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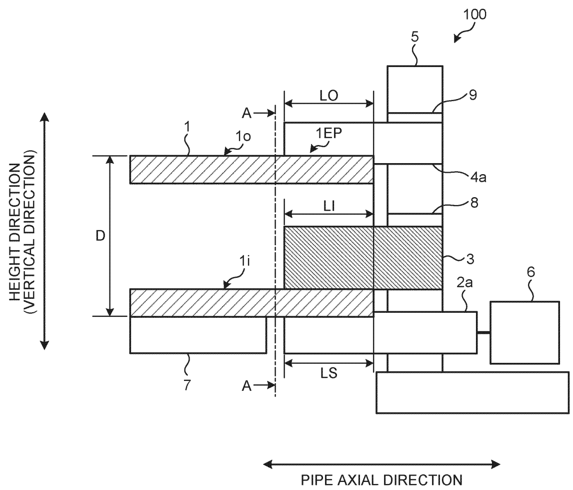
(54) **STEEL PIPE END PROCESSING DEVICE, STEEL PIPE END PROCESSING METHOD, AND STEEL PIPE MANUFACTURING METHOD**

(57) A processing apparatus for a steel pipe end portion is a processing apparatus for a steel pipe end portion that processes a pipe end portion of a steel pipe. The processing apparatus includes: two support rolls each being in contact with an outer circumferential face of a steel pipe end portion and configured to support a steel pipe from below; one inner face pressing roll being configured to press the steel pipe end portion at an intermediate position between the two support rolls from an inner circumferential face side of the steel pipe end portion; two outer face pressing rolls each being in contact with an outer circumferential face of the steel pipe end portion and configured to press the steel pipe end portion from above; and a rotation drive unit being configured to rotate the steel pipe.

FIG.1



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Description

Field

[0001] The present invention relates to a processing apparatus for a steel pipe end portion, a processing method for a steel pipe end portion, and a manufacturing method for a steel pipe.

Background

[0002] A steel pipe, particularly a large-diameter steel pipe such as a UOE steel pipe, is used as line pipes, oil country tubular goods, column materials, and the like by connecting an end portion in the axial center direction thereof to other steel pipes. In this case, once a level difference is generated at the time of connecting the end portions of steel pipes to each other, stress concentration is likely to occur at such a portion, and the portion tends to be a starting point of fracture. Therefore, it is desired to provide a steel pipe in which a level difference is less likely to be generated even when the end portions of steel pipes are connected to each other. The level difference of steel pipes is caused in part by unfavorable roundness at the end portion of a steel pipe. Poor roundness at a steel pipe end portion may lead to a situation where, for example, the thread height or the thread depth of a screw is insufficient to obtain a desired screw shape in threading the end portion of a steel pipe.

[0003] For the purpose of improving the roundness of a steel pipe end portion, the following method has been proposed: at least a pair of correction rolls are disposed on the inner circumferential face side and the outer circumferential face side of the steel pipe end portion, and repeated bending is applied along the circumferential direction of the steel pipe end portion while rotating a steel pipe.

[0004] For example, Patent Literature 1 discloses a method in which two correction rolls are disposed on each of the inner circumferential face side and the outer circumferential face side of a steel pipe end portion, and bending-unbending deformation is applied along the circumferential direction of the steel pipe end portion according to the principle of a three-roll bender. In this case, the roundness of a steel pipe end portion is improved by a first bending correction for applying a curvature larger than the target curvature along the rotation direction of a steel pipe and a second bending correction for bringing the curvature of a steel pipe end portion close to the target curvature.

[0005] Patent Literature 2 discloses a method in which a ring-shaped casing is used and a steel pipe end portion is inserted into an inner circumferential face of a casing and pressed by a correction roll from an inner circumferential face side of the steel pipe end portion to plastically deform the steel pipe end portion. Patent Literature 2 states that the use of the method disclosed in Patent Literature 2 deforms the steel pipe end portion so as to follow the inner circumferential face of the casing and improves the roundness of a steel pipe end portion.

[0006] Patent Literature 3 discloses equipment in which two support rolls that are in contact with the outer circumferential face of the steel pipe end portion and support a steel pipe end portion from below are disposed at an interval in the pipe circumferential direction, and one pressing roll in contact with the inner circumferential face is disposed at the intermediate position between the two support rolls in the pipe circumferential direction. Patent Literature 3 states that the use of the equipment disclosed in Patent Literature 3 to make a configuration capable of changing the interval between the two support rolls, so that the correction effect can be improved, and the roundness of the steel pipe end portion can be improved.

Citation List

Patent Literature

[0007]

Patent Literature 1: JP H06-198337 A
Patent Literature 2: JP 2012-223817 A
Patent Literature 3: JP 2003-170223 A

Summary

Technical Problem

[0008] In the method disclosed in Patent Literature 1, a plurality of rolls are inserted into the inner circumferential face side of a steel pipe end portion to correct the steel pipe end portion. However, this method complicates the structure of equipment for disposing the plurality of rolls on the inner circumferential face side of a steel pipe having a limited space.

Since the plurality of rolls placed on the inner circumferential face side of the steel pipe end portion needs to be disposed along the inner diameter of the steel pipe end portion, this method requires to replace a support unit that supports the plurality of rolls, in accordance with the inner diameter of a steel pipe to be corrected. For this reason, this method has such a problem that every time the inner diameter of a steel pipe to be corrected changes, this method takes time for replacement work of the support unit, and production efficiency decreases. Furthermore, when a plurality of rolls are disposed, the roll diameter on the inner circumferential face side needs to be reduced, but the roll on the inner circumferential face side deflects when the load necessary for correction increases. For this reason, this method has another problem in that a necessary load may not be applied, and a sufficient correction effect cannot be obtained.

[0009] In the method disclosed in Patent Literature 2, the outer diameter of a steel pipe is determined by the diameter of the inner circumferential face of the casing. Therefore, in the method disclosed in Patent Literature 2 a casing conforming to the outer diameter of a steel pipe to be processed is needed. Thus, the method disclosed in Patent Literature 2 has such a problem that a plurality of the casings corresponding to the number of outer diameters of steel pipes to be manufactured need to be prepared, and manufacturing costs increase. This method has another problem in that changing the outer diameter of a steel pipe requires replacement work of the casing, and thus, production efficiency of a steel pipe decreases.

[0010] The equipment disclosed in Patent Literature 3 applies bending deformation to a steel pipe end portion by two support rolls and a pressing roll on the inner circumferential face side disposed between the two support rolls. This configuration can apply deformation of bending a steel pipe end portion so as to project toward the outer circumferential face (deformation of increasing the curvature of a steel pipe in the circumferential direction). However, bending deformation that reduces the curvature of a steel pipe end portion in the circumferential direction cannot be applied. Therefore, this method has room for improvement in that a sufficient correction effect cannot be obtained when the curvature of a steel pipe end portion in the circumferential direction before correction is larger than the target curvature.

[0011] The present invention has been made in view of the above-described problems, and an object thereof is to provide a processing apparatus for a steel pipe end portion, a processing method for a steel pipe end portion, and a manufacturing method for a steel pipe, all of which can effectively improve the roundness of a steel pipe end portion.

Solution to Problem

[0012] To solve the problem and achieve the object, a processing apparatus for a steel pipe end portion, according to the present invention, is the processing apparatus being configured to process a pipe end portion of a steel pipe. The processing apparatus includes: two support rolls each being in contact with an outer circumferential face of a steel pipe end portion, the two support rolls each being configured to support a steel pipe from below; one inner face pressing roll configured to press the steel pipe end portion at an intermediate position between the two support rolls from an inner circumferential face side of the steel pipe end portion; two outer face pressing rolls each being in contact with the outer circumferential face of the steel pipe end portion, the two outer face pressing rolls each being configured to press the steel pipe end portion from above; and a rotation drive unit configured to rotate the steel pipe.

[0013] Moreover, the processing apparatus may further include: an inner face pressing control unit configured to control an amount of pressing by the one inner face pressing roll; and an outer face pressing control unit configured to control an amount of pressing by the two outer face pressing rolls.

[0014] Moreover, the processing apparatus may further include an amount-of-pressing setting unit configured to calculate and set a set value of the amount of pressing by the one inner face pressing roll, and a set value of the amount of pressing by the two outer face pressing rolls.

[0015] Moreover, in the processing apparatus, the two outer face pressing rolls may be disposed such that angles are both less than 45 [°], where the angles are respectively formed by a perpendicular line of a baseline based on the two support rolls, and straight lines connecting a center point of the steel pipe end portion and respective contact points of the two outer face pressing rolls with the steel pipe end portion.

[0016] Moreover, in the processing apparatus, a length over which the two support rolls are in contact with the steel pipe end portion in a pipe axial direction, a length over which the one inner face pressing roll is in contact with the steel pipe end portion in the pipe axial direction, and a length over which the two outer face pressing rolls are in contact with the steel pipe end portion in the pipe axial direction may be 0.2D or more with respect to a pipe outer diameter D of the steel pipe.

[0017] Moreover, a processing method for a steel pipe end portion, according to the present invention, is the processing method for processing a pipe end portion of a steel pipe. The processing method includes: a rotation driving step of rotating a steel pipe placed on two support rolls each being in contact with an outer circumferential face of a steel pipe end portion, the two support rolls each being configured to support the steel pipe from below; and a roll pressing step of pressing the steel pipe end portion by using one inner face pressing roll being disposed at an intermediate position between the two support rolls, and two outer face pressing rolls each being disposed above and each being in contact with the outer circumferential face of the steel pipe end portion, wherein the roll pressing step includes: an inner face pressing step of pressing the steel pipe end portion from an inner circumferential face side of the steel pipe end portion by the one inner face pressing roll; and an outer face pressing step of pressing the steel pipe end portion by the two outer face pressing rolls.

[0018] Moreover, the processing method may further include: a processing step of applying at least one full rotation to the steel pipe while maintaining pressing with respect to the steel pipe end portion by the one inner face pressing roll and the two outer face pressing rolls; and a roll releasing step of releasing the one inner face pressing roll and the two outer face pressing rolls.

[0019] Moreover, in the processing method, at least one set value of an amount of pressing the steel pipe end portion by the one inner face pressing roll and an amount of pressing the steel pipe end portion by the two outer face pressing rolls in the processing step may be set in accordance with attribute information of the steel pipe.

[0020] Moreover, a manufacturing method for a steel pipe, according to the present invention, includes manufacturing a steel pipe using the processing method according to the present invention.

Advantageous Effects of Invention

[0021] The processing apparatus for a steel pipe end portion, the processing method for a steel pipe end portion, and the manufacturing method for a steel pipe according to the present invention have an effect of effectively improving the roundness of a steel pipe end portion.

Brief Description of Drawings

[0022]

FIG. 1 is a side view of a processing apparatus for a steel pipe end portion according to an embodiment.

FIG. 2 is a view of the steel pipe end portion as viewed from a cross section in the pipe axial direction, taken along line A-A in FIG. 1.

FIG. 3 is a view for explaining an example of a support mechanism for an inner face pressing roll and outer face pressing rolls and an adjustment mechanism for an amount of pressing, in a roll support unit.

FIG. 4 is a view for explaining another example of the support mechanism for the inner face pressing roll and the outer face pressing rolls and the adjustment mechanism for an amount of pressing, in the roll support unit.

FIG. 5 is a view for explaining a positional relationship of rolls in the processing apparatus for the steel pipe end portion according to the embodiment.

FIG. 6 is a diagram for explaining a control device included in the processing apparatus for the steel pipe end portion according to the embodiment.

FIG. 7 is a diagram for explaining a processing method for the steel pipe end portion according to the embodiment.

FIG. 8 is a view for explaining a deformed state of the steel pipe end portion when the steel pipe end portion is pressed from the inner circumferential face side of the steel pipe end portion by the inner face pressing roll disposed at the intermediate position between the support rolls.

FIG. 9 is a view for explaining a deformed state of the steel pipe end portion when the steel pipe end portion is pressed by the two outer face pressing rolls disposed above and being in contact with the outer circumferential face of the steel pipe end portion.

FIG. 10 is a view for explaining a deformation of the steel pipe end portion due to both of the pressing to the steel pipe end portion by the inner face pressing roll and the pressing to the steel pipe end portion by the outer face pressing rolls.

Description of Embodiments

[0023] Hereinafter, an embodiment of a processing apparatus for a steel pipe end portion, a processing method for a steel pipe end portion, and a manufacturing method for a steel pipe according to the present invention. Note that the present invention is not limited by the present embodiment.

[0024] FIG. 1 is a side view of a processing apparatus 100 for a steel pipe end portion 1EP according to the embodiment. FIG. 2 is a view of the steel pipe end portion 1EP as viewed from a cross section in the pipe axial direction, taken along line A-A in FIG. 1.

[0025] In the present embodiment, the steel pipe end portion 1EP represents one end portion of a steel pipe 1, and refers to the range from the pipe end of the steel pipe 1 to a position away from the pipe end by a distance of about twice a pipe outer diameter D along the pipe axial direction. The processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment is an apparatus that performs processing for improving roundness on the entire range or a partial range of the steel pipe end portion 1EP described above. In the present embodiment, the pipe end of the steel pipe 1 refers to the endmost portion of the steel pipe end portion 1EP.

[0026] As illustrated in FIGS. 1 and 2, the processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment includes two support rolls 2a and 2b that are in contact with an outer circumferential face 1o of the steel pipe end portion 1EP and support the steel pipe 1 from below. The processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment further includes one inner face pressing roll 3 that presses the steel pipe end portion 1EP from an inner circumferential face 1i side of the steel pipe end portion 1EP at the intermediate position between the two support rolls 2a and 2b. The processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment further includes two outer face pressing rolls 4a and 4b that are in contact with the outer circumferential face 1o of the steel pipe end portion 1EP and press the steel pipe end portion 1EP from above. The processing apparatus 100 of the steel pipe end portion 1EP according to the embodiment further includes a rotation drive unit 6 that is a rotation drive unit configured to rotate the steel pipe 1.

[0027] The support rolls 2a and 2b, the inner face pressing roll 3, and the outer face pressing rolls 4a and 4b are disposed in parallel to the pipe axial direction of the steel pipe 1 and each have a structure rotatable with respect to the respective shaft centers. A roll support unit 5 illustrated in FIG. 1 includes an inner face pressing unit 8 that supports the inner face pressing roll 3 and moves the inner face pressing roll 3 in the vertical direction. The roll support unit 5 further includes an outer face pressing unit 9 that supports the outer face pressing rolls 4a and 4b and moves the outer face pressing rolls 4a and 4b in the vertical direction. Note that the support rolls 2a and 2b may be supported by the roll support unit 5 but may be directly installed on a factory floor or the like separately from the roll support unit 5.

[0028] The support rolls 2a and 2b are rolls that support the steel pipe end portion 1EP of the steel pipe 1. The support rolls 2a and 2b do not need to support the steel pipe 1 as a whole and may be any configuration that supports the steel pipe end portion 1EP so that the steel pipe end portion 1EP is held horizontally. In this case, as illustrated in FIG. 1, the steel pipe 1 is supported as a whole by a steel pipe support unit 7. Preferably, the steel pipe support unit 7 rotatably supports the steel pipe 1 by a pair of rolls the same as or similar to the support rolls 2a and 2b.

[0029] As illustrated in FIG. 1, the support rolls 2a and 2b are disposed so as to be in contact with the steel pipe end portion 1EP in the range of a certain length LS from one pipe end of the steel pipe 1 in the pipe axial direction. The length LS over which the support rolls 2a and 2b support the steel pipe end portion 1EP is preferably in a range of 0.2D or more, more preferably in a range of 1.0D or more with respect to the pipe outer diameter D of the steel pipe 1. The length LS is still more preferably 2.0D or more, which makes it possible to support the entire steel pipe end portion 1EP. The reason for this is to reliably support the steel pipe end portion 1EP.

[0030] As illustrated in FIG. 2, the inner face pressing roll 3 is disposed such that a rotation center O_3 of the inner face pressing roll 3 is positioned at the intermediate position between a rotation center O_{2a} of the support roll 2a and a rotation center O_{2b} of the support roll 2b in the arrangement direction of the support rolls 2a and 2b (horizontal direction) orthogonal to the pipe axial direction. With this arrangement, the inner face pressing roll 3 presses the steel pipe end portion 1EP downward from the inner circumferential face 1i side of the steel pipe 1. Note that the intermediate position between the support rolls 2a and 2b means that the position of the rotation center O_3 of the inner face pressing roll 3 in the horizontal direction is at the midpoint between the positions of the rotation centers O_{2a} and O_{2b} of the two support rolls 2a and 2b in the horizontal direction.

[0031] As illustrated in FIG. 2, the outer face pressing rolls 4a and 4b are disposed so as to be in contact with the outer circumferential face 1o of the steel pipe end portion 1EP and to press the steel pipe end portion 1EP from above. Note that "above the steel pipe end portion 1EP" means at least an upper side in the height direction than a straight line L1 extending in the horizontal direction and passing through a rotation center O_1 of the steel pipe end portion 1EP. Positions at which the outer face pressing rolls 4a and 4b are in contact with the outer circumferential face 1o of the steel pipe end portion 1EP will be described later.

[0032] In the processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment, the positions of the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b are set so as to perform processing in a predetermined range of the steel pipe end portion 1EP.

[0033] As illustrated in FIG. 1, a length LI of the inner face pressing roll 3 in contact with the inner circumferential face 1i of the steel pipe end portion 1EP from the pipe end of the steel pipe 1 along the pipe axial direction is preferably in a range of 0.2D or more, more preferably in a range of 1.0D or more with respect to the pipe outer diameter D of the steel pipe 1. The length LI is preferably equal to or larger than the support length LS of the steel pipe end portion 1EP by the support rolls 2a and 2b. The reason for this is to effectively apply bending deformation to the steel pipe end portion 1EP by the inner face pressing roll 3.

[0034] On the other hand, as illustrated in FIG. 1, a length LO of each of the outer face pressing rolls 4a and 4b in contact with the outer circumferential face 1o of the steel pipe end portion 1EP along the pipe axial direction of the steel pipe end portion 1EP is preferably in a range of 0.2D or more, more preferably in a range of 1.0D or more with respect to the pipe outer diameter D of the steel pipe 1. The length LO is preferably equal to or larger than the length LI over which the inner face pressing roll 3 is in contact with the inner circumferential face 1i of the steel pipe end portion 1EP from the pipe end of the steel pipe 1 along the pipe axial direction (a length over which the inner face pressing roll 3 presses the steel pipe end portion 1EP on the inner circumferential face 1i side of the steel pipe 1). The reason for this is to apply effective unbending deformation by the outer face pressing rolls 4a and 4b to the range of the steel pipe end portion 1EP to which the bending deformation is applied by pressing by the inner face pressing roll 3.

[0035] Provided, however, that the lengths LI and LO over which the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b are in contact with the steel pipe end portion 1EP from the pipe end in the pipe axial direction can be freely set. In this case, a mechanism that can adjust the position of the steel pipe end portion 1EP by moving the steel pipe 1 in the pipe axial direction with respect to the steel pipe support unit 7 can be used. The roll support unit 5 may be movable in the pipe axial direction of the steel pipe 1 together with the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b. To this end, the roll support unit 5 may have a structure that can adjust the position of the roll support unit 5 by placing the roll support unit 5 on the track of the movement.

[0036] As illustrated in FIG. 1, the processing apparatus 100 of the steel pipe end portion 1EP according to the embodiment includes the rotation drive unit 6 that rotates the steel pipe 1. In the present embodiment, the support roll 2a is used as a drive roll, and the support roll 2a is rotationally driven by the rotation drive unit 6 to rotate the steel pipe 1.

[0037] Note that the rotation drive unit 6 may adopt a system of rotating the steel pipe 1 by rotationally driving at least one of the support rolls 2a and 2b, the inner face pressing roll 3, and the outer face pressing rolls 4a and 4b as a driving roll. In this case, the rotation drive unit 6 can employ a system in which the shaft end portion of the drive roll to be rotationally driven is connected to the driving electric motor via a decelerator, as necessary, and the rotation of the drive roll is controlled by controlling the output of the driving electric motor. As the roll to be rotationally driven by the rotation drive unit 6, the steel pipe 1 is preferably rotated by selecting one or both of the support rolls 2a and 2b as the drive roll. This is because the frictional force for rotating the steel pipe 1 is increased due to the own weight of the steel pipe 1, the slipping between the drive roll and the steel pipe 1 is prevented, and stable rotation of the steel pipe 1 is easily achieved. Provided, however, that the rotation drive unit 6 may be a mechanism that rotates a roll constituting the steel pipe support unit 7, or may be a system that rotates the steel pipe 1 using a mechanism that directly holds the steel pipe 1.

[0038] Note that FIG. 1 illustrates the processing apparatus 100 of the steel pipe end portion 1EP for one pipe end portion of the steel pipe 1 in the pipe axial direction, but the similar processing apparatus 100 may be disposed also for the other end portion of the steel pipe 1 in the pipe axial direction.

[0039] FIG. 3 is a view for explaining an example of a support mechanism for the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b and the adjustment mechanism for an amount of pressing, in the roll support unit 5. FIG. 4 is a view for explaining another example of the support mechanism for the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b and the adjustment mechanism for an amount of pressing, in the roll support unit 5.

[0040] One end portion of the inner face pressing roll 3 is supported by a bearing (not illustrated), and the bearing is held by an inner face roll chock 10. With this structure, the inner face pressing roll 3 is cantilevered by the roll support unit 5. The roll support unit 5 includes a guide unit (not illustrated) on the inner face side of a housing 51 of the roll support unit 5 so that the inner face pressing roll 3 is movable in the vertical direction.

[0041] The roll support unit 5 further includes: the inner face pressing unit 8 that changes the amount of pressing the steel pipe end portion 1EP by the inner face pressing roll 3; and an inner face pressing position detector 12 that detects a position of the inner face pressing roll 3 in the vertical direction.

[0042] In the example illustrated in FIG. 3, the housing 51 includes a housing beam 52 fixed to two support columns. The inner face pressing unit 8 is fixed to the housing beam 52 and has a structure in which the inner face pressing roll 3 can be moved in the vertical direction by the inner face pressing unit 8.

[0043] On the other hand, in the example illustrated in FIG. 4, the inner face pressing roll 3 can be moved in the vertical direction by the inner face pressing unit 8 fixed to the lower portion of the housing 51.

[0044] In any of the structures illustrated in FIGS. 3 and 4, the inner face pressing unit 8 moves the inner face pressing roll 3 in the vertical direction by changing the position of the inner face roll chock 10 in the vertical direction by using a drive source such as a hydraulic, pneumatic, or electric motor-based drive source.

[0045] The inner face pressing position detector 12 is a device that measures the relative displacement of the inner face pressing roll 3 with respect to the housing 51 that holds the inner face roll chock 10 by a contact or non-contact displacement sensor. Provided, however, that the relative displacement may be measured between the inner face pressing roll 3 and the support roll 2a or the support roll 2b as a fixing structure other than the housing 51.

[0046] The processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment further includes an inner face pressing control unit 13 that is an inner face pressing control unit configured to control the amount of pressing the steel pipe end portion 1EP by the inner face pressing roll 3. The inner face pressing control unit 13 controls the inner face pressing unit 8 so that the amount of pressing by the inner face pressing roll 3 reaches and maintains a predetermined value on the basis of the positional information of the inner face pressing roll 3 detected by the inner face pressing position detector 12.

[0047] The end portion of each of the outer face pressing rolls 4a and 4b is supported by a bearing (not illustrated), and the bearing is held by an outer face roll chock 11. With this structure, the outer face pressing rolls 4a and 4b are cantilevered by the roll support unit 5. The roll support unit 5 further includes a guide unit (not illustrated) on the inner face side of the housing 51 of the roll support unit 5 so that the outer face pressing rolls 4a and 4b are movable in the vertical direction.

[0048] The roll support unit 5 further includes: the outer face pressing unit 9 for changing the amount of pressing the steel pipe end portion 1EP by the outer face pressing rolls 4a and 4b; and an outer face pressing position detector 14 that detects a position of the outer face pressing rolls 4a and 4b in the vertical direction.

[0049] The outer face pressing unit 9 is a device that moves the outer face pressing rolls 4a and 4b in the vertical direction by changing the position of the outer face roll chock 11 in the vertical direction by using a drive source such as a hydraulic, pneumatic, or electric motor-based drive source.

[0050] The outer face pressing position detector 14 is a device that measures the relative displacement of the outer face pressing rolls 4a and 4b with respect to the housing 51 that holds the outer face roll chock 11 by a contact or non-contact displacement sensor. Provided, however, that the relative displacement may be measured between the outer face pressing rolls 4a and 4b and the support roll 2a or the support roll 2b as a fixing structure other than the housing 51.

[0051] The processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment further includes an outer face pressing control unit 15 that is an outer face pressing control unit configured to control the amount of pressing the steel pipe end portion 1EP by the outer face pressing rolls 4a and 4b. The outer face pressing control unit 15 controls the outer face pressing unit 9 so that the amount of pressing by the outer face pressing rolls 4a and 4b reaches and maintains a predetermined value on the basis of the positional information of the outer face pressing rolls 4a and 4b detected by the outer face pressing position detector 14.

[0052] Note that the processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment may be configured as follows. That is, the processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment includes the two outer face roll chocks 11 that hold the outer face pressing rolls 4a and 4b, respectively. The processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment further includes the outer face pressing unit 9 that can move each of the two outer face roll chocks 11 in the vertical direction. The processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment further includes the outer face pressing position detector 14 that detect the positional information of the outer face pressing rolls 4a and 4b. The processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment causes the outer face pressing control unit 15 to control the amount of pressing by each of the outer face pressing rolls 4a and 4b.

[0053] The inner face pressing unit 8 may have any structure as long as the inner face pressing unit 8 can move the inner face pressing roll 3 in the vertical direction, and the direction of applying pressing by the inner face pressing unit 8 and the moving direction of the inner face pressing roll 3 are not necessarily parallel to each other. This is because, for example, when the cam mechanism is employed as the inner face pressing unit 8, the direction of applying pressing by the inner face pressing unit 8 and the moving direction of the inner face pressing roll 3 are not parallel to each other.

[0054] Similarly, the outer face pressing unit 9 may have any structure as long as the outer face pressing unit 9 can move the outer face pressing rolls 4a and 4b in the vertical direction, and the direction of applying pressing by the outer face pressing unit 9 and the moving direction of the outer face pressing rolls 4a and 4b are not necessarily parallel to each other.

[0055] As described above, the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b are cantilevered by the roll support unit 5. In this case, the load applied when the inner face pressing roll 3 presses the steel pipe end portion 1EP is approximately 0.1 to 15 [MN], and the load applied when the outer face pressing rolls 4a and 4b press the steel pipe end portion 1EP is approximately 0.02 to 3 [MN]. Therefore, in order for the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b to be able to withstand such loads, a metal roll is preferably used, and a steel roll is more preferably used. Not only the solid roll but also the hollow roll may be applied to the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b in order to reduce the deflection due to the own weight of the roll. The inner face pressing roll 3 and the outer face pressing rolls 4a and 4b are not necessarily limited to metal rolls and may use rolls made of a material having constant rigidity with which deflection deformation of the rolls against the load can be reduced. For example, rolls made of a lightweight material such as a composite material containing carbon fibers may be used as the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b.

[0056] For the outer face pressing rolls 4a and 4b, a support mechanism for reducing the deflection deformation of the outer face pressing rolls 4a and 4b may be separately provided at a position different from the position supported by the outer face roll chock 11. For example, a reinforcing roll may be provided at an end portion of the outer face pressing rolls 4a and 4b opposite to the bearing portion, and the reinforcing roll may be supported by another housing (not illustrated) installed on a factory floor.

[0057] Note that the support rolls 2a and 2b, the inner face pressing roll 3, and the outer face pressing rolls 4a and 4b do not necessarily have a constant diameter along the axial center direction. For example, the following roll may be used. That is, the roll may have a larger roll diameter as the roll support unit 5 is away from the roll support unit 5 in the axial center direction in accordance with the deflection deformation of the roll cantilevered by the roll support unit 5. This is because the amount of pressing the steel pipe end portion 1EP by the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b can be adjusted to be constant along the pipe axial direction.

[0058] FIG. 5 is a view for explaining a positional relationship of rolls in the processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment.

[0059] FIG. 5 illustrates an example in which the support rolls 2a and 2b that support the steel pipe end portion 1EP are rolls having the same roll diameter, and the positions (heights) of the rotation centers of the rolls in the vertical direction are also the same. Here, a baseline BL1 based on the support rolls 2a and 2b is defined for the two support rolls 2a and 2b. The baseline BL1 based on the support rolls 2a and 2b refers to an upper tangent line among common tangent lines of two circles specified from the sectional shapes of the two support rolls 2a and 2b in a section perpendicular (orthogonal) to the pipe axial direction of the steel pipe end portion 1EP. In the example illustrated in FIG. 5, the baseline BL1 based on the support rolls 2a and 2b is a straight line extending in the horizontal direction.

[0060] In the present embodiment, an imaginary perfect circle having a diameter D0 corresponding to the outer diameter of the steel pipe 1 is assumed for the two support rolls 2a and 2b, and this perfect circle is referred to as an imaginary perfect circle 1A. The center of the circle when the imaginary perfect circle 1A is placed on the two support rolls 2a and 2b is referred to as a center point O_{1A} of the steel pipe end portion 1EP. Then, a coordinate system (x-y coordinate) is defined as follows: the center point O_{1A} of the steel pipe end portion 1EP is the origin, a direction perpendicular to the baseline BL1 based on the support rolls 2a and 2b and directed downward is a y-coordinate, and a direction orthogonal to the y-coordinate is an x-coordinate.

[0061] In this case, the inner face pressing roll 3 is disposed such that the x-coordinate of the rotation center O_3 of the inner face pressing roll 3 is at the midpoint between the two x-coordinates of the rotation centers O_{2a} and O_{2b} of the support rolls 2a and 2b. In this way, the inner face pressing roll 3 is disposed at the intermediate position between the two support rolls 2a and 2b in the horizontal direction. The direction in which the inner face pressing roll 3 moves when the inner face pressing roll 3 presses the steel pipe end portion 1EP is the positive direction (downward direction) of the y-axis. The amount of pressing by the inner face pressing roll 3 can be defined by the displacement amount of the inner face pressing roll 3 in the moving direction assuming that a reference (zero point) is a position where the inner circumferential face 1i of the steel pipe end portion 1EP and the inner face pressing roll 3 start to come into contact with each other. Assuming that the inner circumferential face 1i of the steel pipe end portion 1EP has a perfect circular shape, the zero point serving as a reference of the amount of pressing by the inner face pressing roll 3 may be a position where the perfect circular shape and the inner face pressing roll 3 are in contact with each other. In the following description, the amount of pressing by the inner face pressing roll 3 is also referred to as an inner face reduction amount. Note that, as can be seen from the arrangement illustrated in FIG. 5, a too large amount of pressing by the inner face pressing roll 3 causes interference between the support rolls 2a and 2b and the inner face pressing roll 3. Thus, the inner face reduction amount has an upper limit value.

[0062] The outer face pressing rolls 4a and 4b are disposed such that outer circumferential circles of the outer face pressing rolls 4a and 4b are in contact with the imaginary perfect circle 1A. In this case, the outer face pressing roll 4a and the outer face pressing roll 4b are not necessarily disposed bilaterally symmetrically. However, the outer face pressing rolls 4a and 4b are preferably disposed such that both Θ1 and Θ2 are less than 45 [°], where Θ1 and Θ2 are angles respectively formed by a perpendicular line PL1 of the baseline BL1 based on the support rolls 2a and 2b, and straight lines L2 and L3 connecting rotation centers O_{4a} and O_{4b} of the outer face pressing rolls 4a and 4b and the center point O_{1A} of the steel pipe end portion 1EP. In the example illustrated in FIG. 5, Θ1 is less than 45 [°], where Θ1 is the angle formed by the perpendicular line PL1 of the baseline BL1 based on the support rolls 2a and 2b, and the straight line L2 connecting the rotation center O_{4a} of the outer face pressing roll 4a and the center point O_{1A} of the steel pipe end portion 1EP. Moreover, Θ2 is less than 45 [°], where Θ2 is the angle formed by the perpendicular line PL1 of the baseline BL1 based on the support rolls 2a and 2b, and the straight line L3 connecting the rotation center O_{4b} of the outer face pressing roll 4b and the center point O_{1A} of the steel pipe end portion 1EP. This is because if either the angle Θ1 or the angle Θ2 is 45 [°] or more, the effect of pressing the steel pipe end portion 1EP in the downward direction is reduced, so that sufficient bending deformation cannot be applied to the steel pipe end portion 1EP. Provided, however, that, a too small center-to-center distance between the outer face pressing roll 4a and the outer face pressing roll 4b causes interference between the outer face pressing rolls 4a and 4b. Therefore, the lower limit value of the possible range of the angle Θ1 and the angle Θ2 is determined by a geometric relationship depending on the diameters of the outer face pressing rolls 4a and 4b and the diameter D0 of the imaginary perfect circle 1A.

[0063] The amount of pressing by the outer face pressing rolls 4a and 4b can be defined by the displacement amount of the outer face pressing rolls 4a and 4b in the positive direction of the y-axis (downward direction) in which the outer face pressing rolls 4a and 4b move, assuming that a reference (zero point) is a position where the outer circumferential face 1o of the steel pipe end portion 1EP and the outer face pressing rolls 4a and 4b come into contact with each other. Assuming that the outer circumferential face 1o of the steel pipe end portion 1EP has a perfect circular shape, the zero point serving as a reference of the amount of pressing by the outer face pressing rolls 4a and 4b may be a position where the perfect circular shape and the outer face pressing rolls 4a and 4b are in contact with each other. In the following description, the amount of pressing by the outer face pressing rolls 4a and 4b is also referred to as an outer face reduction amount. Note that the moving directions of the outer face pressing roll 4a and the outer face pressing roll 4b are not necessarily limited to the direction of the y-axis in FIG. 5. The outer face pressing roll 4a and the outer face pressing roll 4b may move in the direction toward the center point O_{1A} of the steel pipe end portion 1EP as the amount of pressing the steel pipe end portion 1EP increases. The outer face pressing roll 4a and the outer face pressing roll 4b may move toward a midpoint O_{22} of a straight line L4 connecting the rotation centers O_{2a} and O_{2b} of the support rolls 2a and 2b as the amount of pressing the steel pipe end portion 1EP increases. This is because the effect of deforming the steel pipe end portion 1EP as a whole is maintained even when pressing by the outer face pressing rolls 4a and 4b progresses, and thus the roundness of the steel pipe end portion 1EP is easily improved. Note that the outer face reduction amounts of the two outer face pressing rolls 4a and 4b are not necessarily the same. The outer face reduction amount may be set and controlled for each of the two outer face pressing rolls 4a and 4b.

[0064] Diameters D2a and D2b of the support rolls 2a and 2b can be any selected diameter as long as the pipe end portion of the steel pipe 1 can be supported. In the present embodiment, the diameters D2a and D2b of the support rolls 2a and 2b are preferably in the range of 0.1D0 to 0.5D0 with respect to the diameter D0 of the imaginary perfect circle 1A corresponding to the outer diameter of the steel pipe 1 to be processed. If the diameters D2a and D2b of the support rolls 2a and 2b are smaller than 0.1D0, the strength of the support rolls 2a and 2b may be insufficient to support the steel pipe end portion 1EP. If the diameters D2a and D2b of the support rolls 2a and 2b are larger than 0.5D0, the distance between two points where the support rolls 2a and 2b are in contact with the outer circumferential face 1o of the steel pipe end portion 1EP increases, and sufficient bending deformation may not be able to be applied to the steel pipe end portion 1EP by the inner face pressing roll 3. The interval between the rotation centers O_{2a} and O_{2b} of the support roll 2a and the support roll 2b (support roll interval) can be set to any roll interval (support roll interval) within a range in which the steel pipe end portion 1EP can be supported. The support roll interval in the present embodiment is preferably in the range of 0.2D0 to 0.7D0 with respect to the diameter D0 of the imaginary perfect circle 1A. The reason therefor is described as follows. If the support roll interval is smaller than 0.2D0, support for the steel pipe end portion 1EP by the support rolls 2a and 2b becomes unstable upon the rotation of the steel pipe 1, and the steel pipe 1 may fall from the support rolls 2a and 2b. If the support roll interval is larger than 0.7D, similarly to the above, sufficient bending deformation may not be able to be applied to the steel pipe end portion 1EP even when the inner face pressing roll 3 is pressed. Note that the diameters D2a and D2b of the support rolls 2a and 2b and the support roll interval are set so that the support roll 2a and the support roll 2b do not interfere with each other in terms of a geometric relationship.

[0065] A diameter D3 of the inner face pressing roll 3 can be any selected diameter as long as the inner face pressing roll 3 can be inserted into the inside of the steel pipe 1. In the present embodiment, the diameter D3 of the inner face pressing roll 3 is preferably in the range of 0.1D0 to 0.8D0 with respect to the diameter D0 of the imaginary perfect circle 1A. If the diameter D3 of the inner face pressing roll 3 is smaller than 0.1D0, the strength of the inner face pressing roll 3 may be insufficient when the steel pipe end portion 1EP is pressed. If the diameter D3 of the inner face pressing roll 3 is larger than 0.8D0, the upper limit value of the inner face reduction amount may be limited by the geometric relationship with the support rolls 2a and 2b upon pressing the steel pipe end portion 1EP by the inner face pressing roll 3. Furthermore, if the diameter D3 of the inner face pressing roll 3 is larger than 0.8D0, the bending curvature applied to the steel pipe end portion 1EP is substantially identical to the radius of the inner face pressing roll 3, and sufficient bending deformation may not be applied to the steel pipe end portion 1EP.

[0066] Diameters D4a and D4b of the outer face pressing rolls 4a and 4b can be any selected diameters as long as the purpose of pressing the steel pipe end portion 1EP from above the outer circumferential face 1o of the steel pipe end portion 1EP is achieved. In the present embodiment, the diameters D4a and D4b of the outer face pressing rolls 4a and 4b are preferably in the range of 0.1D0 to 0.5D0 with respect to the diameter D0 of the imaginary perfect circle 1A. This is because if the diameters D4a and D4b of the outer face pressing rolls 4a and 4b are smaller than 0.1D0, upon pressing the steel pipe end portion 1EP from the outer circumferential face 1o, the strength of the outer face pressing rolls 4a and 4b may be insufficient due to a reaction force against the pressing. If the diameter D4b of the outer face pressing roll 4b is larger than 0.5D0, Θ2 is increased, where Θ2 is the angle formed by the perpendicular line PL1 of the baseline BL1 based on the support rolls 2a and 2b, and the straight line L3 connecting the rotation center O_{4b} of the outer face pressing roll 4b and the center point O_{1A} of the steel pipe end portion 1EP. Therefore, if the diameter D4b of the outer face pressing roll 4b is larger than 0.5D0, the effect of deforming the steel pipe end portion 1EP so as to press the steel pipe end portion 1EP and increase the oblateness thereof as a whole may be deteriorated.

[0067] In the processing apparatus 100 of the steel pipe end portion 1EP illustrated in FIG. 5, the support roll 2a and the support roll 2b have the same roll diameter (diameter) and are disposed at the same height. However, the support roll 2a and the support roll 2b do not necessarily have the same roll diameter (diameter) and may not be disposed at the same height. In such a case, the baseline BL1 based on the support rolls 2a and 2b is not a line in the horizontal direction but a line having a constant inclination. Accordingly, the present invention may employ a configuration in which the whole is revolved so as to match the inclination of the baseline BL1 based on the support rolls 2a and 2b while maintaining the relative positional relationship of the rolls illustrated in FIG. 5. This is because the effect of improving the roundness of the steel pipe end portion 1EP does not change even when the entire roll arrangement is inclined as long as the support rolls 2a and 2b can support the steel pipe end portion 1EP upon rotationally driving the steel pipe 1.

[0068] FIG. 6 is a diagram for explaining a control device 20 included in the processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment.

[0069] The processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment includes the control device 20 for processing the steel pipe end portion 1EP. The control device 20 includes a placement setting unit 21 for setting an operation of placing the steel pipe 1 on the support rolls 2a and 2b. The control device 20 further includes a roll position setting unit 22 for setting pressing operations of the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b with respect to the steel pipe end portion 1EP. The control device 20 further includes a rotation operation setting unit 23 for setting the rotation operation of the steel pipe 1. The control device 20 is a computer system having an arithmetic processing function in order to implement functions of the placement setting unit 21, the roll position setting unit 22, and the rotation operation setting unit 23 on computer software, that is, by executing a computer-readable program. The computer system can implement the above-described functions on software by executing various dedicated computer programs stored in advance in hardware.

[0070] The placement setting unit 21 places the steel pipe 1 on the support rolls 2a and 2b and disposes the inner face pressing roll 3 so that the inner face pressing roll 3 is in contact with the steel pipe 1 over a predetermined range from the pipe end of the steel pipe 1 along the pipe axial direction. The operation of the inner face pressing roll 3 may be controlled so as to set the zero point of the inner face reduction amount through moving the inner face pressing roll 3 to a position in contact with the inner circumferential face 1i of the steel pipe end portion 1EP. The placement setting unit 21 adjusts the positions of the outer face pressing rolls 4a and 4b so that the outer face pressing rolls 4a and 4b are in contact with the steel pipe 1 over a predetermined range from the pipe end of the steel pipe 1 along the pipe axial direction. The operations of the outer face pressing rolls 4a and 4b may be controlled so as to set the zero point of the outer face reduction amount through moving the outer face pressing rolls 4a and 4b to come into contact with the outer circumferential face 1o of the steel pipe end portion 1EP.

[0071] The rotation operation setting unit 23 outputs a command, to the rotation drive unit 6 that rotates the steel pipe 1, to rotate the steel pipe 1 at a predetermined rotation speed. The rotation operation setting unit 23 may set the number of rotations and the rotation angle of the steel pipe 1 and issue a command to the rotation drive unit 6 to start or stop the rotation under the set conditions.

[0072] The roll position setting unit 22 includes an inner face pressing operation setting unit 221, an outer face pressing operation setting unit 222, and a pressing pattern setting unit 223.

[0073] The inner face pressing operation setting unit 221 outputs a command for controlling the position of the inner face pressing roll 3 to the inner face pressing control unit 13 so that the pressing to the steel pipe end portion 1EP by the inner face pressing roll 3 reaches and maintains a set inner face reduction amount. The inner face pressing operation setting unit 221 may set timing to start pressing by the inner face pressing roll 3 or timing to finish pressing and release the inner face pressing roll 3 in controlling the position of the inner face pressing roll 3. Alternatively, the inner face pressing operation setting unit 221 may set a speed of pressing by the inner face pressing roll 3 or a speed of releasing the inner face pressing roll 3 in controlling the position of the inner face pressing roll 3.

[0074] The outer face pressing operation setting unit 222 outputs a command for controlling the positions of the outer face pressing rolls 4a and 4b to the outer face pressing control unit 15 so that the pressing to the steel pipe end portion 1EP by the outer face pressing rolls 4a and 4b reaches and maintains a set outer face reduction amount. The outer face pressing operation setting unit 222 may set timing to start pressing by the outer face pressing rolls 4a and 4b or timing to finish pressing and release the outer face pressing rolls 4a and 4b in controlling the positions of the outer face pressing rolls 4a and 4b. Alternatively, the outer face pressing operation setting unit 222 may set a speed of pressing by the outer face pressing rolls 4a and 4b or a speed of releasing the outer face pressing rolls 4a and 4b in controlling the positions of the outer face pressing rolls 4a and 4b.

[0075] Note that, for the setting of the inner face reduction amount and the outer face reduction amount, for example, set values input by an operator for each steel pipe 1 to be processed can be used. In this case, the control device 20 is communicably connected to an input unit (not illustrated). The control device 20 sends the roll position setting unit 22 the respective set values of the inner face reduction amount and the outer face reduction amount input at the input unit, and the roll position setting unit 22 sets the operations of the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b.

[0076] The pressing pattern setting unit 223 is an amount-of-pressing setting unit configured to calculate and set a set value of the amount of pressing by the inner face pressing roll 3 (inner face reduction amount) and a set value of the amount of pressing by the two outer face pressing rolls 4a and 4b (outer face reduction amount). The pressing pattern setting unit 223 may set timing to start pressing, a pressing speed at which pressing is performed, and the like when the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b press the steel pipe end portion 1EP. The pressing pattern setting unit 223 may set the number of rotations of the steel pipe 1 when the steel pipe end portion 1EP is processed while maintaining a predetermined reduction amount, timing to end the pressing and release the rolls, a moving speed upon releasing the rolls, and the like.

[0077] The pressing pattern setting unit 223 accumulates past processing results for each of the steel pipes 1 to be processed and generates a setting table on the basis of the accumulated database. The pressing pattern setting unit 223 may set the inner face reduction amount and the outer face reduction amount in accordance with the steel pipe 1 to be processed. On the other hand, the pressing pattern setting unit 223 preferably calculates the inner face reduction amount and the outer face reduction amount in accordance with the attribute information of the steel pipe 1 to be processed. The attribute information of the steel pipe 1 refers to dimensional information and material information of the steel pipe 1. The dimensional information of the steel pipe 1 is information related to dimensions of the steel pipe 1, such as an outer diameter, an inner diameter, and a wall thickness of the steel pipe 1. The dimensional information of the steel pipe 1 may include information related to the roundness of the steel pipe end portion 1EP before processing and information related to the target roundness after processing. The material information of the steel pipe 1 is information related to mechanical properties of the steel pipe 1, such as yield stress, tensile strength, and hardness of the steel pipe 1. The attribute information of the steel pipe 1 affects the bending curvature, the unbending curvature, and the processing reaction force upon applying bending deformation to the steel pipe end portion 1EP in the circumferential direction, and affects the roundness of the processed steel pipe end portion 1EP.

[0078] The inner face reduction amount and the outer face reduction amount set by the pressing pattern setting unit 223 are preferably set on the basis of a condition that the surface of the steel pipe end portion 1EP yields when the steel pipe end portion 1EP to be processed is subjected to bending deformation and unbending deformation. This is because plastic deformation occurs at or near the surface of the steel pipe end portion 1EP, whereby the effect of uniformizing the curvature along the circumferential direction can be obtained.

[0079] The plastic deformation occurs at or near the surface of the steel pipe end portion 1EP due to, for example, applying a curvature change $\Delta\kappa 0$ represented in the following Mathematical Expression (1) to the steel pipe end portion 1EP, assuming that t is a pipe wall thickness of the steel pipe 1, E is a Young's modulus of the steel pipe 1, and Y is a yield strength of the steel pipe 1.

$$\Delta\kappa 0 = \frac{2Y}{Et} \qquad \cdots (1)$$

[0080] Therefore, the pressing pattern setting unit 223 set the inner face reduction amount such that a curvature change larger than the curvature change $\Delta\kappa 0$ represented in the above-described Mathematical Expression (1) occurs from the initial curvature of the steel pipe end portion 1EP. Specifically, all the diameters of the two support rolls 2a and 2b, the one inner face pressing roll 3, and the two outer face pressing rolls 4a and 4b are assumed to be 300 [mm]. When the distance between the rotation centers O_{2a} and O_{2b} of the support rolls 2a and 2b is 450 [mm], the inner face reduction amount of the steel pipe 1 having the outer diameter of 914.4 [mm], the pipe wall thickness of 38.1 [mm], and the yield strength of 450 [MPa] is preferably set to 1.7 [mm] or more. Provided, however, that an excessive inner face reduction amount makes the gap between the inner face pressing roll 3 and the support rolls 2a and 2b substantially equal to the pipe wall thickness, and thus the inner face reduction amount is preferably 50 [mm] or less.

[0081] On the other hand, the condition that the surface of the steel pipe end portion 1EP yields due to the pressing by the outer face pressing rolls 4a and 4b is obtained as follows. The relationship between the outer face reduction amount and the bending moment applied to the steel pipe end portion 1EP is calculated by numerical calculation on the basis of the theory regarding the elastic deflection deformation of the curved beam. Then, the outer face reduction amount is set such that the bending moment per unit length in the axial center direction of the steel pipe end portion 1EP is larger than an elastic limit bending moment Me of the following Mathematical Expression (2).

$$\mathrm{Me} = \frac{t^2}{6} Y \qquad \cdots (2)$$

[0082] The outer face reduction amount by the outer face pressing rolls 4a and 4b is preferably set to, for example, a value of 0.5 to 5 [%] with respect to the diameter D0 of the imaginary perfect circle 1A. This is because the steel pipe end portion 1EP is deformed so as to be pressed and to increase the oblateness thereof as a whole by the outer face pressing rolls 4a and 4b, and plastic deformation occurs at or near the surface of the steel pipe end portion 1EP. Specifically, in the above-described example, when the distance between the rotation centers O_{4a} and O_{4b} of the two outer face pressing rolls 4a and 4b is 450 [mm], the outer face reduction amount is preferably set to 4.5 [mm] or more. Provided, however, that an excessive outer face reduction amount makes the shape of the steel pipe end portion 1EP crushed due to the pressing by the outer face pressing rolls 4a and 4b, and effective processing cannot be performed. Therefore, the outer face reduction amount is preferably 45 [mm] or less.

[0083] The processing method for the steel pipe end portion 1EP according to the embodiment is performed by a process including a rotary driving step and a roll pressing step. In the rotary driving step, a rotation is applied to the steel pipe 1 placed on the two support rolls 2a and 2b that are in contact with the outer circumferential face 1o of the steel pipe end portion 1EP and support the steel pipe end portion 1EP from below. In the roll pressing step, the one inner face pressing roll 3 disposed at the intermediate position between the two support rolls 2a and 2b presses the steel pipe end portion 1EP from the inner circumferential face 1i side of the steel pipe end portion 1EP. At the same time, in the roll pressing step, the two outer face pressing rolls 4a and 4b disposed above and being in contact with the outer circumferential face 1o of the steel pipe end portion 1EP presses the steel pipe end portion 1EP. The processing method for the steel pipe end portion 1EP according to the embodiment preferably includes, after the roll pressing step, a processing step of applying at least one full rotation to the steel pipe 1 while maintaining the pressing by the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b. The processing method for the steel pipe end portion 1EP according to the embodiment preferably further includes, after the roll pressing step, a roll releasing step of releasing the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b. At least one of the inner face reduction amount and the outer face reduction amount in the roll pressing step is preferably set in accordance with the attribute information of the steel pipe 1 to be processed.

[0084] In the processing method for the steel pipe end portion 1EP according to the embodiment, the steel pipe 1 to be processed may be of any type as long as the steel pipe 1 is a metal pipe. Among them, a pipe to be processed is preferably a welded steel pipe. For a welded steel pipe, generally, an open pipe is formed by performing a U press, a press bending method, or the like on a steel plate serving as a material, butt welding is performed, and then pipe expansion using an expander is performed. In that case, pipe expansion is often performed by an expander including a plurality of divided dies. The shape of the steel pipe end portion 1EP in the circumferential direction tends to be polygonal, and there is a high need to improve roundness. Due to this factor, a welded steel pipe is preferred.

[0085] From the above-described viewpoints, the processing method for the steel pipe end portion 1EP according to the embodiment is preferably performed on the steel pipe 1 having an outer diameter of 400 to 1625.4 [mm], a pipe wall thickness of 6.35 to 50.8 [mm], a yield strength of 170 to 900 [MPa], and a tensile strength of 310 to 1033 [MPa]. This is because pipe expansion using an expander is generally performed in many cases. In particular, the steel pipe 1 having a yield strength of 414 [MPa] or more and a tensile strength of 517 [MPa] or more has a large springback, and the shape in the open pipe forming step and the pipe expanding step is likely to fluctuate. Thus, the processing method for the steel pipe end portion 1EP according to the embodiment is more preferably performed on the above-described steel pipe 1 having relatively high strength. When the steel pipe end portions 1EP are butted, the level difference of the steel pipe end portions 1EP may be managed so as to have a constant value (e.g., 2.4 [mm] or less). In this case, the ratio of the level difference to the outer diameter needs to be managed with higher accuracy as the outer diameter of the steel pipe end portion 1EP increases. Therefore, the processing method for the steel pipe end portion 1EP according to the embodiment is preferably applied to the steel pipe 1 in which the outer diameter of the steel pipe end portion 1EP is 600 [mm] or more. At the time of butting the steel pipe end portions 1EP, the steel pipe end portions 1EP need to be restrained for eliminating the level difference during construction. At this time, the steel pipes 1 having a large pipe wall thickness require that a very large restraint force be applied thereto. Therefore, the pipe wall thickness is preferably 19 [mm] or more from the viewpoint of ensuring good processability of the steel pipe end portion 1EP before construction for improving the roundness thereof. In this case, the processing method for the steel pipe end portion 1EP according to the embodiment is preferably applied to the steel pipe 1 in which the ratio of the pipe wall thickness to the outer diameter of the steel pipe end portion 1EP is 2.0 [%] or more.

[0086] FIG. 7 is a flowchart illustrating an example of control of the processing method for the steel pipe end portion 1EP according to the embodiment. In the processing method for the steel pipe end portion 1EP according to the embodiment illustrated in FIG. 7, a placing step S1 of the steel pipe 1, a rotation driving step S2 of the steel pipe 1, a roll pressing step S3, a processing step S4, and a roll releasing step S5 are performed.

[0087] The placing step S1 of the steel pipe 1 is a step of placing the steel pipe 1 to be processed on the support rolls 2a and 2b and performing the following setting. That is, in the placing step S1 of the steel pipe 1, the length of contact between the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b along the pipe axial direction of the steel pipe 1 is adjusted, and the reference points (zero points) of the amounts of pressing by the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b are set. The placing step S1 of the steel pipe 1 can be performed by the placement setting unit 21 in the control device 20. When the steel pipe 1 to be processed is placed in the processing apparatus 100 for the steel pipe end portion 1EP according to the embodiment and preparation for processing is completed, the placing step S1 of the steel pipe 1 ends, and the process proceeds to the rotation driving step S2 of the steel pipe 1.

[0088] The rotation driving step S2 is a step of rotating the steel pipe end portion 1EP supported by the support rolls 2a and 2b at a predetermined rotation speed. The rotation driving step S2 can be performed by the rotation operation setting unit 23 in the control device 20. Note that when the rotation driving step S2 of the steel pipe 1 is started, the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b are not necessarily in contact with the steel pipe end portion 1EP. The inner face pressing roll 3 and the outer face pressing rolls 4a and 4b may be set in advance to standby positions where the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b are not in contact with the steel pipe end portion 1EP, and the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b may be in the standby positions until the steel pipe end portion 1EP rotates at a set speed. This is because when the rotation of the steel pipe 1 is started while the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b are in contact with the steel pipe end portion 1EP, a scratch may occur on or in the steel pipe end portion 1EP. The rotation driving step S2 of the steel pipe 1 ends when the steel pipe 1 rotates at a preset rotation speed, and the process proceeds to the roll pressing step S3.

[0089] The roll pressing step S3 includes a pressing step S31 by the inner face pressing roll 3, in which the inner face pressing roll 3 presses the steel pipe end portion 1EP. The roll pressing step S3 further includes a pressing step S32 by the outer face pressing rolls 4a and 4b, in which the outer face pressing rolls 4a and 4b press the steel pipe end portion 1EP. The pressing step S31 by the inner face pressing roll 3 is a step of controlling the position of the inner face pressing roll 3 so that the inner face pressing roll 3 shifts from the standby position to the position satisfying the set inner face reduction amount. The pressing step S32 by the outer face pressing rolls 4a and 4b is a step of controlling the positions of the outer face pressing rolls 4a and 4b so that the outer face pressing rolls 4a and 4b shift from the standby position to the respective positions satisfying the set outer face reduction amount. The pressing step S31 by the inner face pressing roll 3 and the pressing step S32 by the outer face pressing rolls 4a and 4b are not necessarily performed at the same time, and either one of the steps may be precedingly performed, and the other step may be performed with a delay. These operations can be performed on the basis of conditions set by the roll position setting unit 22 in the control device 20. The roll pressing step S3 ends if both the pressing step S31 by the inner face pressing roll 3 and the pressing step S32 by the outer face pressing rolls 4a and 4b end. Accordingly, the process proceeds to the processing step S4.

[0090] The processing step S4 is a step of rotating the steel pipe 1 at a predetermined number of rotations or a predetermined rotation angle while maintaining the inner face reduction amount and the outer face reduction amount set as the amounts of pressing the steel pipe end portion 1EP by the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b. The processing step S4 can be executed by the roll position setting unit 22 in the control device 20. As the number of rotations or the rotation angle of the steel pipe 1 in the processing step S4, a set value set in advance by the operator through the input unit may be used, or conditions set by the pressing pattern setting unit 223 in the control device 20 on the basis of the attribute information of the steel pipe 1 may be used. In these cases, at least one full rotation is preferably applied to the steel pipe 1 while the steel pipe end portion 1EP is pressed by the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b in the state of maintaining the set inner face reduction amount and outer face reduction amount. This is because roundness is easily improved by bending the steel pipe end portion 1EP over the entire length along the circumferential direction. The processing step S4 ends when the rotation at a predetermined number of rotations or a predetermined rotation angle is executed, and the process proceeds to the roll releasing step S5.

[0091] The roll releasing step S5 includes a releasing step S51 of the inner face pressing roll 3, in which the inner face pressing roll 3 is released from the position corresponding to the set inner face reduction amount to the position not in contact with the steel pipe end portion 1EP. The roll releasing step S5 further includes a releasing step S52 of the outer face pressing rolls 4a and 4b, in which the outer face pressing rolls 4a and 4b are released from the positions corresponding to the set outer face reduction amount to the positions not in contact with the steel pipe end portion 1EP. The roll releasing step S5 may be operated in accordance with the conditions set at the roll position setting unit 22 in the control device 20. In this case, the releasing step S51 of the inner face pressing roll 3 and the releasing step S52 of the outer face pressing rolls 4a and 4b are not necessarily performed at the same time, and either one of the steps may be precedingly performed, and the other step may be performed with a delay. Note that the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b are preferably released slowly rather than rapidly. In the releasing step S51 of the inner face pressing roll 3, the releasing speed of the inner face pressing roll 3 is preferably set so that the steel pipe 1 makes one full rotation or more in a period from when the inner face pressing roll 3 reaches the position satisfying the inner face reduction amount until the inner face pressing roll 3 is brought out of contact with the steel pipe end portion 1EP. Similarly in the releasing step S52 of the outer face pressing rolls 4a and 4b, the releasing speed of the outer face pressing rolls 4a and 4b is preferably set so that the steel pipe 1 makes one full rotation or more in a period from when the outer face pressing rolls 4a and 4b reach the positions satisfying the outer face reduction amount until the outer face pressing rolls 4a and 4b are brought out of contact with the steel pipe end portion 1EP. This is because when the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b are rapidly released, the rotation state of the steel pipe 1 becomes unstable, and the roundness of the steel pipe end portion 1EP may be deteriorated.

[0092] FIG. 8 is a view for explaining a deformed state of the steel pipe end portion 1EP when the steel pipe end portion 1EP is pressed from the inner circumferential face 1i side of the steel pipe end portion 1EP by the inner face pressing roll 3 disposed at the intermediate position between the support rolls 2a and 2b. Note that FIG. 8 illustrates only a part of the steel pipe end portion 1EP.

[0093] As illustrated in FIG. 8, when the steel pipe end portion 1EP is pressed by the inner face pressing roll 3, a portion between the two support rolls 2a and 2b and the inner face pressing roll 3 is bended in the manner of three-point bending. In this way, a portion of the steel pipe end portion 1EP between the two support rolls 2a and 2b is deformed such that the curvature of the steel pipe end portion 1EP along the circumferential direction in the steel pipe 1 indicated by solid lines in FIG. 8 is larger than the initial curvature before the steel pipe end portion 1EP of the steel pipe 1 is bended, which is indicated by broken lines in FIG. 8.

[0094] FIG. 9 is a view for explaining a deformed state of the steel pipe end portion 1EP when the steel pipe end portion 1EP is pressed by the two outer face pressing rolls 4a and 4b disposed above and being in contact with the outer circumferential face 1o of the steel pipe end portion 1EP.

[0095] As illustrated in FIG. 9, when the steel pipe end portion 1EP is pressed by the outer face pressing rolls 4a and 4b, the steel pipe end portion 1EP supported by the support rolls 2a and 2b is deformed so as to be pressed from above and to increase the oblateness thereof as a whole. By pressing the steel pipe end portion 1EP by the two outer face pressing rolls 4a and 4b, a portion of the steel pipe end portion 1EP that is passing a region between the two outer face pressing rolls 4a and 4b is deformed so that the curvature along the circumferential direction is smaller than the initial curvature. In this way, the steel pipe end portion 1EP is subjected to unbending deformation along the circumferential direction. The reason for which the present embodiment uses the two outer face pressing rolls 4a and 4b is as follows. That is, in the present embodiment, the two outer face pressing rolls 4a and 4b are used to apply deformation for reducing the curvature of the steel pipe end portion 1EP along the circumferential direction to a portion of the steel pipe end portion 1EP between the two outer face pressing rolls 4a and 4b. Accordingly, in the present embodiment, the use of the two outer face pressing rolls 4a and 4b can maintain the unbending deformation while the steel pipe end portion 1EP passes between the two outer face pressing rolls 4a and 4b, and can enhance the effect of improving the roundness.

[0096] Through the rotation of the steel pipe 1, the steel pipe end portion 1EP is subjected to bending deformation in which the curvature is increased by the inner face pressing roll 3 and unbending deformation in which the curvature is reduced by the outer face pressing rolls 4a and 4b. Bending deformation and unbending deformation of the steel pipe end portion 1EP along the circumferential direction converges the curvature of the steel pipe end portion 1EP along the circumferential direction to a constant value. As a result, the roundness of the steel pipe end portion 1EP is improved.

[0097] FIG. 10 is a view for explaining a deformation of the steel pipe end portion 1EP due to both of the pressing to the steel pipe end portion 1EP by the inner face pressing roll 3 and the pressing to the steel pipe end portion 1EP by the outer face pressing rolls 4a and 4b. Note that, in FIG. 10, a region FA surrounded by a one-dot chain line is a region to which bending deformation for increasing the curvature of the steel pipe end portion 1EP is applied. In FIG. 10, a region FB surrounded by a two-dot chain line is a region to which unbending deformation for reducing the curvature of the steel pipe end portion 1EP is applied.

[0098] FIG. 10 illustrates a state in which the steel pipe 1 rotates in the counterclockwise direction. At this time, at the position of the steel pipe end portion 1EP in the direction of six o'clock in the circumferential direction, deformation for increasing the curvature of the steel pipe end portion 1EP is applied due to pressing by the inner face pressing roll 3, and the steel pipe end portion 1EP is subjected to unbending deformation by coming into contact with the support roll 2b. At the position thereof in the direction of three o'clock, bending deformation for increasing the curvature of the steel pipe end portion 1EP is applied, and at the position thereof in the direction of zero o'clock, unbending deformation is applied to a portion of the steel pipe end portion 1EP between the two outer face pressing rolls 4a and 4b. Then, at the position in the direction of nine o'clock, bending deformation is applied again so as to increase the curvature, and at the position in contact with the support roll 2a, unbending deformation is applied.

[0099] In this way, three times of bending deformation and three times of unbending deformation are alternately applied until the steel pipe 1 makes one full rotation. As a result, the curvature of the steel pipe end portion 1EP along the circumferential direction is made to have a constant value and the roundness of the steel pipe end portion 1EP is improved. At this time, since the curvatures obtained by the bending deformation and the unbending deformation at the respective positions can be changed depending on the set values of the inner face reduction amount and the outer face reduction amount, the effect of improving the roundness of the steel pipe end portion 1EP can be enhanced.

[0100] The curvature of the steel pipe end portion 1EP before processing in the circumferential direction often varies along the circumferential direction, and the steel pipe end portion 1EP before processing as a product often includes a region having a curvature larger than a target curvature and a region having a curvature smaller than the target curvature. On the other hand, with the processing method for the steel pipe end portion 1EP according to the embodiment, the curvature is reduced in the region having the larger curvature due to the unbending deformation between the two outer face pressing rolls 4a and 4b. In addition, with the processing method for the steel pipe end portion 1EP according to the embodiment, the curvature is increased in the region having the smaller curvature due to the bending deformation by the inner face pressing roll 3. In this way, with the processing method for the steel pipe end portion 1EP according to the embodiment, the deformation of increasing and reducing the curvature of the steel pipe end portion 1EP along the circumferential direction can be repeatedly applied. Therefore, even when the steel pipe end portion 1EP before processing has both a region having a curvature larger than the target curvature and a region having a smaller curvature than the target curvature, the curvature of the processed steel pipe end portion 1EP can be made uniform.

[0101] The present invention can be applied as a processing method for a steel pipe end portion included in the manufacturing method of a steel pipe for manufacturing the steel pipe 1, and the pipe end portion of the steel pipe 1 may be processed in publicly known or existing manufacturing steps.

(Example 1)

[0102] In Example 1 of the present invention, the processing apparatus 100 for the steel pipe end portion 1EP is used. The details thereof is as follows: all the diameters of the two support rolls 2a and 2b, the one inner face pressing roll 3, and the two outer face pressing rolls 4a and 4b are 300 [mm], and the length of an elongated body is 900 [mm]. In Example 1 of the present invention, the steel pipe end portion 1EP was processed using the above-described processing apparatus 100 for the steel pipe end portion 1EP. The result is described below.

[0103] In the processing apparatus 100 for the steel pipe end portion 1EP of Example 1, the center-to-center distance between the two support rolls 2a and 2b is 450 [mm], and the center-to-center distance between the two outer face pressing rolls 4a and 4b is 450 [mm]. The inner face pressing roll 3 and the two outer face pressing rolls 4a and 4b were disposed so as to be bilaterally symmetrical with respect to the two support rolls 2a and 2b in the roll arrangement illustrated in FIG. 5.

[0104] The steel pipe 1 to be processed was a steel pipe having an outer diameter of 36 inches (914.4 [mm]), a pipe wall thickness of 1.5 inches (38.1 [mm]), and a length of 40 feet (12.8 [m]), and its tensile strength was 560 [MPa]. First, the placing step S1 was performed as a preparation for processing the steel pipe end portion 1EP to be processed. That is, the steel pipe end portion 1EP was placed such that the support rolls 2a and 2b, the inner face pressing roll 3, and the outer face pressing rolls 4a and 4b had a contact length of 600 [mm] from the pipe end of the steel pipe 1 along the pipe axial direction. Assuming that the inner circumferential face 1i of the steel pipe end portion 1EP had a perfect circular shape, the zero point serving as a reference of the amount of pressing by the inner face pressing roll 3 was set to a position where the perfect circular shape and the inner face pressing roll 3 were in contact with each other. Assuming that the outer circumferential face 1o of the steel pipe end portion 1EP had a perfect circular shape, the zero point serving as a reference of the amount of pressing by the outer face pressing rolls 4a and 4b was set to a position where the perfect circular shape and the outer face pressing rolls 4a and 4b were in contact with each other. Next, as the rotation driving step S2 of the steel pipe 1, the rotation operation setting unit 23 performed control to rotate the steel pipe 1 at a preset rotation speed.

[0105] Next, as the roll pressing step S3, the roll position setting unit 22 performed control so that the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b had predetermined amounts of pressing, respectively. At this time, the inner face reduction amount and the outer face reduction amount were set to 1.8 [mm] and 18 [mm], respectively, so that the yield condition is satisfied at or near the surface of the steel pipe end portion 1EP. The inner face pressing roll 3 and the outer face pressing rolls 4a and 4b were controlled so that the time from the start to the completion of the pressing was the same. In Example 1, the roll position setting unit 22 performed control so that the reduction amount by the inner face pressing roll 3 changed from zero to 1.8 [mm] and the reduction amount by the outer face pressing rolls 4a and 4b changed from zero to 18 [mm] until the steel pipe 1 made one full rotation. When the roll pressing step S3 was completed, the process proceeded to the processing step S4. In the processing step S4, the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b applied two full rotation to the steel pipe 1 while maintaining the predetermined inner face reduction amount and outer face reduction amount. In this way, bending deformation and unbending deformation were applied to the entire circumference of the steel pipe end portion 1EP along the circumferential direction. Subsequently in the roll releasing step S5, the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b were released until the inner face reduction amount and the outer face reduction amount were reduced to their respective half values during one full rotation of the steel pipe 1. Then, the rolls were released such that the amount of pressing by the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b reached and maintained zero in one subsequent full rotation.

[0106] On the other hand, as comparative examples of the present invention, Comparative Example 1 and Comparative Example 2 were validated under the following conditions. As conditions of Comparative Example 1, the same processing apparatus 100 for the steel pipe end portion 1EP as in Example 1 is used, and the setting of the inner face reduction amount by the inner face pressing roll 3 is the same as that in Example 1. On the other hand, in Comparative Example 1, the outer face pressing rolls 4a and 4b were retracted to positions not in contact with the steel pipe end portion 1EP, and did not press the steel pipe end portion 1EP. As conditions of Comparative Example 2, the setting of the outer face reduction amount by the outer face pressing rolls 4a and 4b is the same as that in Example 1. On the other hand, in Comparative Example 2, the inner face pressing roll 3 was retracted to a position not in contact with the steel pipe end portion 1EP, and did not press the steel pipe end portion 1EP. Note that the steel pipes 1 to be processed are all UOE steel pipes. As the steel pipe 1 to be processed, 20 of the steel pipes 1 processed under the same operating condition of the expander in each of Example 1, Comparative Example 1, and Comparative Example 2 were prepared. The processing under each condition was performed by the above-described processing apparatus 100 for the steel pipe end portion 1EP.

[0107] The results of measuring the roundness of each of the processed steel pipe end portions 1EP are provided in

Table 1. Note that the roundness of the steel pipe end portion 1EP is an index indicating the degree of deviation from the perfect circle in terms of the outer diameter shape of the steel pipe end portion 1EP. The roundness was defined herein as (Dmax - Dmin)/D0, where Dmax and Dmin respectively represented a maximum diameter and a minimum diameter of the outer diameter of the steel pipe end portion 1EP measured at 360 positions obtained by dividing the steel pipe end portion 1EP into 360 pieces in the circumferential direction. The diameter D0 of the imaginary perfect circle 1A in this case is 457.2 [mm]. Note that the closer the roundness is to zero, the closer the sectional shape of the steel pipe end portion 1EP is to a perfect circle. Regarding the acceptance of the roundness of the steel pipe end portion 1EP, the case in which the roundness was 0.5 [%] or less was determined as "acceptable", and the case in which the roundness exceeded 0.5 [%] was determined as "unacceptable". Then, the acceptance rate with respect to the total number of processed steel pipes 1 was calculated.

Table 1

	Inner face reduction amount [mm]	Outer face reduction amount [mm]	Roundness [%] (Before processing)	Roundness [%] (After processing)	Acceptance [%]
Example 1	1.8	18	0.7 to 1.5	0 to 0.2	100
Comparative Example 1	1.8	-	0.7 to 1.5	0.7 to 1.5	0
Comparative Example 2	-	18	0.7 to 1.5	0.7 to 1.5	0

[0108] As can be seen from Table 1, according to Example 1 of the present invention, the roundness of the processed steel pipe end portion 1EP is greatly improved by pressing the steel pipe end portion 1EP using both the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b. On the other hand, almost no improvement effect on the roundness after processing was seen in Comparative Example 1 in which the steel pipe end portion 1EP was processed while the outer face pressing rolls 4a and 4b were released and Comparative Example 2 in which the steel pipe end portion 1EP was processed while the inner face pressing roll 3 was released.

(Example 2)

[0109] In Example 2 of the present invention, the steel pipe end portions 1EP were processed under conditions A to F set by changing the center-to-center distance between the two outer face pressing rolls 4a and 4b within the range of 300 to 700 [mm] in the processing apparatus 100 for the steel pipe end portion 1EP used in Example 1. The results are described below. As the steel pipes 1 to be processed, steel pipes manufactured in the same process as in Example 1 were used.

[0110] In Example 2, as in Example 1, the placing step S1 and the rotation driving step S2 of the steel pipe 1 were performed. In Example 2, the operations of the inner face pressing roll 3 and the outer face pressing rolls 4a and 4b in the roll pressing step S3, the processing step S4, and the roll releasing step S5, as well as the setting of the inner face reduction amount and the outer face reduction amount were also the same as those in Example 1. The steel pipe end portion 1EP were processed in this manner, and the roundness of each of the steel pipe end portions 1EP was measured. The results are provided in Table 2.

Table 2

Condition	Center-to-center distance between two outer face pressing rolls [mm]	Roundness [%] (Before processing)	Roundness [%] (After processing)	Acceptance [%]
A	300	0.7 to 1.5	0.1 to 0.5	100
B	375	0.7 to 1.5	0 to 0.3	100
C	450	0.7 to 1.5	0 to 0.2	100
D	525	0.7 to 1.5	0 to 0.2	100
E	600	0.7 to 1.5	0 to 0.3	100
F	700	0.7 to 1.5	0.2 to 1.0	80

[0111] As can be seen from Table 2, according to Example 2 of the present invention, in the case of the smallest center-to-center distance between the two outer face pressing rolls 4a and 4b of 300 [mm] (condition A), and in the case of the largest center-to-center distance therebetween of 700 [mm] (condition F), the roundness after processing tends to be worse than the other cases. On the other hand, according to Example 2 of the present invention, the roundness of each of the steel pipe end portions 1EP is seen to be improved as compared with that before processing under any conditions.

Industrial Applicability

[0112] The present invention can provide a processing apparatus for a steel pipe end portion, a processing method for a steel pipe end portion, and a manufacturing method for a steel pipe, all of which can effectively improve the roundness of a steel pipe end portion.

Reference Signs List

[0113]

1	STEEL PIPE
1A	IMAGINARY PERFECT CIRCLE
1EP	STEEL PIPE END PORTION
1i	INNER CIRCUMFERENTIAL FACE
1o	OUTER CIRCUMFERENTIAL FACE
2a, 2b	SUPPORT ROLL
3	INNER FACE PRESSING ROLL
4a, 4b	OUTER FACE PRESSING ROLL
5	ROLL SUPPORT UNIT
6	ROTATION DRIVE UNIT
7	STEEL PIPE SUPPORT UNIT
8	INNER FACE PRESSING UNIT
9	OUTER FACE PRESSING UNIT
10	INNER FACE ROLL CHOCK
11	OUTER FACE ROLL CHOCK
12	INNER FACE PRESSING POSITION DETECTOR
13	INNER FACE PRESSING CONTROL UNIT
14	OUTER FACE PRESSING POSITION DETECTOR
15	OUTER FACE PRESSING CONTROL UNIT
20	CONTROL DEVICE
21	PLACEMENT SETTING UNIT
22	ROLL POSITION SETTING UNIT
23	ROTATION OPERATION SETTING UNIT
51	HOUSING
52	HOUSING BEAM
100	PROCESSING APPARATUS
221	INNER FACE PRESSING OPERATION SETTING UNIT
222	OUTER FACE PRESSING OPERATION SETTING UNIT
223	PRESSING PATTERN SETTING UNIT

Claims

1. A processing apparatus for a steel pipe end portion, the processing apparatus being configured to process a pipe end portion of a steel pipe, the processing apparatus comprising:

two support rolls each being in contact with an outer circumferential face of a steel pipe end portion, the two support rolls each being configured to support a steel pipe from below;
one inner face pressing roll configured to press the steel pipe end portion at an intermediate position between the two support rolls from an inner circumferential face side of the steel pipe end portion;
two outer face pressing rolls each being in contact with the outer circumferential face of the steel pipe end

portion, the two outer face pressing rolls each being configured to press the steel pipe end portion from above; and
a rotation drive unit configured to rotate the steel pipe.

2. The processing apparatus according to claim 1, further comprising:

an inner face pressing control unit configured to control an amount of pressing by the one inner face pressing roll; and
an outer face pressing control unit configured to control an amount of pressing by the two outer face pressing rolls.

3. The processing apparatus according to claim 2, further comprising
an amount-of-pressing setting unit configured to calculate and set

a set value of the amount of pressing by the one inner face pressing roll, and
a set value of the amount of pressing by the two outer face pressing rolls.

4. The processing apparatus according to any one of claims 1 to 3, wherein the two outer face pressing rolls are disposed such that angles are both less than 45 [°], where the angles are respectively formed by a perpendicular line of a baseline based on the two support rolls, and straight lines connecting a center point of the steel pipe end portion and respective contact points of the two outer face pressing rolls with the steel pipe end portion.

5. The processing apparatus according to any one of claims 1 to 4, wherein a length over which the two support rolls are in contact with the steel pipe end portion in a pipe axial direction, a length over which the one inner face pressing roll is in contact with the steel pipe end portion in the pipe axial direction, and a length over which the two outer face pressing rolls are in contact with the steel pipe end portion in the pipe axial direction are 0.2D or more with respect to a pipe outer diameter D of the steel pipe.

6. A processing method for a steel pipe end portion, the processing method being for processing a pipe end portion of a steel pipe, the processing method comprising:

a rotation driving step of rotating a steel pipe placed on two support rolls each being in contact with an outer circumferential face of a steel pipe end portion, the two support rolls each being configured to support the steel pipe from below; and
a roll pressing step of pressing the steel pipe end portion by using

one inner face pressing roll being disposed at an intermediate position between the two support rolls, and
two outer face pressing rolls each being disposed above and each being in contact with the outer circumferential face of the steel pipe end portion,

wherein the roll pressing step includes:

an inner face pressing step of pressing the steel pipe end portion from an inner circumferential face side of the steel pipe end portion by the one inner face pressing roll; and
an outer face pressing step of pressing the steel pipe end portion by the two outer face pressing rolls.

7. The processing method according to claim 6, further comprising:

a processing step of applying at least one full rotation to the steel pipe while maintaining pressing with respect to the steel pipe end portion by the one inner face pressing roll and the two outer face pressing rolls; and
a roll releasing step of releasing the one inner face pressing roll and the two outer face pressing rolls.

8. The processing method according to claim 7, wherein at least one set value of an amount of pressing the steel pipe end portion by the one inner face pressing roll and an amount of pressing the steel pipe end portion by the two outer face pressing rolls in the processing step is set in accordance with attribute information of the steel pipe.

9. A manufacturing method for a steel pipe, the manufacturing method comprising
manufacturing a steel pipe using the processing method according to any one of claims 6 to 8.

FIG.1

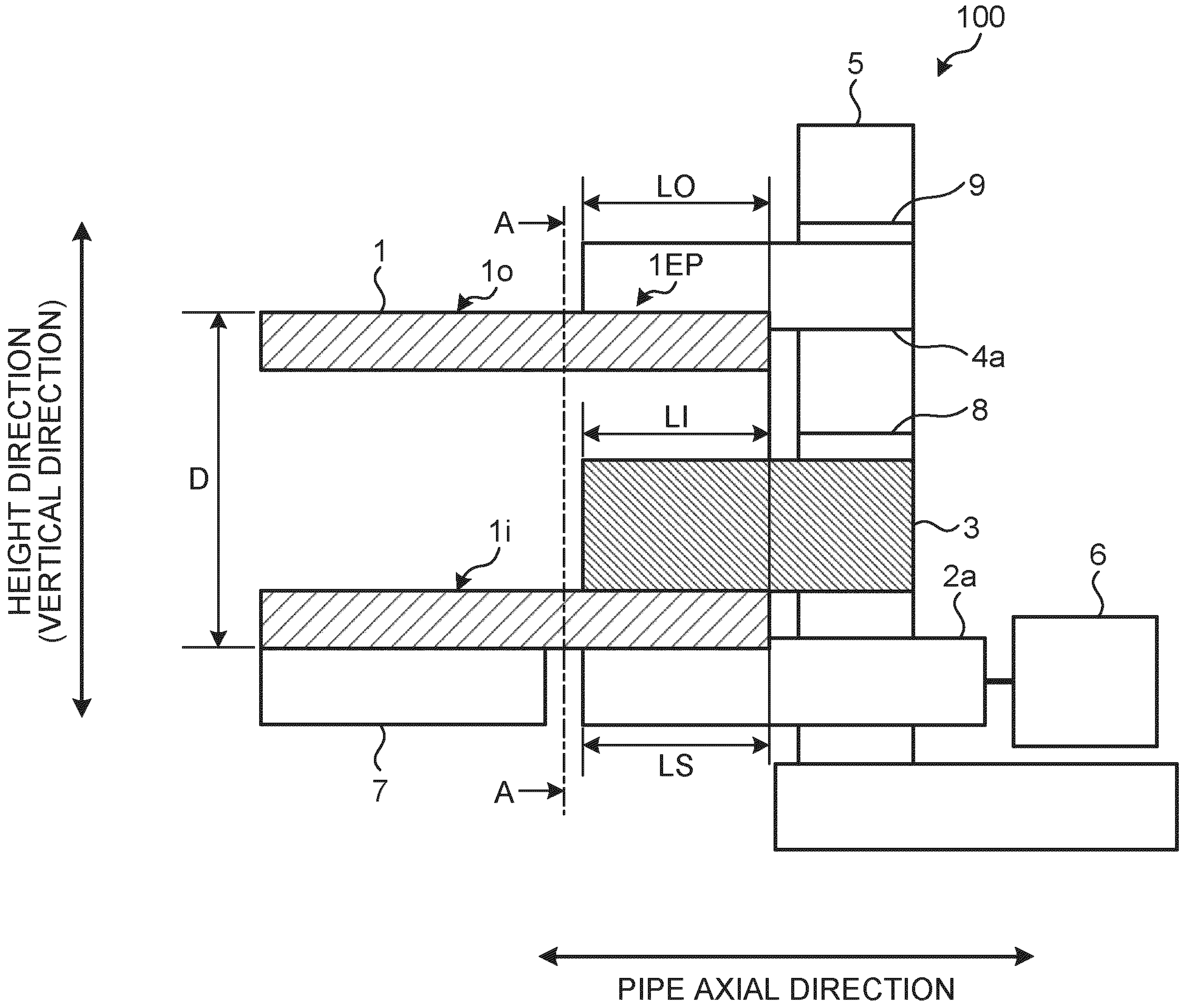

100
5
9
LO
A
1
1o
1EP
4a
8
LI
D
HEIGHT DIRECTION
(VERTICAL DIRECTION)
3
1i
6
2a
7
A
LS
PIPE AXIAL DIRECTION

FIG.2

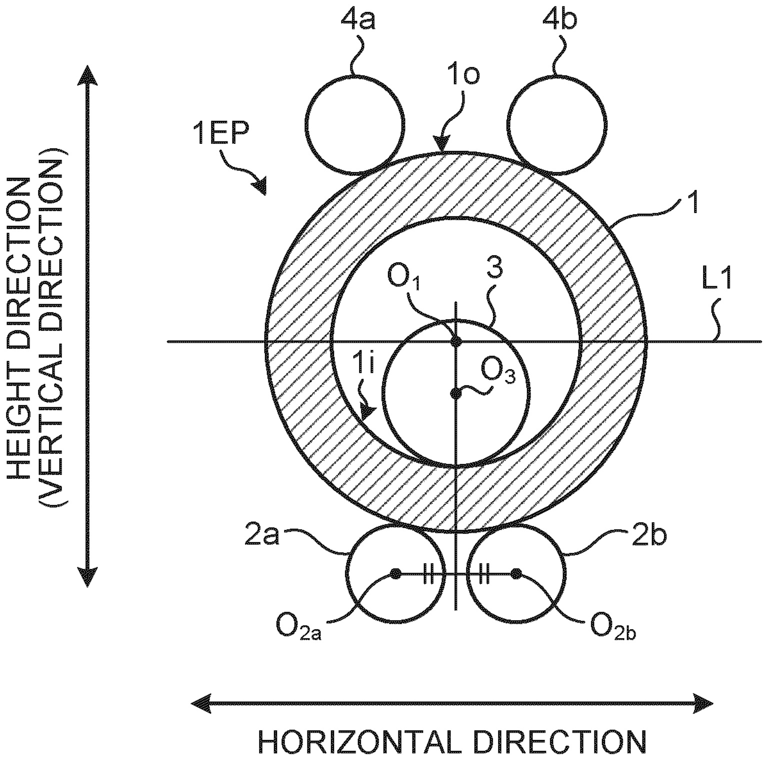

4a
4b
1o
1EP
1
O1
3
L1
1i
O3
HEIGHT DIRECTION
(VERTICAL DIRECTION)
2a
2b
O2a
O2b
HORIZONTAL DIRECTION

FIG.3

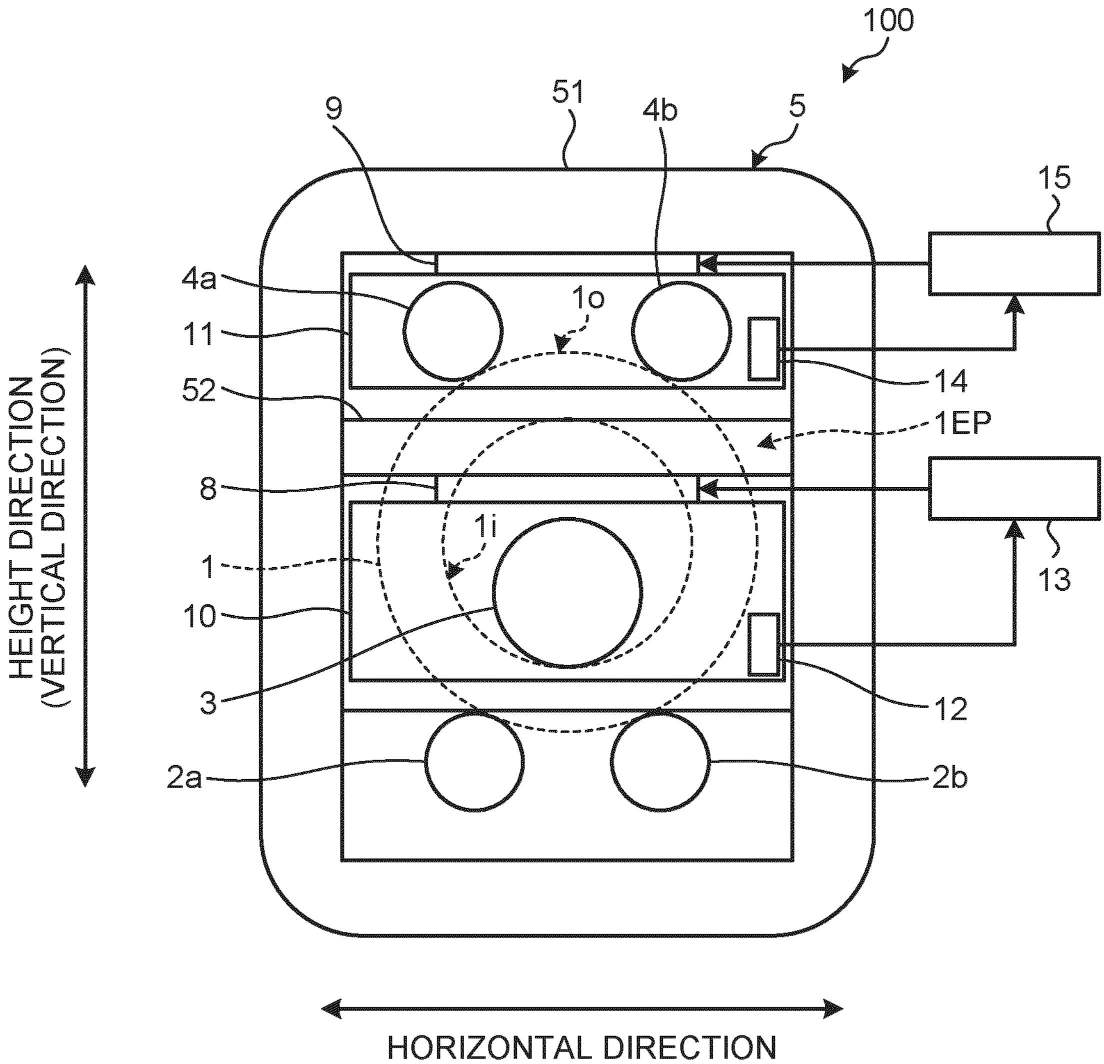

100
51
9
4b
5
15
4a
1o
11
14
52
1EP
8
1i
1
13
10
3
12
2a
2b
HEIGHT DIRECTION
(VERTICAL DIRECTION)
HORIZONTAL DIRECTION

FIG.4

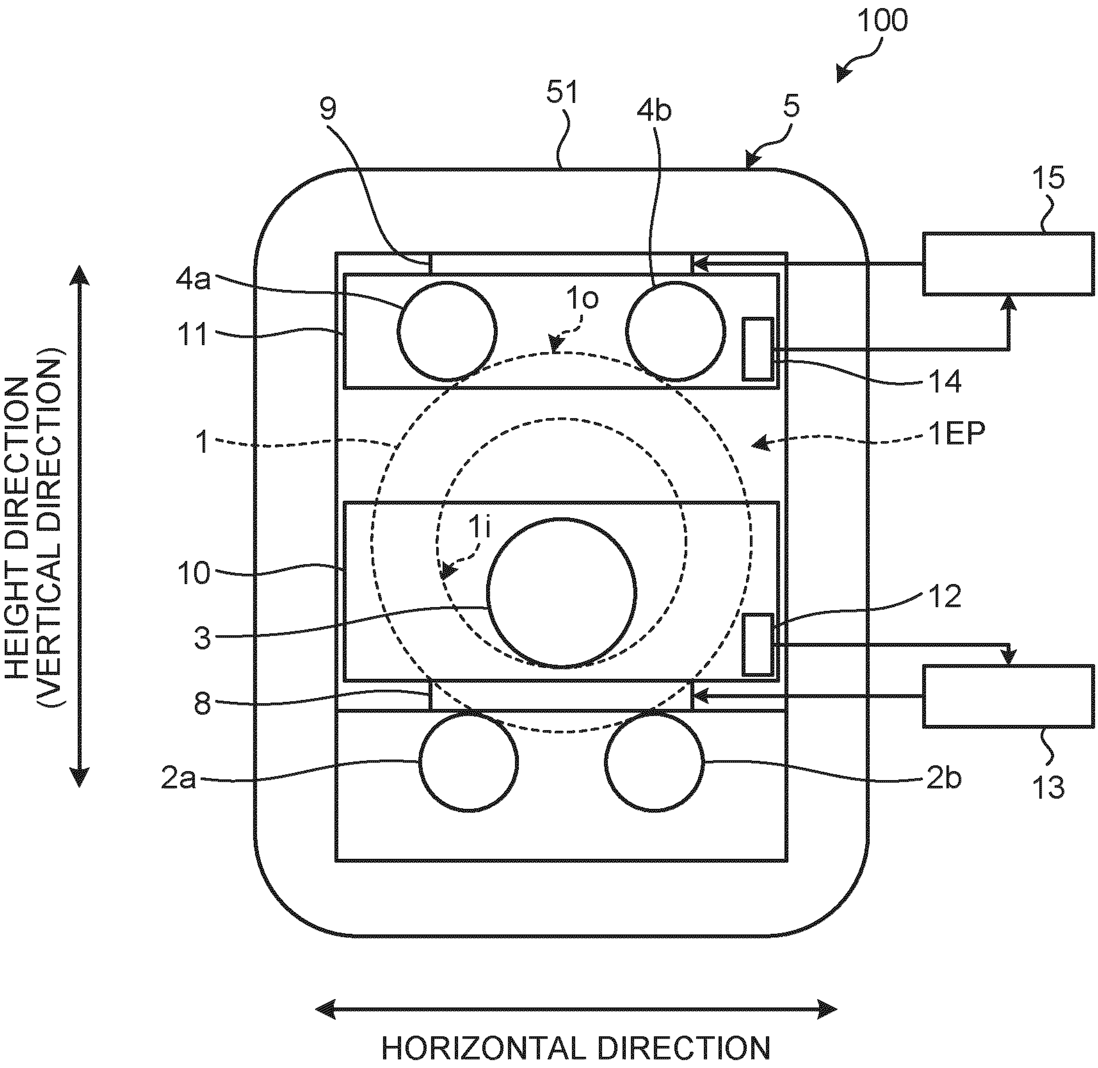

100
51
9
4b
5
15
4a
1o
11
14
1
1EP
1i
10
12
3
8
13
2a
2b
HEIGHT DIRECTION
(VERTICAL DIRECTION)
HORIZONTAL DIRECTION

FIG.5

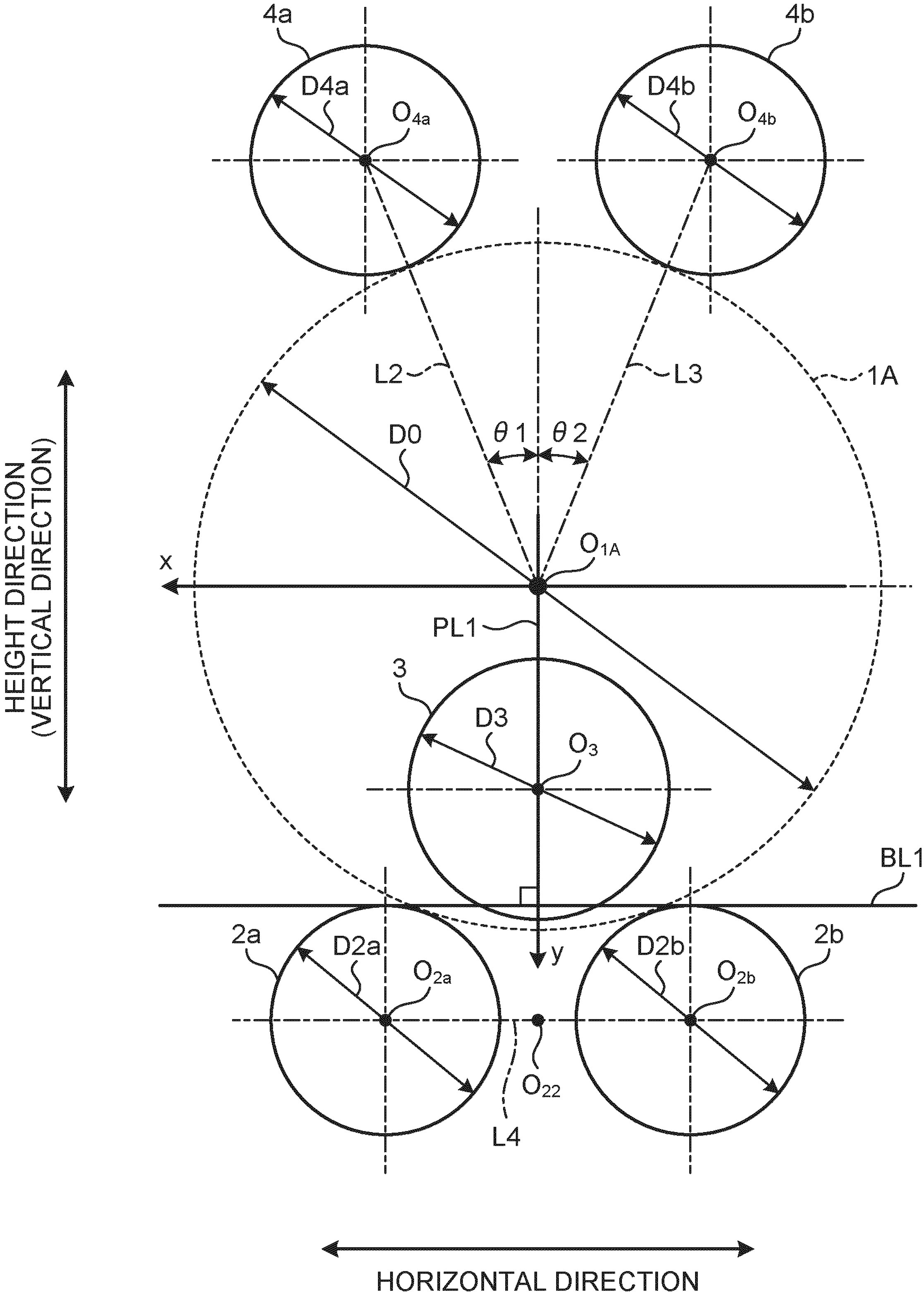

4a
4b
D4a
O4a
D4b
O4b
L2
L3
1A
D0
θ1
θ2
x
O1A
PL1
3
D3
O3
BL1
2a
D2a
O2a
y
D2b
O2b
2b
O22
L4
HEIGHT DIRECTION
(VERTICAL DIRECTION)
HORIZONTAL DIRECTION

FIG.6

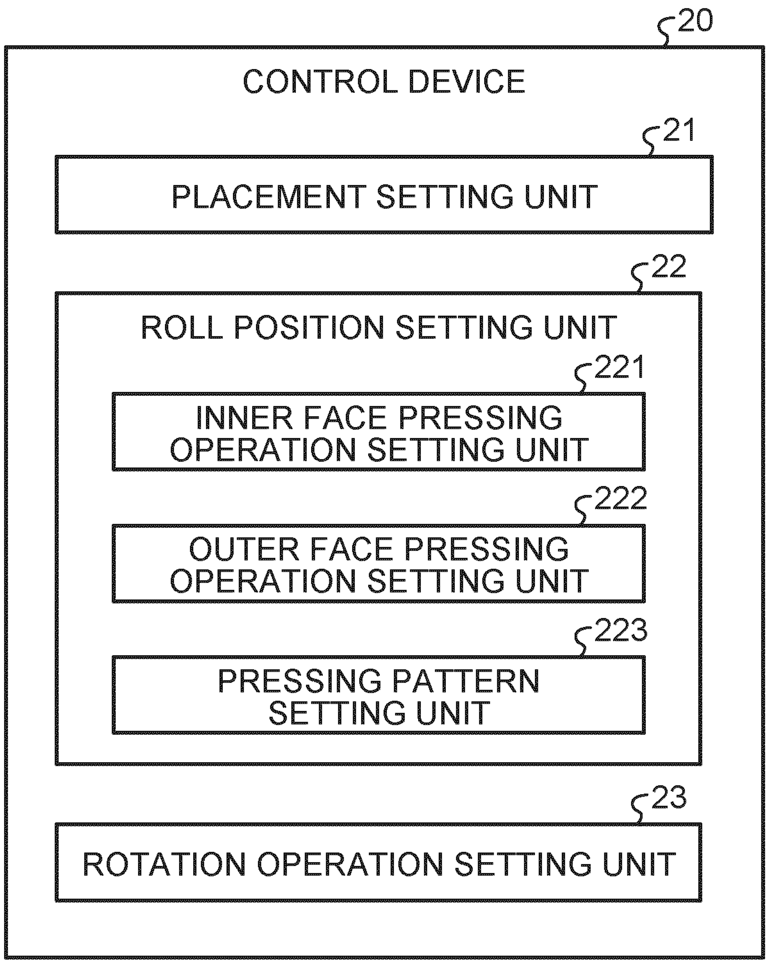

20
CONTROL DEVICE
21
PLACEMENT SETTING UNIT
22
ROLL POSITION SETTING UNIT
221
INNER FACE PRESSING OPERATION SETTING UNIT
222
OUTER FACE PRESSING OPERATION SETTING UNIT
223
PRESSING PATTERN SETTING UNIT
23
ROTATION OPERATION SETTING UNIT

FIG.7

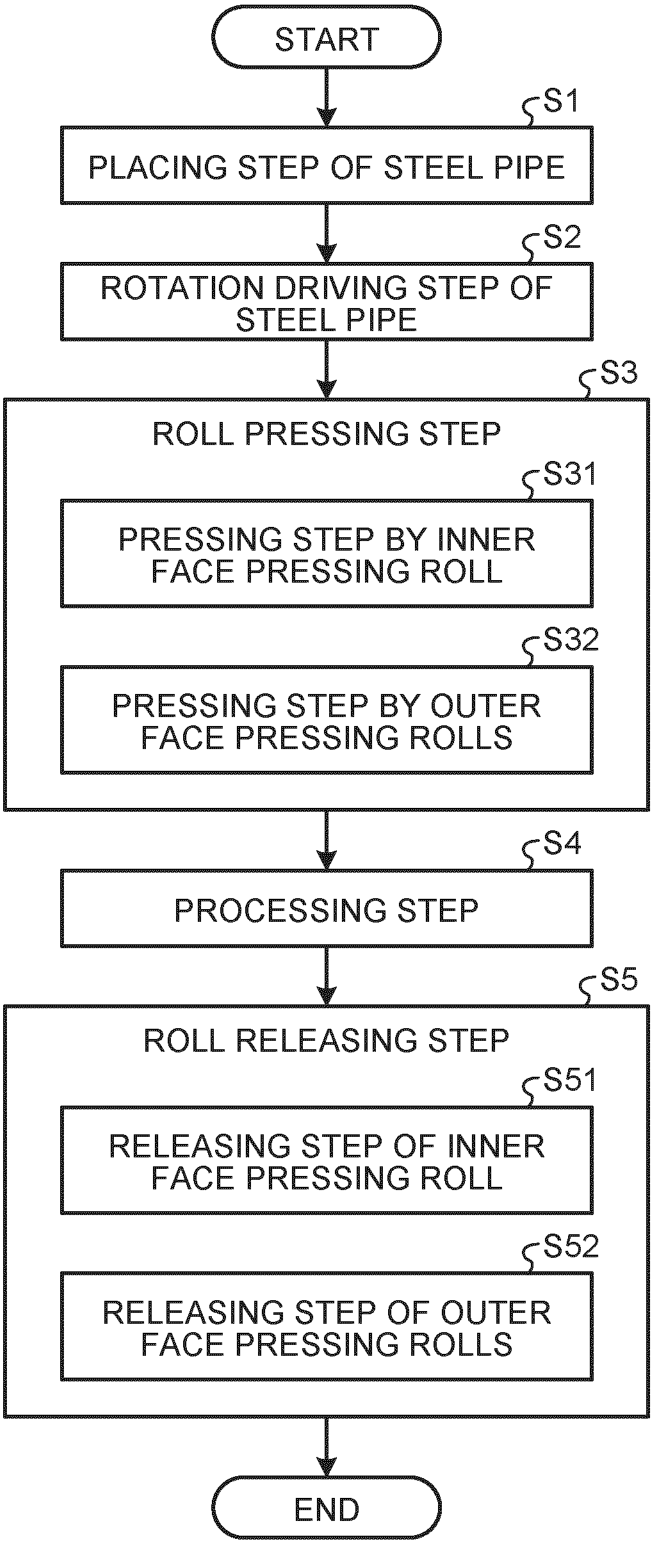

START
S1
PLACING STEP OF STEEL PIPE
S2
ROTATION DRIVING STEP OF STEEL PIPE
S3
ROLL PRESSING STEP
S31
PRESSING STEP BY INNER FACE PRESSING ROLL
S32
PRESSING STEP BY OUTER FACE PRESSING ROLLS
S4
PROCESSING STEP
S5
ROLL RELEASING STEP
S51
RELEASING STEP OF INNER FACE PRESSING ROLL
S52
RELEASING STEP OF OUTER FACE PRESSING ROLLS
END

FIG.8

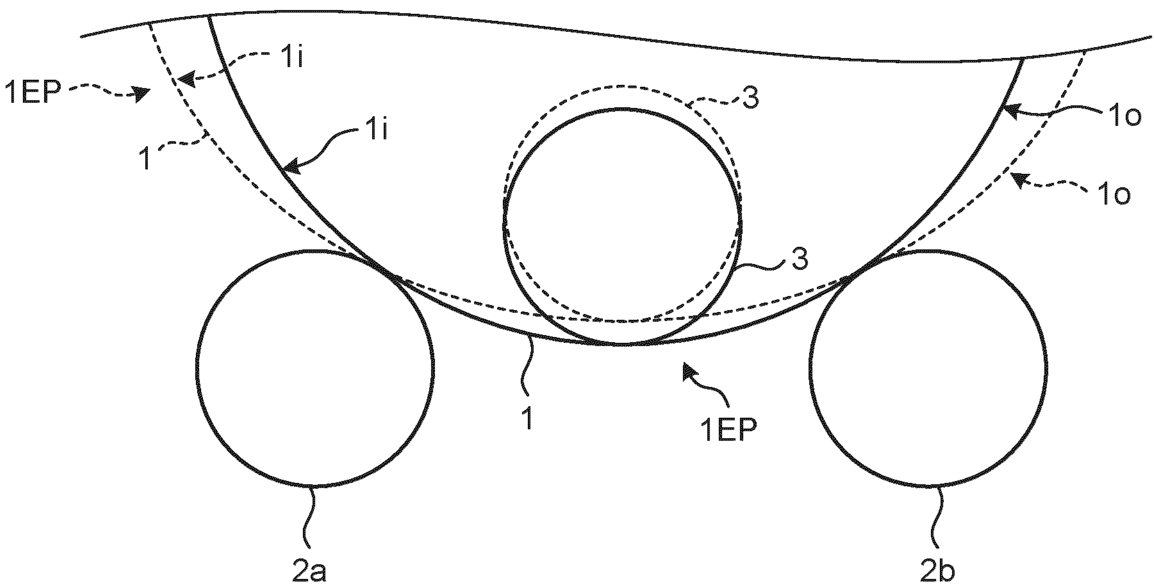


FIG.9

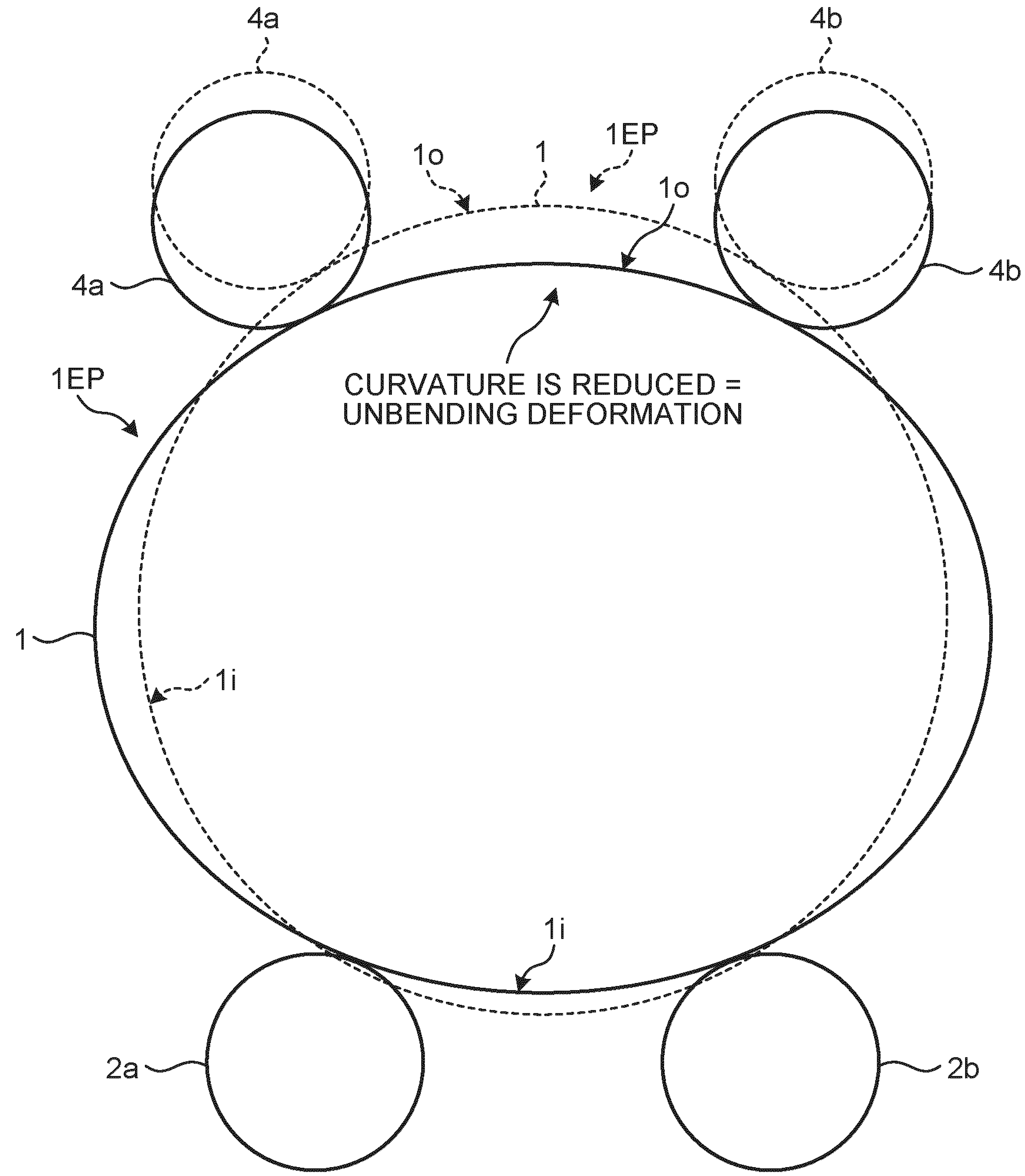
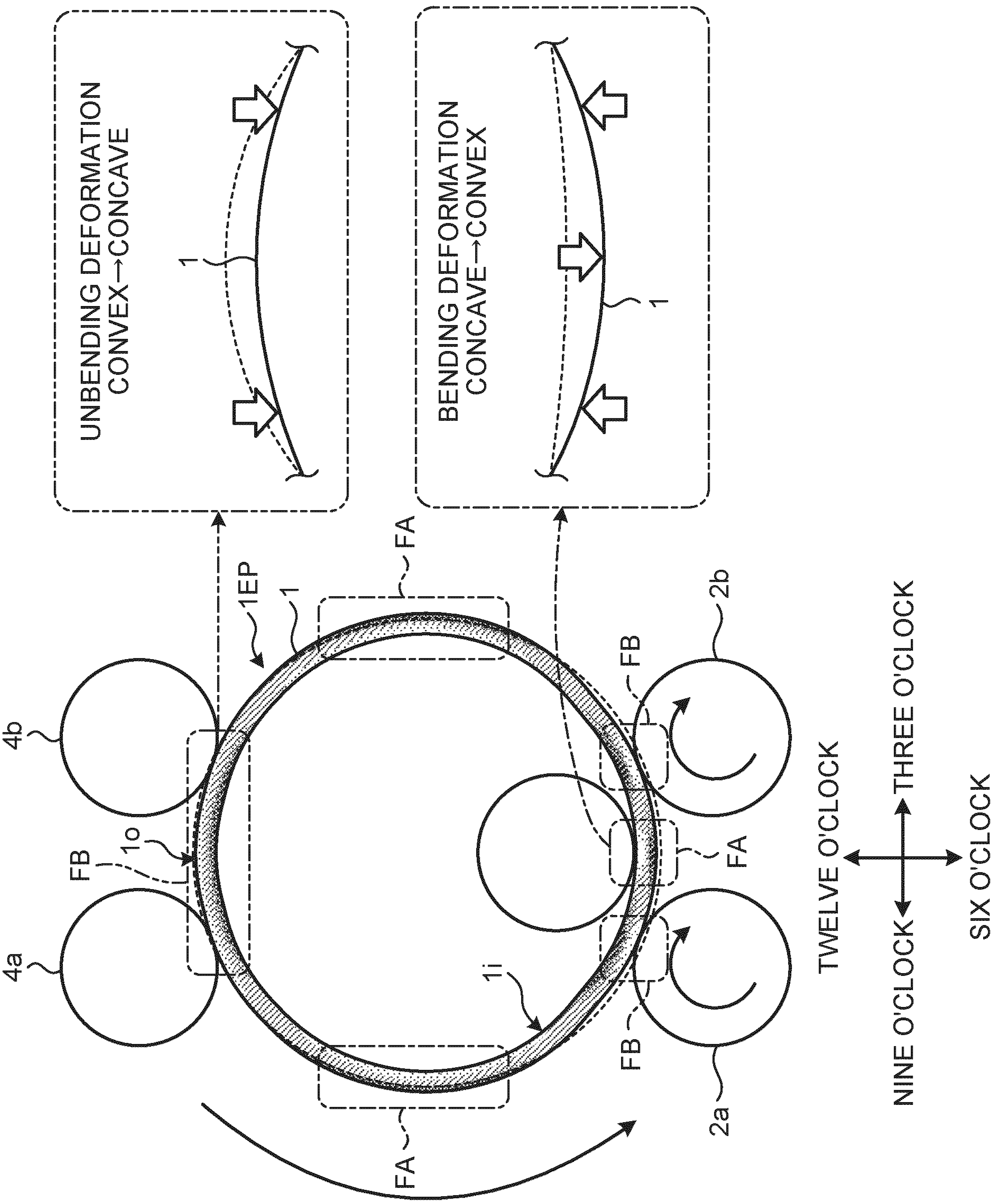

4a
4b
1o
1
1EP
1o
4a
4b
1EP
CURVATURE IS REDUCED =
UNBENDING DEFORMATION
1
1i
1i
2a
2b

FIG.10


UNBENDING DEFORMATION
CONVEX→CONCAVE
1
BENDING DEFORMATION
CONCAVE→CONVEX
1
FA
1EP
1
2b
FB
4b
1o
FB
FA
4a
1i
FB
2a
FA
TWELVE O'CLOCK
THREE O'CLOCK
NINE O'CLOCK
SIX O'CLOCK

INTERNATIONAL SEARCH REPORT

International application No. **PCT/JP2022/044180**

A. CLASSIFICATION OF SUBJECT MATTER

B21D 3/14(2006.01)i; ***B21B 23/00***(2006.01)i
FI: B21D3/14 B; B21B23/00 A

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)

B21D3/14; B21B23/00; B21D41/02; B21D41/04

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 202008011983 U1 (KRUMMENAUER GMBH & CO. KG) 11 February 2010 (2010-02-11) entire text, all drawings	1-9
A	JP 60-221128 A (SUMITOMO KINZOKU KOGYO KK) 05 November 1985 (1985-11-05) entire text, all drawings	1-9
A	JP 06-198337 A (SUMITOMO KINZOKU KOGYO KK) 19 July 1994 (1994-07-19) entire text, all drawings	1-9
A	JP 2012-223817 A (NIPPON STEEL ENGINEERING CO., LTD.) 15 November 2012 (2012-11-15) entire text, all drawings	1-9
A	JP 2003-170223 A (NKK CORP.) 17 June 2003 (2003-06-17) entire text, all drawings	1-9

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 February 2023	**21 February 2023**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/044180

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
DE 202008011983 U1	11 February 2010	(Family: none)	
JP 60-221128 A	05 November 1985	(Family: none)	
JP 06-198337 A	19 July 1994	(Family: none)	
JP 2012-223817 A	15 November 2012	EP 2695685 A1 entire text, all drawings WO 2012/137924 A1 AU 2012240903 A1 KR 10-2013-0133906 A	
JP 2003-170223 A	17 June 2003	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP H06198337 A **[0007]**
- JP 2012223817 A **[0007]**
- JP 2003170223 A **[0007]**