive the reaction to the swinging of the pressure unit near the first and second unit, and to reliably hold the rod-shaped member that is the work using the first and second unit and the pressure unit.

[0011] The pressure unit may include a pressure roller including the holding channel that includes an arc-shaped part, and the machining unit may further include: a first driving unit that rotates the first unit and the second unit about a first axis in a state where the first unit and the second unit are closed; and a second driving unit that rotates the pressure unit about the first axis independently of the first driving unit in a state where the pressure unit is closed. It is possible to carry out a draw bending process in one of the left and right directions by the clamp and a compression bending process in another of the left and right directions by rotating the pressure unit. The upper and lower clamp portions that form a pair may include clamp portions that are common to leftward and rightward bending and include clamping channels that intersect in an X shape. It is possible to machine the rod-shaped member in four modes that are left and right, compression and draw, bending.

[0012] The pressure unit may include at least one pressure unit disposed at one out of two positions on the left and right. That is, the pressure unit may include left and right pressure units disposed at two positions on the left and right or a single pressure unit disposed on one side. The second driving unit may open and close the left and right pressure units or the single pressure unit. It is possible to carry out draw bending in the left and right directions or draw bending in one of such directions. One example of the second driving unit that drives the left and right pressure units includes left and right opening-clos-

ing cams that respectively open and close the left and right pressure units and an inclined cylindrical cam that rotates about the first shaft so as to close one of the left and right opening-closing cams.

[0013] Another aspect of the present invention is a machining apparatus including: the machining unit described above, a work supporting unit that supports the rod-shaped member; and a moving unit that moves at least one of the machining unit and the work supporting unit to carry out a first operation that sets a center axis of an unmachined part of the rod-shaped member supported by the work supporting unit at the setting center of the machining unit and a second operation that sets the center axis of the unmachined part at a withdrawn position away from the setting center. Since it is possible to open and close the first and second units and the pressure unit that hold the rod-shaped member in three directions, the moving unit can move the center axis of an unmachined part of the rod-shaped member supported by the work supporting unit relatively in a straight line between the setting center and the withdrawn position. Accordingly, it is possible to reduce the machining time (processing time).

[0014] It is desirable for the moving unit to relatively move the center axis of the unmachined part of the rod-shaped member supported by the work supporting unit in a first direction, for example, the vertical direction, and to support the machining unit so that the opening-closing direction of the first unit and the second unit is inclined to the vertical direction. It is possible to simplify the relative movement of the rod-shaped member to be machined and to provide a machining apparatus with a simplified configuration.

[0015] If the machining unit includes a mechanism that bends the rod-shaped member leftward and rightward, the moving unit may include a first moving unit that swings the machining unit leftward and rightward while moving the machining unit up and down. It is possible to set the machining unit in accordance with initial positions for leftward and rightward bending. As one example, the first moving unit includes: a base; a holder that swings relative to the base; a slide plate that supports the machining unit so as to slide up and down inside the holder; a first cam channel in the vertical direction provided in the base; a second cam channel provided in the slide plate in a direction perpendicular to a direction in which the slide plate slides; a turn gear that includes a turn roller that moves inside the first cam channel and the second cam channel; and a turn motor that is held by the holder and rotationally drives the turn gear. By moving the turn gear using the turn motor, it is possible to swing the slide plate to the left and right together with moving up and down. This means it is possible to swing the machining unit supported by the slide plate to the left and right while moving up and down and possible to move the setting center where the rod-shaped member is set to initial positions for leftward and rightward bending.

[0016] A machining apparatus may include a machin-

ing unit and a twist unit that supports the machining unit so as to rotate about the second axis that passes the setting center. The twist unit may include: a twist gear that is ring shaped, supports the machining unit, and includes a first cutaway portion where one part towards a center is missing; a twist driving unit that drives the twist gear; a plurality of guide rollers that support the outer circumferential surface of the twist gear so that the twist gear rotates about the second axis; and a support unit that supports the plurality of guide rollers. The support unit of the machining apparatus may include: a second opening that is centered on the second axis and is larger than a first opening inside a ring of the twist gear; and a second cutaway portion that reaches the second opening and is open in a direction perpendicular to the second axis, the plurality of guide rollers may be disposed facing the second opening and at least part of the twist gear may be supported so as to rotate inside the second opening. It is possible to provide a machining apparatus that is a twist shaft-less rotary mechanism and has a short bending impossible region.

[0017] The machining apparatus may further include: a chuck unit that supports an unmachined part of the rod-shaped member along the second axis on an opposite side of the machining unit with the support unit in between; and a feeding unit that controls a relative distance between the chuck unit and the support unit. The chuck unit may include a work holding portion that extends along the second axis and passes through the first opening when a distance between the support unit and the chuck unit is reduced.

[0018] Yet another aspect of the present invention is a method (manufacturing method, control method) including carrying out a bending process on a rod-shaped member using a machining apparatus including a machining unit. The machining unit includes: upper and lower split die portions that form a pair and include a bending channel; upper and lower clamp portions that form a pair and hold the rod-shaped member inserted into the bending channel; and a pressure unit that includes a holding channel that holds the rod-shaped member in the bending channel from an outer circumferential side of the bending channel. The method includes setting the rod-shaped member by moving, before the carrying out the bending process and in a state where the upper split die portion and the upper clamp portion, the lower split die portion and the lower clamp portion, and the pressure unit have been opened in three different directions with respect to a setting center which is a position of a center axis of the rod-shaped member in a state where the rod-shaped member is set in the bending channel, the rod-shaped member relatively to the setting center in a straight line.

[0019] The setting may include inclining the machining unit and supplying and discharging on a common path for leftward and rightward bending by moving the rod-shaped member in a straight line. The machining may also include bending in a left-right direction of the rod-

shaped member set at the setting center at the setting center. Since the movement distance of the rod-shaped member can be shortened, it is possible to reduce the machining time.

[0020] For a machining apparatus that includes a twist unit, a turn unit, and a chuck unit, it is possible to include the twist driving unit rotating, before the setting, the twist gear so that the first cutaway portion and the second cutaway portion match; and the turn unit setting the attachment angle so that a direction in which the rod-shaped member is released when the first unit, the second unit, and the pressure unit are opened and a direction of the first cutaway portion and the second cutaway portion are in a straight line, and the setting may include moving the chuck unit and the twist unit relatively in a direction of the straight line to set the rod-shaped member at the second axis. It is possible to provide a rotary bender capable of supplying and discharging the rod-shaped member in a straight line.

[0021] For a machining apparatus that includes a feeding unit, it is possible to include: the feeding unit reducing, before the carrying out the bending process, a distance between the support unit and the chuck unit and passing the work holding portion through the second opening; and the work holding portion re-holding (releasing and holding again), once the rod-shaped member has been held by the machining unit and the feeding unit increases the distance between the support unit and the chuck unit, the rod-shaped member. By releasing and holding again the rod-shaped member, it is possible to carry out a bending process even at a center portion of the rod-shaped member.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022]

[FIG. 1]

FIG. 1 is a front view showing an overview of a machining apparatus.

[FIG. 2]

FIG. 2 is a side view showing an overview of the machining apparatus.

[FIG. 3]

FIG. 3 is a view showing an overview of a machining unit.

[FIG. 4]

FIG. 4 is a cross-sectional view showing the overall configuration of the machining unit.

[FIG. 5]

FIG. 5 is a series of diagrams showing how an upper and lower die and a pressure roller are opened and closed, where FIG. 5(a) is a view showing a die opened state, FIG. 5(b) is a view showing a die closed state, FIG. 5(c) is a view showing movement for a leftward bending process, and FIG. 5(d) is a view showing movement for a rightward bending process.

[FIG. 6]

FIG. 6 is a series of diagrams for explaining an overview of a bending die clamp, where FIG. 6(a) is an enlarged plan view from above which is centered on the bending die clamp, FIG. 6(b) is a view of a state where a work is held by a clamping channel when looking from the direction of the clamping channel, and FIG. 6(c) is a view of a state where a work is held by a second clamping channel when looking from the direction of the second clamping channel.

[FIG. 7]

FIG. 7 is a series of views showing the construction of a lower die of the bending die clamp, where FIG. 7(a) is a plan view, FIG. 7(b) is a side view in a direction in which the clamping channel extends, and FIG. 7(c) is a side view in a direction in which the second clamping channel extends.

[FIG. 8]

FIG. 8 is a series of plan views showing an example of a bending process by the machining unit, where FIG. 8(a) is a view showing leftward draw bending, FIG. 8(b) is a view showing rightward draw bending, FIG. 8(c) is a view showing leftward compression bending, and FIG. 8(d) is a view showing rightward compression bending.

[FIG. 9]

FIG. 9 is a series of views showing the configuration and movement of the moving unit, where FIG. 9(a) and FIG. 9(d) are views showing a state where the machining unit is set in a leftward bending state, FIG. 9(b) and FIG. 9(e) are views showing a state where the machining unit has moved downward, and FIG. 9(c) and FIG. 9(f) are views showing a state where the machining unit is set in a rightward bending state.

[FIG. 10]

FIG. 10 is a series of views further showing the configuration of the moving unit, where FIG. 10(a) is a cross-sectional view in the horizontal direction and FIG. 10(b) is a cross-sectional view in the vertical direction.

[FIG. 11]

FIG. 11 is a flowchart showing a procedure where a work is machined by the machining apparatus.

[FIG. 12]

FIG. 12 is a series of plan views showing a different machining unit, where FIG. 12(a) is a diagram showing a leftward draw bending process and FIG. 12(b) is a diagram showing a rightward compression bending process.

[FIG. 13]

FIG. 13 is a plan view showing yet another machining unit.

[FIG. 14]

FIG. 14 is a side view of the machining unit shown in FIG. 13.

[FIG. 15]

FIG. 15 is a plan view showing an example of a machining unit equipped with two pressure rollers.

[FIG. 16]

FIG. 16 is a front view showing an overview of a different machining apparatus.

[FIG. 17]

FIG. 17 is a plan view showing an overview of the machining apparatus shown in FIG. 16.

[FIG. 18]

FIG. 18 is a front view showing an overview of a twist unit.

[FIG. 19]

FIG. 19 is a cross-sectional view showing an overview of the twist unit.

[FIG. 20]

FIG. 20 is a plan view showing an overview of the twist unit.

[FIG. 21]

FIG. 21 is a series of views showing the overall configuration of a chuck unit, where FIG. 21(a) is a front view and FIG. 21(b) is a side view.

[FIG. 22]

FIG. 22 is a flowchart showing a procedure by which a work is machined by the machining apparatus shown in FIG. 16.

[FIG. 23]

FIG. 23 is a front view showing an overview of a different twist unit.

[FIG. 24]

FIG. 24 is a side view showing an overview of the twist unit shown in FIG. 23.

[FIG. 25]

FIG. 25 is a plan view showing an overview of the twist unit shown in FIG. 23.

[FIG. 26]

FIG. 26 is a plan view showing an overview of a different machining unit.

[FIG. 27]

FIG. 27 is a cross-sectional view showing the overall configuration of a bending unit shown in FIG. 26.

[FIG. 28]

FIG. 28 is a series of views showing how the upper and lower die and the pressure roller open and close, where FIG. 28(a) shows a die opened state and FIG. 28(b) shows a die closed state.

DETAIL DESCRIPTION

[0023] FIG. 1 shows, by way of a front view, an overview of a machining apparatus that bends a rod-shaped member. One example of a rod-shaped member that is the processing or machining object (i.e., the "(work" or "workpiece") is a pipe. The machining apparatus (processing apparatus) 1 includes a mount 2, a work supporting unit 5 that supports a pipe that is the work W in the horizontal direction, a machining unit (processing unit) 10 that bends the work (machining object) W, a moving unit 80 that supports the machining unit 10 on the mount 2 so as to move in the up-down direction, and a control unit 9. The control unit 9 has functions that re-

spectively control the work supporting unit 5, the machining unit 10, and the moving unit 80. The work W may be a pipe, a tube, or another rod-shaped member.

[0024] The work supporting unit 5 includes a holder (clamp) 5a that holds the work W in the horizontal direction, a motor 5b that rotates about an axis (central axis) in the longitudinal direction of the work W, and a moving unit 5c that moves the work supporting unit 5 above the mount 2 to control the distance from the machining unit 10. The moving unit 5c controls the machining position (processing position) in the longitudinal direction (length direction) of the work W. In this example, the moving unit 5c is a horizontal moving unit that moves the work W in the horizontal direction. The work supporting unit 5 may include a unit that moves the work supporting unit 5 up and down above the mount 2 to change the height of the work W held by the holder 5a.

[0025] The control unit 9 includes a machining position control function (machining position control unit) 9a that controls the motor 5b of the work supporting unit 5 and the horizontal moving unit 5c to control the relative angle between the machining unit 10 and the work W and the distance between the machining unit 10 and the work supporting unit 5. By changing the relative positions of the machining unit 10 and the work supporting unit 5 and/or changing the angle, it is possible to control the relative angle of the machining unit 10 and the work W and the distance between the machining unit 10 and the work supporting unit 5.

[0026] The control unit 9 includes a bending process control unit 9b that controls the machining unit 10 to control the bending direction of the work W and the bending method (draw bending and compression bending). The process control unit (machining process control unit) 9b includes mode 1 (M1) that carries out leftward draw bending, mode 2 (M2) that carries out rightward draw bending, mode 3 (M3) that carries out leftward compression bending, and mode 4 (M4) that carries out rightward compression bending.

[0027] The control unit 9 further includes a clamp control function (clamp control unit) 9c that controls the machining unit 10 and the moving unit 80 to have the machining unit 10 hold (clamp) or release the work W at a predetermined position. The clamp control function 9c includes a function which, when switching between leftward and rightward bending, uses the moving unit 80 to move the machining unit 10 up and down so as to clamp the work W at predetermined positions for leftward and rightward bending.

[0028] By moving the machining unit 10, the moving unit (quick turn unit) 80 switches the positional relationship between the machining unit 10 and the work W between leftward bending and rightward bending positions. The moving unit 80 first moves the machining unit 10 downward relative to the work W to release the work W from the machining unit 10, and then moves the machining unit 10 in the upward direction to have the machining unit 10 hold the work W with a different posture.

[0029] FIG. 2 shows the machining apparatus 1 when looking from the machining unit 10 side. The machining unit 10 is attached to the mount 2 so that a bending axis (first axis) 11 is inclined to the vertical direction. As described later, for the leftward bending and for the rightward bending, it is necessary to reverse the direction of inclination of the bending axis 11. The moving unit 80 carries out a first operation that sets the center axis of an unmachined part of the work W supported by the work supporting unit 5 at a setting center C of the machining unit 10 and a second operation that sets the center axis of an unmachined part at a withdrawn position away from the setting center C. Accordingly, as shown by the dot-dash line 89, the moving unit 80 moves the machining unit 10 up and down in a straight line while swinging in the left-right direction and as a result, the part that clamps is lowered and raised relative to the work W so as to trace a U shape or a C shape, and while doing so, the inclination of the bending axis 11 is reversed. Due to this operation of the moving unit 80, the machining unit 10 moves relative to the work W in a straight line to the position (setting center) C where the work W is clamped. The work W moves in a straight line relative to the machining unit 10 from the withdrawn position to the position C where the work W is clamped (held).

[0030] FIG. 3 shows an overview of the machining unit 10 that has been extracted. FIG. 4 shows the overall configuration by way of a cross section along the bending axis 11 of the machining unit 10. The machining unit 10 includes a bending die clamp 20 that rotates about the bending axis (first axis) 11, a roller-type pressure unit (presser, pressure die, pressure roller) 30 that operates in concert with (together with) the bending die clamp 20 to bend the work W, a first driving unit (draw bending mechanism) 40 that rotates the bending die clamp 20 about the bending axis 11, a second driving unit (compression bending mechanism) 50 that rotates the pressure roller 30 about the bending axis 11 independently of the first driving unit 40, and an opening-closing unit (opening/closing unit) 69 that opens and closes the bending die clamp 20 and the pressure unit roller 30. The opening-closing unit 69 includes a die opening-closing mechanism (first opening-closing unit) 60 that opens and closes the bending die clamp 20 in the up/down direction, and a link unit (pressure unit swinging mechanism, second opening-closing unit) 70 that operates linked with (in concert with) the die opening-closing mechanism 60 to swing the pressure roller 30 relative to the bending die clamp 20. The machining unit 10 includes a slide plate 49 that is slidably attached to the mount 2 via the moving unit 80, and the mechanisms 40 to 70 are supported via the slide plate 49.

[0031] The bending die clamp 20 includes upper and lower split die portions (an upper and lower die, first and second units) 23 and 22 that form a pair and include an arc-shaped part, in the present embodiment a ring-shaped bending channel 24, and is used to bend the work W, such as a pipe, along the bending channel 24. The

pressure roller 30 includes a holding channel 31 with a semicircular cross section that holds the rod-shaped work W from an outer circumference side of the bending channel 24 into the bending channel 24, which also has a semicircular cross section, of the bending die clamp 20. The holding channel 31 includes an arc-shaped part and in the present embodiment, a ring-shaped channel is provided around the entire circumference of the pressure roller 30.

[0032] The draw bending mechanism (first driving unit) 40 that rotationally drives the bending die clamp 20 includes a hollow shaft 45 that is supported so as to rotate around the bending axis 11 relative to the slide plate 49, a first motor (draw bending motor) 41 that drives the hollow shaft 45, and gears 42a and 42b that link the draw bending motor 41 and the hollow shaft 45. The draw bending motor 41 is fixed to the slide plate 49 via a support plate 48a. The hollow shaft 45 is rotatably attached via bearings 47a and 47b to support plates 48b and 48c that are fixed to the slide plate 49. When the hollow shaft 45 is rotationally driven by the draw bending motor 41, the bending die clamp 20 is rotationally driven about the bending axis 11 via an upper die opening-closing shaft 63 and a lower die opening-closing shaft 62 that rotate together with the hollow shaft 45.

[0033] The compression bending mechanism (second driving unit) 50 that rotationally drives the pressure unit roller 30 includes a housing 55 that is rotatably attached to a circumference of the hollow shaft 45, a second motor (compression bending motor) 51 that rotationally drives the housing 55 and gears 52a and 52b that link the compression bending motor 51 and the housing 55. The pressure roller 30 is attached via the pressure unit swinging mechanism 70 to the housing 55 and when the compression bending motor 51 rotationally drives the housing 55, the pressure roller 30 rotates together with the housing 55 around the bending axis 11. The housing 55 is attached to the hollow shaft 45 by bearings 57a and 57b provided on the outer circumference of the hollow shaft 45. The compression bending motor 51 is fixed to the slide plate 49 by a support plate 48c.

[0034] Together with the pressure unit swinging mechanism (second opening-closing unit) 70, the die opening-closing mechanism (first opening-closing unit) 60 constructs the opening-closing unit 69 that opens and closes the upper die (first unit) 23, the lower die (second unit) 22, and the pressure unit 30 in three different directions with respect to the setting center C of the work W. The die opening-closing mechanism 60 that is the first opening-closing unit is a mechanism that opens and closes the upper die (first unit) 23 and the lower die (second unit) 22, which are split die portions of the bending die clamp 20 that form a pair of upper and lower dies, in the up and down direction. The die opening-closing mechanism 60 includes the lower die opening-closing shaft 62 that is inserted into the hollow shaft 45 so as to be slidable in the up and down direction along the bending axis 11, the upper die opening-closing shaft 63 that is inserted

inside the lower die opening-closing shaft 62 so as to be slidable in the up and down direction along the bending axis 11, a left-hand and right-hand screw 65 including different (left-hand and right-hand) screw threads for the lower die opening-closing shaft 62 and the upper die opening-closing shaft 63, and a third motor (die opening-closing motor, opening-closing motor) 61 that rotationally drives the left-hand and right-hand screw 65. The die opening-closing motor 61 is fixed via a support portion 48d to the slide plate 49 and the left-hand and right-hand screw 65 is rotatably attached via a bearing 67 to the support plate 48a.

[0035] The upper die 23 of the bending die clamp 20 is screwed to the upper die opening-closing shaft 63 and the lower die 22 is screwed to the lower die opening-closing shaft 62. At least some of the parts of the upper die opening-closing shaft 63 and the lower die opening-closing shaft 62 that connect to (or pass through) the upper die 23, the lower die 22, and the hollow shaft 45 include locking shapes with a rectangular cross section or the like, so that the upper die opening-closing shaft 63 and the lower die opening-closing shaft 62 rotate reciprocally linked (in concert) about the bending axis 11. The left-hand and right-hand screw 65 includes a left-hand screw (left external screw) 65b for example at a part that is connected to the upper die opening-closing shaft 63 and includes a right-hand screw (right external screw) 65b at a part that is connected to the lower die opening-closing shaft 62. The upper die opening-closing shaft 63 includes a left hand female screw thread 63a and the lower die opening-closing shaft 62 includes a right hand female screw thread 62a formed in a nut 64. The left-hand screw and the right-hand screw may be reversed. Accordingly, when the left-hand and right-hand screw 65 is rotated in forward and reverse by the die opening-closing motor 61, the upper die opening-closing shaft 63 and the lower die opening-closing shaft 62 move in different directions in the up and down direction and the upper die 23 and the lower die 22 are opened and closed ("balanced opening and closing") in a balanced manner (where both move) in the up-down direction. The distances moved by the upper die 23 and the lower die 22 may be equal, or by changing the pitch of the screw threads corresponding to the upper die 23 and the lower die 22, it is possible to change the distances moved by the upper die 23 and the lower die 22. The nut 64 is attached to the lower die opening/closing shaft 62 so as to be capable of being fixed with an arbitrary rotational phase to enable adjustment of the die closing height.

[0036] It is desirable for the left-hand and right-hand screw 65 to use a trapezoidal screw thread or the like with a lead angle that enables self-locking by frictional forces. Compared to opening and closing by a typical ball screw or a hydro-pneumatic cylinder, it is possible to miniaturize the periphery of the bending axis, and self-locking by the die opening force makes it possible to miniaturize the die opening-closing motor 61. Also, by using the left-hand and right-hand screw 65, it is possible to reduce

the range of interference around the bending axis 11 and to increase the space efficiency, which makes it possible to provide a compact machining unit 10.

[0037] The pressure unit swinging mechanism (link unit) 70 that is one example of the second opening-closing unit is a mechanism that links the housing 55 that rotates around the bending axis 11 and the pressure roller 30. The pressure unit swinging mechanism 70 includes a holder 71 that rotatably supports the pressure roller 30, a stay 74 that supports the holder 71 on the housing 55 via a pivot pin 72 so as to be capable of swinging, an opening screw 77 that applies a pulling force to the holder 71 in an opened state, a cylindrical cam 75 that moves up and down together with the lower die opening-closing shaft 62, and a cam follower 73 contacts an outer circumference of the cylindrical cam 75 and swings the holder 71 by resisting the force of the opening spring 77.

[0038] When the upper and lower dies 23 and 22 of the bending die clamp 20 are opened (when the die is open), the pressure roller 30 is opened by the opening spring 77. When the upper and lower dies 23 and 22 are closed (when the die is closed), the cam follower 73 is caused by the cylindrical cam 75, which is provided on the lower die opening-closing shaft 62 and is shaped like a skirt that is narrow in the direction of the bending die clamp 20 and widens at the bottom, to swing along an inclined surface 75a of the cylindrical cam 75. The holder 71, which is integrated with the cam follower 73 and is supported by the pivot pin 72 on the stay 74 so as to swing so as to become inclined to the bending axis 11, swings together with the cam follower 73 and closes the pressure roller 30 to a position that contacts the work W. During bending, the cam follower 73 contacts an outer cylindrical portion 75b on the outside of the inclined surface 75a of the cylindrical cam 75 and the cam follower 73 rotates around the bending axis 11 at a position that away from the bending axis 11. The cam follower 73 receives the opening force of the pressure roller 30 and together with the bending die clamp 20 clamps the work W.

[0039] For this reason, in the machining unit 10, holding energy is not required for the die clamping force. It is possible to open and close the upper and lower dies 23 and 22 and the pressure roller 30 with the die opening-closing motor 61, so that it is possible with the die opening-closing mechanism 60 and the pressure unit swinging mechanism 70 to realize a mechanism that opens and closes in three directions using a single motor. This means that in the machining unit 10, the upper and lower dies 23 and 22 and the pressure roller 30 are opened and closed in synchronization using a small and energy efficient opening/closing means.

[0040] In addition, in the pressure unit swinging mechanism (link unit) 70, the stay 74 that supports the holder 71 via the pivot pin 72 so as to be capable of swinging includes a linking portion 74a that is rotatably linked to the circumference of the lower die opening-closing shaft 62. The linking portion 74a includes a slide bearing that

transfers the load in the periphery of the pivot pin 72 of the stay 74 to the lower die opening-closing shaft 62 that extends along the bending axis 11. Accordingly, it is possible for a reaction force to bending, which acts upon the link unit 70 when bending with the work W held between the upper die 23, the lower die 22, and the pressure roller 30, to be received near the bending die clamp 20 that is the bending unit. This means that it is possible to reduce the load on the bearings 57a and 57b that are linked to the housing 55 and also on the bearings 47a and 47b around the bending axis 11. It is also possible to reduce deformation due to the bending moment of the link unit 70 that includes the stay 74 and the like, which means that the work W can be held more precisely. When it is not necessary to consider the influence of the bending moment of the link unit 70, it is possible to use a configuration where the stay 74 does not include the linking portion 74a.

[0041] FIG. 5 shows how the upper and lower dies 23 and 22 and the pressure roller 30 open and close. FIG. 5(a) shows the die opened state. A state where the upper and lower dies 23 and 22 of the bending die clamp 20 and the pressure roller 30 have been opened in three directions centered on the position (the position of the center axis of the work W, the setting center) C where the work W is set (placed) is shown. FIG. 5(b) shows the die closed state. A state where the upper and lower dies 23 and 22 of the bending die clamp 20 and the pressure roller 30 have been closed is shown. Note that a state where the linking portion 74a of the stay 74 has been cut away to show the operation of the cam follower 73 and the like is shown in these drawings.

[0042] In the machining unit 10, the die opening-closing mechanism 60 that opens and closes the upper die 23 and the lower die 22 of the bending die clamp 20 and the pressure unit swinging mechanism 70 that opens and closes the pressure roller 30 operate inter-connectedly via the skirt-shaped cylindrical cam 75 so that opening and closing of the pressure roller 30 follows the opening and closing of the upper and lower dies 23 and 22 and is simultaneously carried out. This means that a special opening-closing actuator for the pressure roller 30 is unnecessary, a sensor that detects the opening-closing position for the pressure roller 30 is also unnecessary, and a mechanism for controlling the operation of the pressure roller 30 is also unnecessary.

[0043] Although the pressure roller 30 is formed in this example as a circular roll that is rotatably supported, the pressure roller 30 may be formed by supporting a pressure unit with a rectangular external form so as to be capable of swinging in a range required for leftward and rightward bending or so as to be capable of swinging and of sliding in the direction of the pipe axis.

[0044] As shown in FIG. 5(a), the upper die (first unit) 23 and the lower die (second unit) 22 of this opening/closing mechanism are opened and closed uniformly (i.e., in a balanced manner) up and down along the bending axis 11 by the die opening-closing mechanism 60 and the

pressure unit 30 is opened and closed in a substantially vertical direction (i.e., a direction that is perpendicular to) the bending axis 11 by the pressure unit swinging mechanism 70 that operates together or in concert with the die opening-closing mechanism 60. Accordingly, the upper die 23, the lower die 22, and the pressure unit 30 can be opened and closed in three different directions centered on the center (center axis, setting center) C of a work W (unmachined work W) that has not been machined at a sufficient distance to prevent interference when the work W moves. This means that it is possible to move the work W between the setting center C and a withdrawn position E along a linear path 13.

[0045] In this machining apparatus 1, the position of the work W actually does not move and the machining unit 10 is moved up and down by the moving unit 80. Accordingly, when the work W is taken in and out (loaded and unloaded, supplied and discharged) in the vertical direction (the perpendicular direction), as shown in FIG. 5(c), when bending leftward, the work W can be accessed by inclining (rotating, swinging) the bending axis 11 to the upper left in the drawing relative to the work W to produce a gap through which the work W can move without interference in the vertical direction between the upper die 23 and the pressure unit 30 and moving the machining unit 10 upward (in the vertical direction) along the linear path 13. At this time, the machining unit 10 may be inclined as far as an angle where a clamp portion 23b of the upper die 23 does not interfere with the path 13 and/or the bending die clamp 20 may be rotated around the bending axis 11 to withdraw the clamp portion 23b to a position that does not interfere with the path 13. Since the load (moment) caused by heavy objects such as a motor increases when the inclination of the machining unit 10 increases, it is desirable to avoid interference with the clamp portion 23b by rotating the bending die clamp 20. By closing the upper die 23, the lower die 22, and the pressure unit 30 in a state where the center of the work W has reached the setting center C, it is possible to clamp the work W and to commence a bending process.

[0046] When it is necessary to change the angle of the bending process, the bending axis 11 of the machining unit 10 may be rotated to a predetermined angle in the die opened state in FIG. 5(a) or the work supporting unit 5 may be rotated so that the work W is at a predetermined angle. When releasing the work W, the upper die 23, the lower die 22, and the pressure unit 30 are opened once again in three directions and the machining unit 10 may be lowered along the path 13 to below and/or the work W may be moved an appropriate distance and/or rotated by a predetermined angle by the work supporting unit 5 with the work W in the released state. Also, instead of raising and lowering the machining unit 10 using the moving unit 80, it is also possible to raise and lower using the work supporting unit 5.

[0047] On the other hand, when machining to bend a work W rightward, as shown in FIG. 5(d), it is possible to access the work W by moving the machining unit 10 up-

ward (in the vertical direction) along the linear path 3 using the moving unit 80 in a state where the bending axis 11 has been inclined upward to the right in the drawing with respect to the work W. The linear paths 13 in FIG. 5(c) and FIG. 5(d) are the same path for leftward bending and rightward bending. Accordingly, it is possible to easily switch between rightward bending and leftward bending of the work W by changing the position of the pressure unit 30 around the bending axis 11 and changing the inclination of the bending axis 11 while moving the machining unit 10 in the up-down direction using the moving unit 80.

[0048] FIG. 6 shows an overview of the bending die clamp 20. FIG. 6(a) shows an enlargement of the machining unit 10 when looking from above, that is, the direction of the bending die clamp 20 and is centered on the bending die clamp 20. FIG. 6(b) shows a state where the work W is held by a clamping channel 25 of the bending die clamp 20 when looking from the direction in which the work W extends (the direction in which the clamping channel 25 extends). FIG. 6(c) shows a state where the work W is held by a second clamping channel 26 of the bending die clamp 20 when looking from the direction in which the second clamping channel 26 extends.

[0049] FIG. 7 shows the lower die 22 of the bending die clamp 20 extracted as a representative part, with FIG. 7(a) a plan view, FIG. 7(b) a side view in a direction in which the clamping channel 25 extends, and FIG. 7(c) a side view in a direction in which the second clamping channel 26 extends. The configuration of the upper die 23 that forms a pair with the lower die 22 is the same as the lower die 22 and is omitted from the drawings.

[0050] The bending die clamp 20 includes the upper and lower split die portions 23a and 22a that form a pair and include the bending channel 24 that has an arc-shaped part and upper and lower clamp portions 23b and 22b that form a pair and hold the rod-shaped work W that has been inserted into the bending channel 24. The pair of upper and lower clamp portions 23b and 22b protrude in the circumferential direction of the bending channel from the pair of upper and lower split die portions 23a and 22a. The upper die (first unit) 23 is constructed by integrating the first clamp portion (upper clamp portion) 23b that is the upper clamp portion out of the pair of clamp portions and the first split die portion (upper split die portion) 23a that is the upper split die portion out of the pair of split die portions. Similarly, the lower die (second unit) 22 is constructed by integrating the second clamp portion (lower clamp portion) 22b that is the lower clamp portion out of the pair of clamp portions and the second split die portion (lower split die portion) 22a that is the lower split die portion out of the pair of split die portions.

[0051] The upper and lower clamp portions 23b and 22b that form a pair respective include the clamping channel 25 and the second clamping channel 26 that intersect in an X shape and each channel (groove) 25 and 26 is connected to the bending channel 24 as to extend from the bending channel (groove) 24 in tangential directions.

The clamp portions 23b and 22b are protruding portions that protrude in the form of trapezoids from positions on the outer circumference of the upper and lower split bending dies toward the outside, and two semicircular channels 25 and 26 for clamping a pipe for leftward and rightward bending that are tangentially connected to the bending radius of the bending channel 24 are integrated and compactly provided so as to intersect in an X shape with left-right symmetry. The clamping channel 25 and the second clamping channel 26 are used as pipe clamping channels for leftward bending and rightward bending, respectively. In the present embodiment, the clamping channel 25 is a clamping channel for bending the work W to the left when looking from above and the second clamping channel 26 is a clamping channel for bending the work W to the right when looking from above.

[0052] The bending die clamp 20 is a single bending die clamp that is compatible with leftward bending and rightward bending and is a bending die clamp shared between leftward bending and rightward bending. This means that in the machining unit 10 and the machining apparatus 1 that uses the bending die clamp 20, it is possible to flexibly and efficiently machine a rod-shaped member (work) W such as a pipe or a tube.

[0053] A number of bending processes that can be executed by the machining unit 10 are shown in FIG. 8. FIG. 8(a) shows a leftward draw bending process (first mode), FIG. 8(b) shows a rightward draw bending process (second mode), FIG. 8(c) shows a leftward compression bending process (third mode), and FIG. 8(d) shows a rightward compression bending process (fourth mode). The respective drawings show the bending start positions. The bending die clamp 20 is capable of rotating by 360°. The pressure roller 30 is capable of rotating in a range where there is no interference with the slide plate 49, the support plate 48b that connects the slide plate 49 and the machining unit 10, and the like.

[0054] In the leftward draw bending process (first mode) shown in FIG. 8(a), the work W is set on the right side of the bending die clamp 20 and the clamp portions 23b and 22b of the bending die clamp 20 are set in the bending direction with respect to the pressure roller 30. The draw bending motor 41 is driven to use the draw bending mechanism 40 to rotate the bending die clamp 20 to the left (in the clockwise direction, a first direction of rotation) when looking from above. The pressure roller 30 is not rotated and the bending die clamp 20 is rotated relative to the pressure roller 30.

[0055] In the rightward draw bending process (second mode) shown in FIG. 8(b), the work W is set on the left side of the bending die clamp 20 and the clamp portions 23b and 22b of the bending die clamp 20 are set in the bending direction with respect to the pressure roller 30. The draw bending motor 41 is driven to rotate the bending die clamp 20 to the right (in the counterclockwise direction, a second direction of rotation) when looking from above. The pressure roller 30 is not rotated and the bending die clamp 20 is rotated relative to the pressure roller

30.

[0056] In the leftward compression bending process (third mode) shown in FIG. 8(c), the work W is set on the right side of the bending die clamp 20 and the pressure roller 30 is set in the bending direction with respect to the clamp portions 23b and 22b of the bending die clamp 20. The compression bending motor 51 is driven and the compression bending mechanism 50 is used to rotate the pressure roller 30 to the left (in the clockwise direction) when looking from above. The bending die clamp 20 is not rotated and the pressure roller 30 is rotated relative to the bending die clamp 20.

[0057] In the rightward compression bending process (fourth mode) shown in FIG. 8(d), the work W is set on the left side of the bending die clamp 20 and the pressure roller 30 is set in the bending direction with respect to the clamp portions 23b and 22b of the bending die clamp 20. The compression bending motor 51 is driven to rotate the pressure roller 30 to the right (in the counterclockwise direction) when looking from above. The bending die clamp 20 is not rotated and the pressure roller 30 is rotated relative to the bending die clamp 20.

[0058] In the machining unit 10, by independently selecting rotation of the bending die clamp 20 with the draw bending motor 41 and rotation of the pressure roller 30 with the compression bending motor 51, it is possible to carry out four patterns of mixed bending composed of left-right bending and draw-compression bending.

[0059] In addition, in the bending die clamp 20, the clamping channels 25 and 26 for leftward and rightward bending are integrated with left-right symmetry at one position compactly on the outer circumference of the upper and lower split dies 23 and 22 that open and close in the direction of the bending axis 11. This means that it is possible to minimize the interference by the clamp mechanism (clamp portions) 23b and 22b in the radial direction and the direction of rotation of the bending axis 11. In addition, by independently rotating the pressure roller 30 and the bending die clamp 20, it is possible to freely rotate the pressure position and clamp position to various angles around the bending axis 11, including start positions and end positions of leftward and rightward, and draw bending and compression bending. This means that the bending die clamp 20 is a bending clamp that is common to leftward and rightward draw and compression bending and is compatible with large bending angles, and that the machining unit 10 that uses the bending die clamp 20 which is capable of rotating independent of the pressure roller 30 is capable of a variety of bending processes and also compatible with large bending angles.

[0060] FIG. 9 and FIG. 10 show the overall configuration of the moving unit (turn unit) 80. FIGS. 9(a), (b) and (c) show the moving unit 80 and FIGS. 9(d), (e) and (f) show the machining unit 10 moved by the moving unit 80. FIG. 9(a) shows the first operation in a state where, as shown in FIG. 9(d), the machining unit 10 has been set by the moving unit 80 so as to be positioned on the left (clockwise direction) in a leftward bending state when

viewed from above the bending die clamp 20. FIG. 9(c) shows also the first operation but in a state where, as shown in FIG. 9(f), the machining unit 10 has been set by the moving unit 80 in a rightward bending state. FIG. 9(b) shows the second operation in a state where, as shown in FIG. 9(e), the machining unit 10 has been moved downward by the moving unit (quick turn unit) 80 in a state when switching (quick turn) from leftward bending to rightward bending or vice versa. FIG. 10(a) is a cross-sectional view in the horizontal direction of the moving unit 80 and FIG. 10(b) is a cross-sectional view in the vertical direction along the center axis of the moving unit 80.

[0061] The moving unit 80 includes a function as a first moving unit that swings the machining unit 10 to the left or right while moving the machining unit 10 up and down. The moving unit 80 includes a connecting plate (base) 81 that is attached and fixed to the mount 2, a plate-like holder 83 that is supported so as to swing to the left and right relative to the connecting plate 81 about a swinging shaft 82 (as a pivot), and the slide plate 49 that slides in the longitudinal direction (axial direction) 83c of the holder 83. The machining unit 10 is attached to the slide plate 49. A lower end 81a of the connecting plate 81 is bent into a convex so as to form part of an arc centered on the center of the swinging shaft 82. The holder 83 includes a guide piece 83a that guides so that the holder 83 swings to the left and right along the lower end 81a of the connecting plate 81. An upper surface 83b of the guide piece 83a forms a concave guide surface that contacts the lower end 81a of the connecting plate 81.

[0062] The moving unit 80 includes a turn gear 84 that is incorporated at a position along a center axis (axial direction) 83c of the holder 83 so as to be capable of rotating on an outer circumferential guide, and a turn motor 85 that is held on the holder 83 and drives the turn gear 84 via coupling gears 86a and 86b. The turn gear 84 includes a turn roller 84a that is incorporated into the holder 83 so as to be sandwiched between the slide plate 49 and the connecting plate 81 and protrudes in the forward/backward (front/rear) direction at an off-center position along an axis 83c. A rear side of the turn roller 84a is inserted into a first cam channel 81x that extends in the vertical direction (perpendicular direction) along an axis 81c of the connecting plate 81 and when the turn gear 84 rotates, the turn roller 84a moves up and down along the first cam channel 81x. A front side of the turn roller 84a is inserted into a second cam channel 49x that extends in a direction perpendicular to the sliding direction (axial direction) 83c of the slide plate 49 and due to the turn roller 84a moving along the second cam channel 49x when the turn gear 84 rotates, the holder 83 swings to the left and right centered on the swinging shaft 82 and the slide plate 49 moves up and down.

[0063] The work W is supported by the work supporting unit 5 on the axis 81c of the connecting plate 81. The machining unit 10 is supported so that the bending axis 11 matches the axis 83c of the holder 83 and the slide

plate 49. Accordingly, when the turn gear 84 is rotationally driven in the clockwise direction by the turn motor 85 from the state shown in FIG. 9(b), the turn roller 84a moves along the second cam channel 49x and the slide plate 49 revolves in the counterclockwise direction about the swinging shaft 82. In addition, the turn roller 84a moves along the first cam channel 81x and the slide plate 49 moves upward along the axis 83c, producing the state shown in FIG. 9(a).

[0064] As a result, as shown in FIG. 9(d), due to the first operation by the moving unit 80, the machining unit 10 that is attached to the slide plate 49 moves upward in a state where the bending axis 11 is inclined and the work W reaches the setting center C in a state where the upper die 23, the lower die 22, and the pressure unit 30 are opened at the initial position for leftward bending. Next, the machining unit 10 closes the upper die 23, the lower die 22, and the pressure unit 30 in this state to hold the work W at a predetermined position and commences a leftward bending process.

[0065] When shifting to the rightward bending process after the leftward bending process is completed, by rotationally driving the turn gear 84 in the counterclockwise direction using the turn motor 85 from the state shown in FIG. 9(a), the moving unit 80 is placed in the state shown in FIG. 9(b). Accordingly, as shown in FIG. 9(e), due to the second operation by the moving unit 80, the machining unit 10 attached to the slide plate 49 moves downward and the work W moves (is relatively moved) from the setting center C to the withdrawn position E that is separated in the upward direction from the machining unit 10.

[0066] By further rotationally driving the turn gear 84 in the counterclockwise direction using the turn motor 85, the turn roller 84a moves along the second cam channel 49x and the slide plate 49 revolves in the clockwise direction about the swinging shaft 82. The turn roller 84a moves along the first cam channel 81x and the slide plate 49 moves upward along the axis 83c to produce the state shown in FIG. 9(c).

[0067] As a result, as shown in FIG. 9(f), the machining unit 10 that is attached to the slide plate 49 moves upward in a state where the bending axis 11 is inclined in the opposite direction to FIG. 9(d) and the work W reaches the setting center C in a state where the upper die 23, the lower die 22, and the pressure unit 30 are opened at the initial position for leftward bending. Next, the machining unit 10 closes the upper die 23, the lower die 22, and the pressure unit 30 in this state to hold the work W at a predetermined position and commences a rightward bending process.

[0068] Accordingly, as shown in FIG. 2, by first moving the machining unit 10 downward and swinging left-right in the opposite direction, changing the orientations of the upper die 23, the lower die 22, and the pressure unit 30, and moving back upward, it is possible to carry out bending processes on the work W while switching from rightward bending to leftward bending or vice versa. As shown in FIG. 8, the rightward bending and the leftward bending

may be draw bending or may be compression bending.

[0069] The position of the swinging shaft 82 and the rotational radius and angle of rotation of the turn roller 84a can be selected so that the movement of the rod-shaped member (work) W that is bent leftward or rightward when the machining unit 10 has moved upward matches a supply-discharge path 13 of the machining unit 10. The position of the swinging shaft 82 and the rotational radius and angle of rotation of the turn roller 84a can also be selected so that when the bending axis 11 is switched between left and right, the machining unit 10 is capable of achieving the trajectory and raising/lowering stroke required for the work W to be diverted to the withdrawn position E with an appropriate clearance. Here, if a clamp portion of the bending die clamp 20 that is an integrated clamp interferes with the linear movement path 13 of the work W, it is possible to avoid interference by rotating the bending die clamp 20 around the first axis 11, which makes it possible to supply and discharge the work W in a straight line.

[0070] Note that in the above description, an example is described where the turn roller 84a is rotated by the turn motor 85 via the coupling gears 86a and 86b, the raising/lowering of the slide plate 49 and the left-right swinging of the holder 83 are performed simultaneously, and the machining unit 10 moves in a U shape 89. It is also possible, in place of a linear channel in the horizontal direction, to make the second cam channel 49x provided on the slide plate 49 an arc-shaped channel or a V shaped channel that are symmetrical about a center line. It is also possible to perform the up and down movement of the machining unit 10 and the switching of the inclination between left and right in order. It is also possible to change the stroke for raising and lowering the machining unit 10 and the turn trajectory as appropriate. While the machining unit 10 is withdrawn from the work W, it is desirable for the upper and lower dies 23 and 22 and the pressure unit 30 in the opened state to revolve by an appropriate angle around the bending axis 11 and for the clamp portions (protrusions) 23b and 22b of the bending die clamp 20 to be set (withdrawn by rotation) at positions that do not interfere with the work W.

[0071] In addition, as shown in FIG. 10(b), the moving unit 80 may include a balancing mechanism 87 that applies pressure (presses) to the slide plate 49 upward and a locking mechanism 88 that locks the holder 83 to the connecting plate 81 in a state where the holder 83 has swung to the left or right. It is desirable for the balancing mechanism 87 to include a pressing means such as an air cylinder or a spring that supplies all or part of an upward thrust required to press the slide plate 49 upward together with the weight of the machining unit (bending unit) 10. Since all or part of the weight of the machining unit 10 can be supported by the balancing mechanism 87, it is possible to reduce the output of the turn motor 85 that rotationally drives the turn gear 84.

[0072] The locking mechanism 88 includes the guide piece 83a fixed to the holder 83 and a means for fixing

to the connecting plate 81, for example a taper key, and reliably supports the load applied to the turn motor 85 attached to the holder 83. The machining unit (bending unit) 10 is capable of being used for a rotary bending process that twists around the setting center C, and in such case, although a inertia moment of the twisting is likely to act upon the turn motor 85, it is possible to suppress the influence of the inertia moment by fixing the connecting plate 81 and the holder 83 using the locking mechanism 88 after switching the machining unit 10 between the left and right bending positions.

[0073] In this example, although locking to prevent further swinging of the machining unit 10 at the left and right bending positions is achieved by the connecting plate 81 and the guide piece 83a of the holder 83, the locking force applying position may be carried out by the holder 83 and the turn gear 84. Also, in place of moving the machining unit 10 up and down using the moving unit 80, it is possible to move the work W to the withdrawn position E by providing the work supporting unit 5 with a raising and lowering function. In such case, since the slide plate 49 and the holder 83 can be integrally constructed, it is possible to omit the horizontal channel (second cam channel) 49x for raising and lowering the slide plate 49 and the turn roller 84a that passes through such channel, and to use a configuration where the bending axis 11 of the machining unit 10 is simply inclined to the left and right.

[0074] The unit (moving unit) that switches the orientation of the machining unit 10 may be equipped with other mechanisms, such as an XY perpendicular slide. This moving unit 80 has a characteristic in that the low number of actuators and component parts enables miniaturization and a reduction in weight and, by feeding a pipe between the bend points and twisting as overlapping operations with the pipe axis fixed, is capable of instantly switching between leftward and rightward bending positions by rotating the turn gear 84 by less than one revolution. This means that the time required to switch between leftward bending and rightward bending can be greatly reduced.

[0075] FIG. 11 shows, by way of a flowchart, an overview of a method (bending method, machining method, control method of a machining apparatus) of machining a work W using the machining apparatus 1. In step 201, the clamp control function 9c of the control unit 9 controls the die opening/closing mechanism 60 to open the upper die 23, the lower die 22, and the pressure unit 30 in three different directions centered on the setting center C to release the work W. In addition, the machining position control unit 9a controls the work supporting unit 5 to move the work W so that a position to be machined reaches the machining unit 10. The machining position control unit 9a also controls the angle (angle of rotation) of the work W so that the bending direction is oriented in a desired direction.

[0076] Once the work W reaches a point where the bending process is to occur, in step 202 the process con-

trol unit 9b determines the processing mode (machining mode) and if the mode is leftward draw bending (the first mode M1), in step 203 the machining unit 10 is set at the first mode (leftward draw bending). That is, in a state where the upper die 23, the lower die 22, and the pressure unit 30 have been opened in three different directions with respect to the setting center C of the work W, the machining unit 10 is inclined and the work W is relatively moved in a straight line to the setting center C.

[0077] In step 209, the clamp control function 9c closes the upper die 23, the lower die 22, and the pressure unit 30 to clamp the work W and carries out a bending process in the set mode. If the mode differs to the previous bending process that was carried out, in step 203, the process control unit 9b carries out a process that uses the moving unit 80 to raise and lower the machining unit 10 as described earlier and changes the orientation of the machining unit 10 relative to the work W.

[0078] To switch the clamp position of the bending die clamp 20 and the left-right bending position of the pressure roller 30, after the machining unit 10 has been lowered, the pressure roller 30 rotationally moves to the next bending start position, and the clamp portions (protruding portions) 22b and 23b of the bending die clamp 20 rotationally move to the bending start position at the raising. Such switching processes between leftward and rightward bending and compression bending and draw bending can be carried out in parallel with the feeding of the work in step 201. The switching between the leftward and rightward bending positions may be carried out by raising and lowering the pipe chuck (work supporting unit 5) and left-right movement of the bending axis 11 of the machining unit 10, or may be carried out by raising and lowering and rotating the work supporting unit 5.

[0079] In the same way, in step 204 if the mode is rightward draw bending (the second mode M2), in step 205 the machining unit 10 is set at the second mode (rightward draw bending). In step 209, the work W is clamped and a bending process is carried out in the set mode. In step 206 if the mode is leftward compression bending (the third mode M3), in step 207 the machining unit 10 is set at the third mode (leftward compression bending). In step 209, the work W is clamped and a bending process is carried out in the set mode. If the mode is none of the above modes, in step S208 the machining unit 10 is set at the fourth mode (rightward compression bending). In step 209, the work W is clamped and a bending process is carried out in the set mode.

[0080] In the bending process, in a state where the upper and lower dies 23 and 22 of the bending die clamp 20 and the pressure unit roller 30 are closed, the work W is held in one of the clamping channels 25 and 26 of the upper and lower dies 23 and 22. When draw bending, that is performed by rotating the upper and lower dies 23 and 22, the upper and lower dies 23 and 22 are rotated together with the bending hollow shaft 45 by the draw bending motor 41 via the gears 42a and 42b. When compression bending, that is performed by rotating the pres-

sure roller 30 supported by the housing 55, the pressure roller 30 is rotated around the bending die clamp 20 by the compression bending motor 51 via the gears 52a and 52b and the work W is bent along the bending channel 24 formed in the upper and lower dies 23 and 22.

[0081] In step 210, it is determined whether the bending process has completed and if there is a following bending process, the processing returns to step 201 and the process is repeated. The control unit 9 that controls this processing method (machining method, control method) can be realized by computer resources that include a CPU and memory, and the processing method (machining method, control method) can be provided as a program (program product) that has been recorded on an appropriate recording medium.

[0082] According to this method, the trailing end of the rod-shaped work W, such as a pipe, is chucked by the pipe feeding unit (work supporting unit) 5, feeding and twisting is carried out by the work supporting unit 5 from a first bend point at the front end of the work W to a final bend point on the chucking side, which makes it possible to machine the work W into a variety of forms.

[0083] The feeding method in the axial direction of the work W may be an arrangement where the machining unit 10 and the switching unit (moving unit) 80 that switches between the leftward and rightward bending positions are mounted in a feeding unit that moves along the work W and a mechanism on the pipe twisting chuck (pipe feeding unit) side is fixed.

[0084] In this machining apparatus 1, it is possible to carry out a continuous bending process in which methods of leftward and rightward bending directions and draw and compression bending are mixed (combined). This means that a control program (machining data) for bending processes can be generated by selecting and designating the bending direction and the bending method without interference at each bending position. As one example, identification flags for the bending direction and bending method may be added to a machining data table for feeding, twisting, and bending of each bending position in a typical control program (data) for single-direction, single-method bending. By using a control program corresponding to the identification flags that have been selected and designated, in the machining apparatus 1, the bending die clamp 20 and the pressure roller 30 are rotated to the bending start positions and switching between the leftward and rightward bending positions is carried out as necessary by the moving unit 80. The subsequent bending operation may be carried out in the same way as typical control for a single-direction, single-method bending operation. The switching operation for the bending direction and the bending method can be controlled so as to be automatically and continuously performed so as to overlap a feeding and twisting operation between bend points.

[0085] To feed a length of pipe equal to the length of the bending arc, the control unit 9 may be equipped with an automatic calculation function for the arc length in

keeping with the bending radius and the bending angle. It is possible to control the feeding of the work W so that during draw bending, feeding is synchronized with the bending rotation and during compression bending, in addition to feeding a length of straight pipe between the bend points, feeding is carried out before the bending process.

[0086] By opening and closing the integrated clamp and bending die in a balance manner, the machining unit 10 described above is capable of performing feeding, twisting, bending, and realigning as overlapping operations with a minimal opening/closing stroke. This means that high-speed bending is possible. In addition, the upper and lower bending dies (upper die and lower die) 23 and 22 and the pressure unit (pressure die) 30 are opened and closed in three directions by a single motor using the die opening-closing mechanism 60 and the pressure unit swinging mechanism 70. By using this kind of energy-efficient opening and closing means, it is possible to provide a machining unit 10 capable of executing a variety of bending processes at high speed with small and lightweight equipment.

[0087] A conventional leftward-rightward bending machining apparatus is not equipped with a function for releasing all of the bending die, the clamp, and the pressure die with respect to the pipe machining axis (the clamp center C). This means that when automatically supplying and discharging in a direction that is perpendicular to the pipe axis, it is difficult to supply and discharge on a short linear path due to interference with the clamp or the bending die, which makes movement necessary in a plurality of directions. Accordingly, there have been a problem that the supplying/discharging time increases, a problem that the conveying means is complex, and the same problems when switching between the leftward and rightward bending positions.

[0088] That is, when supplying a pipe in a vertical direction where there is little interference with the bending mechanism and a pipe that has been bent, with a construction where the lower die is fixed and a middle die and upper die are opened and closed in a single direction, to set a pipe in the clamping channel in the lower die, it is necessary to lower to an intermediate position in the die opening gap that does not interfere with the outer diameter of the upper die, to then move horizontally to the clamping channel position with the bending radius, and to further lower until the lower die clamping channel is contacted. This means that when switching the bending direction, in the same way raising and lowering and horizontal movement in the opposite direction were necessary. Even with a construction that clamps from the horizontal direction using a bending die in which the upper and lower die are integrated, movement in the vertical direction and the horizontal direction were necessary to set the pipe in a bending channel on the outer circumference of the bending mold.

[0089] Also, with an integrated clamp and bending die where the lower die is fixed and which opens in one di-

rection, an operation of feeding, twisting, bending, and returning between bend points when continuously carrying out bending at a plurality of positions needs to be carried out after raising the pipe away from the clamping channel of the lower die to provide clearance. In the case of compression bending with a pressure die, it has been necessary to first return the pressure die to the bending starting position, to open the clamp, and to move to produce clearance so as to avoid contact damage between the bending die and the pipe. Accordingly, since it is not possible for feeding, twisting, bending, and realigning to overlap with the pipe axis fixed, there has been the problem of bending processes taking a long time.

[0090] On the other hand, the machining apparatus 1 described above is capable of linear supplying and discharging (linear setting in and out) over a short distance in a direction that is perpendicular to the axis (for example, pipe axis) of the work W at a position that is common to leftward and rightward bending. The machining apparatus 1 is equipped with the machining unit (bending unit) 10 that opens and closes the clamp integrated upper-lower bending die 20 and the pressure die 30 in three directions centered on the axis C of the pipe to be machined, and disposes the bending axis 11 of the machining unit 10 so as to be inclined so that the linear supplying and discharging path 13 matches the supplying and discharging direction of a supplying and discharging loader (the pipe feeding unit) 5 with a gap between the upper die 23 and the pressure die 30 as a gap that prevents interference with outer diameter of the pipe on the linear supplying and discharging path 13 that joins the pipe axis center (setting center) C. Also, during supplying and discharging, the clamp protruding portions (clamp portions) 23b and 22b of the bending die clamp 20 are rotated and withdrawn to positions that do not interfere with the pipe supplying and discharging path 13. By doing so, it is possible to supply and discharge on a linear path that is perpendicular to the pipe axis and to feed in a single direction with the pipe axis fixed, and for a process having leftward and rightward bending, the moving unit (quick turn unit) 80 diverts the bending die clamp 20 of the machining unit 10 to below the work W and switches to the pipe axis and the supplying and discharging path 13 that are common to leftward and rightward bending. By using this configuration, it is possible to carry out, at a common position for leftward and rightward bending, supplying and discharging on a linear path and single direction feeding with the pipe axis fixed (the setting center C of the work W fixed). Accordingly, it is possible to provide a high-speed pipe bending apparatus capable of a carrying out feeding, twisting, bending, returning, and switching between leftward/rightward bending positions as overlapping operations with the pipe axis fixed (without moving the pipe axis).

[0091] Note that the machining apparatus 1 described above is one example and in place of an apparatus that twists and feeds on the pipe side (work side) with the machining unit 10, which is the bending unit, fixed, it is

possible to carrying out twisting on the machining unit 10 side and possible to incorporate the machining unit 10 according to the present embodiment into a rotary bending apparatus or a robot bending apparatus that carries a bending unit. In an arrangement where the machining unit 10 is carried by a robot and feeding and twisting are carried out on the robot side, since the machining unit 10 has a simple configuration and can be made lightweight, in addition to a reduction in the carried weight, opening/closing with a short stroke, and the ability to perform high speed bending via overlapping operations, by bending both leftward and rightward, it is possible to half the range of twist operations which for robot bending are time consuming and often involve interference. This makes it possible to carry out robot bending at high speed.

[0092] FIG. 12 shows a different example of the machining unit 10. This machining unit 10 carries out a draw bending process in one direction and a compression bending process in the opposite direction. The machining unit 10 shown in FIG. 12(a) and FIG. 12(b) includes a single-direction bending die clamp 20a equipped with one clamping channel that is continuous with the bending channel 24 and a pressure die (pressure unit, presser) 30 in the form of a pressure roller. As shown in FIG. 12(a), a leftward draw bending process can be carried out by pressing the work W with the pressure roller 30 and rotating the bending die clamp 20a in the clockwise direction. As shown in FIG. 12(b), a rightward compression bending process can be carried out by pressing the work W with the bending die clamp 20a and rotating the pressure roller 30 in the counterclockwise direction.

[0093] Although the bending die clamp 20a shown in FIGS. 12(a) and (b) is a bending die for leftward draw bending and rightward compression bending, by interchanging a bending die with a clamp position in the opposite direction, it is possible to provide a machining unit 10 that carries out rightward draw bending and leftward compression bending that are the opposite to the above.

[0094] Note that when only a typical draw bending function is sufficient, it is possible to use a configuration where the pressure unit 30 may be fixed, the second driving unit (compression bending mechanism) 50 that rotationally drives the pressure unit 30 is omitted, and the housing 55 that supports the pressure unit 30 is fixed to the slide plate 49. It is also possible to configure a machining unit 10 that is common to leftward and rightward bending using a configuration where the pressure unit 30 is rotated to the leftward and rightward bending positions manually or using a jig, and is fixed at such position.

[0095] FIG. 13 and FIG. 14 show yet another example of the machining unit 10. FIG. 13 is a plan view and FIG. 14 is a side view. This machining unit 10 includes a bending die clamp 20b equipped with clamps for leftward and rightward bending at two positions on different sides and two fixed-type left and right pressure units (pressure dies) 30a and 30b that are disposed on the left and right. In place of the compression bending mechanism 50 that

rotates the pressure unit 30a, this machining unit 10 includes a pressure unit opening-closing mechanism (third driving mechanism) 90 that selectively opens and closes the pressure units 30a and 30b.

[0096] The pressure unit opening-closing mechanism 90 includes a pressure unit opening-closing cam 93 that operates cam followers (opening-closing cams) 73a and 73b that open and close the pressure units 30a and 30b, and a pressure unit opening-closing motor 95 that drives the pressure unit opening-closing cam 93 via gears 94a, 94b, and 94c. Using the pressure unit opening-closing motor 95, the pressure unit opening-closing cam 93 is rotated around the bending axis 11 to selectively swing an arbitrary one of pressure units 30a or 30b open and closed.

[0097] If the pressure units 30a and 30b are provided on both sides of the bending axis 11, it is necessary to carry out the bending process in a state where the pressure unit 30a or 30b that is not being used has been opened to below the bending surface of the pipe to prevent interference with the clamp protruding portions 23b and 22b of the bending die clamp 20b that rotate during bending and the work W (for example, a pipe) to be bent. The pressure unit opening-closing cam 93 opens and closes only the pressure unit 30a or 30b on one side by rotating. To do so, the pressure unit opening-closing cam 93 has an inclined cylindrical cam shape, and the inclined cylindrical cam shape is equipped in the radius direction with a part of the maximum radius portion that closes the pressure unit 30a or 30b and a part of the minimum radius portion that opens the pressure unit 30a or 30b by the necessary gap, and has parts in between formed so as to be smoothly joined via inclined surfaces in keeping with the swing trajectories of the cam followers 73a and 73b. Accordingly, by rotating the pressure unit opening-closing cam 93 using the pressure unit opening-closing motor 95, it is possible to independently operate the opening-closing cams 73a and 73b and possible to independently open and close the pressure unit 30a or 30b.

[0098] Note that in an arrangement where the semicircular holding channels 31 are on a straight line and the pressure units 30a and 30b in FIG. 13 use straight pressure dies that slide inside a slide channel of the holder 71 so as to follow the bending in the pipe axis direction, the pressure units 30a and 30b are returned to the bending start position by return cylinders 78, springs, or the like. The pressure units 30a and 30b may use the roller-type pressure dies (pressure rollers) 30 described earlier.

[0099] FIG. 15 shows, by way of a plan view, an example of a machining unit 10 equipped with roller-type pressure units 30. This machining unit 10 includes the bending die clamp 20b equipped with the clamp portions 23b and 22b for leftward and rightward bending at two positions on different sides and two pressure rollers 30 disposed on the left and the right. By providing a mechanism that causes one of the pressure rollers 30 disposed on the left and right to move away, it is possible to carry out a leftward or rightward draw bending process.

[0100] The bending die clamp 20 in FIGS. 13 to 15 may be equipped with the clamping channels for leftward and rightward bending channels described earlier in FIGS. 6 to 8 that intersect in an X shape and are compactly and integrally provided at a single location. Although the configurations in FIG. 13 to FIG. 15 are compatible for mixed bending composed of leftward and rightward draw bending, when bending both leftward and rightward is unnecessary, it is possible to provide only one of the pressure rollers, and in such case, a mechanism that manually switches the pressure roller between left and right positions may be provided. It is also possible to use a configuration where the pressure unit opening-closing mechanism 90 is omitted and a single pressure unit mechanism is opened and closed by the skirt-shaped cylindrical cam 75 provided in the lower die opening-closing shaft 62 depicted in FIG. 3 to FIG. 5 described earlier.

[0101] This machining unit 10 also includes the clamp-integrated upper and lower bending die 20b that opens and closes in a balanced manner centered on the pipe axis (setting center) C and the pressure units 30a and 30b (or two pressure rollers 30) that open and close in directions that are perpendicular to the die opening-closing direction, and is characterized by the machining unit 10 having a three-directional opening-closing construction. This means that it is possible to dispose the bending axis 11 of the machining unit 10 so as to be inclined so that the supplying and discharging direction of the supplying and discharging loader matches the linear supplying and discharging path 13, with the opening gap between the upper die 23 and the pressure units 30a and 30b (or the two pressure rollers 30) as a gap that prevents interference with the pipe outer diameter on the linear supplying and discharging path 13 that connects such gap and the pipe axis center C. It is also desirable for the clamp protruding portions 23b and 22b of the bending die clamp 20b to be rotated and withdrawn during supplying and discharging to a position that does not interfere with the pipe supplying and discharging path 13. With this machining unit 10 also, it is possible to supply and discharge over a shorter linear path in a direction perpendicular to the pipe axis and to feed in a single direction with the pipe axis fixed.

[0102] Note that although the skirt-shaped cylindrical cam 75 is configured so as to be integrated with the lower die opening-closing shaft 62 in the above description, it is also possible to rotatably attach the cylindrical cam 75 to the lower die opening-closing shaft 62 via a bearing and to change the cam follower 73 of the pressure unit swinging mechanism (link unit) 70 to a cam block that does not rotate.

[0103] FIG. 16 shows, as another machining apparatus, a two-end simultaneous bending apparatus that holds an intermediate portion of the work W with a chuck and carries out successive bending while moving twist units from ends of the work W toward the intermediate portion. FIG. 17 is a plan view of the machining apparatus 1a.

[0104] The machining apparatus 1a includes the mount 2, a chuck unit 160 that is disposed in the center of the mount 2, a pair of twist units 100 disposed so as to face one another with the chuck unit 160 in between, a pair of bending units (machining units) 10 that are mounted on the pair of twist units 100, a pair of feeding units 140 that control the respective distances between the pair of twist units 100 and the chuck unit 160, and a control unit 90 that controls such components. The pair of twist units 100, the pair of bending units 10, and the pair of feeding units 140 are disposed so that units of the same configuration face each other with the chuck unit 160 in between.

[0105] The control unit 90 includes a position control function (position control unit) 93 that decides the position (i.e., position adjusting, aligning) of the work W to be bent by controlling the feeding units 140, a process control function (process control unit, bending control unit, machining process control unit) 95 that controls the bending process method carried out by the twist units 100 and the machining units 10, a supplying and discharging control function (supplying and discharging control unit) 97 that controls supplying and discharging (setting in and out, loading and unloading) of a work W, and a re-holding control function (re-holding control unit, changing hold control unit) 98 that controls changes or shifts the holding condition of the work W (switching the grip position). The process control unit 95 has a mode 1 (M1) that carries out a leftward draw bending process, a mode 2 (M2) that carries out a rightward draw bending process, a mode 3 (M3) that carries out a leftward compression bending process, and a mode 4 (M4) that carries out a rightward compression bending process. The process control unit 95 is also capable of combining these four bending process modes with control by the twist units 100 to carry out a bending process in three dimensions (rotary bending process, rotating bending process, twisting process).

[0106] The machining apparatus 1 includes two sets of bending-feeding units 150 where a rotary bending unit that includes the machining unit 10 and a twist unit 100 is mounted on a feeding unit 140 and such sets are disposed facing one another along a second axis 200 (co-axially) on which the work W is set during machining. The machining apparatus 1 controls the chuck unit 160 and the feeding-bending units 150 on both sides in accordance with a program (bending data) 91 installed in the control unit 90, and automatically carries out two-end simultaneous bending successively from both ends of the work W toward the intermediate portion. In addition, the twist units 100 of the respective feeding-bending units 150 are capable of a rotary bending process by twisting the machining unit 10 around the second axis 200 and are capable of twisting, which decides the bending direction, and bending by a predetermined angle.

[0107] The feeding units 140 each include a moving mount 148 that is attached so as to slide forward and backward (left and right) on rails 149 on the mount 2 and a feed motor 145 that drives the moving mount 148 via

a ball screw 147. Each twist unit 100 is mounted on each moving mount 148 and the distance from the chuck unit 160 is controlled by each feeding unit 140.

[0108] The twist units 100 support the bending units (machining units) 10 that bend the rod-shaped member (work, pipe) W around the first axis 11 so as to rotate around the second axis (setting center) 200. The twist units 100 include a ring-shaped twist gear 101 that supports the machining unit 10, a twisting driving unit 110 that drives the twist gear 101, a guide roller 120 that supports an outer circumferential surface (outer circumferential portion) 106 of the twist gear 101 so that the twist gear 101 rotates about the second axis 200, and a support plate (support unit) 130 that supports the twist gear 101 via the guide roller 120. The support plate 130 is mounted on the moving mount 148 and the distance between the twist unit 100 and the chuck unit 160 is controlled by the feeding unit 140. The machining unit 10 is attached to the twist gear 101 via the turn unit (moving unit) 80 that controls the angle of the first axis (bending axis) 11.

[0109] The twist gear 101 includes the first cutaway portion 102 where one part is cutaway toward the center. The support plate 130 includes a second opening (through-hole region) 135 that is larger than an opening (first opening, internal void, internal space) 105 on the inside of the ring-shaped twist gear 101 and in the present embodiment, the twist gear 101 is held in the second opening 135. That is, the support plate 130 includes the second opening 135 that is larger than the first opening 105 inside the ring-shaped twist gear 101 with the second axis 200 at the center. The first opening 105 is substantially circular and it is desirable for the second opening 135 to be a circular opening with a larger diameter than the inner diameter of the first opening 105.

[0110] The support plate (support unit) 130 further includes a second cutaway portion 132 that is open in a direction that is perpendicular to the second axis 200 and is a second cutaway portion 132 that reaches the second opening 135. By disposing the first cutaway portion 102 of the ring gear (twist gear) 101 and the second cutaway portion 132 of the support plate 130 in a straight line, a supplying and discharging path 139 for supplying and discharging the work W to the position (the second axis 200) during bent processing (machining) is formed. In the machining apparatus 1a according to the present embodiment, the supplying and discharging path 139 is provided in the vertical direction, and when the work W held by the chuck unit 160 is supplied and discharged (loaded and unloaded), the work W is moved in the vertical direction (up and down). Although the support unit 130 is in the form of a plate, the support unit 130 may be constructed of a frame.

[0111] The chuck unit 160 includes chuck plates 161 that extend along the second axis 200 for machining a work, an opening-closing cylinder 163 that opens and closes the chuck plates 161, a raising-lowering cylinder 165 that moves the chuck plates 161 up and down when

supplying and discharging the work W, and a withdrawing cylinder 164 that temporarily lowers the chuck plates 161 below the second axis 200 when re-holding (releasing and holding again) the work W. The chuck plates 161 are formed with a depression in a center thereof and protrudes beyond the opening-closing cylinder 163 in the movement direction (hereinafter, left and right) of the feeding units 140 along the second axis 200. The depressed part in the center of the chuck plates 161 is a clearance portion 168 that provides clearance to allow a machined work W to be held, and the parts that protrude on the left and right are holding portions (work gripping portions) 167 that hold the work W.

[0112] FIG. 18 to FIG. 20 show a twist unit 100 that has been extracted. FIG. 18 is a front view of the twist unit 100, FIG. 19 is a vertical cross-sectional view, the cross-section including the second axis 200 of the twist unit 100, and FIG. 20 is a plan view of the twist unit 100. FIG. 18 shows a state where the first axis (bending axis) 11 of the bending unit 10 has been set in a state for supplying and discharging a work W, and FIG. 19 and FIG. 20 show a state where the first axis 11 has been set in the vertical direction. Also, in FIG. 19, for ease of explanation, the configuration of the twisting driving unit 110 has been superimposed on the cross-sectional view using solid lines.

[0113] The twist unit 100 includes the ring-shaped twist gear 101 that supports the bending unit 10 via the turn unit 80 so as to rotate around the second axis 200, the support plate 130 that supports the twist gear 101 via the guide roller 120, and the twisting driving unit 110 that drives the twist gear 101. Note that since the bending unit (machining unit) 10 and the turn unit (moving unit) 80 have the same fundamental configuration as the machining unit 10 and the moving unit 80 used in the machining apparatus 1 described earlier, description thereof is omitted below.

[0114] The twist gear 101 is a spur gear that is ring shaped and has no shaft, and includes the first opening (ring opening, internal void, through-hole) 105 whose inner diameter (ring inner diameter) R1 is around 1/3 or more of the outer diameter of the twist gear 101. The first opening 105 of the twist gear 101 not only allows the work W to pass through but also has a size that enables the holding portions 167 of the chuck plates 161 of the chuck unit 160 to enter and exit (i.e., be inserted) and therefore functions as a through-hole for chucked part (chuck through-hole). The twist gear 101 further includes the first cutaway portion 102 that is open in a direction perpendicular to the second axis 200, with the first cutaway portion 102 functioning as a releasing channel for supplying and discharging and allowing the work W to enter and exit the first opening 105.

[0115] The support plate (support unit) 130 is a plate-like member that extends in the vertical direction and includes the second opening 135 at a central upper portion thereof and the opening 135 houses the twist gear 101. Although the twist gear 101 is housed in the support

plate 130 in the machining apparatus 1a according to the present embodiment, it is also possible to attach the twist gear 101 to the outside of the support plate 130 and in such case, it is desirable for the inner diameter of the second opening 135 to be equal to or larger than the inner diameter R1 of the first opening 105 to enable the first opening 105 of the twist gear 101 to function as the through-hole for chucking parts. In the present embodiment, the twist gear 101 is housed in the support plate 130 and the twist gear 101 is prevented from coming out of the support plate 130 to the front or rear. To do so, the diameter (inner diameter) of the second opening 135 is the same size or larger than the outer diameter of the twist gear 101. By housing the twist gear 101 inside the support plate 130 and preventing the twist gear 101 from coming out, it is possible to reduce a distance L1 between the support plate 130 and the first axis (bending axis) 11, which makes the region (length) of the work W which is difficult to machine (bend) shorter.

[0116] A plurality of guide rollers 120 that face the inside are disposed in the second opening 135. These guide rollers 120 rotatably support an outer circumferential portion 106 of the twist gear 101 housed in the second opening 135 by sandwiching from the front and back (left and right), so that the twist gear 101, which is a spur gear with no shaft, rotates smoothly on the inside of the support plate 130. The rotational support arrangement of the twist gear 101 has inclined surfaces as guide surfaces on both outer circumferential surfaces of the twist gear 101 and such guide surfaces are sandwiched from both sides by the guide rollers 120 of a cam follower or the like. The support plate 130 is provided with a function as a stopper for limiting the movement of the twist gear 101 in the front-back direction, and the guide rollers 120 may support the twist gear 101 horizontally.

[0117] The support plate 130 also includes the second cutaway portion 132 that is open in the vertical direction with respect to the second axis 200 and connects to the second opening 135. The second cutaway portion 132 functions as a release channel for putting (taking) in and out (supplying and discharging) the work W into and out of the second opening 135. Accordingly, by rotating the twist gear 101, which rotates on the inside of the second opening 135, so that the first cutaway portion 102 is aligned in the vertical direction, the first cutaway portion 102 and the second cutaway portion 132 become aligned in a straight line to construct the supplying and discharging channel 139 for putting in and out (introducing and removing) the work W into and out of the first opening 105 of the twist gear 101. As described above, with the bending unit (machining unit) 10, by opening the upper die 23, the lower die 22, and the pressure roller 30 in three directions, it is possible to linearly putting in and out (supply and discharge) the work W into and out of the position of the second axis 200 that is the setting position (setting center) C for machining. This means that it is possible to move the work W through the supplying and discharging channel (supplying and discharging

path) 139 along with the path 13 that is linear in the vertical direction to the withdrawn position E. Note that when doing so, the clamp portion of the upper die 23 that is on the path 13 in FIG. 18 can be withdrawn from the path 13 by rotating the upper die 23 and the lower die 22 around the bending axis 11.

[0118] The twist unit 100 further includes the twisting driving unit 110 that rotationally drives the twist gear 101 that is rotationally supported by being held from in front and behind between a plurality of pairs (in this example, around eight pairs) of guide rollers 120 attached to the inside of the support plate 130. The twisting driving unit 110 includes a twisting motor 115 that is fixed via an attachment plate 119 to the support plate 130 and a plurality of drive gears 112 that transmit the driving force of the twisting motor 115 to the twist gear 101. The twist gear 101 is rotated inside the support plate 130 in a range of 360° by the twisting motor 115.

[0119] The plurality of drive gears 112 include a pair of drive gears 112a and 112b that are connected to the twist gear 101, a drive gear 112c that drives the drive gears 112a and 112b in synchronization, and bevel gears 112d and 112e that drive the shared drive gear 112c. The direction of the driving axis of the twisting motor 115 is changed by 90° by the bevel gears 112d and 112e so as to extend along the support plate 130 so that the length (dimension) by which the twisting motor 115 protrudes from the support plate 130 is reduced. When the first cutaway portion 102 has rotated and arrived between the pair of drive gears 112a and 112b, the pair of drive gears 112a and 112b will contact the twist gear 101 on both sides of the first cutaway portion 102, which means that it is possible to keep the driving force of the twist gear 101 stable. Half of the drive gears 112a and 112b in the axial direction contacts the twist gear 101 on the inside of the support plate 130 and the other half contacts the synchronization gear 112c on the outside of the support plate 130. By synchronously driving with a plurality of drive gears in contact with the twist gear 101 that has a cutaway part, it is possible to precisely control the angle of rotation regardless of the position to which the first cutaway portion 102 has moved.

[0120] In this way, the twist unit 100 has a twist shaft-less twist unit construction without a dedicated twist shaft for rotating the twist gear 101 that enables the twist gear 101 to include the first opening 105 that serves as the through-hole for the chucking part, and the twist gear with the first cutaway portion 102 that serves as the release channel for supplying and discharging is directly supported by the guide rollers 120 so as to be capable of being rotationally driven within the plate thickness of the support plate 130 which is provided with the second cutaway portion 132 that also serves as the release channel. By disposing the rotational guide mechanism (guide rollers) 120 and the twist gear 101 within the plate thickness of the support plate 130 in this twist shaft-less construction, it is possible to reduce the L dimension (L1) from the support plate end surface to the bending axis center 11,

and it is possible to reduce the length between the bend points that can be subjected to a final bending in two-end simultaneous bending.

[0121] That is, for the length between the bend points in a final bending of a pipe intermediate portion, even with a construction where the chuck holding portions 167 for a final bending are inserted to the vicinity of the bending axis 11, when bending both ends by 90° to produce a U shape, for example, the gap on the inside of the pipe formed the U shape bending needs to be at least equal to the dimension L so that the work can be discharged after bending, and distances below such length form a bending impossible region. This means that it is possible to reduce the length of the bending impossible region in the final bending by an amount by which the thickness of the twist unit 100 is reduced by the use of the twist shaft-less construction.

[0122] FIG. 21 shows the chuck unit 160 that is extracted. FIG. 21(a) is a front view of the chuck unit 160 and shows a state when looking from a direction that is perpendicular to the second axis 200. FIG. 14(b) is a side view of the chuck unit 160 when looking from the direction of the second axis 200. The chuck unit (pipe chuck) 160 includes the pair of chuck plates 161 that extend along the second axis 200, an opening spring 162 that holds the pair of chuck plates 161 in an opened state, and an opening/closing cylinder 163 that opens and closes the pair of chuck plates 161 by resisting the opening spring 162. The pair of chuck plates 161 are supported so as to rotate around a chuck shaft 166 in the manner of a pinch, and the chuck plates 161 are opened and closed by the opening-closing cylinder 163 inserting and withdrawing a roller 163a toward an operating side 161a of the chuck plates 161.

[0123] The pair of chuck plates 161 have a shape that extends in the direction of the second axis 200 (left and right) so as to overhang the cylinders 163 to 165 and are depressed in the center, with two positions on the left and right sides forming holding portions 167 where a cylindrical channel is formed so as to hold the work W, such as a pipe, which is also cylindrical. The center part (the central portion of the holding portions 167, clearance portion) 168 of the chuck plates 161 has a shape where a cutaway extends in a concave below a lower surface of the work (pipe) W, which makes it possible to hold or grip the nearest part of a work W that has been bent by using the holding portion 167 on one side. Accordingly, by releasing and holding again (re-holding, re-gripping) the work W, it becomes possible to grip the work W by a single holding portion 167 without interference of the machined part (processed part) of work W using the clearance portion 168.

[0124] The holding portions 167 that protrude to the left and right from the cylinders 163 to 165 are smaller as a whole than the opening 105 in the center of the twist gear 101. The twisting driving unit 110 of each twist unit 100 is disposed at one end in the front-back direction of the support plate 130, the twisting driving units 110 are

disposed in a state so as to be separated in the front-back direction from the second axis 200 and so do not interfere with the cylinders 163 to 165 when the chuck unit 160 and the twist unit 100 are brought closest together. Accordingly, when a twist unit 100 has been moved by a feeding unit 140 to the closest position to the chuck unit 160, the twist unit 100 is advanced to a position where the support plate 130 is close to the cylinders 163 to 165.

[0125] Here, the holding portions 167 are inserted into the first opening 105 in the center of the twist gear 101 and substantially pass through the support plate 130 and the twist gear 101. This means that it is possible to bring the position where the work W is chucked by the chuck unit 160 extremely close to the bending unit 10 that is supported on the opposite side of the support plate 130, and to bend the work W up to the vicinity of where the work W is chucked by the chuck unit 160.

[0126] In addition, it is possible to change the way the work W is held using the machining unit 10 of one twist unit 100 that has moved to the closest position to the chuck unit 160. That is, it is possible to temporarily hold the work W with the upper and lower units (upper and lower dies) 23 and 22 and the pressure unit 30 of the bending unit 10, to release the work W by opening the chuck plates 161, to withdraw the chuck plates 161 to below the second axis 200 using the withdrawing cylinder 164, and, after the separating the twist unit 100 from the chuck unit 160 by an appropriate distance, to raise the chuck plates 161 and rehold to change how the work W is held. When doing so, since the chuck plates 161 have the clearance portion 168, it is possible to hold the work W with one holding portion 167 with no interference for a part that has been bent by the other twist unit 100 provided by the clearance portion 168. Accordingly, it is possible to bend the work W while leaving the minimum straight pipe portion (straight portion) necessary for holding using one holding portion 167.

[0127] FIG. 22 shows, by way of a flowchart, an overview of a method (processing method, machining method, control method of a machining apparatus) that machines (processes) the work W using the machining apparatus 1a. In step 211, if it is timing at which supplying and/or discharging of a work W is required, in step 212, the supplying- discharging control unit 97 of the control unit 90 rotates the twist gear 101 to position the first cutaway portion 102 and the second cutaway portion 132 of the support plate 130 in the vertical direction and thereby set the supplying-discharging path 139. Before or after step 212, or in parallel with step 212, in step 213 the supplying-discharging control unit 97 controls the turn unit 80 and the bending unit 10 to release the upper die (first unit) 23, the lower die (second unit) 22, and the pressure unit 30 in three directions, the supply path (supplying-discharging path) 139 and the supplying-discharging direction (supplying-discharging path) 13 are placed in a straight line, and the angle of the bending axis 11 of the machining unit 10 is set so that the work W can be

putting in and out in the vertical direction. At this time, as necessary, the bending die clamp 20 is rotated to withdraw the clamp portions 23b and 22b to a position that does not interfere with the supplying and discharging.

[0128] After this, in step 214, the supplying and discharging control unit 97 raises and/or lowers the chuck unit 160 so that it is possible to discharge (unload) the work W from the second axis 200 that is the machining position and/or to supply (set, load) the work W to the second axis 200. The supplying and discharging of a work W is mainly carried out when setting the work W in the machining apparatus 1a in order to start a series of bending processes on the work W and when unloading the work W from the machining apparatus 1 after the series of bending processes has completed. In a machining apparatus 1 where the turn unit 80 does not have a raising and lowering function, it is possible to use the supplying and discharging function to switch between rightward bending and leftward bending.

[0129] In step 221, it is determined whether timing at which re-holding of the work W is required. Changing the hold of the work W is an operation that is performed, when left side bending processes and right side bending processes have completed at a first chuck position of the chuck unit 160, in step 211, the work W has been moved to the withdrawn position E due to the chuck unit 160 being raised and, an unmachined part remains in the chuck width, in this operation, the grip is released and held again so that the unmachined part in the chucked width is repositioned at a position outside the chucked width where machining is possible.

[0130] If it is timing at which it is necessary to change the hold, the re-holding control unit 98 of the control unit 90 controls the feeding-bending units 150, sets, in step 222, an arbitrary one of the feeding-bending units 150 on the left and the right as a bending completed side, and withdraws the unit on the bending completed side to a withdrawn position (a position separated from the chuck unit, normally the first bending start position on the trailing end side) that does not interfere with lowering of the work W that has been machined on one side. In step 223, the chuck unit 160 is lowered to the setting center C and the re-holding control unit 98 closes the upper die 23, the lower die 22, and the pressure unit 30 of the machining unit 10 on the opposite side to the bending completion side to temporarily hold the work W.

[0131] In step 224, the grip changing control unit 98 has the chuck unit 160 release the work W, withdraws the chuck plates 161 to below, and adjusts the position of the one of the twist units 100 using the feeding unit 140. The position of the twist unit 100 is controlled so that the location held by the one holding portions 167 of the chuck plates 161 is at least a straight pipe, and after this, in step 225, the chuck plates 161 are raised again and the work W is held once again. By carrying out such switching of the hold, it is possible to subject substantially the entire range of the work W to a bending process, aside from a part that is held by the one of holding portions

167.

[0132] If the supplying, discharging and/or the switching of grip have been completed or such processes are unnecessary, in step 200, the position control unit 93 and the process control unit (machining process control unit) 95 of the control unit 90 move both twist units 100 and carry out a predetermined bending process at a predetermined position of the work W in accordance with the machining data 91. In step 230, it is confirmed whether the bending process has completed and if a next process that includes a supplying/discharging process remains, the processing returns to step 211 and the processes described earlier are repeatedly carried out.

[0133] The processes in the bending process in step 200 include step 201 to step 209 of the machining method described based on FIG. 11. That is, in step 201, the position control unit 92 controls the die opening-closing mechanism 60 to open the upper die 23, the lower die 22, and the pressure unit 30 in three different directions centered in the setting center C to release the work W. In addition, the pair of twist units 100 are set by the feeding units 140 on both sides at the position of the next bending process. When the twist units 100 reach the point of a bending process, the process control unit 95 determines the machining mode and sets the work W at the setting center C by relatively moving the chuck unit 160 and the twist units 100 in a straight line. After this, machining in the modes M1 to M4 is carried out. At this time, if it is necessary to control the bending direction, the twist gear 101 of each twist unit 100 rotates by a predetermined angle. Since it is possible to independently control the rotational angle of the twist gear 101 in each twist unit 100, it is possible to independently control the angle of the bending axis 11 of each machining unit 10 and to independently carry out bending processes from each end.

[0134] When machining in each machining mode, it the mode differs to the bending process previously carried out, the process control unit 95 carries out a process that uses the turn unit 80 to raise and lower the machining unit 10 as described earlier and changes the orientation of the machining unit 10 relative to the work W. After such machining (processing) has been completed in step 209, the process returns to the flow shown in FIG. 22.

[0135] The control unit 90 that controls the machining method (processing method, control method) can be realized by computer resources that include a CPU and memory in the same way as the control unit 9 described above, and the machining method (control method) can be provided by being recorded on an appropriate recording medium as a program (program product).

[0136] With this method, it is possible to chuck the center (a periphery of an intermediate portion) of a rod-shaped work W such as a pipe with the chuck unit 160 and to machine the work W into a variety of shapes while feeding the twist unit 100 from both ends of the work W toward the center. In particular, the machining apparatus 1a has two rotary bending units (twist units) 100 disposed

facing one another on the same axis, holds the periphery of an intermediate portion of the pipe with the chuck unit 160, and carries out simultaneous bending at both ends by successively moving the rotary bending units 100 from both ends toward the intermediate portion (center portion). In addition, with the machining apparatus 1a, the re-holding process (hold switching process) that uses the bending die clamp 20 of the machining unit 10 is provided and it is possible to reduce the length of the bending impossible region of the intermediate portion without adding an auxiliary chuck or withdrawing the pipe chuck from the pipe axis.

[0137] In addition, the machining apparatus 1 is a both end simultaneous bending apparatus and is configured with two feeding bending units 150 disposed facing one another on the same axis centered on the pipe chuck 160 provided in the vicinity of an intermediate portion of the mount 2 and so as to include bending units 10 on the opposite sides to the pipe chuck 160 with the support plates 130 in between. Also, the holding portions 167 of the pipe chuck 160 are capable of being inserted through the openings (chuck through-holes) 105 of the twist gears 101. This means that it is possible to bring the chuck unit 160 to the immediate vicinity of the machining unit 10, which also makes it possible to reduce the length of the bending impossible region of the work W.

[0138] In a bending operation, first the holding portions 167 on both sides of the chuck plates 161 hold the vicinities of bend points located at a bend point interval for which bending is possible in a final bending and such that the number of bends on the left and right sides of the pipe W is substantially equal, and bending in a range where there is no interference with the chuck plates 161 is simultaneously carried out at both ends while moving the feeding bending units 150 from the ends of the pipe toward the intermediate portion. An arbitrary side that has been bent at the first holding position is set as the bending completed side, and the grip is switched to the vicinity of a final bend point on the bending completed side using the holding portion 167 on the opposite side of the chuck plates 161. By the re-holding (switching the grip), a bend point remaining within the chuck width at the first chuck position is moved to a position outside the chuck width where bending is possible and the remaining bending is carried out.

[0139] It is also possible to carry out the re-holding process in step 222 to 225 including a supplying and discharging process. That is, first, the upper die 23 and the lower die 22 and the pressure unit 30 of the machining unit 10 are released in three directions, and then to enable the pipe W that has been bent to be raised, measured feeding in the chucking direction of the feeding bending units 150, withdrawal by rotation of the clamp portions 23b and 22b, and twisting back so that the center of the release channel 102 of the twist gear 101 reaches a vertical position are carried out. After this, the pipe W is raised above the upper surface of the support plate 130 of the twist unit 100 by the raising-lowering cylinder

165 and the withdrawing cylinder 164, lowering back to the bending height is performed after the feeding bending unit 150 on the bending completed side has been withdrawn to a position that does not interfere with the pipe W, and the bending die clamp 20 of the feeding-bending unit 150 on the side that is to carry out the remaining bending is returned to the bending start position and holds the pipe W. The chuck plates 161 are opened by the opening-closing cylinder 163 and withdrawn downward by the withdrawing cylinder 164, the feeding-bending unit 150 that held the pipe W is then withdrawn by the stroke for switching the grip, the chuck plates 161 are returned to the bending height, and the pipe W is chucked once again. By doing so, it is possible to switch to gripping the periphery of the final bend point on the bending completed side using the holding portion 167 on the opposite side of the chuck plates 161.

[0140] Since the re-holding (grip switching) described above is carried out using the clamp function of the machining units 10 that is necessary for pipe bending, the feeding function of the feeding units 140, and the chucking function and raising-lowering function of the chuck unit 160, it is possible to perform re-holding without adding a new moving mechanism for re-holding.

[0141] Note that if a bending path on the bending completed side after two-end simultaneous bending is oriented downward from the horizontal and this interferes with withdrawal/retraction of the feeding bending units 150 or the chuck plates 161, interference with the re-holding can be avoided by setting the first chuck position at a bend point where interference does not occur or by adding a twisting operation that changes the pipe twisting direction before the first bending using the twisting function or the like of the rotary bending unit 100.

[0142] Such processes can be carried out automatically according to the machining data 91 that includes flags indicating the re-holding points (grip switching points) and re-holding stroke data.

[0143] In this way, the machining apparatus 1a includes the rotary bending unit (twist unit) 100 that is capable of supplying and discharging on a linear path where the length of the bending impossible region of a final bend of an intermediate portion during both-end simultaneous bending is reduced by using a twist shaft-less construction, and the chuck unit 160 that holds the periphery of a bending portion and is an overhanging chuck that is capable of being raised and lowered. The machining apparatus 1a carries out re-holding using the clamp function and feeding function of the feeding bending units 150 that are required for pipe bending. This means that it is possible to reduce the bending impossible region of the intermediate portion without adding a withdrawing mechanism for withdrawing the pipe chuck 160 from the direction in which the feeding bending units 150 advance, a raising/lowering withdrawing mechanism for the rotary bending units 100, an auxiliary chuck, or the like. Accordingly, it is possible to simplify the construction of the machining apparatus 1a that is an apparatus for two-end

simultaneous bending. Also, with the machining apparatus 1a, it is possible to carry out consecutive bending processes using rotary bending (three-dimensional bending) that is a mixture (combination) of left and right bending directions and draw and compression bending methods.

[0144] FIG. 23 to FIG. 28 show a different example of the twist unit 100. This twist unit 100 includes a bending unit 10 dedicated to leftward draw bending. Since switching between leftward and rightward bending is unnecessary, the turn unit is omitted from the bending unit 10, and the twist gear 101 is directly attached by the connecting plate 81 in a state where the first axis (bending axis) 11 is inclined. Accordingly, the configuration of the twist unit 100 is further simplified, the distance L1 between the support plate 130 and the bending axis 11 is further reduced, and the bending impossible region in the intermediate portion of the work W is reduced.

[0145] FIG. 23 is a front view of the twist unit 100, FIG. 24 is a side view of the twist unit 100, and FIG. 25 is a plan view of the twist unit 100.

[0146] FIG. 26 is a plan view showing a bending unit 10 dedicated to draw bending mounted on the twist unit 100 after extraction. FIG. 27 is a cross-sectional view of the machining unit 10 dedicated to draw bending. The bending unit 10 includes the die opening-closing motor 61 and the draw bending motor 41. The configuration of the die opening-closing mechanism 60 of the upper die (first unit) 23, the lower die (second unit) 22, and the pressure die 30 is the same. Accordingly, as shown in FIGS. 28(a) and (b), the upper die 23, the lower die 22, and the pressure die 30 are opened and closed in three directions centered on the second axis 200 by the die opening/closing mechanism 60 and the pressure die swinging mechanism 70. This means that by releasing the upper die 23, the lower die 22, and the pressure die 30, and rotating the bending die clamp 20 that includes the lower die 22 and the upper die 23 to a position where the clamp portion 23b does not interfere, it becomes possible to supply and discharge the work W along a linear (supplying and discharging path) 13.

[0147] Also, although the feeding unit 140 of the machining apparatus 1a described above is one example of using a ball screw, the feeding motor 145 may be installed on the rotary bending unit 100 side as a rack and pinion mechanism. The raising/lowering cylinder 165 and the withdrawing cylinder 164 of the chuck unit 160 may be an electric slider compatible with both strokes.

[0148] As described above, the machining apparatus 1a is capable of reducing the bending impossible region of the intermediate portion using a simplified apparatus construction, and of carrying out a both-end simultaneous bending process on a work that is a rod-shaped member, such as a long pipe, with high precision and high speed by supplying and discharging on a short linear path and feeding in one direction that is fixed at the pipe axis. Also, by being equipped with the leftward-rightward draw-compression bending units 10 and the quick turn

unit 80, it is possible to efficiently carry out bending that is a mix of leftward and rightward and compression and draw bending without moving the pipe axis.

[0149] In addition, as a method of precisely carrying out bending of a long pipe with a small diameter whose bent shape can collapse and deform due to inertia forces if the pipe is twisted at high speed, the machining apparatus 1a is capable of machining a pipe with a so-called "rotary bending method" where the pipe is not twisted and the bending unit 10 is rotated about the pipe axis. The vicinity of the intermediate portion of the pipe is held by the chuck unit 160, and it is possible to carry out successive bending processes while moving bending means from the pipe ends toward the intermediate portion using two sets of rotary bending means 100 and feeding means 140 disposed on the same axis as the pipe axis facing one another on both sides of the pipe chuck 160. With this machining apparatus 1a, both-end simultaneous rotary bending is carried out, and by using both-end bending, it is possible to halve the length of the bending stroke (width or up-down of fluctuation due to bending) and to reduce collapsing and deformation due to post-bending return motion, while avoiding collapsing and deformation caused by twisting of the pipe. This means that it is possible to carry out a bending process on a long pipe with a small diameter in a short time and with high precision using both-end simultaneous bending in which the twisting speed and the bending speed are raised.

[0150] Also, if the bending method described above where, when supplies and discharges a pipe to the bending portion, the releasing direction of the semicircular channel for bending provided in the upper-lower integrated split die and the center of the releasing channel for supplying and discharging purposes provided in the twist mechanism are perpendicular is conventional, the pipe supplying and discharging path requires movement that vertically raises and lowers inside the releasing channel for supplying and discharging purposes and movement in the horizontal direction to enter the semicircular channel of the bending die (i.e., movement in two directions), resulting in the disadvantage of the supplying and discharging time increasing and the problem of the supplying and discharging mechanism becoming complex.

[0151] Also, if the twisting construction of the rotary bending unit is such that the twist shaft (twist plate) that supports rotation of the bending unit and the twist gear for rotational driving are separately constructed and the twist gear is disposed on the outside of the support plate, there is a corresponding increase in the distance from the support plate end surface to the center of the bending axis, resulting in the disadvantage of an increase in the length of the bending impossible region in the intermediate portion for the final bend in the two-end simultaneous bending. When there is no mechanism for withdrawing the pipe chuck from the feeding direction of the bending units, this intermediate portion bending impossible region is at least the sum of double the distance from the support plate end surface to the center of the bending

axis and the width of the pipe chuck mechanism, resulting in the problem that the apparatus is not compatible with bending where the interval between bends is short. Although it would be possible to reduce the bending impossible region of the intermediate portion by providing a mechanism that withdraws the pipe chuck from the pipe axis, another auxiliary chuck that holds the pipe when the pipe chuck is withdrawn, a lowering-withdrawing mechanism for the bending mechanism on one side, or the like, there is the problem that the apparatus construction becomes complex. Note that even if such withdrawing mechanism is provided, approximately the distance from the support plate end surface to the center of the bending axis is still required for the interval between the bend points of the final bend.

[0152] With the machining apparatus 1a described above, it is possible to solve the problems described above and to provide a bending apparatus that reduces the length of the bending impossible region in an intermediate portion of the pipe using a simple construction and has a short machining time due to feeding in one direction and supplying and discharging on a linear path perpendicular to the pipe axis.

[0153] Note that when automatic conveying and supplying and discharging are carried out, positioning of the work W such as a pipe in the axial direction and the direction of rotation may be carried out before supplying by a positioning unit, with the work W being supplied to the bending apparatus according to the present invention in a state where such position is maintained. When manual supplying and discharging is used, pipe positioning units that are capable of moving in the axial direction may be provided on a trailing end of a reference side.

[0154] Also, although an example of a machining apparatus including the pair of twist units 100 disposed so as to face one another on both sides of the chuck unit 100 has been described above, the apparatus may be a one-end bending apparatus with a twist unit 100 disposed on one side of the chuck unit 160.

[0155] The machining apparatus 1a disclosed above includes rotary bending units that has the characteristics such as the linear supplying and discharging path, feeding in a single direction with the pipe axis fixed, miniaturized and has reduced weight by using a simple construction with fewer actuators, carrying out twisting and feeding on the rotary bending unit side and carrying out both-end simultaneous bending in a state where the pipe is fixed, and by such characteristics, it is possible to carry out bending processes with high precision and at high speed while suppressing collapsing and deformation due to inertia forces caused by bending and pipe twisting due to an increase in bending amplitude (width or length of fluctuation due to bending). In addition, by using a twist shaft-less bending mechanism where the bending impossible region is short and by making it possible to insert the holding portions of the pipe chuck through a through-hole in the twist gear of the bending mechanism, it is possible to reduce the bending impossible region at the

intermediate portion, which is a weak point for both-end simultaneous bending.

[0156] As described above, the machining unit and machining apparatus according to the present invention are in no way limited to the embodiments described above and can be subjected to various modifications within a range that does not depart from the scope of the invention.

Claims

1. A machining unit comprising:

a first unit including a first split die portion on an upper side, out of upper and lower split die portions that form a pair and include a bending channel that bends a rod-shaped member, and a first clamp portion on an upper side, out of upper and lower clamp portions that form a pair and hold the rod-shaped member inserted into the bending channel;
a second unit including a second split die portion on a lower side out of the upper and lower split die portions that form a pair and a second clamp portion on a lower side out of the upper and lower clamp portions that form a pair;
a pressure unit that includes a holding channel that holds the rod-shaped member in the bending channel from an outer circumferential side of the bending channel; and
an opening-closing unit that opens and closes the first unit, the second unit, and the pressure unit in three different directions relative to a setting center that is a position of a center axis of the rod-shaped member in a state where the rod-shaped member has been set in the bending channel.

2. The machining unit according to claim 1, wherein the opening-closing unit includes:

a first opening-closing unit that opens and closes the first unit and the second unit in a balanced manner; and
a second opening-closing unit that operates in concert with the first opening-closing unit and moves the pressure unit away from and toward the setting center.

3. The machining unit according to claim 2, wherein the second opening-closing unit includes:

a skirt-shaped cylindrical cam that moves up and down in concert with the first opening-closing unit; and
a cam follower that moves while contacting a circumferential surface of the skirt-shaped cy-

- lindrical cam and, in concert with the skirt-shaped cylindrical cam moving up and down and the first unit and the second unit opening and closing, moves the pressure unit relative to the bending channel so as to open and close the pressure unit.
4. The machining unit according to claim 2 or 3, wherein the first opening-closing unit includes:
- a first opening-closing shaft that moves the first unit up and down;
 - a second opening-closing shaft that moves the second unit up and down;
 - a left-hand and right-hand screw member that moves the first opening-closing shaft and the second opening-closing shaft up and down in opposite directions; and
 - an opening-closing motor that rotates the left-hand and right-hand screw member.
5. The machining unit according to any of claim 2 to 4, wherein the second opening-closing unit includes:
- a holder that supports the pressure unit so as to swing relative to the first opening-closing shaft and the second opening-closing shaft; and
 - a support portion that supports the holder so as to be capable of revolving relative to the first opening-closing shaft and the second opening-closing shaft.
6. The machining unit according to any of claim 1 to 5, wherein the pressure unit includes a pressure roller including the holding channel that includes an arc-shaped part, and the machining unit further comprises:
- a first driving unit that rotates the first unit and the second unit about a first axis in a state where the first unit and the second unit are closed; and
 - a second driving unit that rotates the pressure unit about the first axis independently of the first driving unit in a state where the pressure unit is closed.
7. The machining unit according to claim 6, wherein the pressure unit includes at least one pressure unit disposed on one out of two positions on the left and the right.
8. The machining unit according to claim 7, wherein the second driving unit includes:
- an opening-closing cam follower that opens and closes the at least one pressure unit; and
 - an inclined cylindrical cam that rotates about the first shaft so as to close the opening-closing cam
- follower.
9. The machining unit according to any of claim 1 to 8, wherein the upper and lower clamp portions that form a pair are clamp portions that are common to leftward and rightward bending and include clamping channels that intersect in an X shape.
10. A machining apparatus comprising:
- the machining unit according to any of claim 1 to 9,
 - a work supporting unit that supports the rod-shaped member; and
 - a moving unit that moves at least one of the machining unit and the work supporting unit to carry out a first operation that sets a center axis of an unmachined part of the rod-shaped member supported by the work supporting unit at the setting center of the machining unit and a second operation that sets the center axis of the unmachined part at a withdrawn position away from the setting center.
11. The machining apparatus according to claim 10, wherein the moving unit relatively moves the center axis of the unmachined part of the rod-shaped member supported by the work supporting unit in a straight line in a first direction between the setting center and the withdrawn position, and supports the machining unit so that an opening-closing direction of the first unit and the second unit is inclined to the first direction.
12. The machining apparatus according to claim 10 or 11, wherein the machining unit includes a mechanism that bends the rod-shaped member both of leftward and rightward, and the moving unit includes a first moving unit that swings the machining unit leftward and rightward while moving the machining unit up and down.
13. The machining apparatus according to claim 12, wherein the first moving unit includes:
- a base;
 - a holder that swings relative to the base;
 - a slide plate that supports the machining unit so as to slide up and down inside the holder;
 - a first cam channel in the vertical direction provided in the base;
 - a second cam channel provided in the slide plate in a direction perpendicular to a direction in which the slide plate slides;
 - a turn gear that includes a turn roller that moves inside the first cam channel and the second cam channel; and

a turn motor that is held by the holder and rotationally drives the turn gear.

14. A machining apparatus comprising:

the machining unit according to any of claim 1 to 9; and
a twist unit that supports the machining unit so as to rotate around a second axis that passes the setting center,
wherein the twist unit includes:

a twist gear that is ring shaped, supports the machining unit, and includes a first cutaway portion where one part towards a center is missing;
a twist driving unit that drives the twist gear;
a plurality of guide rollers that support an outer circumferential surface of the twist gear so that the twist gear rotates about the second axis; and
a support unit that supports the plurality of guide rollers,

wherein the support unit includes:

a second opening that is centered on the second axis and is larger than a first opening inside a ring of the twist gear; and
a second cutaway portion that reaches the second opening and is open in a direction perpendicular to the second axis, and the plurality of guide rollers are disposed facing the second opening and at least part of the twist gear is supported so as to rotate inside the second opening.

15. The machining apparatus according to claim 14, further comprising:

a chuck unit that supports an unmachined part of the rod-shaped member along the second axis on an opposite side of the machining unit with the support unit in between; and
a feeding unit that controls a relative distance between the chuck unit and the support unit, wherein the chuck unit includes a work holding portion that extends along the second axis and passes through the first opening when a distance between the support unit and the chuck unit is reduced.

**16. A method comprising carrying out a bending process on a rod-shaped member using a machining apparatus including a machining unit,
the machining unit including:**

upper and lower split die portions that form a

pair and include a bending channel;
upper and lower clamp portions that form a pair and hold the rod-shaped member inserted into the bending channel; and
a pressure unit that includes a holding channel that holds the rod-shaped member in the bending channel from an outer circumferential side of the bending channel,
wherein the method comprises setting the rod-shaped member by moving, before the carrying out the bending process and in a state where the upper split die portion and the upper clamp portion, the lower split die portion and the lower clamp portion, and the pressure unit have been opened in three different directions with respect to a setting center which is a position of a center axis of the rod-shaped member in a state where the rod-shaped member is set in the bending channel, the rod-shaped member relatively to the setting center in a straight line.

17. The method according to claim 16, wherein the setting includes inclining the machining unit and supplying and discharging on a common path for leftward and rightward bending by moving the rod-shaped member in a straight line, and the bending process includes bending in a left-right direction of the rod-shaped member set at the setting center at the setting center.

18. The method according to claim 16, wherein the machining apparatus includes a twist unit that supports the machining unit so as to rotate around a second axis that passes the setting center, wherein the twist unit includes:

a twist gear that is ring shaped, supports the machining unit, and includes a first cutaway portion where one part towards a center is missing;
a twist driving unit that drives the twist gear; and
a support unit that rotationally supports the twist gear and includes: a second opening that is larger than a first opening in a ring of the twist gear and is centered on the second axis; and a second cutaway portion that is open in a direction perpendicular to the second axis and reaches the second opening,
the machining apparatus further includes:

a turn unit that makes an attachment angle of the machining unit to the twist gear inclined to a direction of the first cutaway portion; and
a chuck unit that supports an unmachined part of the rod-shaped member along the second axis on an opposite side of the machining unit with the support unit in between, and

the method further comprises:

the twist driving unit rotating, before the
setting, the twist gear so that the first
cutaway portion and the second cuta- 5
way portion match; and
the turn unit setting the attachment an-
gle so that a direction in which the rod-
shaped member is released when the 10
first unit, the second unit, and the pres-
sure unit are opened and a direction of
the first cutaway portion and the second
cutaway portion are in a straight line,
and
the setting includes moving the chuck 15
unit and the twist unit relatively in a di-
rection of the straight line to set the rod-
shaped member at the second axis.

19. The method according to claim 18, 20
wherein the machining apparatus further includes a
feeding unit that controls a relative distance between
the chuck unit and the support unit,
the chuck unit includes a work holding portion that
extends along the second axis, and 25
the method further comprises:

the feeding unit reducing, before the carrying
out the bending process, a distance between
the support unit and the chuck unit and passing 30
the work holding portion through the second
opening; and
the work holding portion re-holding, once the
rod-shaped member has been held by the ma-
chining unit and the feeding unit increases the 35
distance between the support unit and the chuck
unit, the rod-shaped member.

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Fig. 1

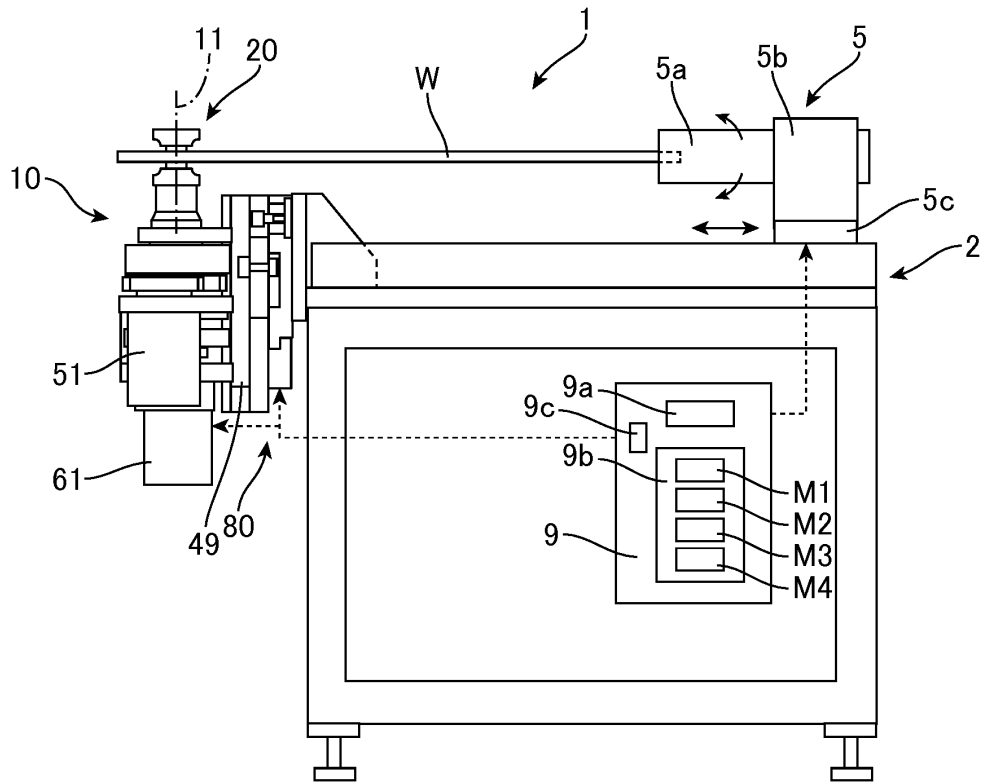


Fig. 2

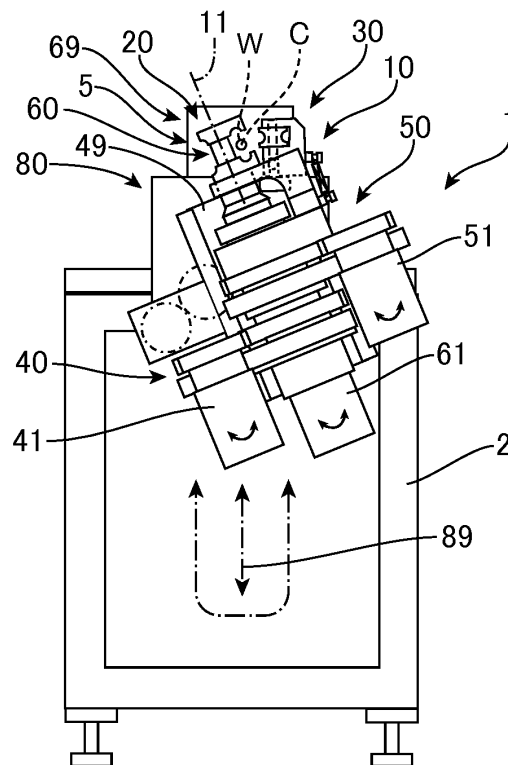


Fig. 3

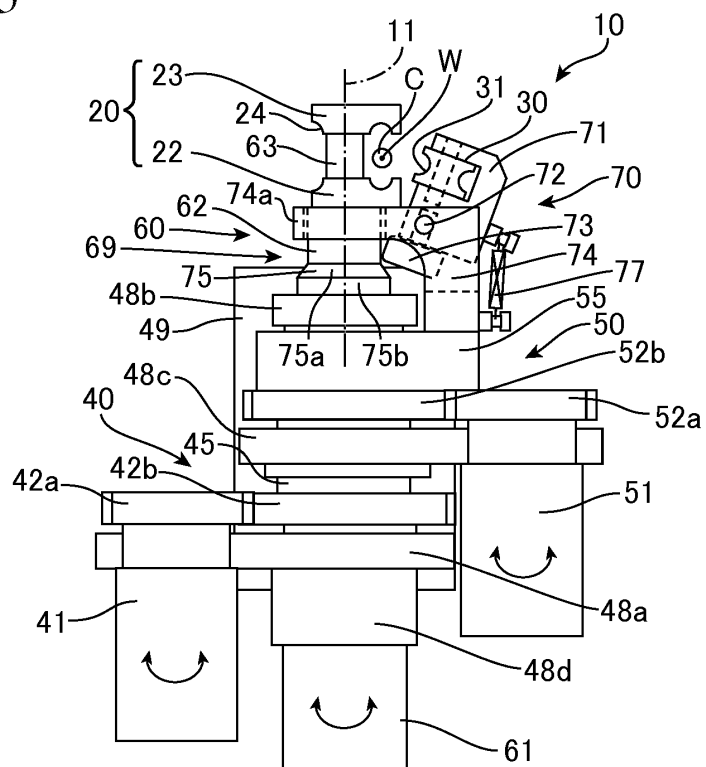


Fig. 4

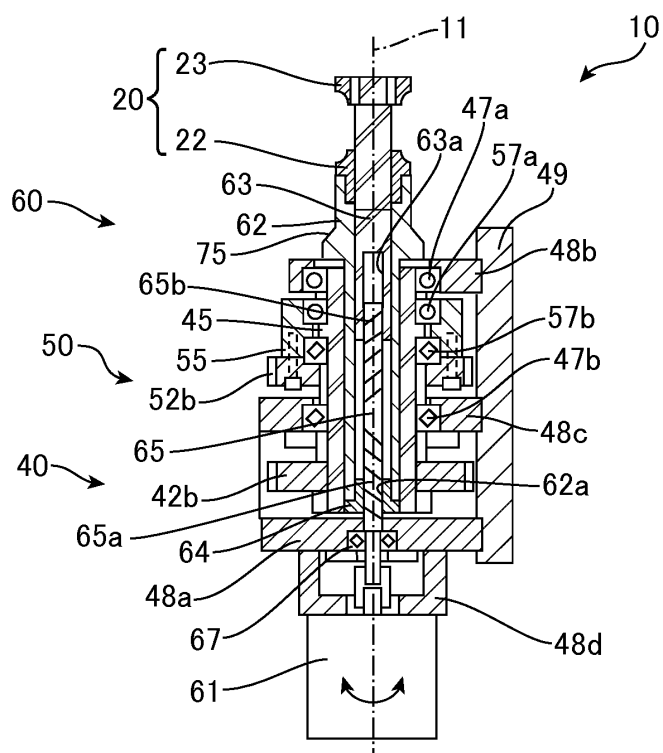


Fig. 5

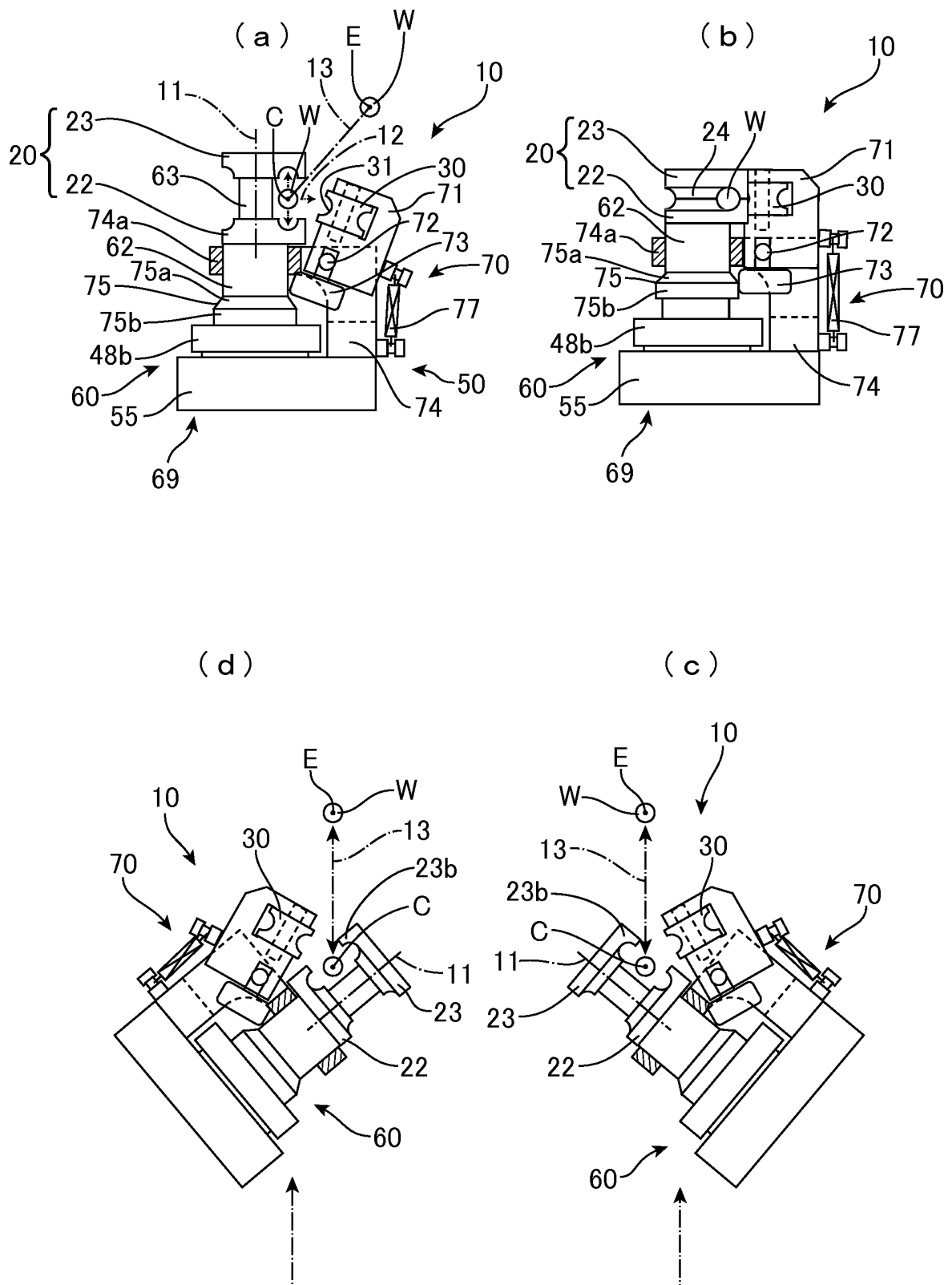


Fig. 6

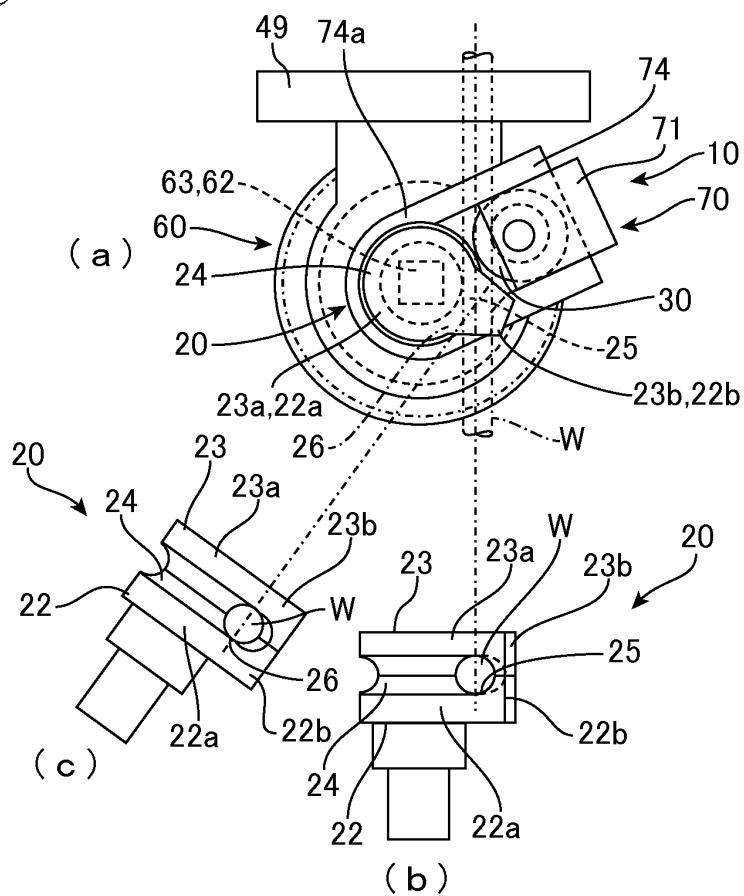


Fig. 7

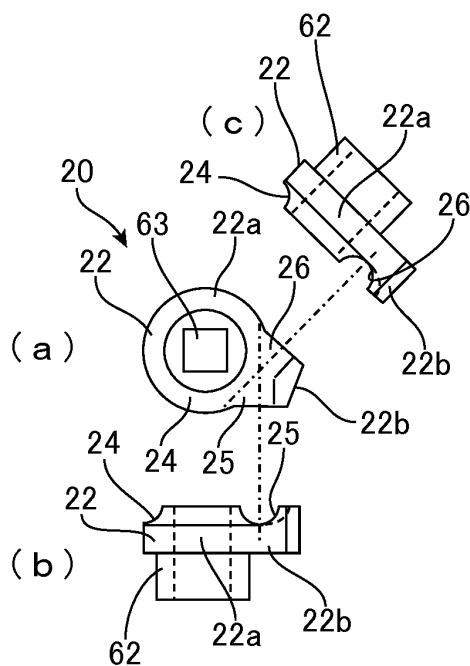


Fig. 8

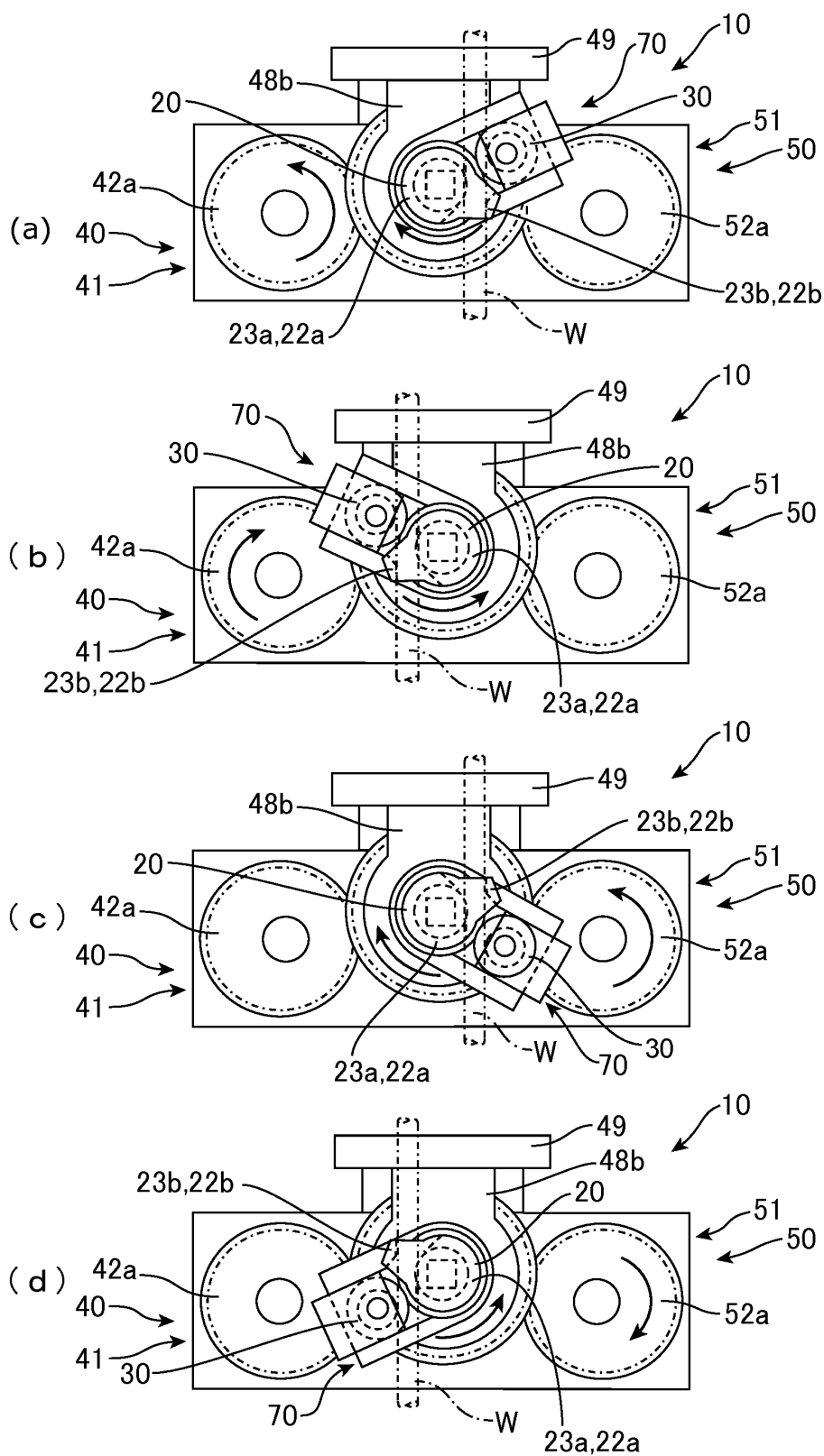


Fig. 9

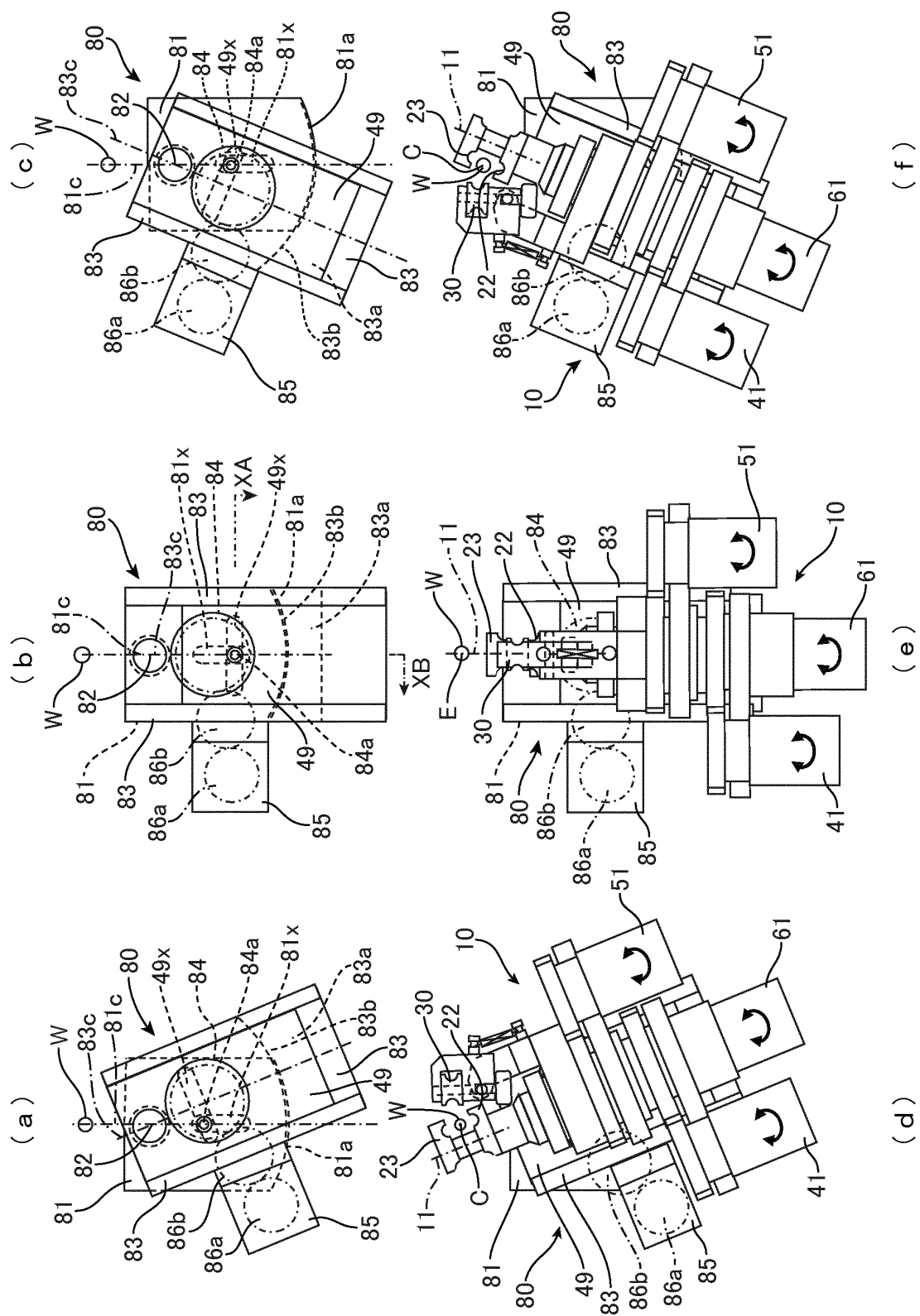


Fig. 10

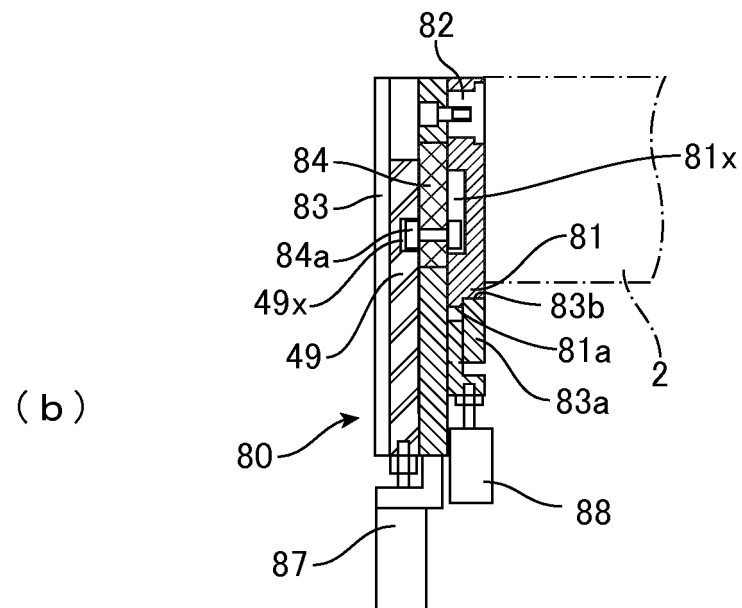
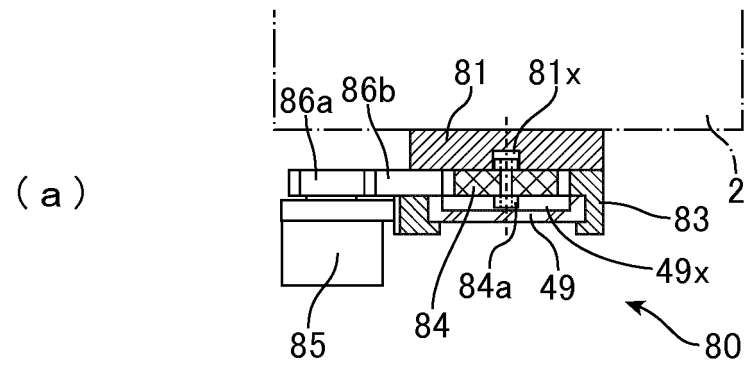


Fig. 11

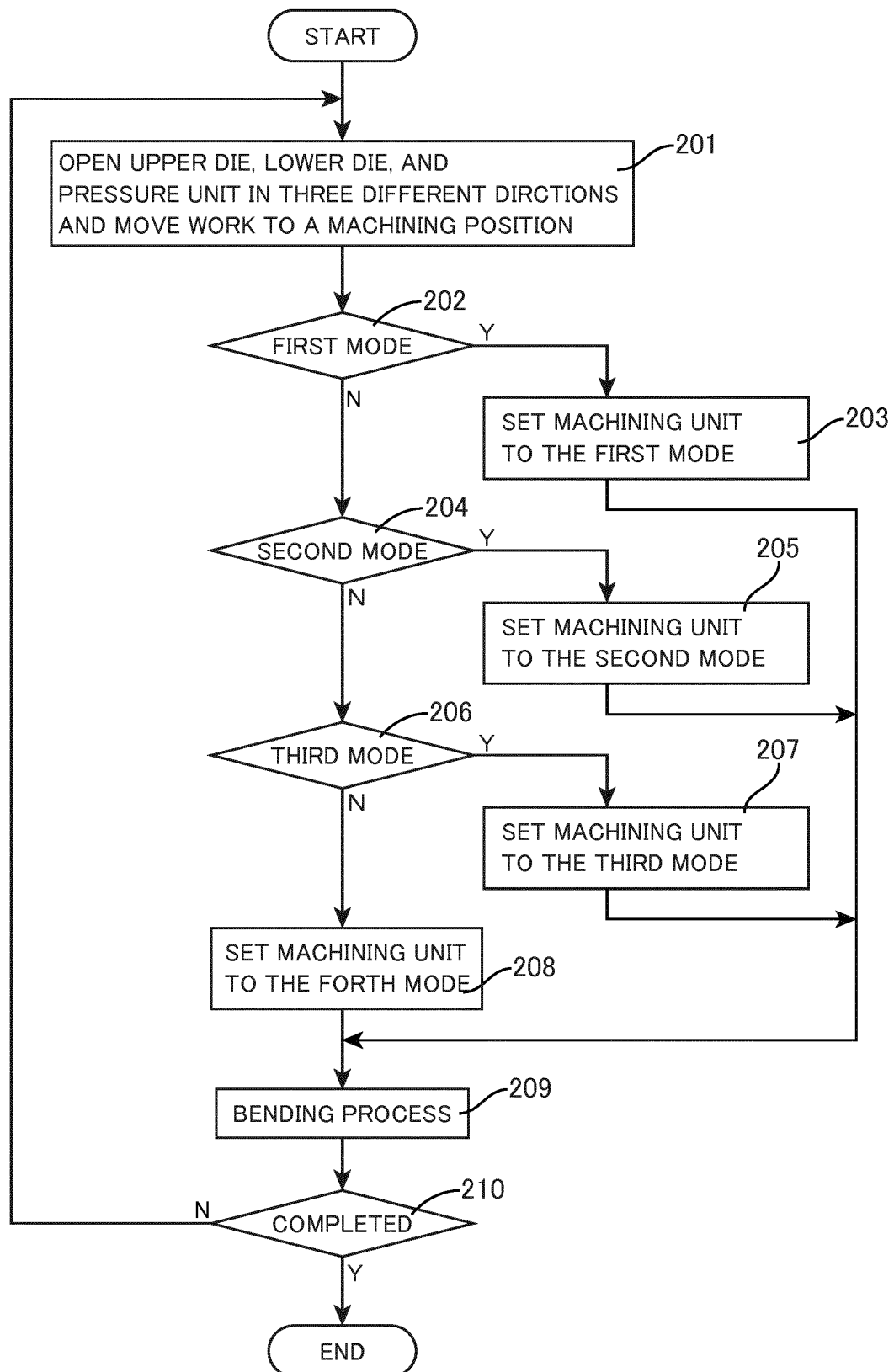


Fig. 12

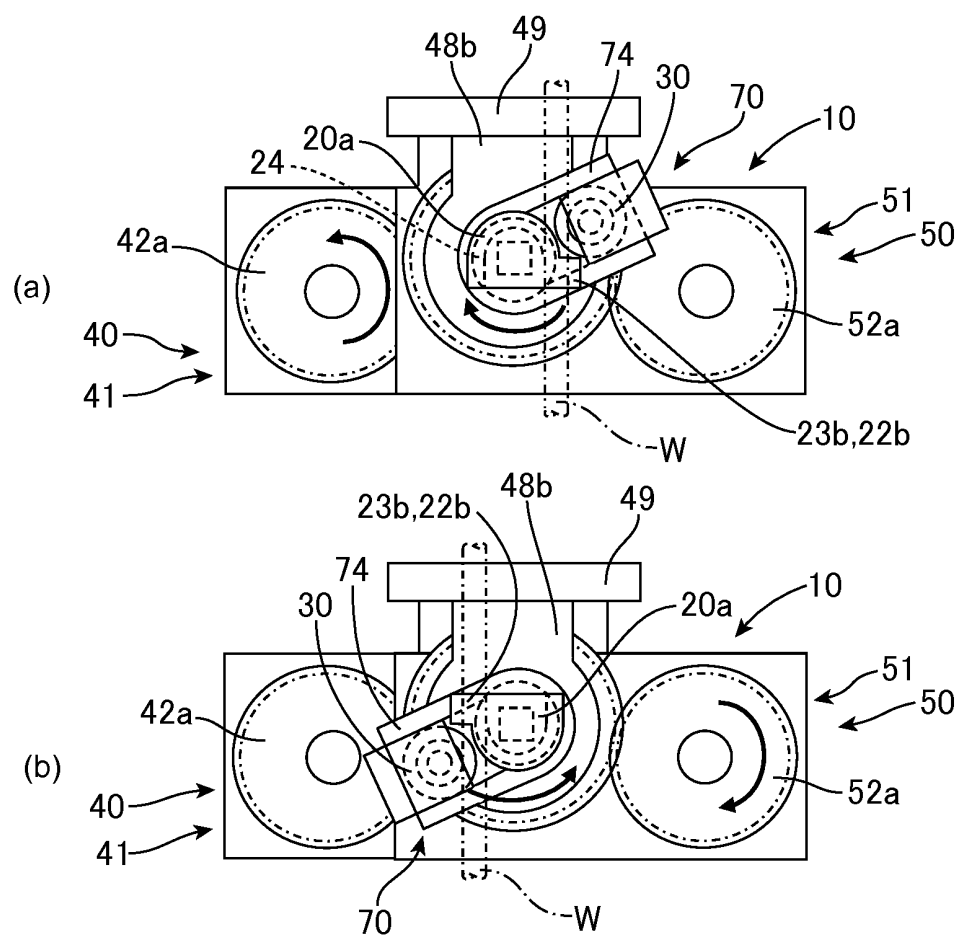


Fig. 13

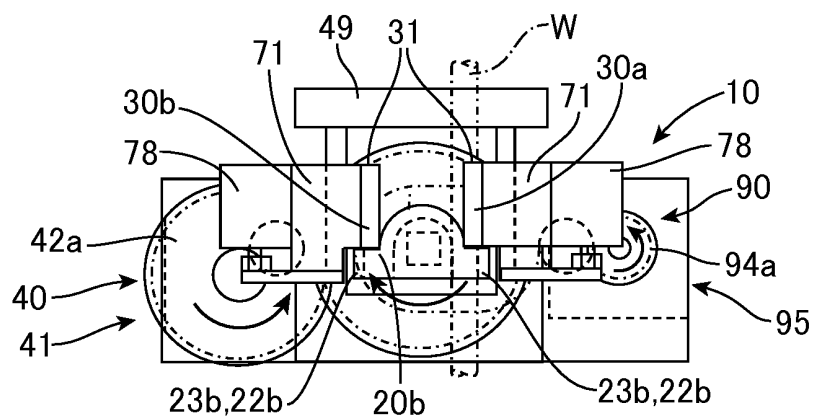


Fig. 14

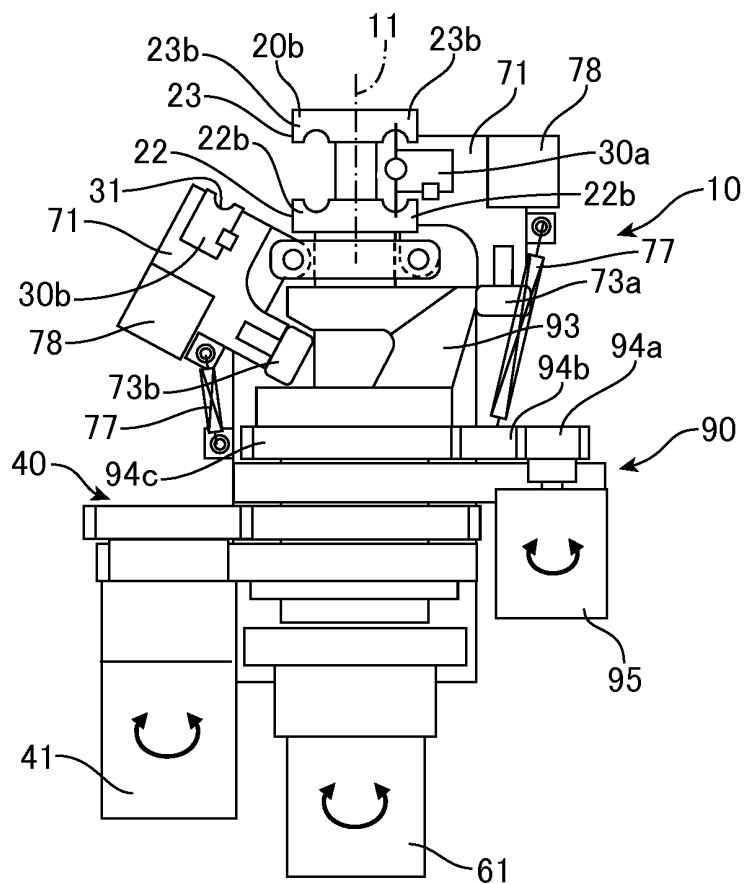


Fig. 15

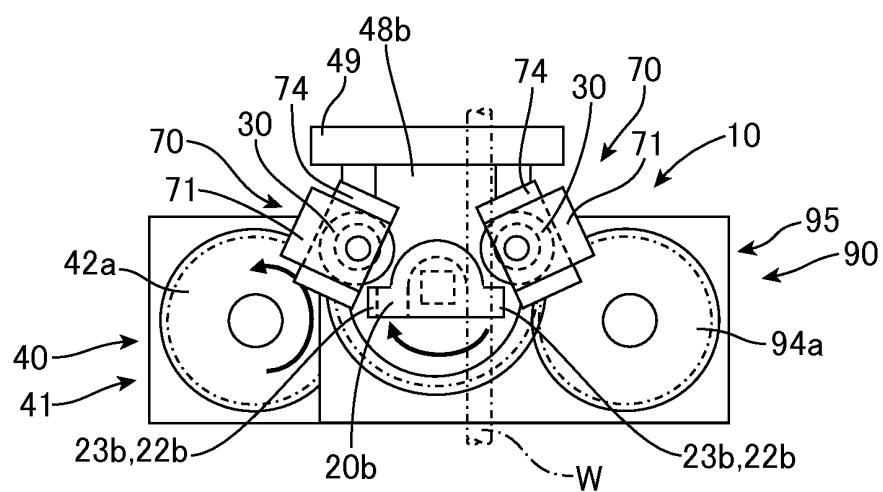


Fig. 16

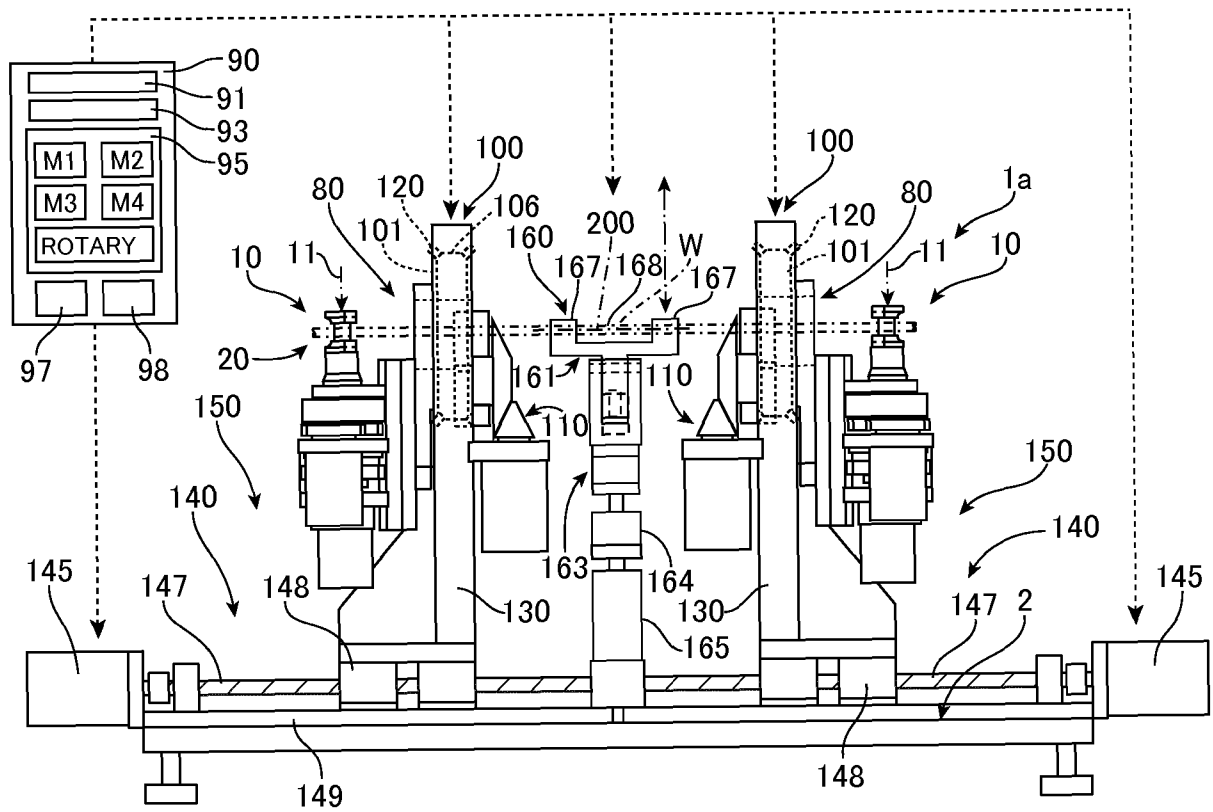


Fig. 17

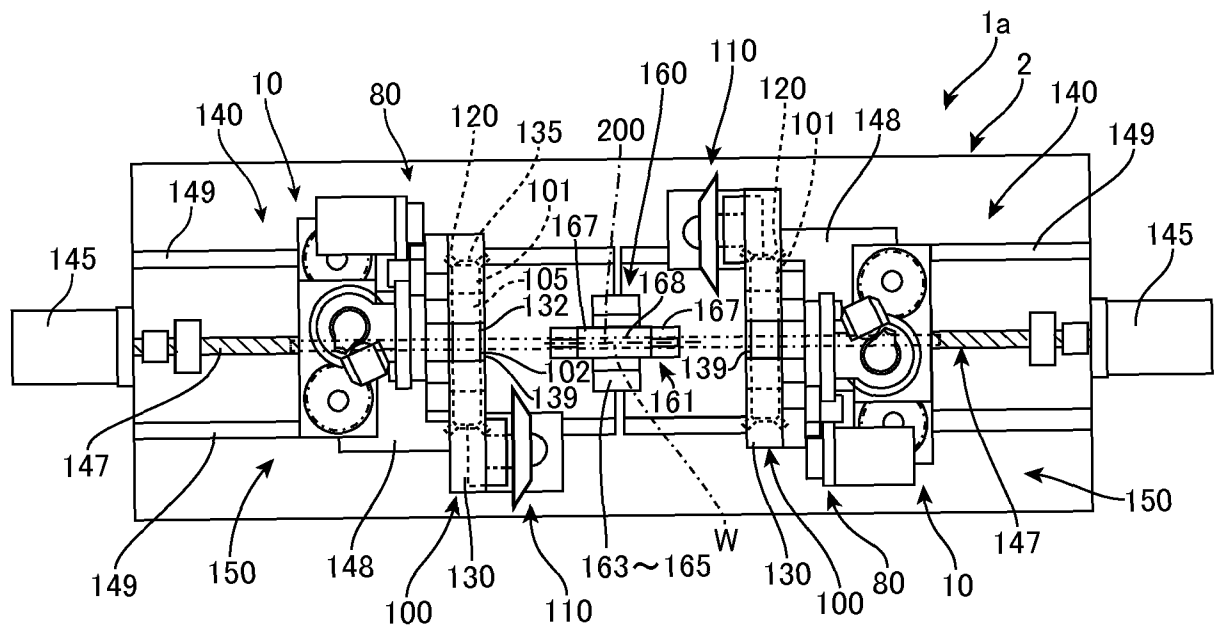


Fig. 18

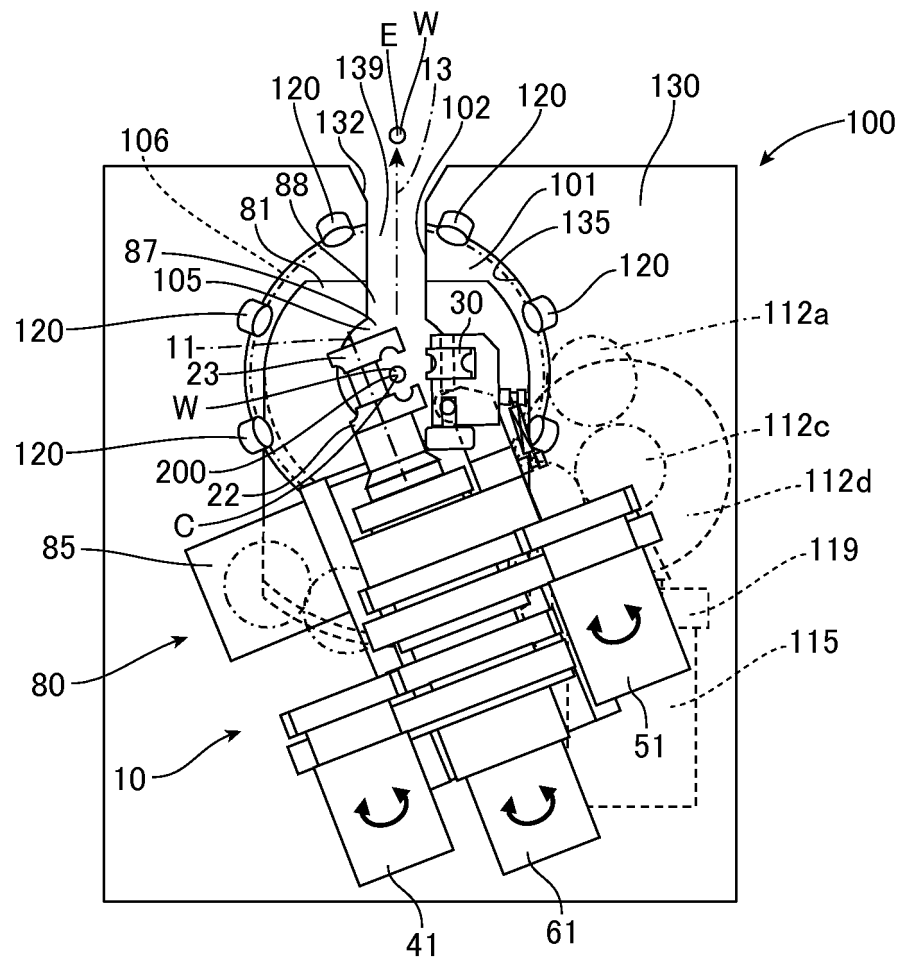


Fig. 19

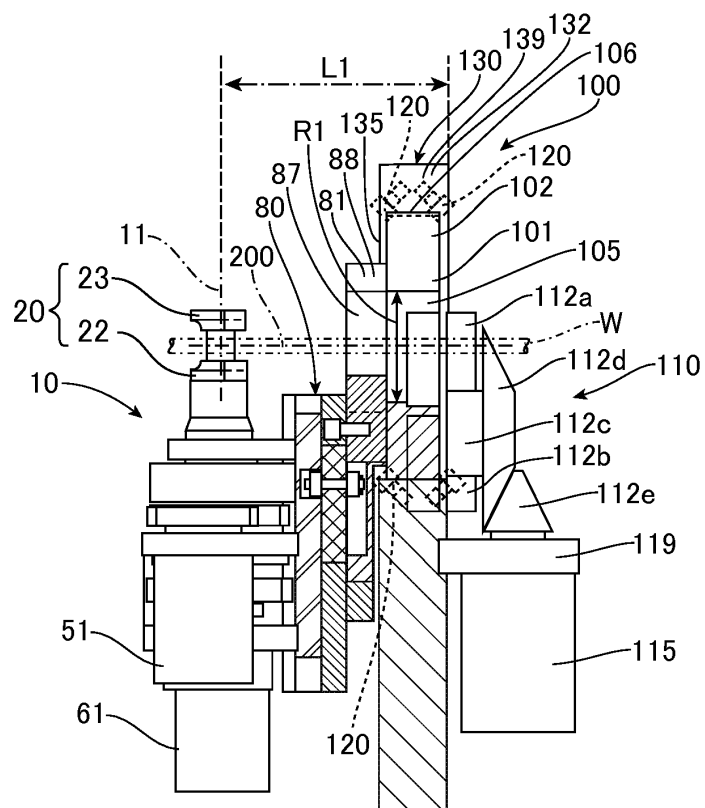


Fig. 20

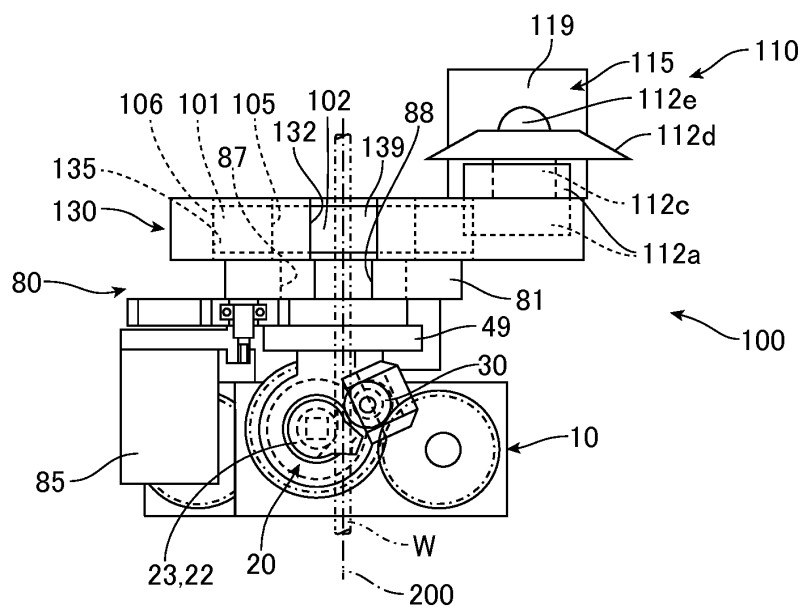


Fig. 21

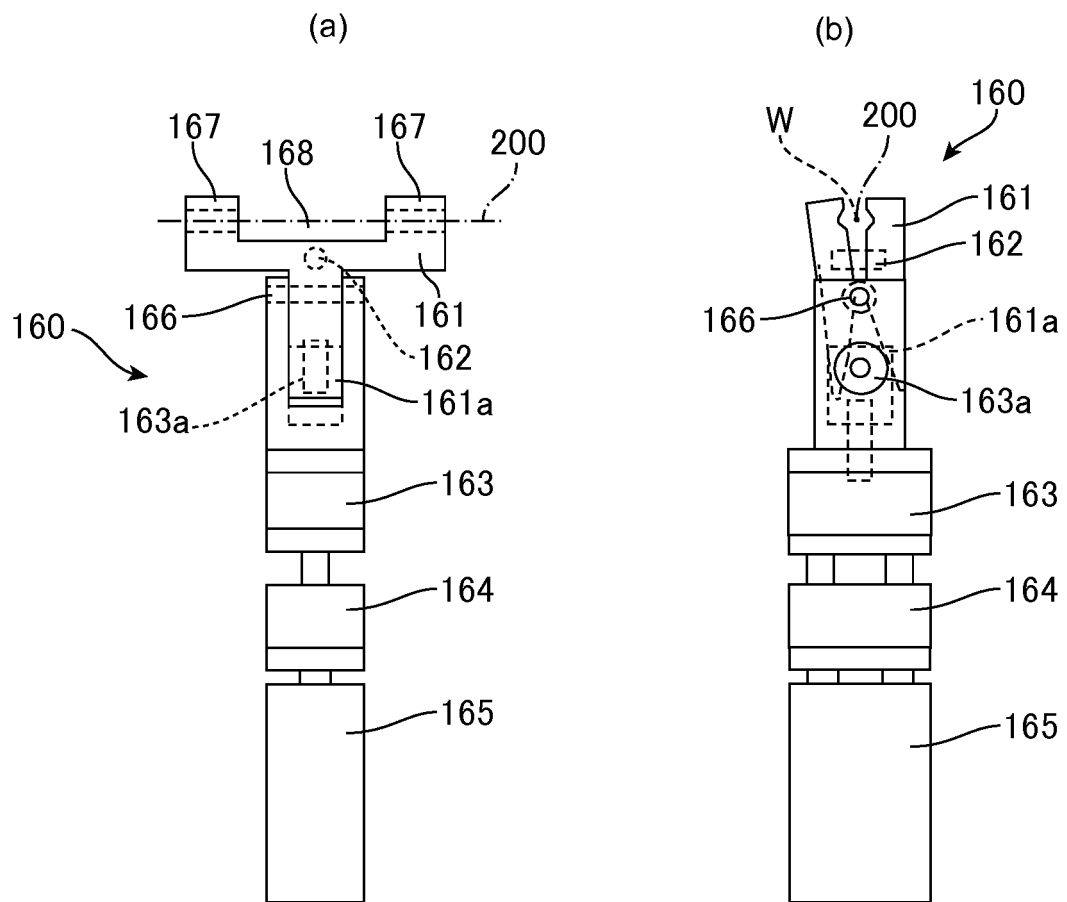


Fig. 22

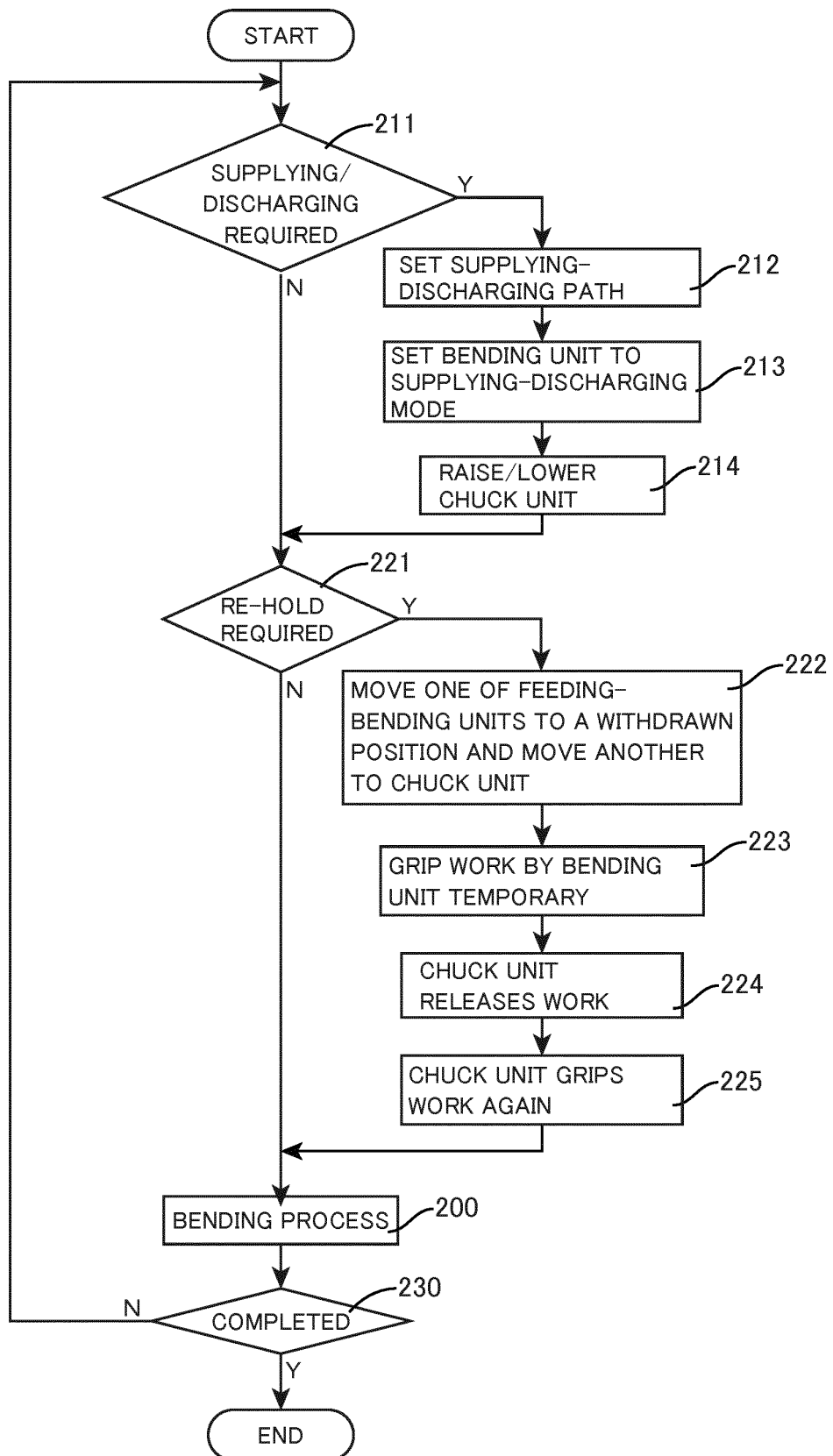


Fig. 23

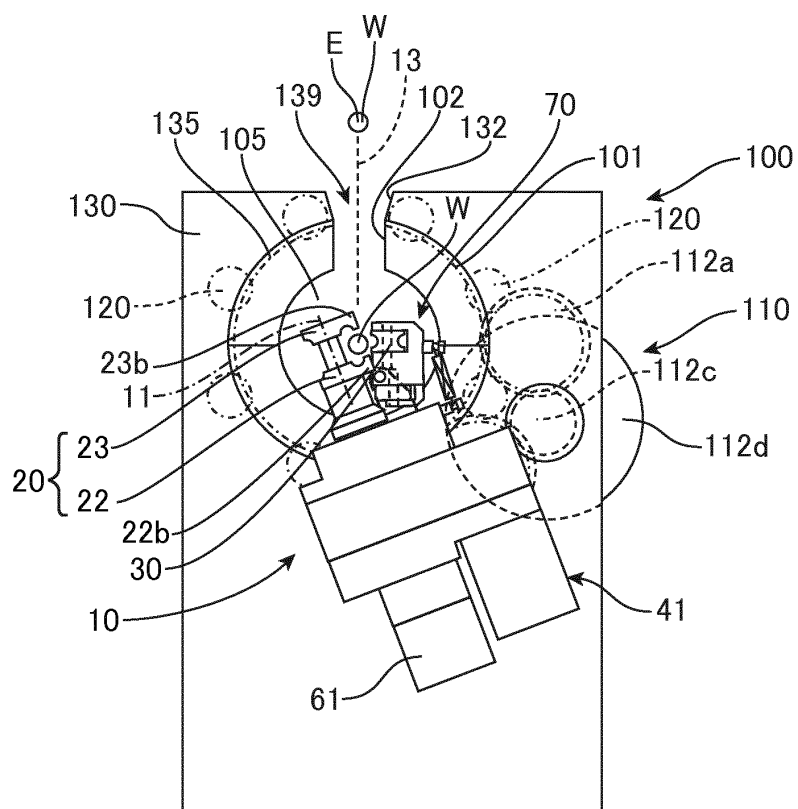


Fig. 24

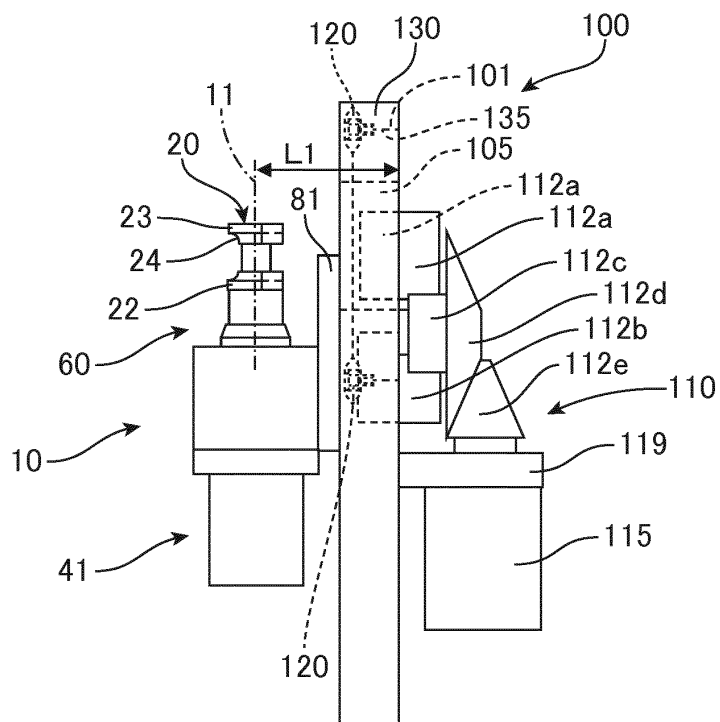


Fig. 25

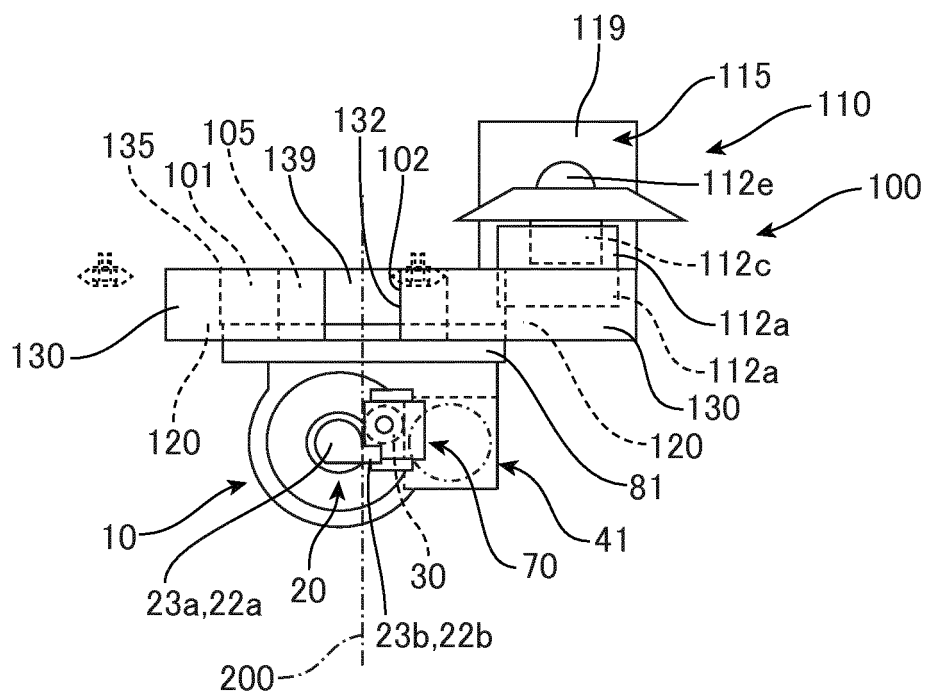


Fig. 26

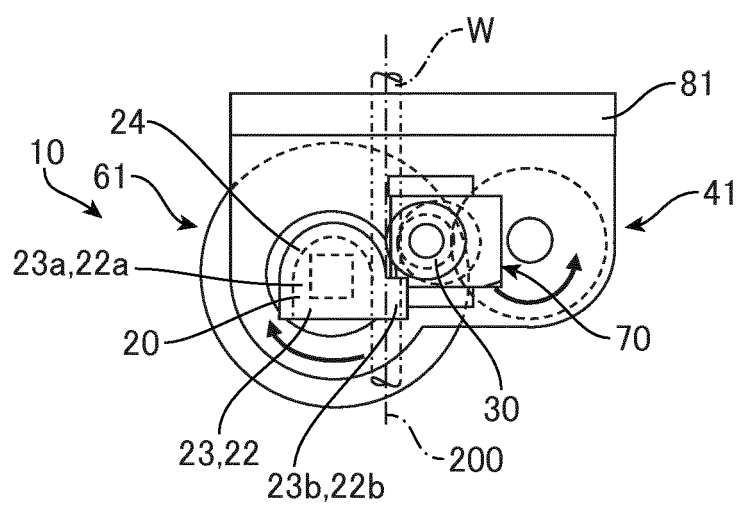


Fig. 27

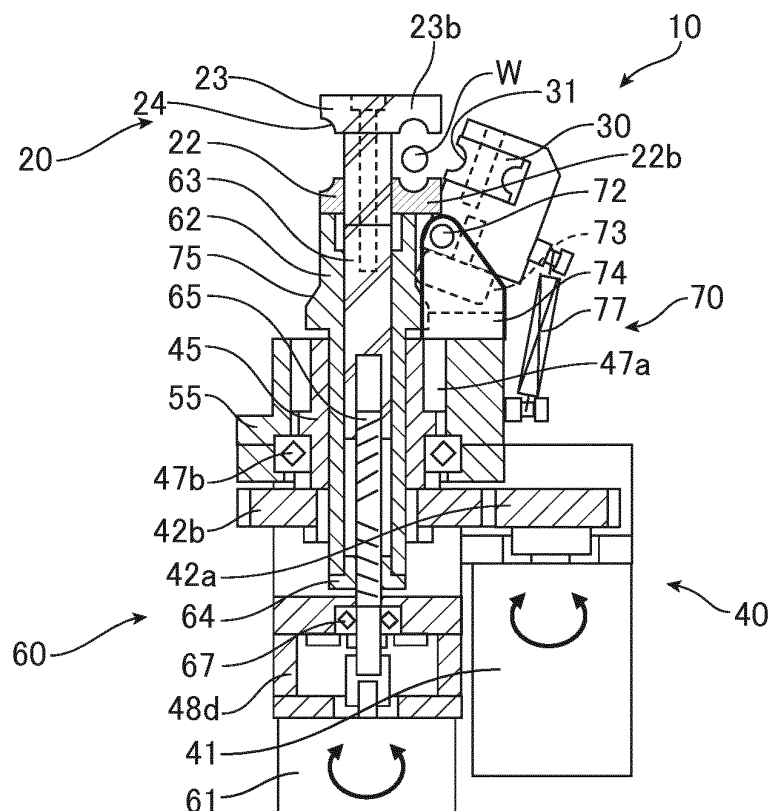
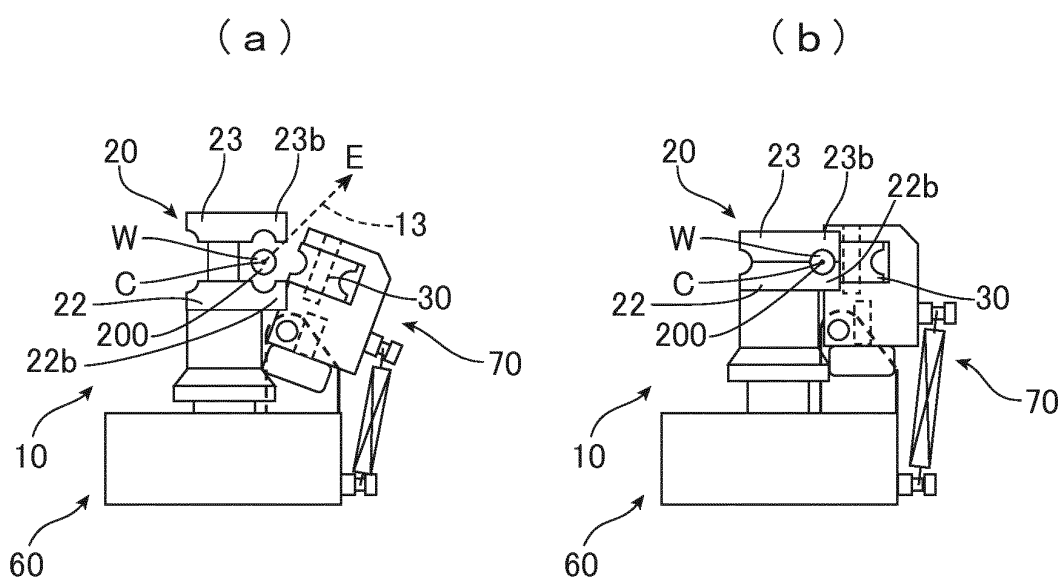


Fig. 28



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/004995

A. CLASSIFICATION OF SUBJECT MATTER

B21D7/025(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)

B21D7/025

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

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 62-296916 A (Mitsubishi Heavy Industries, Ltd.), 24 December 1987 (24.12.1987), claims; page 1, upper right column, line 12 to page 3, upper right column, line 19; fig. 1 to 6 (Family: none)	1-2, 16 4, 6-7, 9-10, 14-15
Y	JP 8-309438 A (Kyowa Machine Co., Ltd.), 26 November 1996 (26.11.1996), paragraph [0019] (Family: none)	4, 6-7, 9-10, 14-15

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

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Date of the actual completion of the international search
08 December, 2014 (08.12.14)Date of mailing of the international search report
16 December, 2014 (16.12.14)Name and mailing address of the ISA/
Japanese Patent Office

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2014/004995

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2009/0126438 A1 (NUMALLIANCE), 21 May 2009 (21.05.2009), fig. 2, 10 to 14 & EP 2012945 A & WO 2007/122346 A1 & FR 2900077 A1 & CA 2641071 A & BR PI0708936 A	6-7, 10, 14-15
Y	JP 46-6857 B1 (Fosta Hoirra Corp.), 20 February 1971 (20.02.1971), fig. 15 to 16 (Family: none)	9-10, 14-15
Y	JP 62-267020 A (Kabushiki Kaisha Chuo Denki Seisakusho), 19 November 1987 (19.11.1987), claims; page 3, upper right column, line 10 to page 4, upper left column, line 10; fig. 1 to 5 (Family: none)	14-15
A	EP 1561522 A1 (BEND HOLDING B.V.), 10 August 2005 (10.08.2005), entire text & DE 602005003378 D & NL 1025410 C1	1-19

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- JP H11138215 B [0002]
- JP 2003305518 A [0003]