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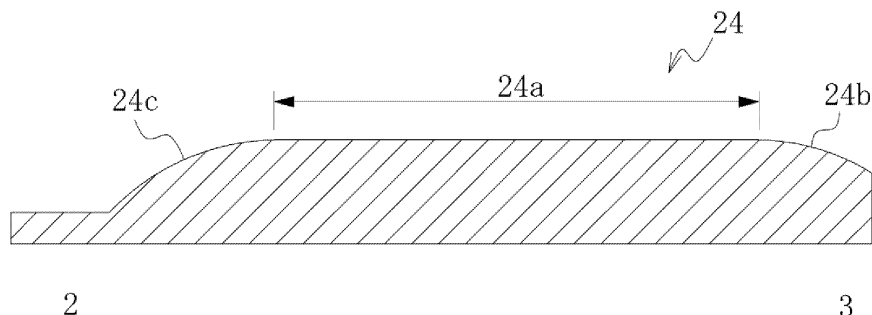
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(54) **METHOD AND DEVICE FOR BENDING EDGE OF STEEL PLATE, AND STEEL PIPE MANUFACTURING METHOD AND EQUIPMENT**

(57) Proposed is an edge bending method of a steel plate in which bending of widthwise edges Sc and Sd of a steel plate S is performed several times by a pair of dies 23 and 24 while the steel plate S is intermittently conveyed by a conveyance mechanism 21 such that the widthwise edges Sc and Sd of the steel plate S are bent across an entire length. Edge bending is performed by using the pair of dies 23 and 24, in which the die 24 that

contacts a surface positioned at the outer side of the edge bending of the widthwise edges Sc and Sd of the steel plate to be bent includes a flat part 24a that contacts the surface positioned at the outer side of the bending and a transition part 24b formed of a curved surface provided adjacent to the flat part 24a on a delivery side in the conveyance direction, and the flat part 24a and the transition part 24b are connected to have a common tangent line.

FIG. 10



**Description**

## TECHNICAL FIELD

**[0001]** The present invention relates to an edge bending method and apparatus for subjecting widthwise edges of a steel plate to edge bending several times separately in a longitudinal direction of the steel plate. Furthermore, the present invention relates to a method and a facility for manufacturing a steel pipe by forming a steel plate subjected to edge bending into a cylindrical shape, butting the widthwise edges to each other, and joining the butted widthwise edges of the steel plate by welding.

## BACKGROUND ART

**[0002]** For manufacture of a large-diameter steel pipe used for a line pipe or the like, there has been used a method in which a steel plate having a predetermined length, width, and thickness is formed by press working into a cylindrical shape having a pipe axis direction in the longitudinal direction of the steel plate, and then the widthwise edges thereof are butt-joined to each other. For the sake of easy formation into a cylindrical shape and appropriate pipe shape, edge bending (crimping) that imparts a predetermined curvature to the widthwise edges of the steel plate is performed prior to the formation into a cylindrical shape.

**[0003]** Such an edge bending is performed in the following manner: a steel plate is arranged between a lower die and an upper die that has a curvature depending on a pipe diameter, and the lower die is lifted by a hydraulic cylinder such that the widthwise edges of the steel plate are pressed against the upper die. However, since the steel plate is longer than the effective length of the dies, the steel plate cannot be pressed across the entire length in a single pressing. Therefore, there has been adopted a method in which bending is performed several times (e.g., three to four times) on the widthwise edges of the steel plate while intermittently feeding the steel plate in the longitudinal direction to perform edge bending across the entire length.

**[0004]** Patent Literatures 1 to 3 disclose a method for obtaining a preferable shape at a butted portion. Patent Literature 1 specifies a feed length  $b$  depending on the thickness or strength of a steel plate. Patent Literature 2 specifies a length  $L_c$  of a region to be bent depending on the thickness or strength of a steel plate. Patent Literature 3 specifies a radius of curvature  $R_1$  of an upper die, a horizontal distance  $u$  from the center of the curvature of the upper die to an edge of a steel plate, and a pressing force  $w$  depending on the thickness or strength of the steel plate. Patent Literature 4 proposes a method of manufacturing a steel pipe in which the variation in shape of a butted portion is small on the basis of the information of the strength of a steel plate. Patent Literature 5 proposes a method for performing edge bending continuously.

**[0005]** Patent Literature 6 discloses a method including a U-ing press process for bending a steel plate over the whole length at the same time in manufacture of a steel pipe, in which a transition part that is tapered toward the edge of the contact face with the steel plate is formed on the both pipe axis direction end portions of the lower rocker shoe of the rocker die in contact with the outer side surface of the steel plate, in order to prevent from locally contacting a portion causing opening deformation at the longitudinal end portion.

## CITATION LIST

## PATENT LITERATURE

**[0006]**

Patent Literature 1: JP-H08-294727 A  
 Patent Literature 2: JP-H10-211520 A  
 Patent Literature 3: JP-2008-119710 A  
 Patent Literature 4: JP-2009-6358 A  
 Patent Literature 5: JP-H07-32049 A  
 Patent Literature 6: JP-2007-245218 A

## SUMMARY OF INVENTION

## TECHNICAL PROBLEM

**[0007]** Patent Literatures 1 to 4 are, however, all aimed at optimization of the shape at a certain cross section of a steel plate and do not take into consideration the variation in edge bending angle between portions adjacent to each

other at a feed boundary of the steel plate. Furthermore, in the method described in Patent Literature 5, it is unclear that a leading end portion, which has no steel plate to the front therefrom, or a trailing end portion, which has no steel plate to the rear therefrom, has the same bending shape as at the middle portion in the longitudinal direction. Moreover, introduction of a new facility is needed. The method described in Patent Literature 6 relates to a method for preventing the opening deformation and does not take into consideration the case of subjecting a part of the steel plate in the longitudinal direction to bending several times while intermittently feeding the steel plate along the longitudinal direction. **[0008]** It is an object of the present invention to solve the problems inherent to the aforementioned conventional techniques and to reduce the variation in edge bending angle between portions adjacent to each other at a feed boundary of a steel plate.

#### MEANS FOR SOLVING THE PROBLEMS

**[0009]** The inventors have studied the variation in edge bending angle between portions adjacent to each other at a feed boundary of a steel plate to figure out the cause thereof, and as a result, arrived at the present invention. A first aspect is an edge bending method of a steel plate using an edge bending apparatus of a steel plate including: a pair of dies configured to be arranged corresponding to a widthwise edge of a steel plate; an actuator configured to clamp the pair of dies with a predetermined pressing force; and a conveyance mechanism configured to convey the steel plate in a direction along a longitudinal direction of the steel plate as a conveyance direction, in which the widthwise edge of the steel plate is subjected to edge bending across an entire length by performing bending of the widthwise edge of the steel plate several times by the pair of dies while the steel plate is intermittently conveyed by the conveyance mechanism, and one of the pair of dies that contacts a surface positioned at the outer side of bending of the widthwise edge of the steel plate to be bent has a flat part that contacts the surface positioned at the outer side of bending and a transition part formed of a curved surface provided adjacent to the flat part at least on a delivery side in the conveyance direction, and the flat part and the transition part are connected to have a common tangent line.

**[0010]** A second aspect is the edge bending method of a steel plate according to the first aspect, in which bending of the widthwise edge of the steel plate is performed with a center of the flat part in the conveyance direction being displaced to the delivery side in the conveyance direction relative to a center of the pressing force generated by the actuator in the conveyance direction.

**[0011]** A third aspect is the edge bending method of a steel plate according to the first or second aspect, in which a leading end portion of the steel plate in the conveyance direction is set to be at a position corresponding to a front end of the flat part in the first pass of bending the widthwise edge of the steel plate.

**[0012]** A fourth aspect is the edge bending method of a steel plate according to any one of the first to third aspects, in which a trailing end portion of the steel plate in the conveyance direction is set to be at a position corresponding to a rear end of the flat part in the final pass for bending the widthwise edge of the steel plate.

**[0013]** A fifth aspect is a method for manufacturing a steel pipe including: an edge bending process of a steel plate using an edge bending apparatus of a steel plate provided with a pair of dies configured to be arranged corresponding to a widthwise edge of a steel plate, an actuator configured to clamp the pair of dies with a predetermined pressing force, and a conveyance mechanism configured to convey the steel plate in a direction along with a longitudinal direction of the steel plate as a conveyance direction, in which the widthwise edge of the steel plate is subjected to edge bending across an entire length by performing bending of the widthwise edges of the steel plate several times by the pair of dies while the steel plate is intermittently conveyed by the conveyance mechanism; a cylinder-forming process in which the steel plate with the widthwise edges subjected to edge bending is formed into a cylindrical shape and the widthwise edges of the steel plate are butted with each other; and a joining process in which the butted widthwise edges of the steel plate are welded, and the edge bending method of a steel plate according to any one of the first to fourth aspects is used as the edge bending process.

**[0014]** A sixth aspect is an edge bending apparatus of a steel plate including: a pair of dies configured to be arranged corresponding to a widthwise edge of a steel plate; an actuator configured to clamp the pair of dies with a predetermined pressing force; and a conveyance mechanism configured to convey the steel plate in a direction along a longitudinal direction of the steel plate as a conveyance direction, in which the widthwise edge of the steel plate is subjected to edge bending across an entire length by performing bending of the widthwise edge of the steel plate several times by the pair of dies while the steel plate is intermittently conveyed by the conveyance mechanism, and one of the pair of dies that contacts a surface positioned at the outer side of bending of the widthwise edge of the steel plate to be bent has a flat part that contacts the surface positioned at the outer side of bending and a transition part formed of a curved surface provided adjacent to the flat part at least on a delivery side in the conveyance direction, and the flat part and the transition part are connected to have a common tangent line.

**[0015]** A seventh aspect is the edge bending apparatus of a steel plate according to the sixth aspect, in which the center of the flat part in the conveyance direction in one of the pair of dies that contacts the surface positioned at the outer side of the edge bending is displaced to the delivery side in the conveyance direction relative to a center of the

pressing force generated by the actuator in the conveyance direction.

**[0016]** An eighth aspect is a facility for manufacturing a steel pipe including:

an edge bending apparatus of a steel plate provided with a pair of dies configured to be arranged corresponding to a widthwise edge of a steel plate, an actuator configured to clamp the pair of dies with a predetermined pressing force, and a conveyance mechanism configured to convey the steel plate in a direction along a longitudinal direction of the steel plate as a conveyance direction, in which the widthwise edge of the steel plate is subjected to edge bending across an entire length by performing bending of the widthwise edge of the steel plate several times by the pair of dies while the steel plate is intermittently conveyed by the conveyance mechanism; a cylinder-forming apparatus configured to form the steel plate with the widthwise edges subjected to edge bending into a cylindrical shape and butt the widthwise edges of the steel plate with each other; and a joining apparatus configured to weld the butted widthwise edges of the steel plate, and the facility for manufacturing a steel pipe includes the edge bending apparatus of a steel plate according to the sixth or seventh aspect as the edge bending apparatus of a steel plate.

## EFFECT OF THE INVENTION

**[0017]** According to the present invention, a steel plate is subjected to edge bending by using a pair of dies in such a configuration that one of the pair of dies that contacts a surface positioned at the outer side of bending of the widthwise edge of the steel plate includes a flat part that contacts the surface positioned at the outer side of bending and a transition part formed of a curved surface provided adjacent to the flat part at least on a delivery side in the conveyance direction, and the flat part and the transition part are connected to have a common tangent line. Thus, the variation in edge bending angle between portions adjacent to each other at the feed boundary of the steel plate can be reduced. As a result, it is possible to manufacture a steel pipe with less weld defects or shape defects at the butt portion.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0018]**

FIG. 1 is a view schematically explaining a facility and method for manufacturing a steel pipe according to an embodiment of the present invention.

FIG. 2 is a plan view illustrating an example of a steel plate subjected to edge bending.

FIG. 3 is a schematic view illustrating an edge bending apparatus of a steel plate according to an embodiment of the present invention.

FIG. 4 is a cross-sectional view in a width direction illustrating a state before edge bending by a press mechanism of the edge bending apparatus of a steel plate of FIG. 3.

FIG. 5 is a cross-sectional view in a width direction illustrating a state during edge bending by a press mechanism of the edge bending apparatus for a steel plate of FIG. 3.

FIG. 6(a) is a cross-sectional view in a conveyance direction illustrating a press mechanism of a conventional edge bending apparatus of a steel plate in a state before edge bending, and FIG. 6(b) illustrates that in a state during edge bending.

FIG. 7 is a graph illustrating a change of a shape of a steel plate by edge bending.

FIG. 8(a) is a view illustrating a relationship between the center of pressing force, the center of a flat part, and the center of bending deformation force in the case of the first edge bending using the conventional edge bending apparatus of a steel plate illustrated in FIG. 6, and FIG. 8(b) is a schematic view illustrating a state in which a lower die is inclined resulting from a relationship between the center of pressing force, the center of a flat part, and the center of bending deformation force.

FIG. 9(a) is a view illustrating a relationship between the center of pressing force, the center of a flat part, and the center of bending deformation force in the case of the second edge bending using the conventional edge bending apparatus of a steel plate illustrated in FIG. 6, and FIG. 9(b) is a schematic view illustrating a state in which a lower die is inclined resulting from a relationship between the center of pressing force, the center of a flat part, and the center of bending deformation force.

FIG. 10 is a cross-sectional view in a conveyance direction illustrating a lower die of an edge bending apparatus of a steel plate according to an embodiment of the present invention.

FIG. 11 is a view illustrating a relationship between the center of pressing force, the center of a flat part, and the center of bending deformation force in the case of first edge bending using an edge bending apparatus of a steel plate of a preferable aspect according to an embodiment of the present invention.

FIG. 12 is a view illustrating a relationship between the center of pressing force, the center of a flat part, and the center of bending deformation force in the case of the second edge bending using an edge bending apparatus of a steel plate of a preferable aspect according to an embodiment of the present invention.

FIG. 13(a) is a view illustrating a relationship between the center of pressing force, the center of a flat part, and the center of bending deformation force in the case of the final edge bending using an edge bending apparatus of a steel plate of a preferable aspect according to an embodiment of the present invention, and FIG. 13(b) is a schematic view illustrating a state in which a lower die is inversely inclined resulting from relationship between the center of pressing force, the center of a flat part, and the center of bending deformation force.

FIG. 14 is a view explaining peaking.

FIG. 15 is a view explaining an edge bending shape and peaking.

## EMBODIMENT FOR CARRYING OUT THE INVENTION

**[0019]** An embodiment of the present invention is described in detail below on the basis of the drawings. Similar constituent elements are designated with the same reference numerals and will not be elaborated as appropriate in the description below. Note that, in the description, "front" or "front side" indicates a "delivery side" or a "direction from entry side to delivery side" in a conveyance direction of a steel plate in an edge bending apparatus described below, and "rear" or "rear side" indicates the opposite direction.

**[0020]** FIG. 1 schematically illustrates a method and a facility for manufacturing a steel pipe according to an embodiment of the present invention for manufacturing a steel pipe from a steel plate which is cut into a predetermined dimension. First, a steel plate S cut into a predetermined dimension is subjected to beveling working on a side surface thereof by an edge miller 10 or an edge planer. In the illustrated example, tab plates St are welded to a leading end portion (longitudinal front end portion) Sa and a trailing end portion (longitudinal rear end portion) Sb of a steel plate S. However, the tab plates St may not be provided. Next, edge bending is performed by an edge bending apparatus (crimping) 20 according to an embodiment of the present invention (edge bending process), and a cylindrical shape is formed by a cylinder-forming apparatus 30 (cylinder-forming process). The cylinder-forming apparatus 30 is not limited to those including a U-ing press 30A that first forms the steel plate S subjected to the edge bending into a U shape, and an O-ing press 30B that then forms the steel plate S into an O shape (cylindrical shape), and may be a bending press 30C including a feed mechanism that feeds the steel plate S in the width direction and gradually forms the steel plate S into a cylindrical shape as a final shape by sequentially feeding the steel plate S in the width direction and performing three-point bending. Next, the widthwise edges of the steel plate S, which are butted with each other as a result of the cylindrical formation, are temporarily welded from the outer surface and then welded by submerged arc welding or the like from the inner surface and the outer surface by a joining apparatus 40 (joining process). Then, the diameter of the steel pipe S' is expanded by a mechanical expander 50 to remove the residual stress, and the steel pipe S' is finished so as to have a predetermined outer diameter and dimension (pipe expansion process). It is noted that other processing such as cleaning, various inspection and bead grinding may be performed in each process or between the processes.

**[0021]** The edge bending apparatus 20 of a steel plate according to an embodiment of the present invention and the edge bending method of a steel plate using the same are described in more detail. FIG. 2 illustrates an example of the steel plate S prior to edge bending. The width of the steel plate S has a wide range, e.g., from 1200 mm to 5100 mm, depending on the outer diameter of a steel pipe product. Furthermore, a steel plate often has a length of about 12 m, which is a standard length of a line pipe. Tab plates St are welded to each widthwise edge of a leading end portion Sa and a trailing end portion Sb of the steel plate S, which becomes a steel pipe body, in the longitudinal direction. However, the tab plates St may be absent.

**[0022]** FIG. 3 illustrates a schematic configuration of the edge bending apparatus 20 of a steel plate. The edge bending apparatus 20 of a steel plate includes a conveyance mechanism 21 that conveys the steel plate S in a direction along with the longitudinal direction thereof as a conveyance direction 1, a press mechanism 22A that bends a widthwise edge Sc, which is on a left side when a delivery side 3 in the conveyance direction is the front side, into a predetermined curvature, a press mechanism 22B that bends a widthwise edge Sd on a right side into a predetermined curvature, and a space adjustment mechanism, which is not illustrated, that adjusts a space between the right and left press mechanisms 22A and 22B depending on the width of the steel plate S on which the edge bending is performed. The conveyance mechanism 21 includes a plurality of conveyance rolls 21a, which are arranged before and after the press mechanisms 22A and 22B. The roll shafts of the conveyance rolls 21a are arranged in a direction perpendicular to the conveyance direction of the steel plate S and are configured to be rotated at a synchronized velocity by a motor and a transmission mechanism, which are not illustrated.

**[0023]** FIG. 4 illustrates a widthwise cross section of the press mechanism 22A that performs edge bending of the left widthwise edge Sc of the steel plate S when viewed in a direction from an entry side 2 to a delivery side 3 of the conveyance direction 1 of the steel plate S. Note that the press mechanism 22A and the press mechanism 22B are bilaterally symmetric and have the same configuration, and accordingly, a detailed illustration of the press mechanism 22B is omitted. The press mechanism 22A and 22B include an upper die 23 and a lower die 24, which are a pair of dies arranged opposite to each other in a vertical direction, a hydraulic cylinder 26, which is an actuator that lifts the lower die 24 together with a tool holder 25 and performs clamping with a predetermined pressing force, and a holding mechanism

27 that releasably holds the steel plate S at each widthwise inner side of the upper die 23 and the lower die 24. Note that the length of the lower die 24 and the upper die 23 in the longitudinal direction of the steel plate S is shorter than the length of the steel plate S. Edge bending is performed several times with the steel plate S being moved (intermittently fed) in the longitudinal direction by the conveyance mechanism 21 to provide edge bending on the widthwise edges Sc and Sd of the steel plate S across the entire length.

**[0024]** FIG. 5 is a cross-sectional view in the width direction at the same position as in FIG. 4 illustrating a state in which the lower die 24 is clamped by being lifted by the hydraulic cylinder 26. When the hydraulic cylinder 26 is advanced from a state before the edge bending indicated by the dotted line, the lower die 24 is lifted and brought into the position of the solid line. The widthwise edges Sc and Sd of the steel plate S are bent into a shape following the arc-shaped processing face of the upper die 23. The width on which the edge bending is performed varies with the width of the steel plate S and is generally about 100 mm to 400 mm. Herein, an example is given of the case where the holding mechanism 27 for holding the steel plate S during the edge bending is performed, but is not limited to the presence or absence of the holding mechanism 27.

**[0025]** FIG. 6 is a cross-sectional view along with the conveyance direction 1 illustrating a state in which the widthwise edges Sc and Sd of the steel plate S are subjected to edge bending. The steel plate S is carried in from the left side of the drawing and carried out to the right side. The lower die 24 includes a flat part 24a that mainly provides the edge bending. Within the portion facing the upper die 23, the flat part 24a indicates a portion that is extended linearly along the conveyance direction 1 and is planar in the cross section along with the conveyance direction 1, but does not mean that it is planar in a widthwise cross section. The shape of the flat part 24a in the widthwise cross section is not particularly limited, and may be an arc shape or straight shape that is inclined to face inward in the width direction. In order to reduce the number of times of edge bending, the effective length of the lower die 24, i.e., the length of the flat part 24a is set to be larger than the width that is subjected to the edge bending. The flat part 24a, for example, has a length of 3 m to 5 m, which is a size about 10 times greater than the width that is subjected to the edge bending. Hence, a plurality of hydraulic cylinders 26 for lifting the lower die 24 is typically arranged along the conveyance direction 1. In this case, in general, a combination of a piston-type hydraulic cylinder 26 that generates a thrust force in two directions: upward and downward and a ram-type hydraulic cylinder 26 that generates a thrust force only during upward movement is used. In the illustrated example, the piston-type hydraulic cylinder 26 is arranged in a middle in the conveyance direction 1 and the ram-type hydraulic cylinders 26 are arranged before and after the piston-type hydraulic cylinder 26. Conventionally, for uniform application of pressing force P, the flat part 24a of the lower die 24 is designed such that a center C1 of the flat part 24a in the conveyance direction 1 matches a center C2 of the pressing force by the hydraulic cylinders 26.

**[0026]** FIG. 6(a) illustrates a state in which the widthwise edges Sc and Sd of the steel plate S are bent by the press mechanisms 22A and 22B and then the steel plate S is conveyed a predetermined conveyance distance by the conveyance mechanism 21. This conveyance distance is set to be smaller than the length of the flat part 24a of the lower die 24. Thus, a rear end of the portion already subjected to edge bending is positioned on the flat part 24a of the lower die 24, and a transition between the already formed portion and a non-formed portion is unfailingly bent at the next edge bending. The steel plate S is arranged such that a rear end portion of the portion already imparted with edge bending is positioned on the flat part 24a as indicated by the dotted line in FIG. 6(b), and the hydraulic cylinders 26 lift the lower die 24 to perform edge bending of the widthwise edges Sc and Sd of the steel plate S as indicated by the solid lines. At this time, a range that has been bent in the previous process is also bent again for its springback amount, while bending occurs at a portion at the entry side 2 (left side in the drawing) of the steel plate S, which is not positioned on the flat part 24a of the lower die 24. As one example, FIG. 7 illustrates results obtained when the edge bending is performed with respect to a range of 170 mm at the widthwise edges of the steel plate S having a plate width of 2755 mm  $\times$  a plate thickness of 28.9 mm and the shape is examined. The flat part 24a of the lower die 24 has a length of 3 m, and the edge bending angle is measured when the first edge bending is performed with respect to the range of 2.8 m from the leading end of the steel plate. The steel plate is then conveyed 2 m, and the edge bending angle is again measured when the second edge bending is performed. Here, the edge bending angle is determined from a difference between an inclination angle in a range of 20 mm at the widthwise edge and an inclination angle of a widthwise middle portion measured by an inclinometer. In FIG. 7, the edge bending angle in the first edge bending is plotted as ●, and the bending angle in the second edge bending is plotted as ▲. Moreover, the range that of the flat part 24a of the lower die in the first edge bending is indicated as Ra1, and the range of the flat part 24a of the lower die in the second edge bending is indicated as Ra2. In the first edge bending, the edge bending angle is large (Da) at the leading end portion Sa of the steel plate S, and bending also occurs at a portion that does not contact the flat part 24a on the entry side 2 for a length of about 0.6 m. In the second edge bending, bending is further applied to the portion that has been bent in the first edge bending, and the edge bending angle becomes larger toward the delivery side 3 (Dc). On the entry side 2, the edge bending angle is slightly large in the vicinity of the end of the flat part 24a. Similar to the first edge bending, bending also occurs at the portion that does not contact the flat part 24a for a length of about 0.6 m. At this time, the amount of lifting of the lower die 24 is larger by 2 mm on the delivery side 3. It is presumed that an inclination of 0.04 degrees is generated during the edge bending such that the leading end portion side is inclined upward (rotation in pitching direction).

**[0027]** Further study is conducted to unravel the cause of this inclination. FIG. 8(a) schematically illustrates the deformation of the steel plate S and distribution of the bending deformation force Df (force against the pressing force P in edge bending; hereinafter also simply referred to the "deformation force") at the time of the first edge bending. The deformation force Df is absent on the delivery side 3 where the steel plate S is absent, while the deformation force Df occurs on the entry side 2 even in a portion that is not positioned on the flat part 24a. Therefore, a center C3 of the deformation force Df is at a position displaced to the entry side 2 relative to the center C1 of the flat part 24a in the conveyance direction 1. FIG. 9(a) illustrates the case of the second edge bending. Since the steel plate S is present on the delivery side 3, the deformation force Df also occurs on the delivery side 3. However, the deformation amount is small as compared to the amount of the springback, and the center C3 of the deformation force Df is at a position displaced to the entry side 2 relative to the center C1 of the flat part 24a. When the center C1 of the flat part 24a matches the center C2 of the pressing force P by the hydraulic cylinders 26, as illustrated in FIGS. 8(b) and 9(b), the force that rotates the leading end portion side in the upward direction (pitching) is applied to the lower die 24, so that the amount of lifting of the lower die 24 becomes large on the delivery side 3.

**[0028]** As illustrated in FIG. 9, when there is a portion that has already been subjected to the edge bending on the delivery side 3, the bending deformation force Df is absent in this portion at the beginning of the subsequent edge bending, and the bending deformation force Df becomes large on the entry side 2. As a result, the lower die 24 does not contact the steel plate S on the delivery side 3, and the center C3 of the bending deformation force Df is displaced to the entry side 2 relative to the center C2 of the pressing force P. Therefore, until the bending deformation occurs on the delivery side 3, the force of rotating the leading end portion of the lower die 24 in the upward direction is applied and the amount of lifting is large on the delivery side 3, so that the edge bending is performed with the lower die 24 being inclined. As a result, there is a concern that the delivery end portion of the flat part 24a contacts the portion that has already been subjected to the edge bending, and as illustrated in FIG. 7 for example, the portion of the steel plate that contacts the delivery end portion is deformed at the second edge bending and thus forms a large step with respect to the portion that has been subjected to the first edge bending on the delivery side 3. That is, the edge bending angle is varied between portions adjacent to each other at a feed boundary of the steel plate S. A steep shape change results in discontinuous welding at the relevant portion, thereby generating defect or discontinuation of welding. Therefore, the change of the edge bending angle in the longitudinal direction is desirably smooth (small).

**[0029]** Thus, the edge bending method and apparatus of a steel plate and a method and facility for manufacturing a steel pipe according to the present invention, the lower die 24, which contacts a surface that is positioned at the outer side of bending of the steel plate to be bent, is provided with a transition part 24b formed of a curved surface adjacent to the flat part 24a on a delivery side 3, and the flat part 24a and the transition part 24b are connected via a common tangent line, as illustrated in FIG. 10. When such a transition part 24b having a curved surface shape continuous with the flat part 24a is provided on the delivery side 3, a step between the portion of the steel plate S subjected to the edge bending in the previous pass and the portion subjected to the edge bending in the subsequent pass (difference in edge bending angle between portions adjacent to each other at the feed boundary) can be reduced. At this time, the step becomes smoother when the change of the angle of the transition part 24b is small, i.e., the change of curvature is continuous, like an involute curve. However, it is necessary that the delivery end portion of the lower die 24 does not contact the portion that has already been subjected to the edge bending. Similarly, a transition part 24c formed of a curved surface may be provided on an entry side 2 of the flat part 24a, and the flat part 24a and the transition part 24c may be connected via a common tangent line. At this time, it is necessary that the transition part 24c such that the bending deformation length L (see, for example, FIG. 11) on the rear side relative to the rear end of the flat part 24a does not become large. The length and angle variation of the transition part 24c are preferable to be set appropriately in consideration of the above points and the amount of edge bending that varies with the width of the steel plate S. As a guide, the length or the angle of the transition part 24c can be changed such that the range in which the transition part 24c contacts the steel plate S becomes not more than half the length L over which the bending deformation occurs on the entry side 2.

**[0030]** The difference in the edge bending angle between portions adjacent to each other at the feed boundary can be further decreased by reducing the inclination of the lower die 24 during the edge bending, as well as by forming the transition parts 24b and 24c continuously to the flat part 24a on the delivery side 3 and the entry side 2. Therefore, in the edge bending method and apparatus of a steel plate and the method and facility for manufacturing a steel pipe according to the present embodiment, the center C1 of the flat part 24a of the lower die 24 is preferably displaced to the delivery side 3 relative to the center C2 of the pressing force P. FIGS. 11 and 12 schematically illustrate the deformation of the steel plate S and the distribution of the deformation force Df in the case where the center C1 of the flat part 24a of the lower die 24 is shifted only displacement amount d to the delivery side 3 relative to the center C2 of the pressing force P. FIG. 11 illustrates the first edge bending, and FIG. 12 illustrates the second edge bending. It can be understood that the deformation force Df on the entry side 2 is small and the center C3 of the deformation force Df is positioned close to the center C2 of the pressing force P. Thus, the inclination (pitching) of the lower die 24 such that the leading end portion is inclined upward during the edge bending can be suppressed by displacing the center C1 of the flat part

24a to the delivery side 3 relative to the center C2 of the pressing force P.

[0031] The preferable displacement amount  $d$  of the center C1 of the flat part 24a with respect to the center C2 of the pressing force P can be determined in the manner described below. As illustrated in FIGS. 8, 9, 11, and 12, in the case where the bending deformation force  $D_f$  that occurs on the entry side 2 of the flat part 24a varies substantially linearly, the sum thereof is half the deformation force  $D_f$  that occurs in the flat part 24a. That is, the deformation force  $D_f$  is applied on the entry side 2 to the position half a bending deformation length  $L$  from the rear end of the flat part 24a (See FIGS. 11 and 12). When the displacement amount  $d$  of the center C1 of the flat part 24a is one fourth of the bending deformation length  $L$  on the entry side 2 relative to the rear end of the flat part 24a, a symmetric force with respect to the center C2 of the pressing force P by the hydraulic cylinders 26 is applied, so that the inclination of the lower die 24 can be minimized.

[0032] However, the length  $L$  of the bending deformation occurred on the entry side 2 relative to the rear end of the flat part 24a varies with the amount of edge bending. When a steel pipe to be manufactured has a small outer diameter, the width of the steel plate is also small. Therefore, the edge bending angle (a difference between the inclination angle in a range of 20 mm at the widthwise edge portion and the inclination angle of the widthwise middle portion) becomes large, and the length  $L$  over which the bending deformation occurs on the entry side 2 becomes large. When the steel plate illustrated in FIG. 7 has a width of 2755 mm, the length  $L$  over which the bending deformation occurs on the entry side 2 is about 0.6 m, and 150 mm, which is one fourth of 0.6 m, is the optimum displacement amount  $d$ . However, when the steel plate has a width of 1200 mm, the length  $L$  over which the bending deformation occurs on the entry side 2 is about 1.0 m, and 250 mm, which is one fourth of 1.0 m, is the optimum displacement amount  $d$ . Accordingly, it is preferable that the displacement amount  $d$  of the center C1 of the flat part 24a with respect to the center C2 of the pressing force P be appropriately set depending on the width of the steel plate to be subjected to the edge bending. Specifically, it is preferable that the displacement amount  $d$  be set large with an increase in the edge bending angle.

[0033] The deformation force  $D_f$  applied on the delivery side 3 is increased as the displacement amount  $d$  is increased. In this case, the amount of lifting on the entry side 2 is increased, so that the amount of edge bending on the entry side 2 is increased. Therefore, it is preferable that the displacement amount  $d$  be not more than half the length  $L$  over which the bending deformation occurs on the entry side 2. FIG. 13 illustrates the deformation of the steel plate S and the distribution of the deformation force  $D_f$  in the case where the widthwise edges  $S_c$  and  $S_d$  of the trailing end portion  $S_b$  of the steel plate S are subjected to edge bending (final pass) with the center C1 of the flat part 24a being displaced toward the delivery side 3 relative to the center C2 of the pressing force P. In this case, the center C3 of the deformation force  $D_f$  is positioned apart from the center C2 of the pressing force P (displaced to the delivery side 3) as compared with the case of FIGS. 11 and 12, and the force of rotating the front side of the lower die 24 downward (pitching) is applied to increase the amount of lifting on the entry side 2. Accordingly, it is desirable that the upper limit of the displacement amount  $d$  be determined such that the edge bending does not become excessively large at the trailing end portion  $S_b$  side of the steel plate S.

[0034] Thus, according to a preferable aspect of the edge bending method and apparatus of a steel plate and the method and facility for manufacturing a steel pipe of the present embodiment, the lower die 24 of the pair of the dies 23 and 24 includes the flat part 24a that contacts the surface positioned at the outer side of the edge bending of widthwise edges  $S_c$  and  $S_d$  of the steel plate S to be subjected to edge bending, and the widthwise edges  $S_c$  and  $S_d$  of the steel plate S are subjected to edge bending with the center C1 of the flat part 24a in the conveyance direction 1 being displaced to the delivery side 3 in the conveyance direction 1 relative to the center C2 of the pressing force P generated by the hydraulic cylinders 26 in the conveyance direction 1, so that the center C3 of the deformation force  $D_f$  moves closer to the center C2 of the pressing force P. As a result, it is possible to suppress the inclination of the lower die 24 during the edge bending and reduce the variation in the amount of bending deformation  $D_f$  of the widthwise edges  $S_c$  and  $S_d$  of the steel plate S in the longitudinal direction. Furthermore, shifting of the center C1 of the flat part 24a relative to the center C2 of the pressing force P can be achieved without introduction of a new facility, for example, by displacing the lower die 24 to the delivery side 3 in the conveyance direction 1 relative to the tool holder 25 and the hydraulic cylinders 26 or by displacing the hydraulic cylinders 26 to the entry side 2 in the conveyance direction 1 relative to the lower die 24 in an existing facility.

[0035] Next, description is given of a positional relationship between the leading end portion (longitudinal front end)  $S_a$  and the trailing end portion (longitudinal rear end)  $S_b$  of the steel plate S and the flat part 24a of the lower die 24. Note that the leading end portion  $S_a$  and the trailing end portion  $S_b$  of the steel plate S are portions that become the longitudinal ends of the steel pipe product excluding, in the presence of the tab plates  $S_t$ , the tab plates  $S_t$  and correspond to the end portions  $S_a$  and  $S_b$  in FIG. 2. As illustrated in FIG. 11, when the leading end portion  $S_a$  of the steel plate S is positioned in the rear of the leading end portion of the flat part 24a in the first (first pass) edge bending, the bending deformation force  $D_f$  does not occur on the delivery side 3 relative to the leading end portion  $S_a$  of the steel plate S. Therefore, the center C3 of the deformation force  $D_f$  is displaced to the entry side 2 relative to the center C2 of the pressing force P. When the leading end portion  $S_a$  of the steel plate S is brought closer to the leading end portion of the flat part 24a, the displacement amount between the center C3 of the deformation force  $D_f$  and the center C2 of the pressing force P becomes small, and it is possible to suppress the variation in the amount of edge bending. At this time,



when the leading end portion Sa of the steel plate S lies on the delivery side 3 relative to the leading end portion of the flat part 24a, the portions where the tab plates St are welded are bent insufficiently and welding is discontinuous at a transition portion from the tab plates St to the steel plate S. Therefore, it is preferable that the position of the leading end portion Sa of the steel plate S be in a position not exceeding the leading end portion of the flat part 24a. Similarly, when the trailing end portion Sb of the steel plate S is positioned to the front of the rear end portion of the flat part 24a in the final (final pass) edge bending, the bending deformation force Df does not occur on the entry side 2 relative to the trailing end portion Sb of the steel plate S. Therefore, the center C3 of the deformation force Df is displaced to the delivery side 3 relative to the center C2 of the pressing force P. When the trailing end portion Sb of the steel plate S is brought closer to the rear end portion of the flat part 24a as illustrated in FIG. 13, the displacement amount between the center C3 of the deformation force Df and the center C2 of the pressing force P becomes small, and it is possible to suppress the variation in the amount of edge bending. In this case, when the trailing end portion Sb of the steel plate S is on the entry side 2 relative to the rear end portion of the flat part 24a, the portions where the tab plates St are welded are bent insufficiently and welding is discontinuous at a transition portion from the tab plates St to the steel plate S. Therefore, it is preferable that the position of the trailing end portion Sb of the steel plate S be in a position not exceeding the rear end portion of the flat part 24a.

**[0036]** The embodiment of the present invention has been described heretofore on the basis of the illustrated examples, but the present invention is not limited thereto. Changes, corrections, additions or the like may be made within the scope of the claims. For example, in the illustrated examples, descriptions are given of the case where the edge bending is performed such that the lower die 24 is lifted by the hydraulic cylinders 26 and the widthwise edges Sc and Sd of the steel plate S are pressed against the upper die 23. However, the lower die 24 may be stationary and the upper die 23 may be movable such that the upper die 23 is pressed downward and the widthwise edges Sc and Sd of the steel plate S are pressed against the lower die 24 so as to bend the plate in the same direction as that of the illustrated example. Furthermore, the bending may be performed by exchanging the positions of the upper die 23 and lower die 24 such that the upper side surface of the steel plate is positioned at the outer side of bending, which is opposite to the illustrated example. In this case, a transition part is provided adjacent to the flat part of the upper die 23, which is positioned at the outer side of bending, on the entry side 2 and the delivery side 3 in the conveyance direction. Alternatively, both of the upper die 23 and the lower die 24 may be configured to be moved in the directions in which they come closer to or move apart from each other. In this case, a transition part is provided adjacent to the flat part each on the entry side 2 and the delivery side 3 in the conveyance direction 1 of either one that is positioned on the outer side of bending, between the upper die 23 or the lower die 24. Furthermore, the number of hydraulic cylinders 26 that clamp the upper die 23 and the lower die 24 is not limited. The clamping may be performed through the use of one, two, or three or more hydraulic cylinders 26. Furthermore, the actuator that clamps the upper die 23 and the lower die 24 is not limited to the hydraulic cylinder 26, but those of a mechanical type that performs clamping by converting the rotation movement of a motor into reciprocation movement with a crank mechanism or the like may be used.

#### EXAMPLE

**[0037]** In order to ascertain the effect of the present invention, the description is made below with respect to the study results of the variation in edge bending in the longitudinal direction performed under different conditions and the influence of the variation on a subsequent welding process.

#### EXAMPLE 1

**[0038]** A steel plate having a tensile strength of 500 MPa, a plate width of 1676 mm  $\times$  a plate thickness of 25.4 mm  $\times$  a length of 12 m including a tab plate having a length of 400 mm  $\times$  a width of 100 mm attached to the leading end portion and the trailing end portion is prepared, and a steel pipe having an outer diameter of 559 mm is manufactured. An edge bending apparatus of a type that lifts the lower die with three hydraulic cylinders (actuators) arranged at intervals of 1000 mm is used for edge bending. The central hydraulic cylinder is of a piston type, and the other two are of a ram type. The output of the central hydraulic cylinder is half the output of each of the other hydraulic cylinders, and the output of the three hydraulic cylinders is 15 MN in total.

**[0039]** The upper die used for the edge bending has a processing face having a radius of curvature of 200 mm. The flat part of the lower die has a straight shape forming an angle of 40 degrees with respect to the horizontal surface in the widthwise cross section. The upper die has the same cross-sectional shape across the entire length. Three types of lower dies are used: one in which the flat part has a length of 3000 mm and both ends thereof in the longitudinal direction are chamfered at C25 mm (hereinafter called the "die A"); another including a gentle transition part of R1600 mm formed continuously from the flat part having a length of 3000 mm on the delivery side 3 (hereinafter called the "die B"); and the other including a gentle transition part of R1600 mm formed continuously from the flat part having a length of 3000 mm on both of the entry side 2 and the delivery side 3 (hereinafter called the "die C").

**[0040]** With a goal of providing an edge bending angle (a difference between the inclination angle in a range of 20 mm at the widthwise edge portion and the inclination angle of the widthwise middle portion) of 33 degrees to a range of 155 mm at the widthwise edges of the steel plate, the steel plate is subjected to the edge bending four times while being fed 2600 mm at each time and then subjected to the fifth edge bending such that the trailing end of the steel plate is stopped at a predetermined position. After the edge bending, the edge bending angle is measured at a pitch of 0.1 m in the longitudinal direction. A difference between the maximum and the minimum in the range of 10 m at the middle in the longitudinal direction is defined as a stationary portion variation, and a difference between the maximum and the minimum across the entire length is defined as an entire length variation, and an angular difference at a step portion where the difference is the largest is assessed as steepness. The edge bending angle is determined from a difference between the inclination angle in a range of 20 mm at the widthwise edge portion and the inclination angle of the widthwise middle portion measured by using an inclinometer. Next, U-ing press and O-ing press are performed for formation into a cylindrical shape, and the widthwise edges of the steel plate subjected to the edge bending are butted, and then the butted widthwise edges are welded to manufacture a steel pipe. The peaking Dp of the steel pipe is measured at a pitch of 0.1 m in the longitudinal direction. The peaking Dp is an index of a pointed shape of the butted portion and is a difference between an outer diameter of a regular steel pipe product (i.e., virtual perfect circle Se) and the actual shape Sp of the steel pipe as illustrated in FIG. 14. As illustrated in FIG. 15, when the amount of edge bending is excessively large, the butted portion of the steel pipe has an inwardly dent shape (minus peaking Dp-), while the amount of edge bending is excessively small, the butted portion of the steel pipe has an outwardly protruding shape (plus peaking Dp+). Note that, similar to the edge bending angle, regarding the peaking Dp, a difference between the maximum and the minimum in the range of 10 m at the middle in the longitudinal direction is defined as a stationary portion variation, and a difference between the maximum and the minimum across the entire length is defined as an entire length variation.

**[0041]** The edge bending conditions and the formation results are indicated in Table 1. The box of the leading/trailing end stop position (stop position of leading end portion and trailing end portion of steel plate) indicates "steel plate" when the boundary between the steel plate and the tab plate is positioned on the delivery side end portion of the flat part of the lower die at the first edge bending and also the boundary between the steel plate and the tab plate is positioned on the entry side end portion of the flat part of the lower die at the fifth edge bending. Furthermore, "tab" is indicated when the entire length of the tab plate is included in the flat part of the lower die and the end portion of the steel plate is positioned 400 mm inward from the flat part of the lower die.

Table 1

Condition No.	Displacement amount d [mm]	Die	Leading/trailing end stop position	Variation in edge bending angle		Angular difference between portions adjacent to each other [°]	Number of stop of welding	Variation in peaking of steel pipe		Remarks
				Stationary portion [°]	Entire length [°]			Stationary portion [mm]	Entire length [mm]	
1	150	B	Steel plate	1.0	1.0	0.6	0	1.0	1.0	Inventive Example
2	150	B	Tab	1.2	1.7	0.5	0	1.1	1.8	Inventive Example
3	0	B	Steel plate	1.6	1.6	1.1	0	2.0	2.0	Inventive Example
4	0	B	Tab	1.7	2.4	1.2	0	2.4	2.8	Inventive Example
5	150	C	Steel plate	0.9	0.9	0.5	0	0.9	0.9	Inventive Example
6	150	C	Tab	1.1	1.5	0.5	0	1.0	1.6	Inventive Example
7	0	c	Steel plate	1.7	1.7	1.1	0	2.3	2.3	Inventive Example
8	0	C	Tab	1.6	2.3	1.2	0	2.4	2.7	Inventive Example
9	0	A	Steel plate	3.4	3.4	3.4	4	3.1	3.1	Comparative Example
10	0	A	Tab	3.2	4.8	3.2	4	3.3	4.0	Comparative Example

**[0042]** As indicated in Table 1, under conditions 1 to 4 in which the die B provided with a gentle transition part on the delivery side 3 is used and conditions 5 to 8 in which the die C provided with a gentle transition part on the entry side 2 and delivery side 3, the feed boundary is hardly recognizable by sight and the angular difference between adjacent portions is about half of the variation of the edge bending angle of the stationary portion. Meanwhile, under conditions 9 and 10 in which the die A is used, the feed boundary is clearly recognizable, and the angular difference between adjacent portions is the same as the variation of the edge bending angle of the stationary portion, and the edge bending angle sharply changes as compared with the case where the die B or C is used. When comparing the conditions 1 with 5, conditions 2 with 6, conditions 3 with 7, and conditions 4 with 8, in which only the die used is different, there are little differences in the variation of the edge bending angle although the variation is smaller in some cases using the die C, and it can be seen that a transition part may be formed at least on the delivery side 3.

**[0043]** Furthermore, under conditions 3, 4, 7 and 8 in which the center C1 of the flat part of the lower die in the conveyance direction is set to be displaced 150 mm (displacement amount d) to the delivery side 3 in the conveyance direction 1 relative to the center of the central hydraulic cylinder, i.e., the center C2 of the pressing force P, the variation of the edge bending angle and the variation of the peaking of the stationary portion are suppressed to about not more than half of those of conditions 1, 2, 5, 6, 9, and 10 in which the center of the flat part of the lower die is set to match the center of the central hydraulic cylinder.

**[0044]** Furthermore, under the conditions 1, 3, 5, 7 and 9 in which the longitudinal end of the steel plate is stopped so as to be positioned at the end of the flat part, the variation of the edge bending angle of the stationary portion is the same as the variation of the edge bending angle of the entire length, and the variation of the peaking of the stationary portion is the same as the variation of the peaking of the entire length, and the amount of edge bending is the same across the entire length. Meanwhile, under the conditions 2, 4, 6, 8, and 10 in which the longitudinal end of the steel plate is positioned on the inner side of the flat part of the lower die, the amount of edge bending is large at the end and the variation across the entire length is large. In particular, under the condition 1 in which the "die B" is use and the longitudinal end of the steel plate is stopped at the position of the end of the flat part and the center C1 of the flat part is displaced to the delivery side 3 in the conveyance direction relative to the center C2 of the pressing force P, and the condition 5 in which the "die C" is used and the longitudinal end of the steel plate is stopped at the position of the end of the flat part and the center C1 of the flat part is displaced to the delivery side 3 in the conveyance direction relative to the center C2 of the pressing force P, the variation of the peaking is 0.9 to 1.0 mm, which is not more than one sixth of  $\pm 3.2$  mm, a peaking tolerance required by API standards, and it can be understood that the shape is superior.

**[0045]** Under the conditions 9 and 10, which do not satisfy the conditions of the present invention, the variations of the peaking and the edge bending angle are large as compared with the inventive examples. In particular, the large difference in the edge bending angle indicates that an abrupt change occurs at the step of the feed boundary. Since this abrupt change exceeds the profiling limit of a welding torch, the welding is stopped urgently.

## EXAMPLE 2

**[0046]** A steel plate having a tensile strength of 550 MPa, a plate width of 2753 mm  $\times$  a plate thickness of 38.1 mm  $\times$  a length of 12 m including a tab plate having a length of 400 mm  $\times$  a width of 100 mm attached to the leading end portion and the trailing end portion is prepared, and a steel pipe having an outer diameter of 914 mm is manufactured. The upper die used for the edge bending has a processing face having a radius of curvature of 335 mm. The edge bending is performed with a goal of providing an edge bending angle of 24 degrees to a range of 180 mm at the widthwise edges of the steel plate. The other edge bending conditions such as the edge bending apparatus, the lower die, and the feed amount of the steel plate are the same as those of Example 1. The edge bending angle is measured after the edge bending, and then the steel plate is formed into a cylindrical shape by a bending press method, followed by welding to give a steel pipe. The edge bending conditions and the formation results are indicated in Table 2. The items and descriptions in Table 2 are the same as those of Example 1.

Table 2

Condition No.	Displacement amount d [mm]	Die	Leading/trailing end stop position	Variation in edge bending angle		Angular difference between portions adjacent to each other [°]	Number of stop of welding	Variation in peaking of steel pipe		Remarks
				Stationary portion [°]	Entire length [°]			Stationary portion [mm]	Entire length [mm]	
1	150	B	Steel plate	0.9	0.9	0.5	0	0.9	0.9	Inventive Example
2	150	B	Tab	1.1	1.5	0.4	0	1.0	1.6	Inventive Example
3	0	B	Steel plate	1.4	1.4	1.0	0	1.8	1.8	Inventive Example
4	0	B	Tab	1.5	2.1	1.1	0	2.1	2.5	Inventive Example
5	150	C	Steel plate	0.8	0.8	0.4	0	0.8	0.8	Inventive Example
6	150	C	Tab	1.0	1.3	0.4	0	0.9	1.4	Inventive Example
7	0	C	Steel plate	1.5	1.5	1.0	0	2.0	2.0	Inventive Example
8	0	C	Tab	1.4	2.0	1.1	0	2.1	2.4	Inventive Example
9	0	A	Steel plate	3.0	3.0	3.0	3	2.7	2.7	Comparative Example
10	0	A	Tab	2.8	4.2	2.8	4	2.9	3.5	Comparative Example

**[0047]** As indicated in Table 2, under conditions 1 to 4 in which the die B provided with a gentle transition part on the delivery side 3 is used and conditions 5 to 8 in which the die C provided with a gentle transition part on the entry side 2 and delivery side 3 is used, the feed boundary is hardly recognizable by sight and the angular difference between adjacent portions is about half of the variation of the edge bending angle of the stationary portion. Meanwhile, under conditions 9 and 10 in which the die A is used, the feed boundary is clearly recognizable, and the angular difference between adjacent portions is the same as the variation of the edge bending angle of the stationary portion, and the edge bending angle sharply changes as compared with the case where the die B or die C is used. When comparing the conditions 1 with 5, conditions 2 with 6, conditions 3 with 7, and conditions 4 with 8, in which only the die used is different, there are little differences in the variation of the edge bending angle although the variation is smaller in some cases using the die C, and it can be seen that a transition part may be formed at least on the delivery side 3.

**[0048]** Furthermore, under the conditions 3, 4, 7 and 8 in which the center C1 of the flat part of the lower die in the conveyance direction is set to be displaced 150 mm (displacement amount d) to the delivery side 3 in the conveyance direction relative to the center of the central hydraulic cylinder, i.e., the center C2 of the pressing force P, the variation of the edge bending angle and the variation of the peaking of the stationary portion are suppressed to about half of those of the conditions 1, 2, 5, 6, 9, and 10 in which the center C1 of the flat part of the lower die is set to match the center of the central hydraulic cylinder.

**[0049]** Furthermore, under the conditions 1, 3, 5, and 7 in which the longitudinal end of the steel plate is stopped so as to be positioned at the end of the flat part, the variation of the edge bending angle of the stationary portion is the same as the variation of the edge bending angle of the entire length, and also the variation of the peaking of the stationary portion is the same as the variation of the peaking of the entire length, and the amount of edge bending is the same across the entire length. Meanwhile, under the conditions 2, 4, 6, and 8 in which the longitudinal end of the steel plate is positioned on the inner side of the flat part of the lower die, the amount of edge bending is large at the end and the variation across the entire length is large. In particular, under the condition 1 in which the "die B" is used and the longitudinal end of the steel plate is stopped at the position of the end of the flat part and the center C1 of the flat part is displaced to the delivery side 3 in the conveyance direction relative to the center C2 of the pressing force P, and the condition 5 in which "die C" is used and the longitudinal end of the steel plate is stopped at the position of the end of the flat part and the center C1 of the flat part is displaced to the delivery side 3 in the conveyance direction relative to the center C2 of the pressing force P, the variation of the peaking is 0.8 to 0.9 mm, which is not more than one seventh of  $\pm 3.2$  mm, a peaking tolerance required by API standards, and it can be understood that the shape is superior.

**[0050]** Under the conditions 9 and 10, which do not satisfy the conditions of the present invention, the variations of the peaking and the edge bending angle are large as compared with the inventive examples. In particular, the large difference in edge bending angle indicates that an abrupt change occurs at the step of the feed boundary. Since this abrupt change exceeds the profiling limit of a welding torch, the welding is stopped urgently.

### EXAMPLE 3

**[0051]** A steel plate having a tensile strength of 500 MPa, a plate width of 3232 mm  $\times$  a plate thickness of 38.1 mm  $\times$  a length of 12 m including a tab plate having a length of 400 mm  $\times$  a width of 100 mm attached to the leading end portion and the trailing end portion is prepared, and a steel pipe having an outer diameter of 1067 mm is manufactured. The upper die used for the edge bending has a processing face having a radius of curvature of 400 mm. The edge bending is performed with a goal of providing an edge bending angle of 22 degrees to a range of 195 mm at the widthwise edges of the steel plate. The other edge bending conditions such as the edge bending apparatus, the lower die, and the feed amount of the steel plate are the same as those of Example 1. The edge bending angle is measured after the edge bending, and then the steel plate is formed into a cylindrical shape by U-ing press and O-ing press, followed by welding to give a steel pipe. The edge bending conditions and the formation results are indicated in Table 3.

Table 3

Condition No.	Displacement amount d [mm]	Die	Leading/trailing end stop position	Variation in edge bending angle		Angular difference between portions adjacent to each other [°]	Number of stop of welding	Variation in peaking of steel pipe		Remarks
				Stationary portion [°]	Entire length [°]			Stationary portion [mm]	Entire length [mm]	
1	150	B	Steel plate	0.8	0.8	0.5	0	0.8	0.8	Inventive Example
2	150	B	Tab	1.0	1.4	0.4	0	0.9	1.5	Inventive Example
3	0	B	Steel plate	1.3	1.3	0.9	0	1.7	1.7	Inventive Example
4	0	B	Tab	1.4	1.9	1.0	0	1.9	2.3	Inventive Example
5	150	C	Steel plate	0.7	0.7	0.4	0	0.7	0.7	Inventive Example
6	150	C	Tab	0.9	1.2	0.4	0	0.8	1.3	Inventive Example
7	0	C	Steel plate	1.4	1.4	0.9	0	1.8	1.8	Inventive Example
8	0	C	Tab	1.3	1.8	1.0	0	1.9	2.2	Inventive Example
9	0	A	Steel plate	2.8	2.8	2.8	3	2.5	2.5	Comparative Example
10	0	A	Tab	2.6	3.9	2.6	4	2.7	3.2	Comparative Example

**[0052]** Under conditions 1 to 4 in which the die B provided with a gentle transition part on the delivery side 3 is used and conditions 5 to 8 in which the die C provided with a gentle transition part on both of the entry side and delivery side is used, the feed boundary is hardly recognizable by sight and the angular difference between adjacent portions is about half of the variation of the edge bending angle of the stationary portion. Meanwhile, under conditions 9 and 10 in which the die A is used, the feed boundary is clearly recognizable, and the angular difference between adjacent portions is the same as the variation of the edge bending angle of the stationary portion, and the edge bending angle sharply changes as compared with the case where the die B is used. When comparing the conditions 1 with 5, conditions 2 with 6, conditions 3 with 7, and conditions 4 with 8, in which only the die used is different, there are little differences in the variation of the edge bending angle although the variation is smaller in some cases using the die C, and it can be seen that a transition part may be formed at least on the delivery side 3.

**[0053]** Furthermore, under the conditions 3, 4, 7 and 8 in which the center C1 of the flat part of the lower die in the conveyance direction is set to be displaced 150 mm (displacement amount d) to the delivery side 3 in the conveyance direction relative to the center C2 of the central hydraulic cylinder, the variation of the edge bending angle and the variation of the peaking of the stationary portion are suppressed to about half of those of the conditions 1, 2, 5, 6, 9, and 10 in which the center C1 of the flat part of the lower die is set so as to match the center of the central hydraulic cylinder.

**[0054]** Furthermore, under the conditions 1, 3, 5, and 7 in which the longitudinal end of the steel plate is stopped to be positioned at the end of the flat part, the variation of the edge bending angle of the stationary portion is the same as the variation of the edge bending angle of the entire length, and the variation of the peaking of the stationary portion is the same as the variation of the peaking of the entire length, and the amount of edge bending is the same across the entire length. Meanwhile, under the conditions 2, 4, 6, and 8 in which the longitudinal end of the steel plate is positioned on the inner side of the flat part of the lower die, the amount of edge bending is large at the end and the variation across the entire length is large. In particular, under the condition 1 in which the "die B" is used and the longitudinal end of the steel plate is stopped at the position of the end of the flat part and the center C1 of the flat part is displaced to the delivery side 3 in the conveyance direction relative to the center C2 of the pressing force P, and the condition 5 in which "die C" is used and the longitudinal end of the steel plate is stopped at the position of the end of the flat part and the center C1 of the flat part is displaced to the delivery side 3 in the conveyance direction relative to the center C2 of the pressing force P, the variation of the peaking is 0.7 to 0.8 mm, which is not more than one eighth of  $\pm 3.2$  mm, a peaking tolerance required by API standards, and it can be understood that the shape is superior.

**[0055]** Under the conditions 9 and 10, which do not satisfy the conditions of the present invention, the variations of the peaking and the edge bending angle are large as compared with the inventive examples. In particular, the large difference in edge bending angle indicates that an abrupt change occurs at the step of the feed boundary. Since this abrupt change exceeds the profiling limit of a welding torch, the welding is stopped urgently.

#### EXAMPLE 4

**[0056]** Similarly to Example 2, a steel plate having a tensile strength of 550 MPa, a plate width of 2753 mm  $\times$  a plate thickness of 38.1 mm  $\times$  a length of 12 m including a tab plate having a length of 400 mm  $\times$  a width of 100 mm attached to each of the leading end portion and the trailing end portion is prepared, and a steel pipe having an outer diameter of 914 mm is manufactured. The upper die used for the edge bending has a processing face having a radius of curvature of 335 mm, and the flat part of the lower die includes a processing face having a radius of curvature of 335 mm so as to match the upper die. The upper die has the same cross-sectional shape across the entire length. The edge bending is performed with a goal of providing an edge bending angle of 24 degrees to a range of 180 mm at the widthwise edges of the steel plate by using three types of lower dies: one in which the flat part has a length of 3000 mm and both ends thereof in the longitudinal direction are chamfered at C25 mm (hereinafter called the "die A"); another including a gentle transition part of R1200 mm formed continuously from the flat part having a length of 3000 mm on the delivery side 3 (hereinafter called the "die B"); and the other including a gentle transition part of R1200 mm formed continuously from the flat part having a length of 3000 mm on both of the entry side 2 and the delivery side 3 (hereinafter called the "die C").

**[0057]** The other edge bending conditions such as the edge bending apparatus and the feed amount of the steel plate are the same as those of Example 2. The edge bending angle is measured after the edge bending, and then the steel plate is formed into a cylindrical shape by a bending press method, followed by welding to give a steel pipe. The edge bending conditions and the formation results are indicated in Table 4. The items and descriptions in Table 4 are the same as those of Example 1.



Table 4

Condition No.	Displacement amount d [mm]	Die	Leading/trailing end stop position	Variation in edge bending angle		Angular difference between portions adjacent to each other [°]	Number of stop of welding	Variation in peaking of steel pipe		Remarks
				Stationary portion [°]	Entire length [°]			Stationary portion [mm]	Entire length [mm]	
1	150	B	Steel plate	0.8	0.8	0.4	0	0.8	0.8	Inventive Example
2	150	B	Tab	0.9	1.3	0.3	0	0.9	1.4	Inventive Example
3	0	B	Steel plate	1.2	1.2	0.9	0	1.5	1.5	Inventive Example
4	0	B	Tab	1.3	1.8	0.9	0	1.8	2.1	Inventive Example
5	150	C	Steel plate	0.7	0.7	0.3	0	0.7	0.7	Inventive Example
6	150	C	Tab	0.9	1.1	0.3	0	0.8	1.2	Inventive Example
7	0	C	Steel plate	1.3	1.3	0.9	0	1.7	1.7	Inventive Example
8	0	C	Tab	1.2	1.7	0.9	0	1.8	2.0	Inventive Example
9	0	A	Steel plate	2.6	2.6	2.6	3	2.3	2.3	Comparative Example
10	0	A	Tab	2.4	3.6	2.4	4	2.5	3.0	Comparative Example

**[0058]** As indicated in Table 4, under conditions 1 to 4 in which the die B provided with a gentle transition part on the delivery side 3 is used and conditions 5 to 8 in which the die C provided with a gentle transition part on both of the entry side 2 and delivery side 3 is used, the feed boundary is hardly recognizable by sight and the angular difference between adjacent portions is about half of the variation of the edge bending angle of the stationary portion. Meanwhile, under conditions 9 and 10 in which the die A is used, the feed boundary is clearly recognizable, and the angular difference between adjacent portions is the same as the variation of the edge bending angle of the stationary portion, and the edge bending angle sharply changes as compared with the case where the die B or die C is used. When comparing the conditions 1 with 5, conditions 2 with 6, conditions 3 with 7, and conditions 4 with 8, in which only the die used is different, there are little differences in the variation of the edge bending angle although the variation is smaller in some cases using the die C, and it can be seen that a transition part may be formed at least on the delivery side 3.

**[0059]** Furthermore, under the conditions 3, 4, 7 and 8 in which the center C1 of the flat part of the lower die in the conveyance direction is set to be displaced 150 mm (displacement amount d) to the delivery side 3 in the conveyance direction relative to the center of the central hydraulic cylinder, i.e., relative to the center C2 of the pressing force P, the variation of the edge bending angle and the variation of the peaking of the stationary portion are suppressed to about half of those of the conditions 1, 2, 5, 6, 9 and 10 in which the center C1 of the flat part of the lower die is set to match the center of the central hydraulic cylinder.

**[0060]** Furthermore, under the conditions 1, 3, 5, and 7 in which the longitudinal end of the steel plate is stopped so as to be positioned at the end of the flat part, the variation of the edge bending angle of the stationary portion is the same as the variation of the edge bending angle of the entire length, and also the variation of the peaking of the stationary portion is the same as the variation of the peaking of the entire length, and the amount of edge bending is the same across the entire length. Meanwhile, under the conditions 2, 4, 6, and 8 in which the longitudinal end of the steel plate is positioned on the inner side of the flat part of the lower die, the amount of edge bending is large at the end and the variation across the entire length is large. In particular, under the condition 1 in which the "die B" is used and the longitudinal end of the steel plate is stopped at the position of the end of the flat part and the center C1 of the flat part is displaced to the delivery side 3 in the conveyance direction relative to the center C2 of the pressing force P, and the condition 5 in which "die C" is used and the longitudinal end of the steel plate is stopped at the position of the end of the flat part and the center C1 of the flat part is displaced to the delivery side 3 in the conveyance direction relative to the center C2 of the pressing force P, the variation of the peaking is 0.8 to 0.9 mm, which is not more than one seventh of  $\pm 3.2$  mm, a peaking tolerance required by API standards, and it can be understood that the shape is superior.

**[0061]** Under the conditions 9 and 10, which do not satisfy the conditions of the present invention, the variations of the peaking and the edge bending angle are large as compared with the inventive examples. In particular, the large difference in edge bending angle indicates that an abrupt change occurs at the step of the feed boundary. Since this abrupt change exceeds the profiling limit of a welding torch, the welding is stopped urgently.

#### EXAMPLE 5

**[0062]** Similarly to Example 3, a steel plate having a tensile strength of 500 MPa, a plate width of 3232 mm  $\times$  a plate thickness of 38.1 mm  $\times$  a length of 12 m including a tab plate having a length of 400 mm  $\times$  a width of 100 mm attached to each of the leading end portion and the trailing end portion is prepared, and a steel pipe having an outer diameter of 1067 mm is manufactured. The upper die used for the edge bending has a processing face having a radius of curvature of 400 mm, and the flat part of the lower die includes a processing face having a radius of curvature of 400 mm so as to match the upper die. The upper die has the same cross-sectional shape across the entire length. The edge bending is performed with a goal of providing an edge bending angle of 22 degrees to a range of 195 mm at the widthwise edges of the steel plate by using three types of lower dies: one in which the flat part has a length of 3000 mm and both ends thereof in the longitudinal direction are chamfered at C25 mm (hereinafter called the "die A"); another including a gentle transition part of R1200 mm formed continuously from the flat part having a length of 3000 mm on the delivery side 3 (hereinafter called the "die B"); and the other including a gentle transition part of R1200 mm formed continuously from the flat part having a length of 3000 mm on both of the entry side 2 and the delivery side 3 (hereinafter called the "die C").

**[0063]** The other edge bending conditions such as the edge bending apparatus and the feed amount of the steel plate are the same as those of Example 3. The edge bending angle is measured after the edge bending, and then the steel plate is formed into a cylindrical shape by a bending press method, followed by welding to give a steel pipe. The edge bending conditions and the formation results are indicated in Table 5. The items and descriptions in Table 5 are the same as those of Example 1.

Table 5

Condition No.	Displacement amount d [mm]	Die	Leading/trailing end stop position	Variation in edge bending angle		Angular difference between portions adjacent to each other [°]	Number of stop of welding	Variation in peaking of steel pipe		Remarks
				Stationary portion [°]	Entire length [°]			Stationary portion [mm]	Entire length [mm]	
1	150	B	Steel plate	0.7	0.7	0.4	0	0.7	0.7	Inventive Example
2	150	B	Tab	0.9	1.2	0.3	0	0.8	1.3	Inventive Example
3	0	B	Steel plate	1.1	1.1	0.8	0	1.4	1.4	Inventive Example
4	0	B	Tab	1.2	1.7	0.9	0	1.7	2.0	Inventive Example
5	150	C	Steel plate	0.6	0.6	0.3	0	0.6	0.6	Inventive Example
6	150	C	Tab	0.8	1.0	0.3	0	0.7	1.1	Inventive Example
7	0	C	Steel plate	1.2	1.2	0.8	0	1.6	1.6	Inventive Example
8	0	C	Tab	1.1	1.6	0.9	0	1.7	1.9	Inventive Example
9	0	A	Steel plate	2.4	2.4	2.4	3	2.1	2.1	Comparative Example
10	0	A	Tab	2.2	3.3	2.2	4	2.3	2.8	Comparative Example

**[0064]** As shown in Table 5, under conditions 1 to 4 in which the die B provided with a gentle transition part on the delivery side 3 is used and conditions 5 to 8 in which the die C provided with a gentle transition part on both of the entry side and delivery side is used, the feed boundary is hardly recognizable by sight and the angular difference between adjacent portions is about half of the variation of the edge bending angle of the stationary portion. Meanwhile, under conditions 9 and 10 in which the die A is used, the feed boundary is clearly recognizable, and the angular difference between adjacent portions is the same as the variation of the edge bending angle of the stationary portion, and the edge bending angle sharply changes as compared with the case where the die B or C is used. When comparing the conditions 1 with 5, conditions 2 with 6, conditions 3 with 7, and conditions 4 with 8, in which only the die used is different, there are little differences in the variation of the edge bending angle although the variation is smaller in some cases using the die C, and it can be seen that a transition part may be formed at least on the delivery side 3.

**[0065]** Furthermore, under the conditions 3, 4, 7 and 8 in which the center C1 of the flat part of the lower die in the conveyance direction is set to be displaced 150 mm (displacement amount d) to the delivery side 3 in the conveyance direction relative to the center of the central hydraulic cylinder, i.e. the center C2 of the pressing force P, the variation of the edge bending angle and the variation of the peaking of the stationary portion are suppressed to about half of those of the conditions 1, 2, 5, 6, 9, and 10 in which the center C1 of the flat part of the lower die is set so as to match the center of the central hydraulic cylinder.

**[0066]** Furthermore, under the conditions 1, 3, 5, and 7 in which the longitudinal end of the steel plate is stopped to be positioned at the end of the flat part, the variation of the edge bending angle of the stationary portion is the same as the variation of the edge bending angle of the entire length, and the variation of the peaking of the stationary portion is the same as the variation of the peaking of the entire length, and the amount of edge bending is the same across the entire length. Meanwhile, under the conditions 2, 4, 6, and 8 in which the longitudinal end of the steel plate is positioned on the inner side of the flat part of the lower die, the amount of edge bending is large at the end and the variation across the entire length is large. In particular, under the condition 1 in which the "die B" is used and the longitudinal end of the steel plate is stopped at the position of the end of the flat part and the center C1 of the flat part is displaced to the delivery side 3 in the conveyance direction relative to the center C2 of the pressing force P, and the condition 5 in which "die C" is used and the longitudinal end of the steel plate is stopped at the position of the end of the flat part and the center C1 of the flat part is displaced to the delivery side 3 in the conveyance direction relative to the center C2 of the pressing force P, the variation of the peaking is 0.7 to 0.8 mm, which is not more than one eighth of  $\pm 3.2$  mm, a peaking tolerance required by API standards, and it can be understood that the shape is superior.

**[0067]** Under the conditions 9 and 10, which do not satisfy the conditions of the present invention, the variations of the peaking and the edge bending angle are large as compared with the inventive examples. In particular, the large difference in edge bending angle indicates that an abrupt change occurs at the step of the feed boundary. Since this abrupt change exceeds the profiling limit of a welding torch, the welding is stopped urgently.

#### Industrial Applicability

**[0068]** According to the present invention, it is possible to reduce variation in edge bending angle between portions adjacent to each other at a feed boundary of a steel plate.

#### DESCRIPTION OF REFERENCE NUMERALS

##### **[0069]**

- 1 conveyance direction
- 2 entry side (upstream side in the conveyance direction)
- 3 delivery side (downstream side in the conveyance direction)
- 10 edge miller
- 20 edge bending apparatus of steel plate
- 21 conveyance mechanism
- 21a conveyance roll
- 22A, 22B press mechanism
- 23 upper die
- 24 lower die
- 24a flat part
- 24b, 24c transition part
- 26 hydraulic cylinder
- 30 cylinder-forming apparatus
- 30A U-ing press

30B O-ing press  
 30C bending press  
 40 joining apparatus  
 50 mechanical expander  
 5 S steel plate  
 Sa leading end portion  
 Sb trailing end portion  
 Sc, Sd widthwise edge  
 St tab plate  
 10 Sp product pipe shape  
 Se virtual perfect circle  
 Ra1 range of flat part 24a of lower die at the first bending  
 Ra2 range of flat part 24a of lower die at the second bending  
 Da angle variation at widthwise edge of steel plate  
 15 Dc angle variation in stationary portion  
 Df deformation force  
 P hydraulic pressure (pressing force)  
 Dp peaking  
 Dp- minus peaking  
 20 Dp+ plus peaking

## Claims

25 1. An edge bending method of a steel plate using an edge bending apparatus of a steel plate comprising:

a pair of dies configured to be arranged corresponding to a widthwise edge of a steel plate;  
 an actuator configured to clamp the pair of dies with a predetermined pressing force; and  
 a conveyance mechanism configured to convey the steel plate in a direction along a longitudinal direction of  
 30 the steel plate as a conveyance direction, in which the widthwise edge of the steel plate is subjected to edge  
 bending across an entire length by performing bending of the widthwise edge of the steel plate several times  
 by the pair of dies while the steel plate is intermittently conveyed by the conveyance mechanism,

### **characterized in that**

one of the pair of dies that contacts a surface positioned at the outer side of bending of the widthwise edge of  
 35 the steel plate comprises

a flat part that contacts the surface positioned at the outer side of bending and

a transition part formed of a curved surface provided adjacent to the flat part at least on a delivery side in the  
 conveyance direction,

and the flat part and the transition part are connected to have a common tangent line.

40 2. The edge bending method of a steel plate according to claim 1, wherein bending of the widthwise edge of the steel  
 plate is performed with a center of the flat part in the conveyance direction being displaced to the delivery side in  
 the conveyance direction relative to a center of the pressing force generated by the actuator in the conveyance  
 direction.

45 3. The edge bending method of a steel plate according to claim 1 or 2, wherein a leading end portion of the steel plate  
 in the conveyance direction is set to be at a position corresponding to a front end of the flat part in the first pass of  
 bending the widthwise edge of the steel plate.

50 4. The edge bending method of a steel plate according to any one of claims 1 to 3, wherein a trailing end portion of  
 the steel plate in the conveyance direction is set to be at a position corresponding to a rear end of the flat part in  
 the final pass of bending the widthwise edge of the steel plate.

55 5. A method for manufacturing a steel pipe comprising:

an edge bending process of a steel plate using an edge bending apparatus of a steel plate comprising

a pair of dies configured to be arranged corresponding to a widthwise edge of a steel plate,

an actuator configured to clamp the pair of dies with a predetermined pressing force,  
 and a conveyance mechanism configured to convey the steel plate in a direction along with a longitudinal  
 direction of the steel plate as a conveyance direction,  
 in which the widthwise edge of the steel plate is subjected to edge bending across an entire length by  
 performing bending of the widthwise edge of the steel plate several times by the pair of dies while the steel  
 plate is intermittently conveyed by the conveyance mechanism;

a cylinder-forming process in which the steel plate with the widthwise edges subjected to edge bending is formed  
 into a cylindrical shape and the widthwise edges of the steel plate are butted with each other; and  
 a joining process in which the butted widthwise edges of the steel plate are welded,  
**characterized in that**  
 the edge bending method of a steel plate according to any one of claims 1 to 4 is used as the edge bending  
 process.

**6.** An edge bending apparatus of a steel plate comprising:

a pair of dies configured to be arranged corresponding to widthwise edge of a steel plate;  
 an actuator configured to clamp the pair of dies with a predetermined pressing force; and  
 a conveyance mechanism configured to convey the steel plate in a direction along a longitudinal direction of  
 the steel plate as a conveyance direction,  
 in which the widthwise edge of the steel plate is subjected to edge bending across an entire length by performing  
 bending of the widthwise edge of the steel plate several times by the pair of dies while the steel plate is inter-  
 mittently conveyed by the conveyance mechanism,

**characterized in that**

one of the pair of dies that contacts a surface positioned at the outer side of bending of the widthwise edge of  
 the steel plate comprises

a flat part that contacts a surface positioned at the outer side of bending and

a transition part formed of a curved surface provided adjacent to the flat part at least on a delivery side in the  
 conveyance direction,

and the flat part and the transition part are connected to have a common tangent line.

**7.** The edge bending apparatus of a steel plate according to claim 6, wherein the center of the flat part in the conveyance  
 direction in one of the pair of dies that contacts the surface positioned at the outer side of the edge bending is  
 displaced to the delivery side in the conveyance direction relative to a center of the pressing force generated by the  
 actuator in the conveyance direction.

**8.** A facility for manufacturing a steel pipe comprising:

an edge bending apparatus of a steel plate comprising

a pair of dies configured to be arranged corresponding to a widthwise edge of a steel plate,  
 an actuator configured to clamp the pair of dies with a predetermined pressing force, and  
 a conveyance mechanism configured to convey the steel plate in a direction along a longitudinal direction  
 of the steel plate as a conveyance direction,  
 in which the widthwise edge of the steel plate is subjected to edge bending across an entire length by  
 performing bending of the widthwise edge of the steel plate several times by the pair of dies while the steel  
 plate is intermittently conveyed by the conveyance mechanism;

a cylinder-forming apparatus configured to form the steel plate with the widthwise edges subjected to edge  
 bending into a cylindrical shape and butt the widthwise edges of the steel plate with each other; and  
 a joining apparatus configured to weld the butted widthwise edges of the steel plate,

**characterized in that**

the facility for manufacturing a steel pipe comprises the edge bending apparatus of a steel plate according to  
 claim 6 or 7 as the edge bending apparatus of a steel plate.

FIG. 1

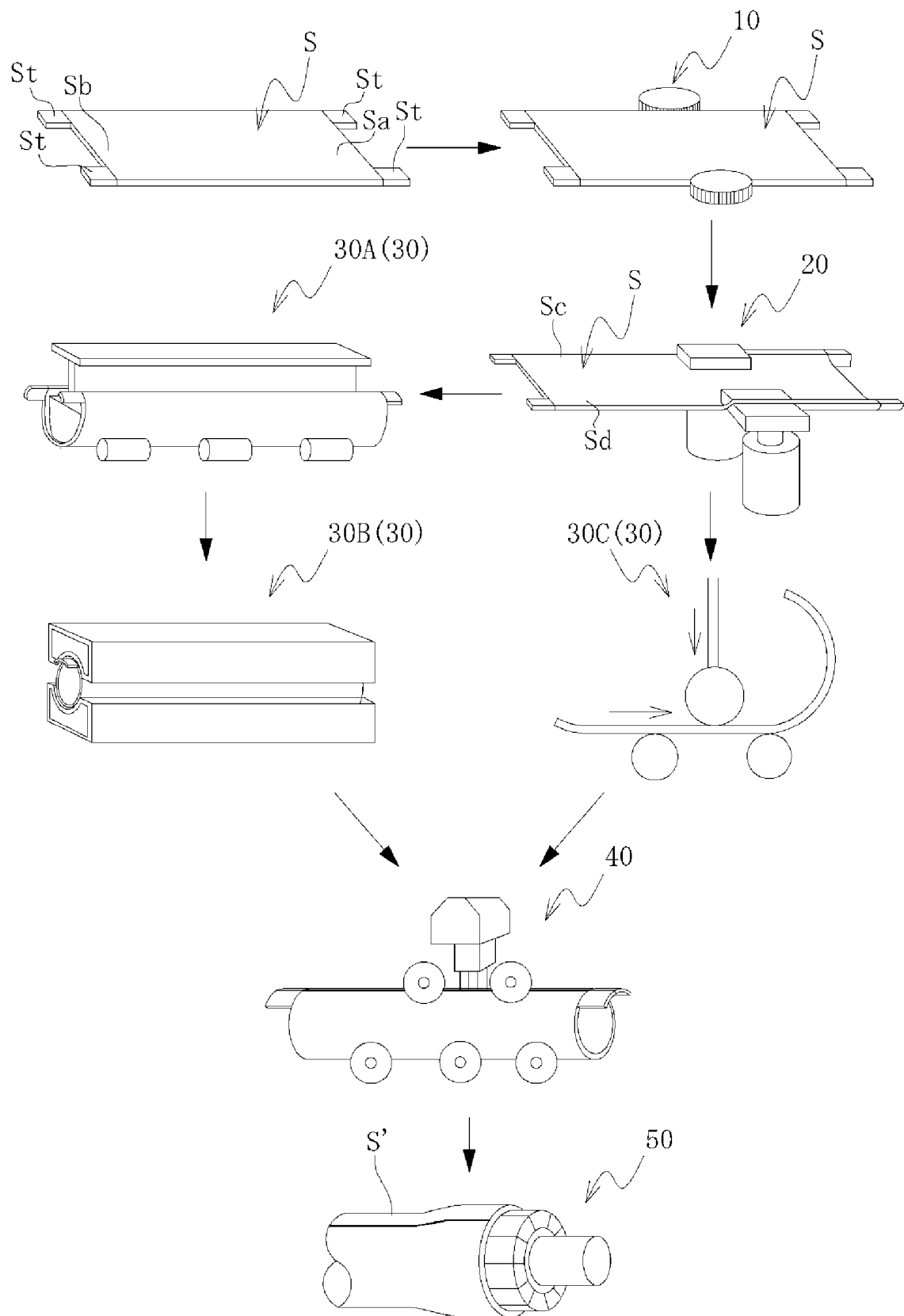


FIG. 2

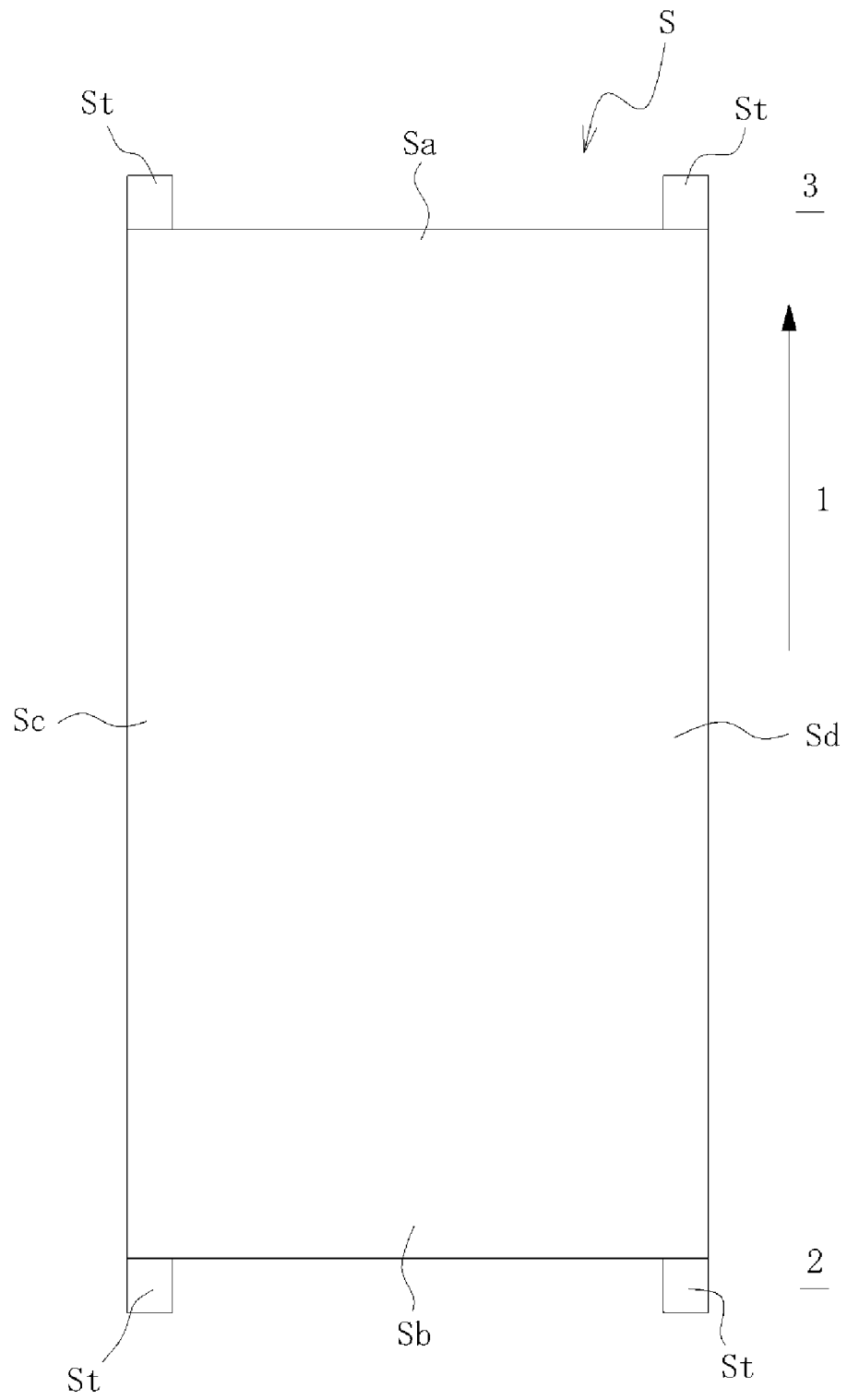




FIG. 3

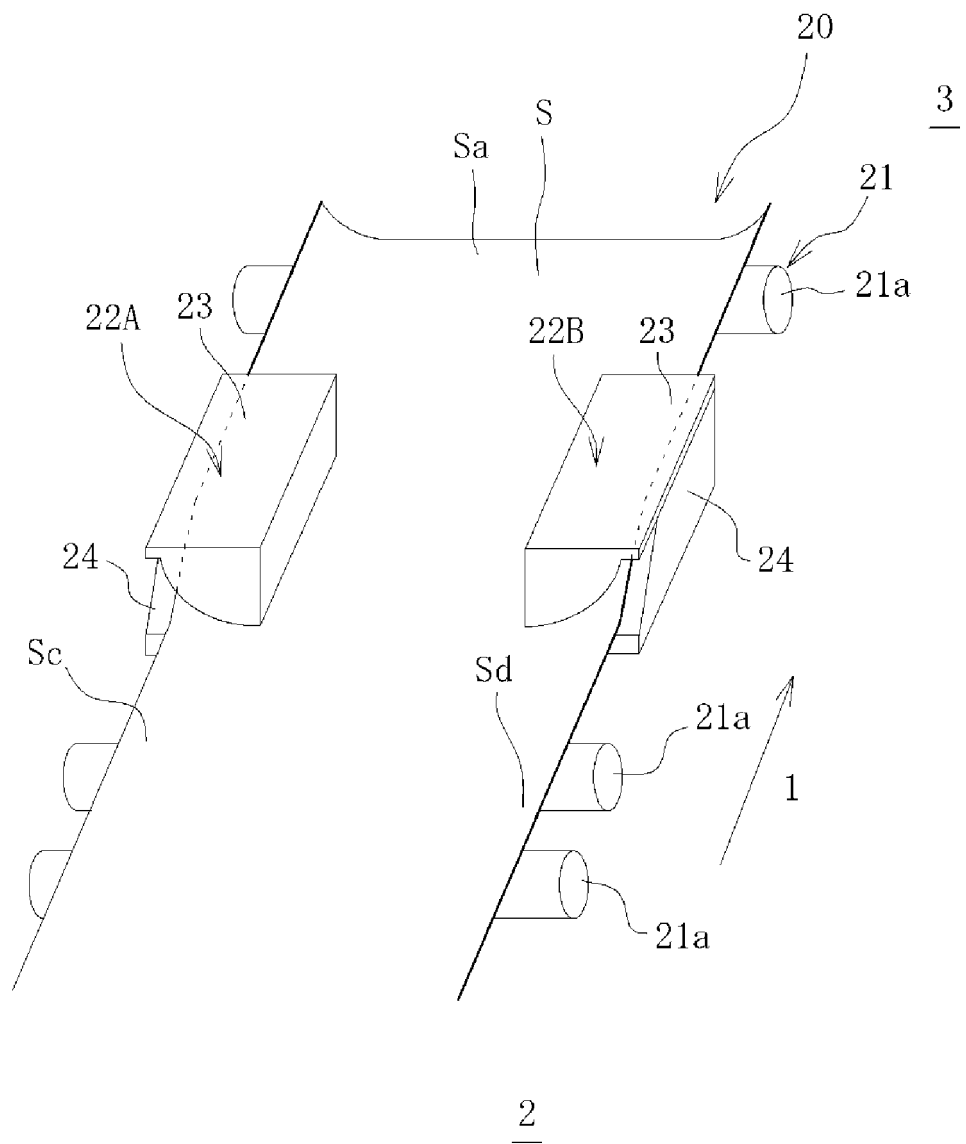


FIG. 4

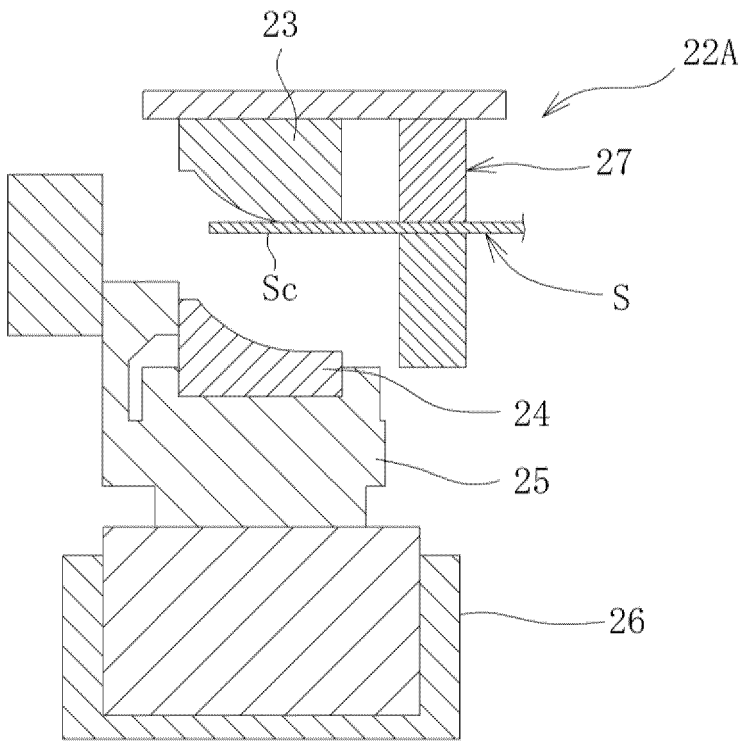


FIG. 5

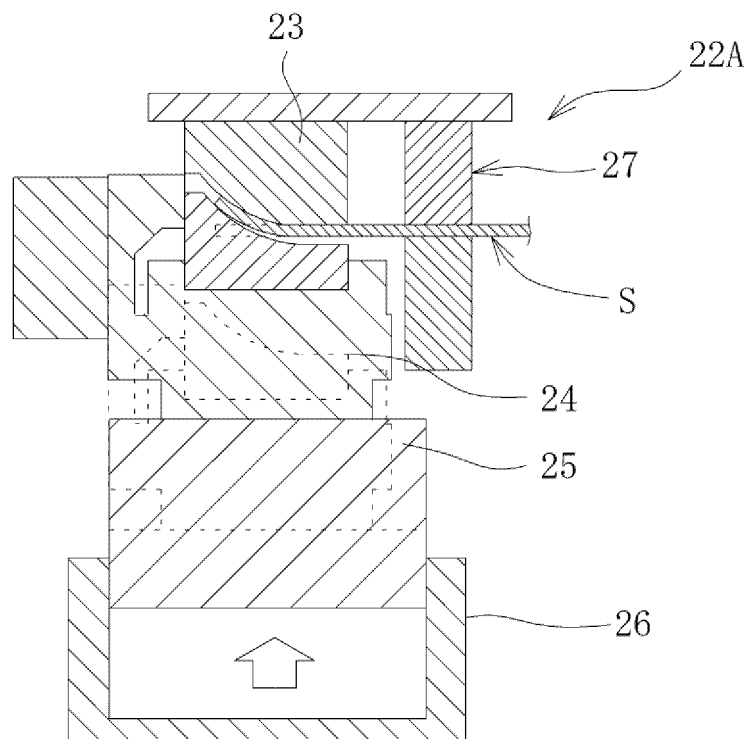


FIG. 6

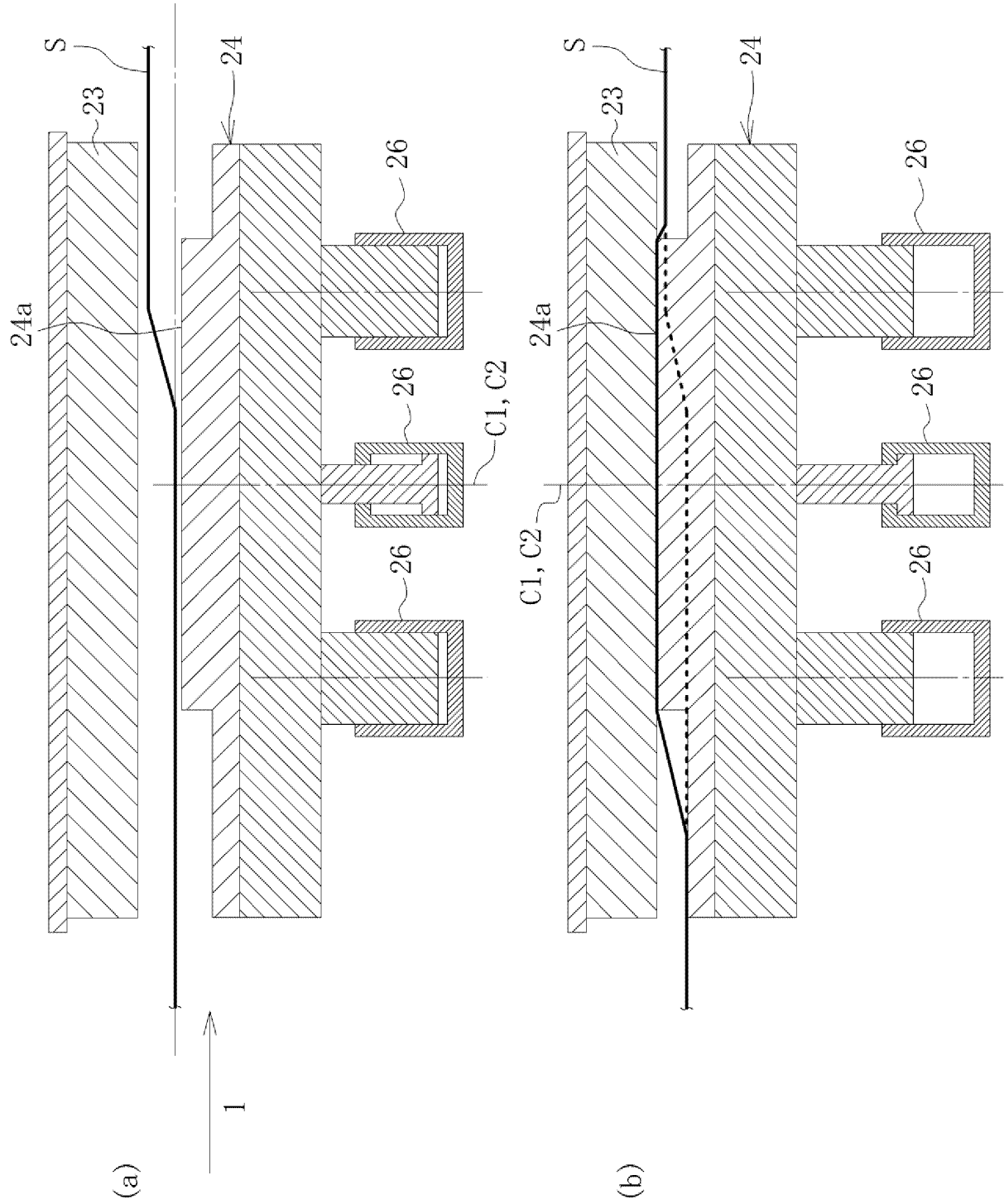


FIG. 7

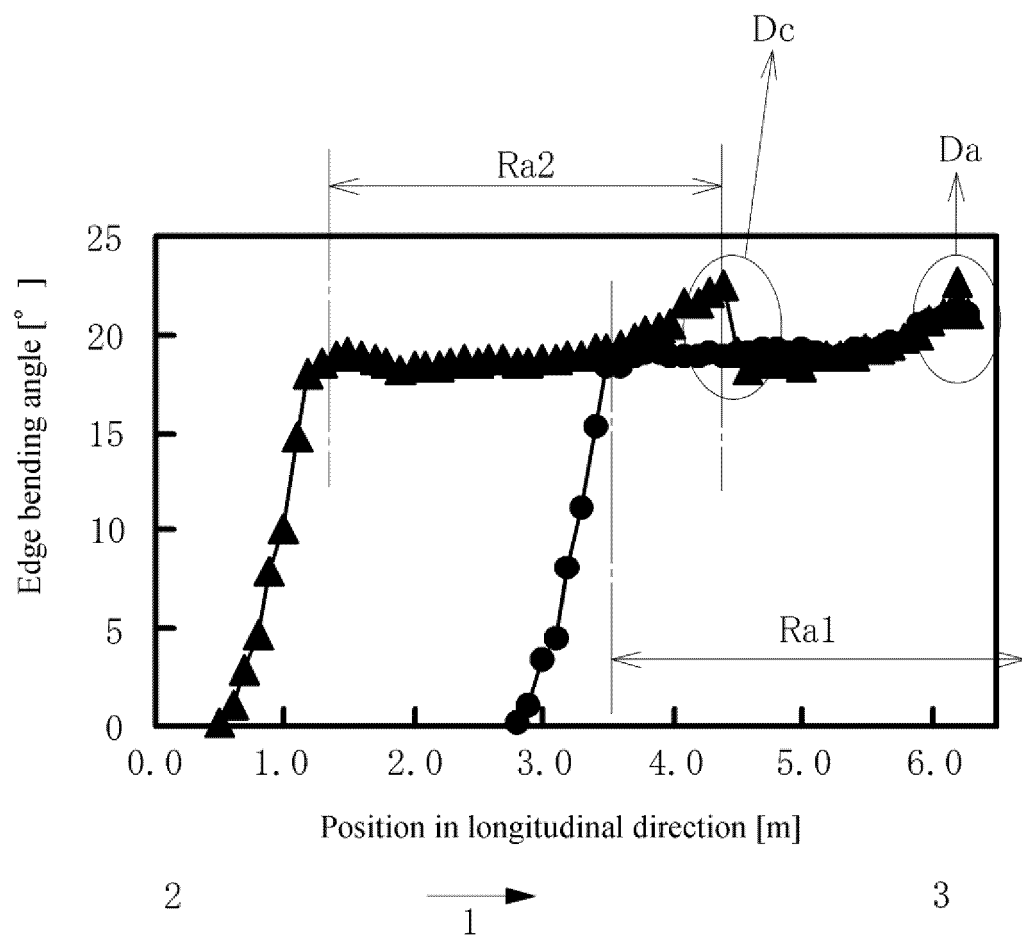


FIG. 8

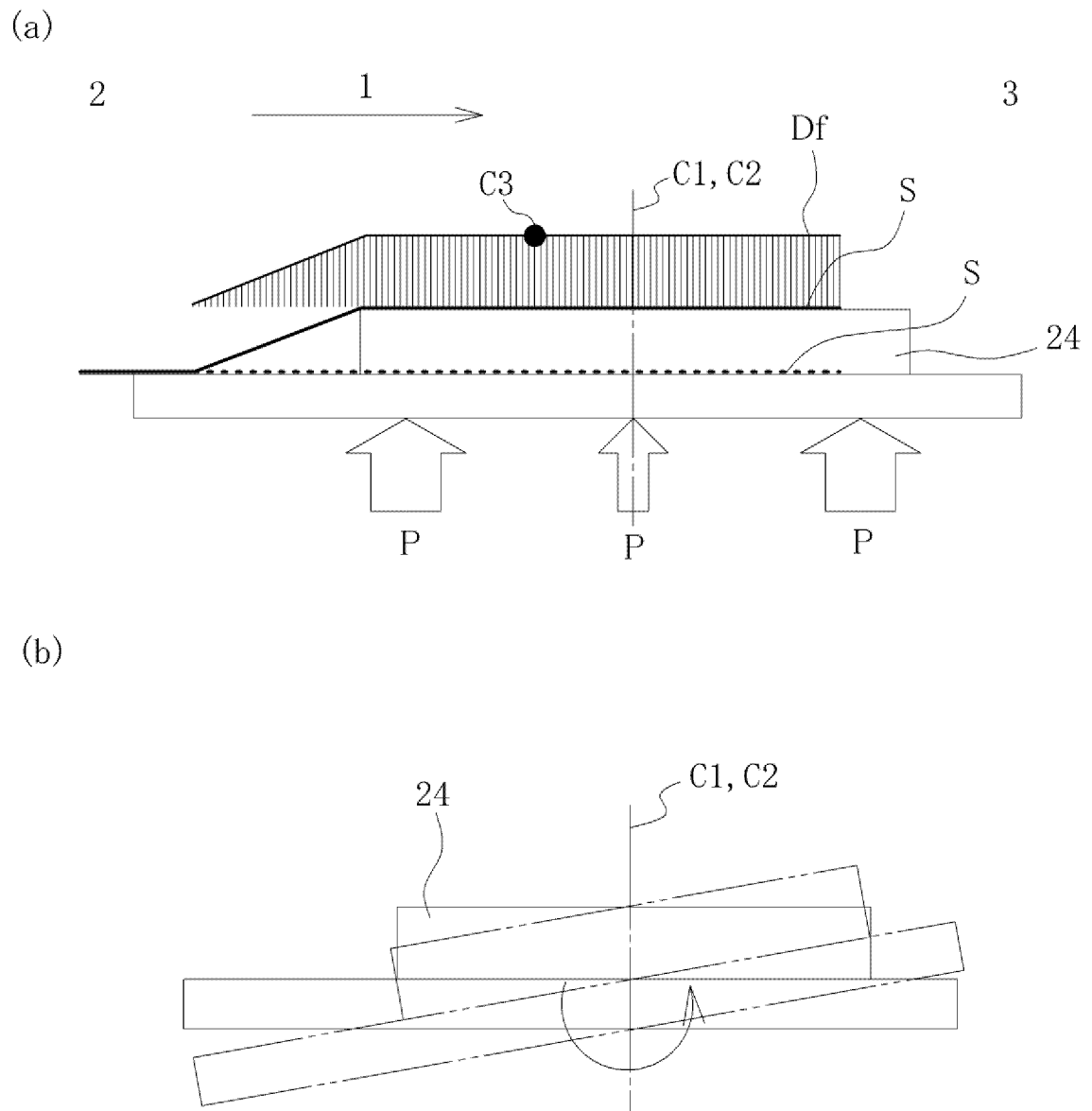


FIG. 9

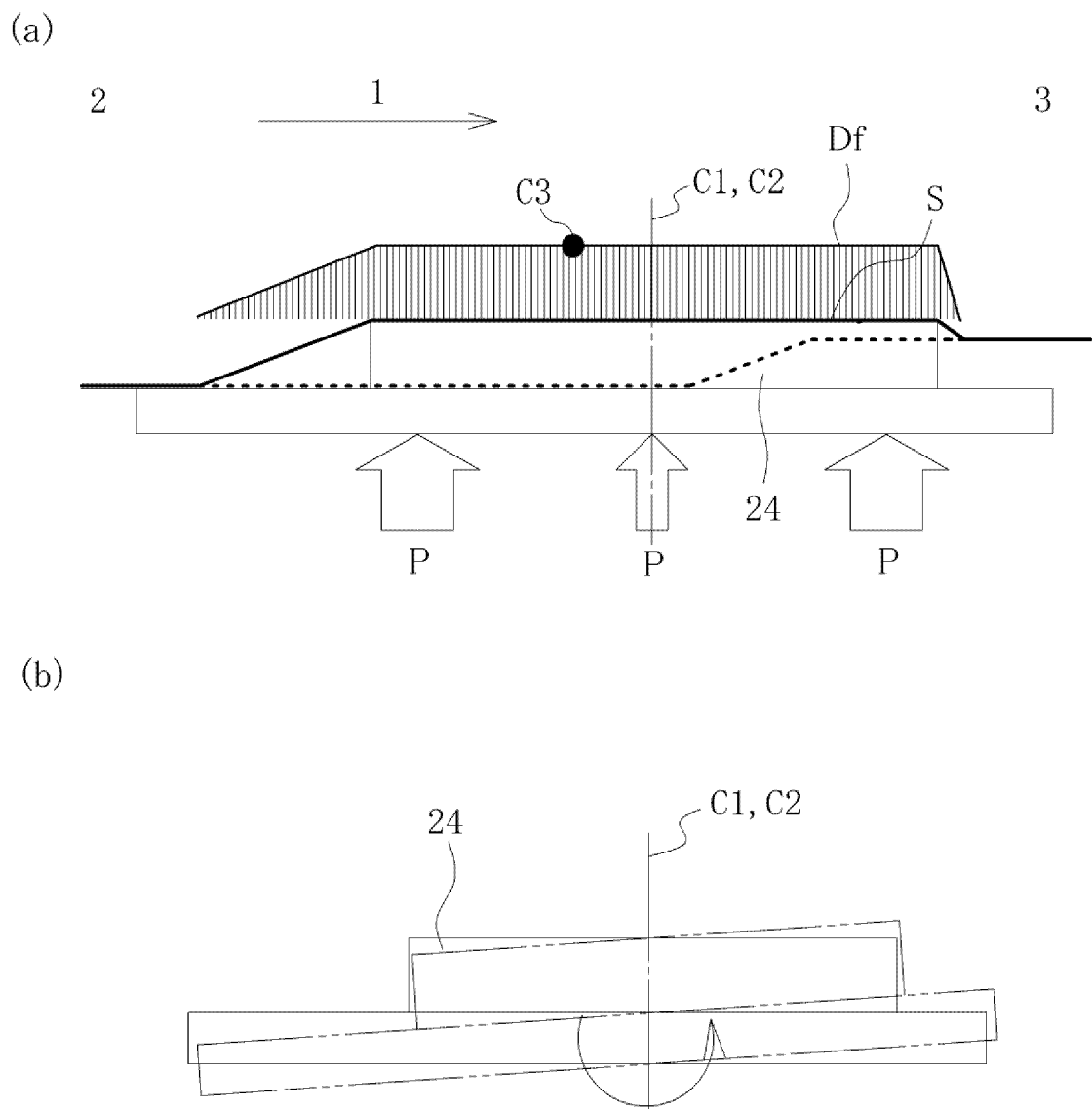


FIG. 10

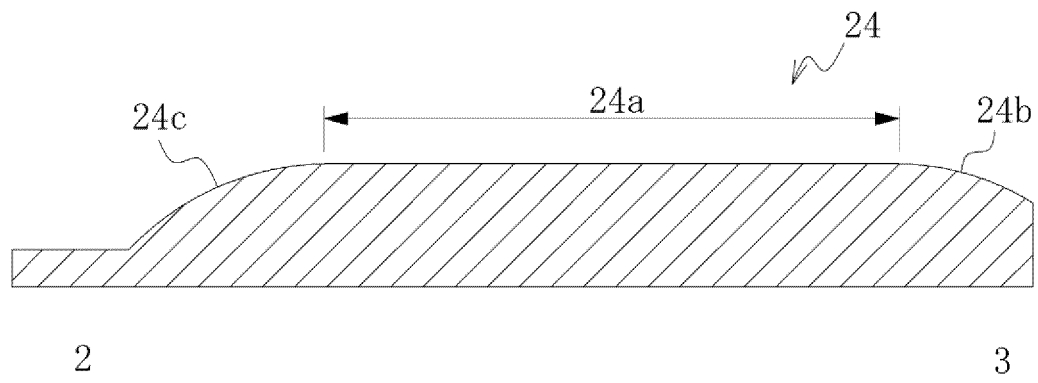


FIG. 11

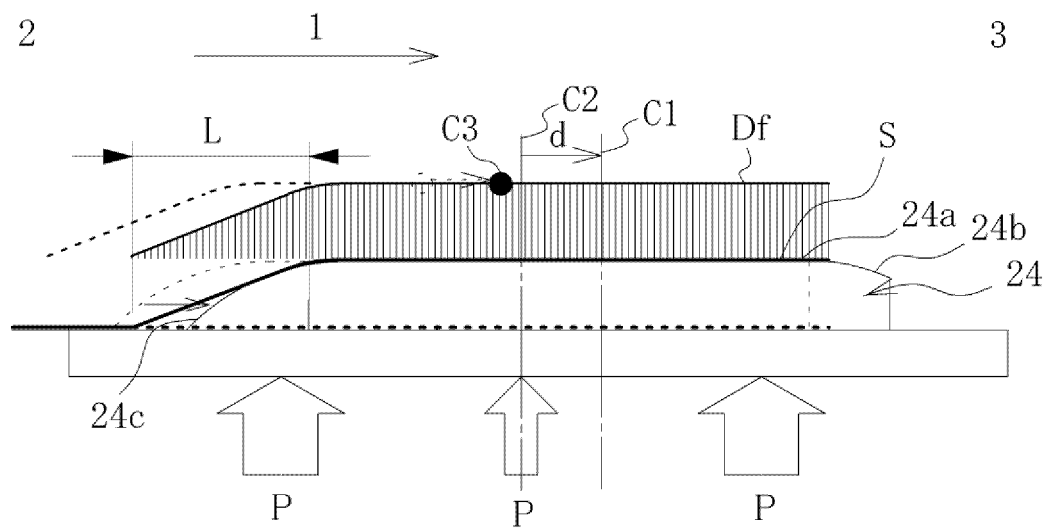




FIG. 12

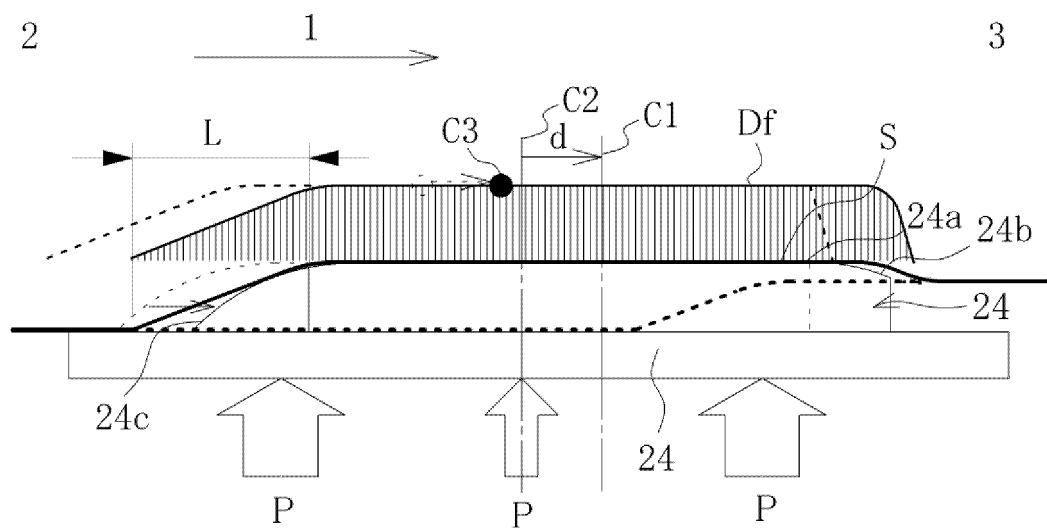
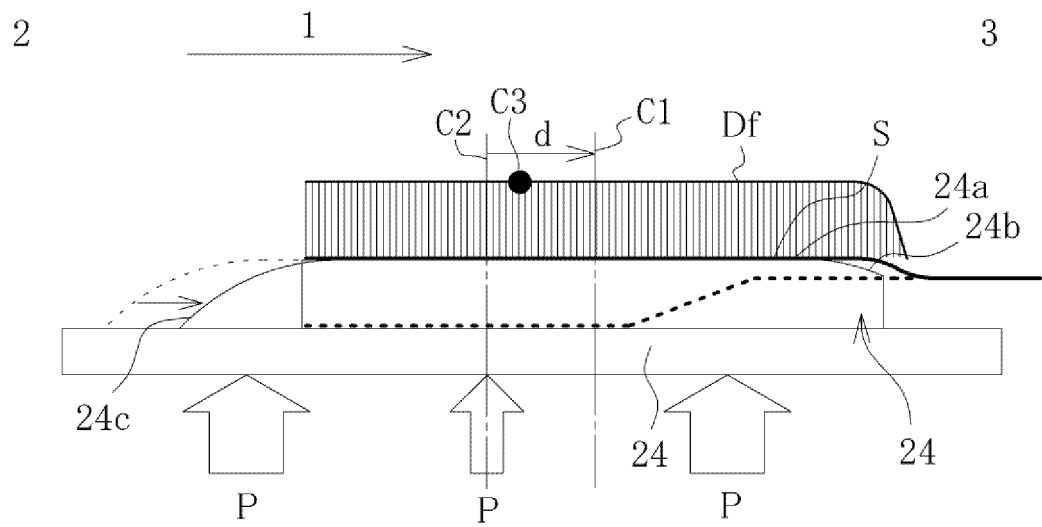


FIG. 13

(a)



(b)

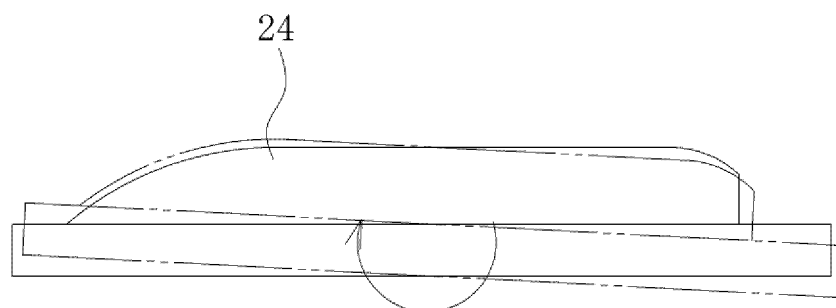


FIG. 14

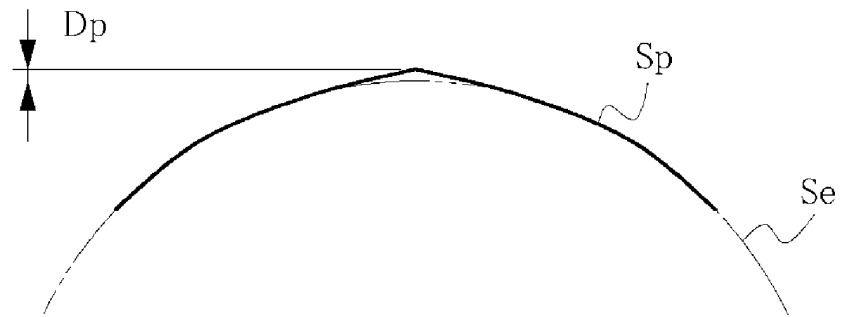
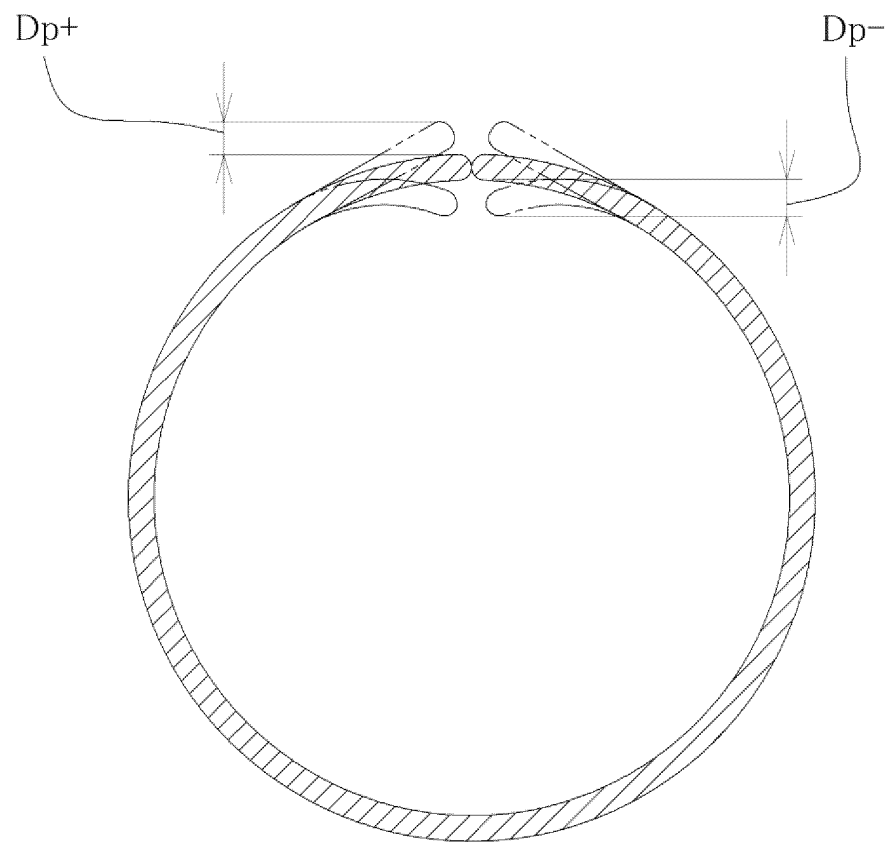


FIG. 15



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/008298

## A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. B21D5/01(2006.01)i, B21C37/08(2006.01)i, B21D19/08(2006.01)i

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

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. B21D5/01, 5/10, 5/12, B21C37/08, B21D19/08

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 1971-2019

Registered utility model specifications of Japan 1996-2019

Published registered utility model applications of Japan 1994-2019

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	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 132530/1979 (Laid-open No. 50510/1981) (NKK CORP.) 06 May 1981 (Family: none)	1-8
A	JP 58-81517 A (SHIN NIPPON SEITETSU KK) 16 May 1983 (Family: none)	1-8



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents:

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Date of the actual completion of the international search

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Name and mailing address of the ISA/

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Telephone No.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/008298

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 106418/1982 (Laid-open No. 10918/1984) (SUMITOMO METAL INDUSTRIES, LTD.) 24 January 1984 (Family: none)	1-8

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**REFERENCES CITED IN THE DESCRIPTION**

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