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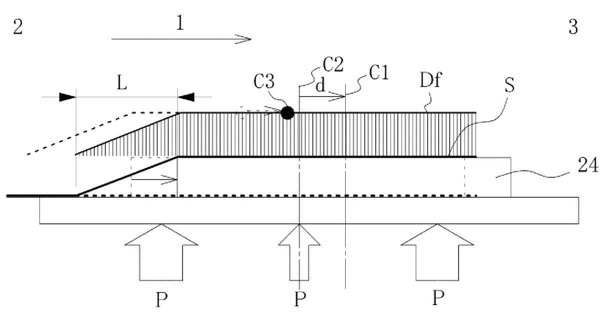
(54) **METHOD AND DEVICE FOR BENDING EDGE OF STEEL PLATE, AND STEEL PIPE MANUFACTURING METHOD AND EQUIPMENT**

(57) Proposed an edge bending method 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 subjected to edge bending across an entire length. The lower die 24 that contacts a surface positioned at the outer side of edge bending of the widthwise edges Sc and Sd of the steel plate S to be bent between the pair of dies 23 and 24 has a flat part 24a that contacts the surface positioned at the outer side of edge bending, and edge bending is performed on the widthwise edges Sc and Sd of the steel plate S with a center C1 of the flat part 24a in the conveyance direction 1 being displaced to a delivery side 3 in the conveyance direction 1 relative to a center C2 of the pressing force P generated by the actuator in the conveyance direction 1.

FIG. 10



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Description

TECHNICAL FIELD

[0001] The present invention relates to an edge bending method and apparatus of a steel plate for subjecting widthwise edges of the 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 edge 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 Lc of a region to be bent depending on the thickness or strength of a steel plate. Patent Literature 3 specifies a radius of curvature R1 of an upper die, a horizontal distance u relative to the center of the curvature of the upper die to an end 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 end 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 variation in the edge bending shape of the steel plate in the longitudinal direction. In particular, in the case of a steel plate having a large thickness and high strength, the edge bending shape is sometimes not uniform in the longitudinal direction of the steel plate, resulting in defective welding at a butted portion or a defective shape of a butted portion of a steel pipe product. 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 obtain an edge bending shape of a steel plate with less variation across the entire length, without introducing a new facility.

MEANS FOR SOLVING THE PROBLEMS

[0009] The inventors have studied how the edge bending shape is varied in a longitudinal direction of the 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 edge 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 edge 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 edge bending, and edge bending is performed on the widthwise edge of the steel plate with a center of the flat part in the conveyance direction being displaced to a delivery side in the conveyance direction relative to a center of the pressing force generated by the actuator in the conveyance direction.

[0010] A second aspect is the edge bending method of a steel plate according to the first aspect, in which the die that contacts the surface positioned at the outer side of edge bending includes a transition part formed of a curved surface and 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.

[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 at a position corresponding to a front end of the flat part in the first pass of edge 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 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 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 edge 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, and one of the pair of dies that contacts a surface positioned at the outer side of edge 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 edge bending, and edge bending is performed on the widthwise edge of the steel plate with a center of the flat part in the conveyance direction being displaced to a delivery side in the conveyance direction relative to a center of the pressing force generated by the actuator in the conveyance direction.

[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 edge 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 edge bending of the widthwise edge of the steel plate to be bent includes a flat part that contacts the surface positioned at the outer side of edge bending, and a center of the flat part in the conveyance direction is displaced to a delivery side in the conveyance direction relative to a center of the pressing force generated by the actuator in the conveyance direction.

[0015] A seventh aspect is the edge bending apparatus of a steel plate according to the sixth aspect, in which the die that contacts the surface positioned at the outer side of edge bending includes 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.

[0016] An eight 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 edge 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 one of the pair of dies that contacts a surface positioned at the outer side of edge bending of the widthwise edge of the steel plate to be bent includes a flat part that contact the surface positioned at the outer side of edge bending, and a center of the flat part in the conveyance direction is displaced to a delivery side in the conveyance direction relative to a center of the pressing force generated by the actuator in the conveyance direction.

[0017] A ninth aspect is the facility for manufacturing a steel pipe according to the eight aspect, in which the die that contacts the surface positioned at the outer side of edge bending includes 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.

EFFECT OF THE INVENTION

[0018] According to the present invention, one of a pair of dies that contacts a surface positioned at the outer side of edge bending of a widthwise edge of a steel plate to be bent includes a flat part that contacts the surface positioned at the outer side of edge bending, and edge bending is performed on the widthwise edge of the steel plate with a center of the flat part in the conveyance direction being displaced to a delivery side in the conveyance direction relative to a center of the pressing force in the conveyance direction generated by the actuator, whereby a center of bending deformation force moves closer to the center of the pressing force. As a result, inclination of the die during the edge bending can be suppressed, and the variation of the amount of bending deformation of the widthwise edge of the steel plate in the longitudinal direction can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

FIG. 1 is a view schematically explaining a method and facility 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 of 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 the edge bending, and FIG. 6(b) illustrates that in a state during the 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 due to 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 due to 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 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 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 the second edge bending using an edge bending apparatus of a steel plate according to an embodiment of the present invention.

FIG. 12(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 according to an embodiment of the present invention, and FIG. 12(b) is a schematic view illustrating a state in which a lower die is inversely inclined due to a relationship between the center of pressing force, the center of a flat part, and the center of bending deformation force.

FIG. 13 is a cross-sectional view along a conveyance direction illustrating a lower die of another example in which a transition part, which can preferably be used in the present invention, is provided adjacent to a flat part.

FIG. 14 is a view explaining peaking.

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

EMBODIMENT FOR CARRYING OUT THE INVENTION

[0020] 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.

[0021] 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 side end portion) Sa and a trailing end portion (longitudinal rear side 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). The cylinder-forming apparatus 30 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.

[0022] 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 the 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.

[0023] 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.

[0024] FIG. 4 illustrates a widthwise cross section of the press mechanism 22A that bends 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. It is configured such that 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.

[0025] 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 pressing 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.

[0026] 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, 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 may be a 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 has, for example, 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, typically, a plurality of hydraulic cylinders 26 for lifting the lower die 24 is arranged along the conveyance direction. 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 in the conveyance direction 1 of flat part 24a the matches a center C2 of the pressing force P by the hydraulic cylinders 26.

[0027] 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 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 subjected to 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 on 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 × 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 leading end portion 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 (Dc) toward the delivery side 3. 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 time, 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).

[0028] 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. 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.

[0029] FIGS. 10 and 11 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 a displacement amount d to the delivery side 3 relative to the center C2 of the pressing force P according to the present invention. FIG. 10 illustrates the first edge bending, and FIG. 11 illustrates the second edge bending. It can be seen 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.

[0030] 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 to 11, in the case where the bending deformation force Df that occurs on the entry side 2 of the flat part 24a varies substantially lineally, the sum thereof is half of the deformation force Df that occurs in the flat part 24a. That is, the deformation force Df 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. 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.

[0031] 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.

[0032] The deformation force Df 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. 12 illustrates the deformation of the steel plate S and the distribution of the deformation force Df in the case where the widthwise edges Sc and Sd of the trailing end portion Sb of the steel plate S are bent 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 Df is positioned apart relative to the center C2 of the pressing force P (displaced to the delivery side 3) as compared with the cases of FIGS. 10 and 11, 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 Sb side of the steel plate S.

[0033] Thus, in the edge bending apparatus 20 of a steel plate of the present embodiment and the edge bending method of a steel plate using the same, the lower die 24, of the pair of dies 23 and 24, that contacts the surface positioned at the outer side of edge bending of the widthwise edges Sc and Sd of the steel plate S to be subjected to edge bending has the flat part 24a that contacts the surface at the outer side of edge bending of the steel plate S during bending, and the widthwise edges Sc and Sd 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 Df moves closer to the center C2 of the pressing force P. As a result, it is possible to suppress inclination of the lower die 24 during the edge bending and reduce the variation in the amount of bending deformation of the widthwise edges Sc and Sd 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.

[0034] Next, description is given of a positional relationship between the leading end portion (longitudinal front end) Sa and the trailing end portion (longitudinal rear end) Sb of the steel plate S and the flat part 24a of the lower die 24. Note that the leading end portion Sa and the trailing end portion Sb 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 St, the tab plates St and correspond to the end portions Sa and Sb of FIG. 2. As illustrated in FIG. 10, when the leading end portion Sa 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 Df does not occur on the delivery side 3 relative to the leading end portion Sa of the steel plate S. Therefore, the center C3 of the deformation force Df is displaced to the entry side 2 relative to the center C2 of the pressing force P. When the leading end portion Sa 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 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. 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 at a position not exceeding the leading end portion of the flat part 24a. Similarly, as illustrated in FIG. 12, when the trailing end portion Sb of the steel plate S is positioned in 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, 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 at a position not exceeding the rear end portion of the flat part 24a.

[0035] Next, description is given of another preferable lower die that can be applied to the present invention. 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 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 steel plate portion that contacts the delivery end portion is deformed at the second edge bending, resulting in forming a large step with respect to the portion that has been subjected to the first edge bending on the delivery side 3. Such 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 is desirably smooth (small).

[0036] Thus, with an edge bending method and apparatus of a steel plate according to another embodiment of the present invention and a method and a facility for manufacturing a steel pipe, as illustrated in FIG. 13, the lower die 24, which is one of the pair of dies, may include a transition part 24b formed of a curved surface provided adjacent to the flat part 24a on the delivery side 3 in the conveyance direction 1. In this case, it is preferable that the flat part 24a and the transition part 24b be connected to have a common tangent line. When such a transition part 24b having a curved shape continuous to the flat part 24a is provided on the delivery side 3, it is possible to provide a smooth step between the portion of the steel plate S that subjected to the edge bending in the previous pass and the portion subjected to the edge bending in the subsequent pass. 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. A similar transition part 24c may be provided on the entry side 2. In this case, it is necessary to form the transition part 24c such that the bending deformation length L (see, for example, FIG. 10) 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.

[0037] 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, the center C1 of a flat part of the upper die 23 in the conveyance direction that is positioned on the outer side of bending is displaced to the delivery side 3 relative to the center C2 of the pressing force P in the conveyance direction 1. 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, the center C1 of the flat part in the conveyance direction of either one die that is positioned at the outer side of bending between the upper die 23 and the lower die 24 is displaced to the delivery side 3 the conveyance direction 1 relative to the center C2 of the pressing force P. 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

[0038] 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

[0039] A steel plate having a tensile strength of 500 MPa, a plate width of 1676 mm × a plate thickness of 25.4 mm × a length of 12 m including a tab plate having a length of 400 mm × 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.

[0040] 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 R25 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") .

[0041] 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 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 in the longitudinal direction at a pitch of 0.1 m. 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.

[0042] 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 the steel plate) indicates "steel plate" when the boundary between the steel plate and the tab plate is positioned at the delivery side end portion of the flat part of the lower die at the first edge bending and the boundary between the steel plate and the tab plate is positioned at 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	A	Steel plate	1.1	1.1	1.1	0	1.2	1.2	Inventive Example
2	150	A	Tab	1.0	1.4	1.0	0	1.1	1.6	Inventive Example
3	150	B	Steel plate	1.0	1.0	0.6	0	1.0	1.0	Inventive Example
4	150	B	Tab	1.2	1.7	0.5	0	1.1	1.8	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	A	Steel plate	2.8	2.8	2.8	4	3.1	3.1	Comparative Example
8	0	A	Tab	3.2	4.8	3.2	4	3.3	4.0	Comparative Example

[0043] As indicated in Table 1, under conditions 1 to 6 (inventive examples) in which the center C1 of the flat part 24a of the lower die in the conveyance direction 1 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 Dc of the edge bending angle and the variation of the peaking of the stationary portion are suppressed to about half of those of conditions 7 and 8 (comparative examples) in which the center C1 of the flat part 24a of the lower die is set to match the center C2 of the central hydraulic cylinder.

[0044] Furthermore, under the conditions 3 and 4 in which the die B provided with a gentle transition part on the deliver side 3 is used, and conditions 5 and 6 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 of the stationary portion. Meanwhile, under the conditions 1, 2, 7 and 8 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, 3 and 5, and conditions 2, 4 and 6, 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.

[0045] 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 3 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 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, 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.

[0046] Under the conditions 7 and 8 that do not satisfy the conditions of the present invention, as compared with the inventive examples, the variations of the peaking and the edge bending angle are large. 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 2

[0047] 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.

[0048] 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. As indicated in Table 2, under conditions 1 to 6 (inventive examples) in which the center C1 of the flat part 24a 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 half of those of conditions 7 and 8 (comparative examples) in which the center C1 of the flat part 24a of the lower die is set to match the center C2 of the central hydraulic cylinder.

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	A	Steel plate	1.0	1.0	1.0	0	1.1	1.1	Inventive Example
2	150	A	Tab	0.9	1.2	0.9	0	1.0	1.4	Inventive Example
3	150	B	Steel plate	0.9	0.9	0.5	0	0.9	0.9	Inventive Example
4	150	B	Tab	1.1	1.5	0.4	0	1.0	1.6	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	A	Steel plate	2.5	2.5	2.5	3	2.7	2.7	Comparative Example
8	0	A	Tab	2.8	4.2	2.8	4	2.9	3.5	Comparative Example

[0049] Furthermore, under the conditions 3 and 4 in which the die B provided with a gentle transition part on the delivery side 3 is used, and conditions 5 and 6 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 the conditions 1, 2, 7 and 8 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.

[0050] When comparing the conditions 1, 3 and 5, and conditions 2, 4 and 6, 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.

[0051] 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 3 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 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, the variation of the peaking is 0.8 to 0.9 mm, which is not more than one seventh of ± 3.2 mm, a peaking tolerance required by API standards, and it can be understood that the shape is superior.

[0052] Under the conditions 7 and 8 that do not satisfy the conditions of the present invention, as compared with the inventive examples, the variations of the peaking and the edge bending angle are larger. 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

[0053] A steel plate having a tensile strength of 500 MPa, a plate width of 3232 mm × a plate thickness of 38.1 mm × a length of 12 m including a tab plate having a length of 400 mm × 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.

[0054] The edge bending conditions and the formation results are indicated in Table 3. The items and descriptions in Table 3 are the same as those of Example 1. As shown in Table 3, under conditions 1 to 6 (inventive examples) 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 conditions 7 and 8 (comparative examples) in which the center C1 of the flat part of the lower die is set to match the center C2 of the central hydraulic cylinder.

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	A	Steel plate	0.9	0.9	0.9	0	1.0	1.0	Inventive Example
2	150	A	Tab	0.8	1.1	0.8	0	0.9	1.3	Inventive Example
3	150	B	Steel plate	0.8	0.8	0.5	0	0.8	0.8	Inventive Example
4	150	B	Tab	1.0	1.4	0.4	0	0.9	1.5	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	A	Steel plate	2.3	2.3	2.3	3	2.5	2.5	Comparative Example
8	0	A	Tab	2.6	3.9	2.6	4	2.7	3.2	Comparative Example

[0055] Furthermore, under the conditions 3 and 4 in which the die B provided with a gentle transition part on the delivery side 3 is used, and conditions 5 and 6 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 visually hardly recognizable and the angular difference between adjacent portions is about half of the variation of the edge bending angle of the stationary portion. Meanwhile, under the conditions 1, 2, 7 and 8 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, 3 and 5, and conditions 2, 4 and 6, 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.

[0056] 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 3 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 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, the variation of the peaking is 0.7 to 0.8 mm, which is not more than one eighth of ± 3.2 mm, a peaking tolerance required by API standards, and it can be understood that the shape is superior.

[0057] Under the condition Nos. 7 and 8 that do not satisfy the conditions of the present invention, as compared with the inventive examples, the variations of the peaking and the edge bending angle are large. 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

[0058] Similarly in Example 2, a steel plate having a tensile strength of 550 MPa, a plate width of 2753 mm × a plate thickness of 38.1 mm × a length of 12 m including a tab plate having a length of 400 mm × 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, and the flat part of the lower die has a processing face having a radius of curvature of 335 mm so as to match the upper die. 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 in the conveyance direction (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").

[0059] 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.

[0060] As indicated in Table 4, under conditions 1 to 6 (inventive examples) in which the center C1 of the flat part 24a of the lower die in the conveyance direction 1 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 half of those of conditions 7 and 8 (comparative examples) in which the center C1 of the flat part 24a of the lower die is set to match the center C2 of the central hydraulic cylinder.

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 of steel pipe		Remarks
				Stationary portion [°]	Entire length [°]			Stationary portion [mm]	Entire length [mm]	
1	150	A	Steel plate	1.0	1.0	0.9	0	0.9	0.9	Inventive Example
2	150	A	Tab	0.7	1.0	0.8	0	0.9	1.3	Inventive Example
3	150	B	Steel plate	0.9	0.8	0.4	0	0.8	0.9	Inventive Example
4	150	B	Tab	1.0	1.5	0.4	0	0.9	1.6	Inventive Example
5	150	C	Steel plate	0.7	0.8	0.4	0	0.7	0.8	Inventive Example
6	150	C	Tab	0.8	1.2	0.4	0	0.8	1.2	Inventive Example
7	0	A	Steel plate	2.5	2.1	2.2	3	2.6	2.6	Comparative Example
8	0	A	Tab	2.4	3.9	2.8	4	2.4	3.4	Comparative Example

[0061] Furthermore, under the conditions 3 and 4 in which the die B provided with a gentle transition part on the delivery side 3 is used, and conditions 5 and 6 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 visually hardly recognizable and the angular difference between adjacent portions is about half of the variation of the edge bending angle of the stationary portion. Meanwhile, under the conditions 1, 2, 7 and 8 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, 3 and 5, and conditions 2, 4 and 6, 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.

[0062] 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 3 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 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, the variation of the peaking is 0.8 to 0.9 mm, which is not more than one seventh of ± 3.2 mm, a peaking tolerance required by API standards, and it can be understood that the shape is superior.

[0063] Under the condition Nos. 7 and 8 that do not satisfy the conditions of the present invention, as compared with the inventive examples, the variations of the peaking and the edge bending angle are large. 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

[0064] Similarly to Example 3, a steel plate having a tensile strength of 500 MPa, a plate width of 3232 mm × a plate thickness of 38.1 mm × a length of 12 m including a tab plate having a length of 400 mm × 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, and the flat part of the lower die has a processing face having a radius of curvature of 400 mm so as to match the upper die. 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 in the longitudinal direction (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").

[0065] 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.

[0066] Under conditions 1 to 6 (inventive examples) 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 C 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 conditions 7 and 8 (comparative examples) in which the center C1 of the flat part of the lower die is set to match the center C2 of the central hydraulic cylinder.

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	A	Steel plate	1.0	1.0	0.9	0	0.9	0.9	Inventive Example
2	150	A	Tab	0.7	1.0	0.8	0	0.9	1.3	Inventive Example
3	150	B	Steel plate	0.9	0.8	0.4	0	0.8	0.9	Inventive Example
4	150	B	Tab	1.0	1.5	0.4	0	0.9	1.6	Inventive Example
5	150	C	Steel plate	0.7	0.8	0.4	0	0.7	0.8	Inventive Example
6	150	C	Tab	0.8	1.2	0.4	0	0.8	1.2	Inventive Example
7	0	A	Steel plate	2.5	2.1	2.2	3	2.6	2.6	Comparative Example
8	0	A	Tab	2.4	3.9	2.8	4	2.4	3.4	Comparative Example

[0067] Furthermore, under the conditions 3 and 4 in which the die B provided with a gentle transition part on the delivery side 3 is used, and conditions 5 and 6 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 visually hardly recognizable and the angular difference between adjacent portions is about half of the variation of the edge bending angle of the stationary portion. Meanwhile, under the conditions 1, 2, 7 and 8 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, 3 and 5, and conditions 2, 4 and 6, 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.

[0068] 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 3 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 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, 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.

[0069] Under the condition Nos. 7 and 8 that do not satisfy the conditions of the present invention, as compared with the inventive examples, the variations of the peaking and the edge bending angle are large. 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

[0070] According to the present invention, it is possible to obtain an edge bending shape with less variation across the entire length without introducing a new facility.

DESCRIPTION OF REFERENCE NUMERALS

[0071]

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
S steel plate
Sa leading end portion
Sb trailing end portion
Sc, Sd widthwise edge

St tab plate
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
Dc angle variation in stationary portion
Df deformation force
P hydraulic pressure (pressing force)
Dp peaking
Dp- minus peaking
Dp+ plus peaking

Claims

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 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 edge 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 edge 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 edge bending, and edge bending is performed on the widthwise edge of the steel plate with a center of the flat part in the conveyance direction being displaced to a delivery side in the conveyance direction relative to a center of the pressing force generated by the actuator in the conveyance direction.

2. The edge bending method of a steel plate according to claim 1,
wherein the die that contacts the surface positioned at the outer side of edge bending comprises 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.

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 at a position corresponding to a front end of the flat part in a first pass of bending the widthwise edge of the steel plate.

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 at a position corresponding to a rear end of the flat part in a final pass for bending the widthwise edge of the steel plate.

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 the widthwise edge of the 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 edge 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
one of the pair of dies that contacts a surface positioned at the outer side of edge 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 edge bending,
and edge bending is performed on the widthwise edge of the steel plate with a center of the flat part in the conveyance direction being displaced to a delivery side in the conveyance direction relative to a center of the pressing force generated by the actuator in the conveyance direction.

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 edge 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 edge 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 edge bending,
and a center of the flat part in the conveyance direction is displaced to a delivery side in the conveyance direction relative to a center of the pressing force generated by the actuator in the conveyance direction.

7. The edge bending apparatus of a steel plate according to claim 6, wherein the die that contacts the surface positioned at the outer side of edge bending comprises 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.

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 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 edge 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
one of the pair of dies that contacts a surface positioned at the outer side of edge 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 edge bending, and
a center of the flat part in the conveyance direction is displaced to a delivery side in the conveyance direction relative to a center of the pressing force generated by the actuator in the conveyance direction.

9. The facility for manufacturing a steel pipe according to claim 8,
wherein the die that contacts the surface positioned at the outer side of edge bending comprises 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.

FIG. 1

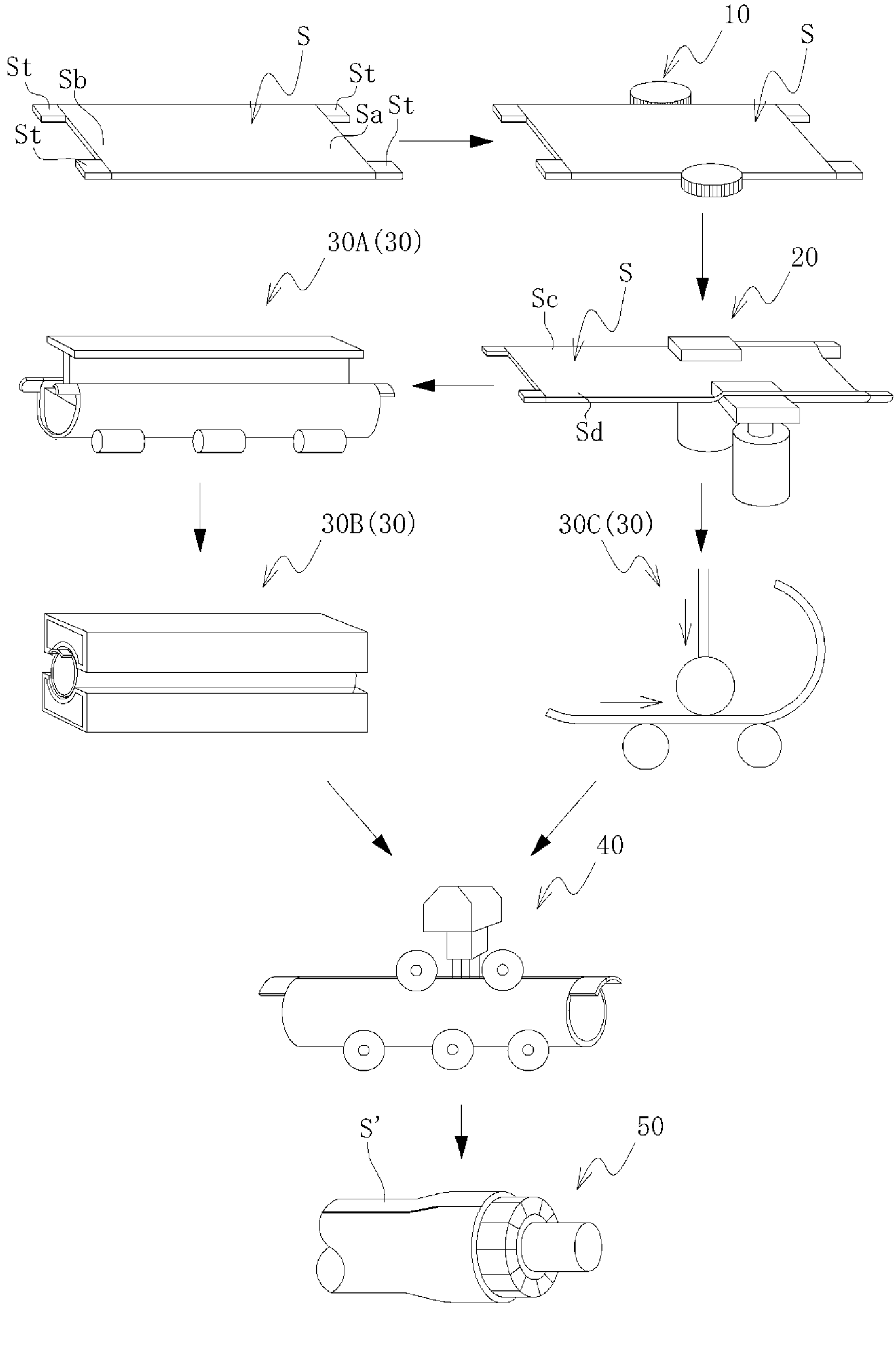


FIG. 2

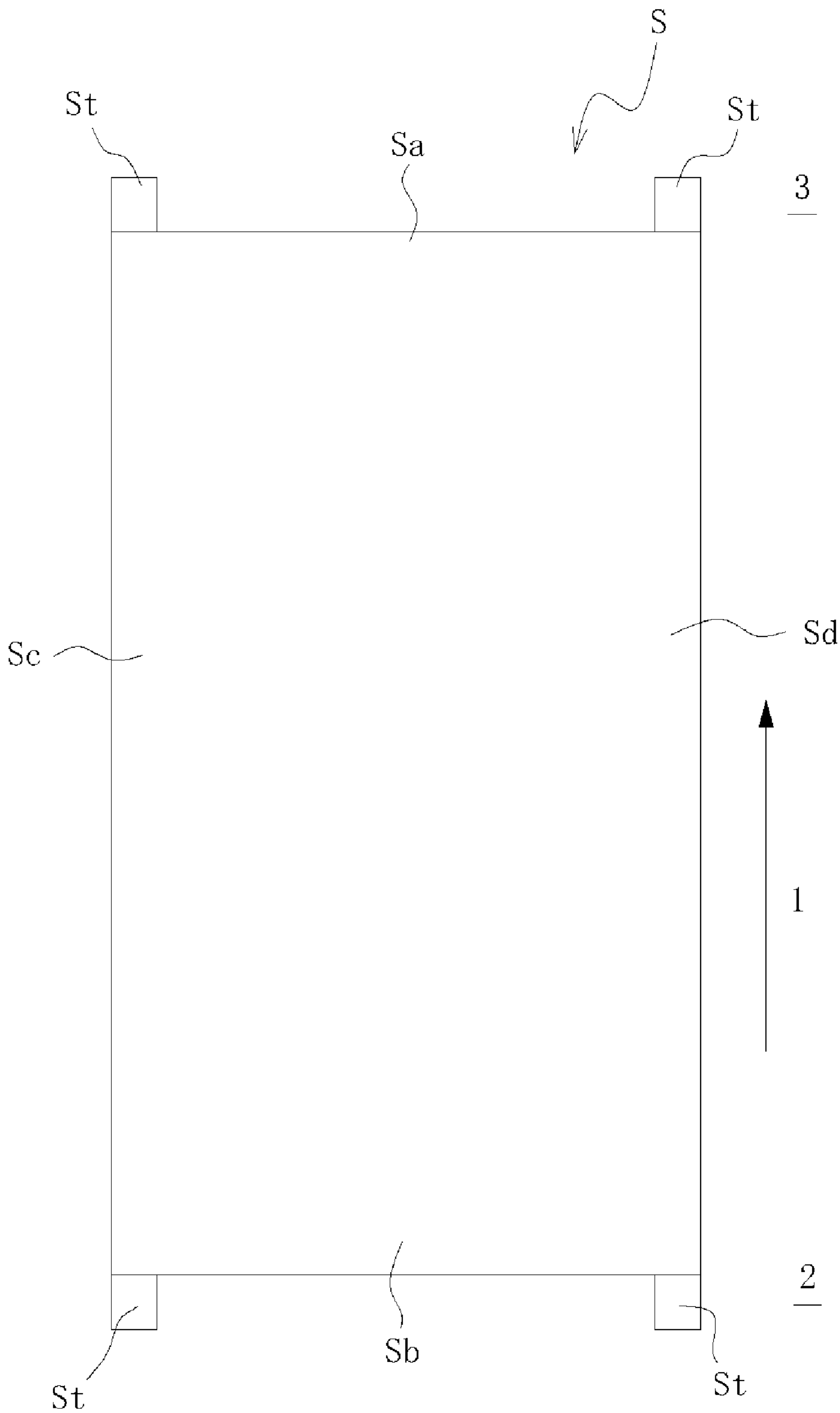


FIG. 3

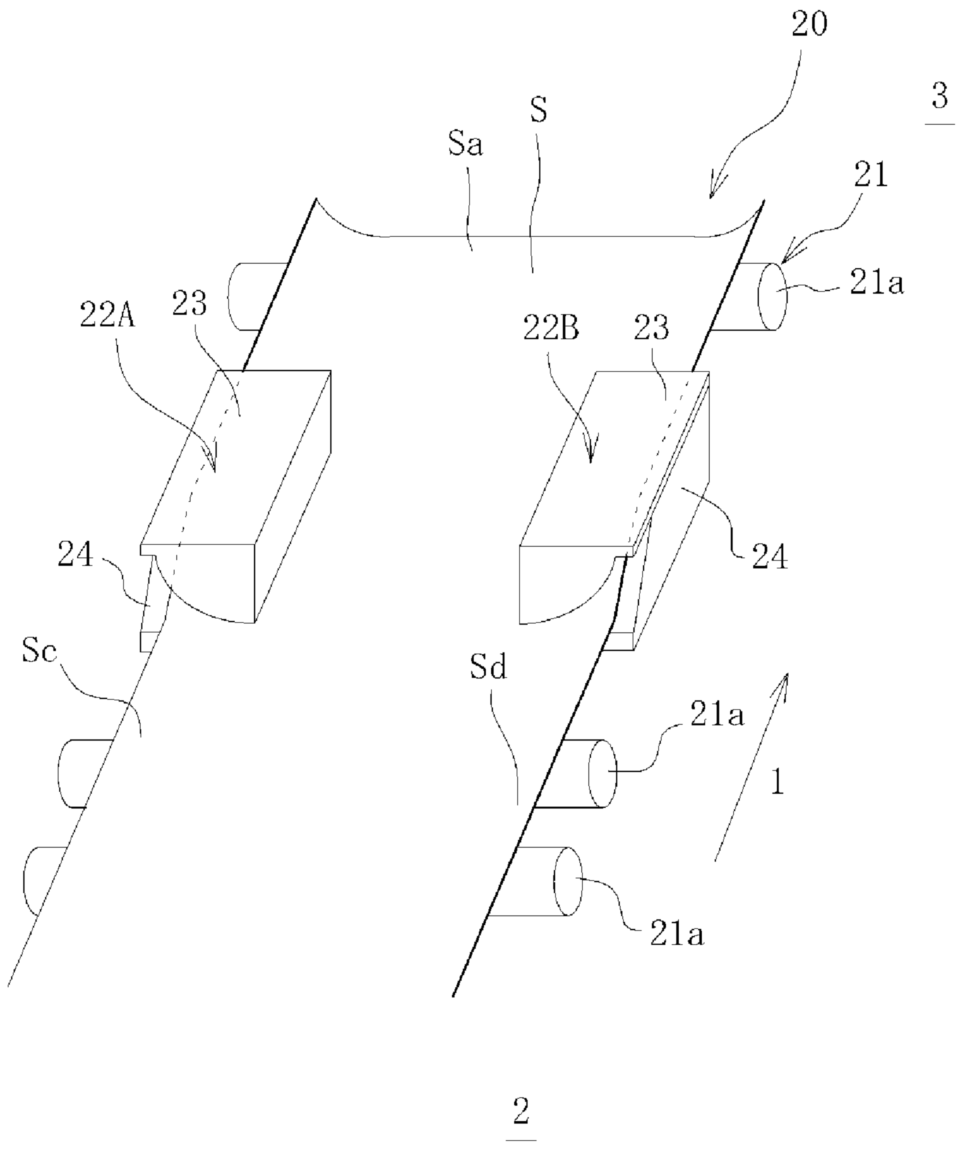


FIG. 4

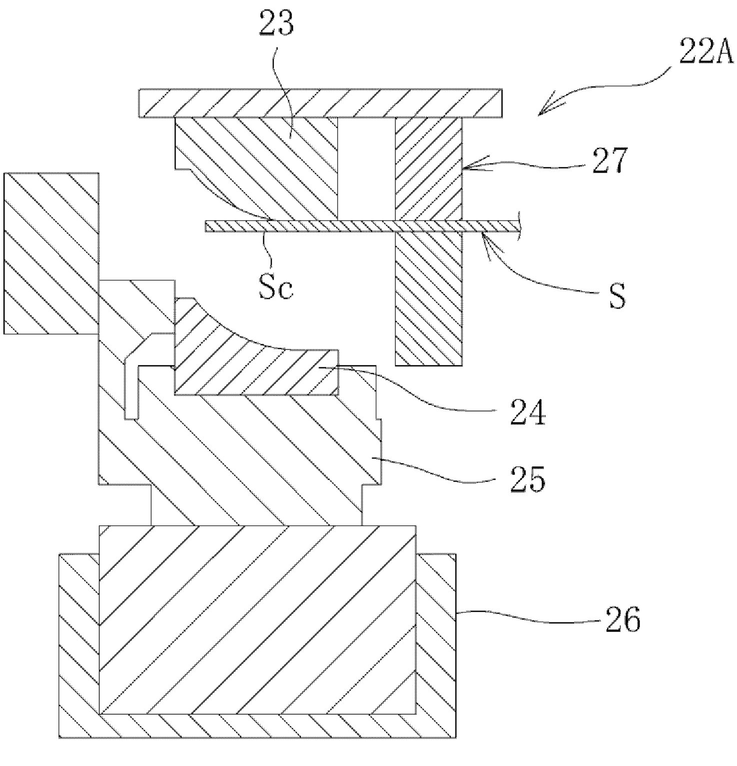


FIG. 5

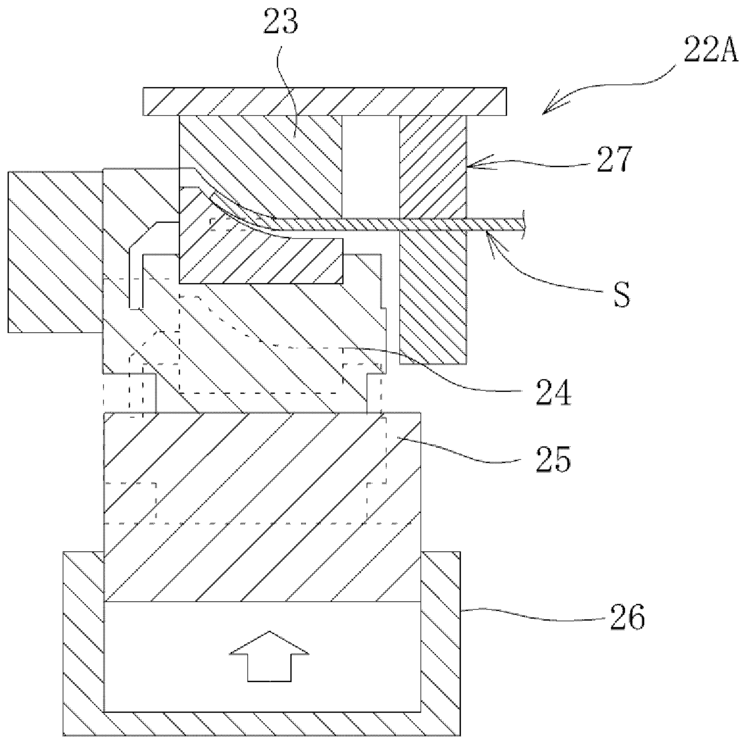


FIG. 6

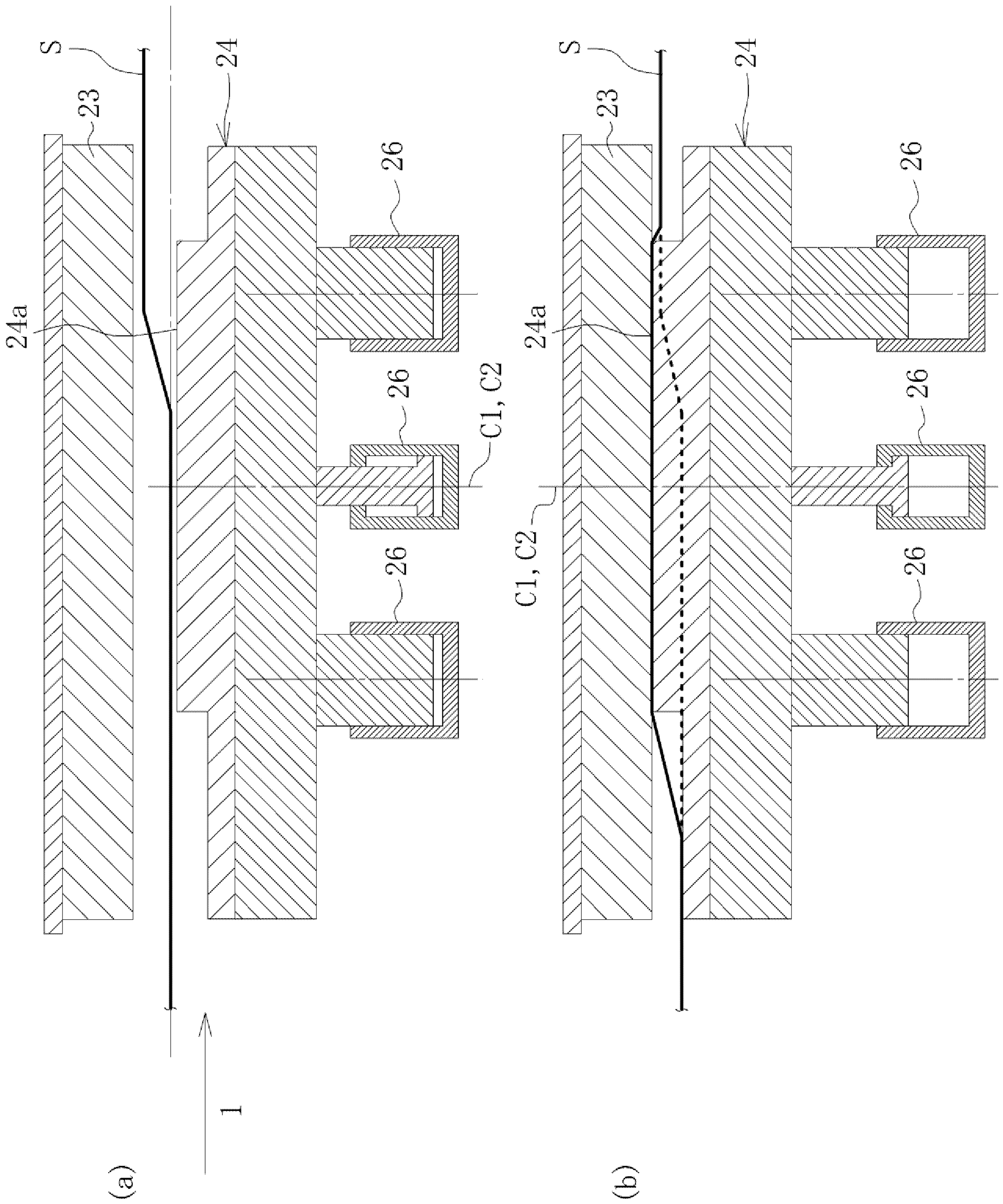


FIG. 7

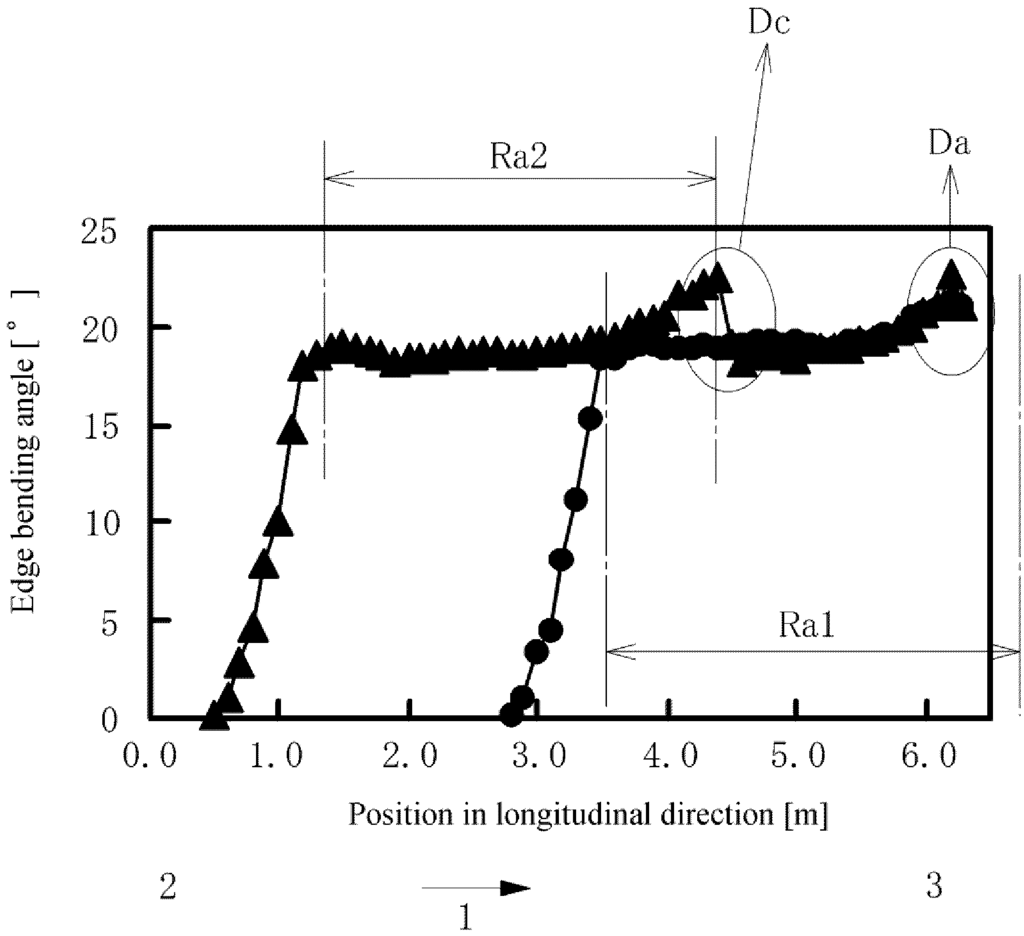
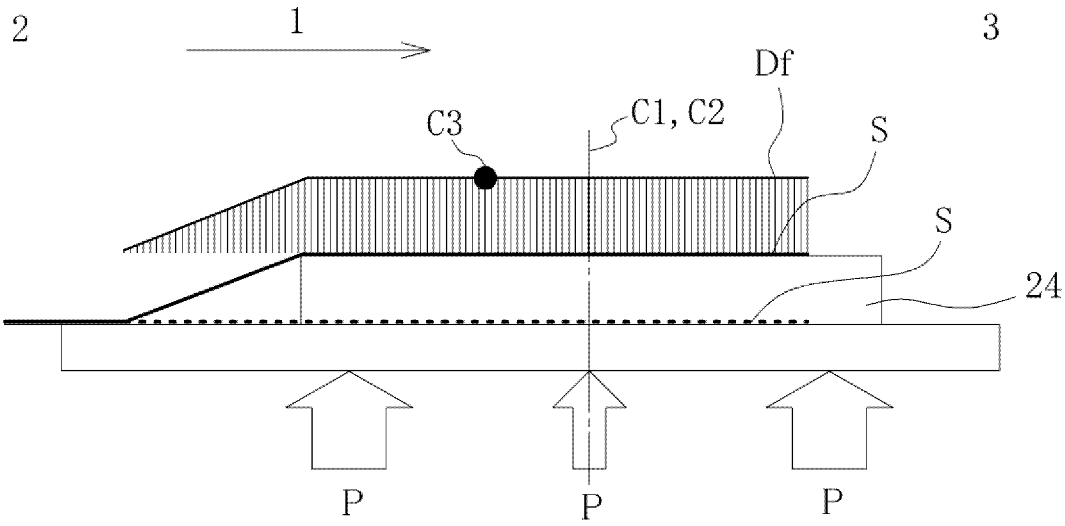

Dc
Da
Ra2
Ra1
25
20
15
10
5
0
Edge bending angle [°]
0. 0
1. 0
2. 0
3. 0
4. 0
5. 0
6. 0
Position in longitudinal direction [m]
2
1
3

FIG. 8

(a)



(b)

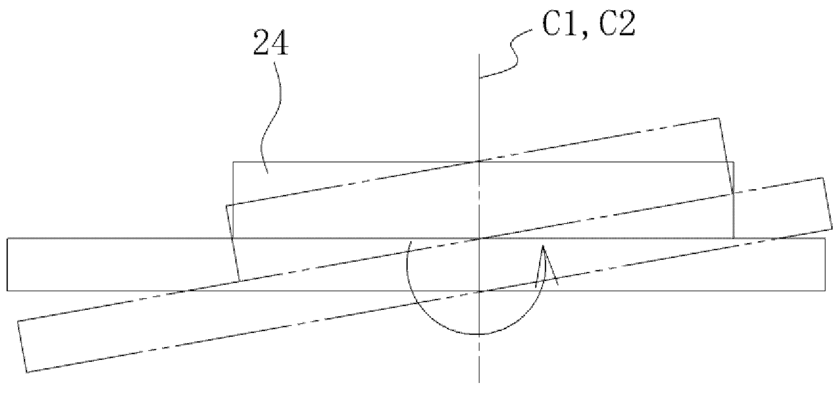
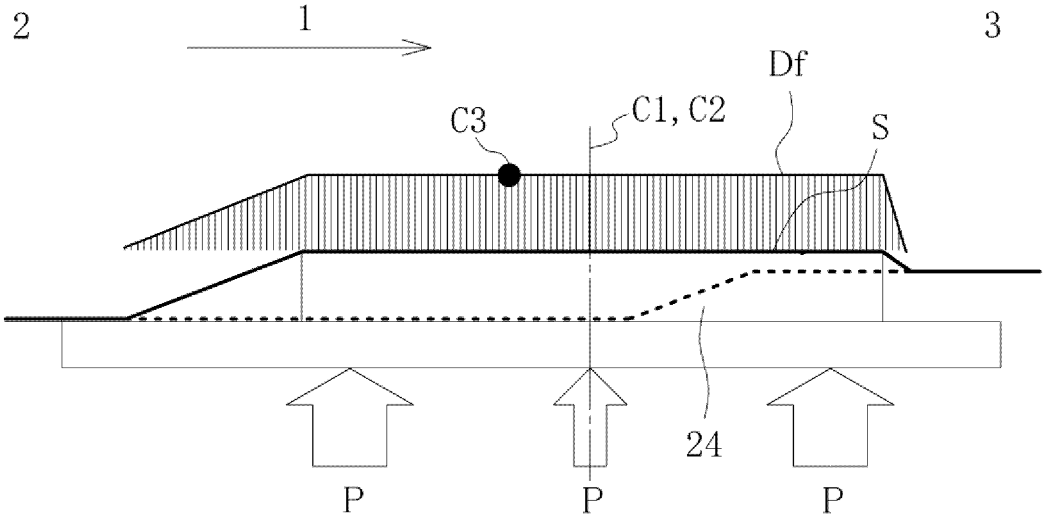


FIG. 9

(a)



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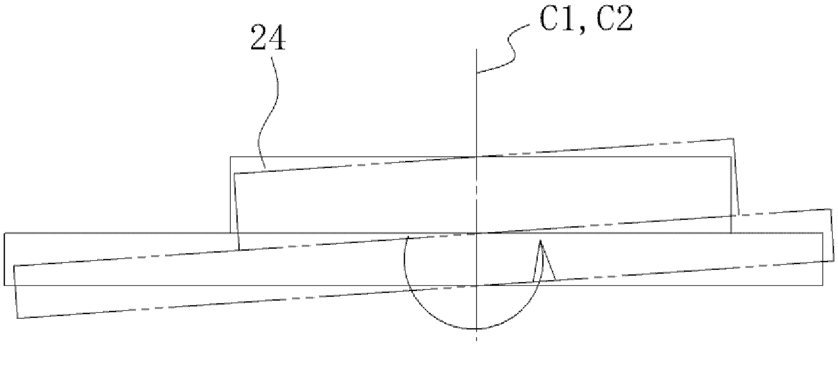


FIG. 10

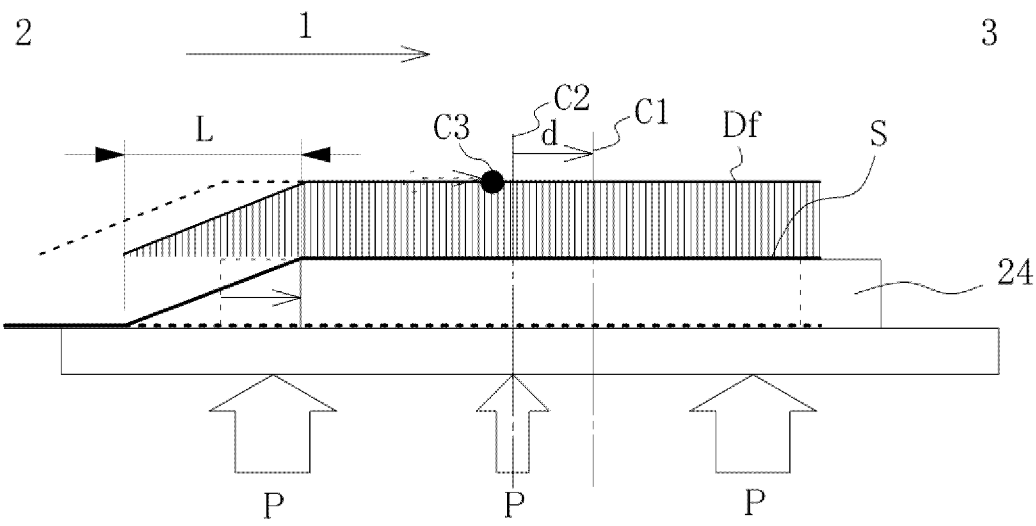


FIG. 11

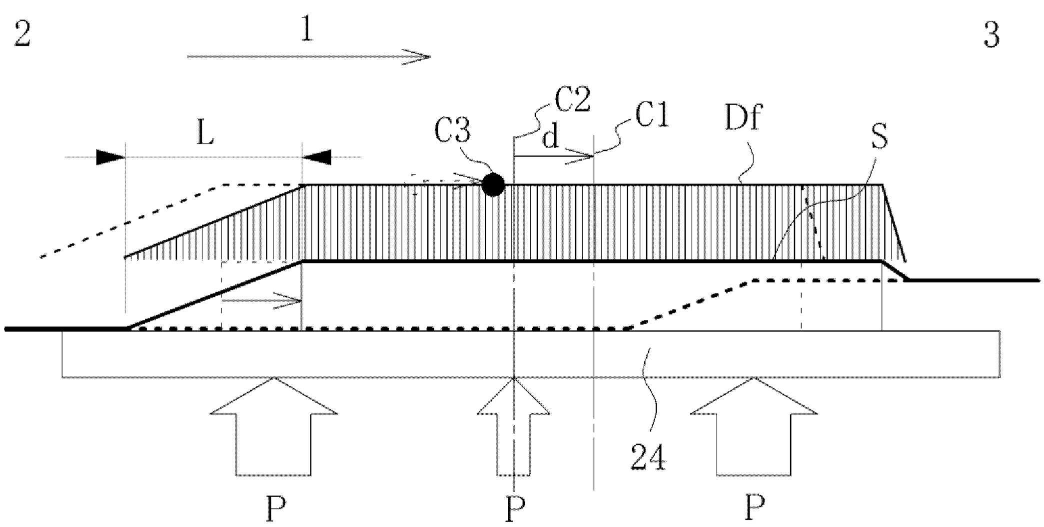
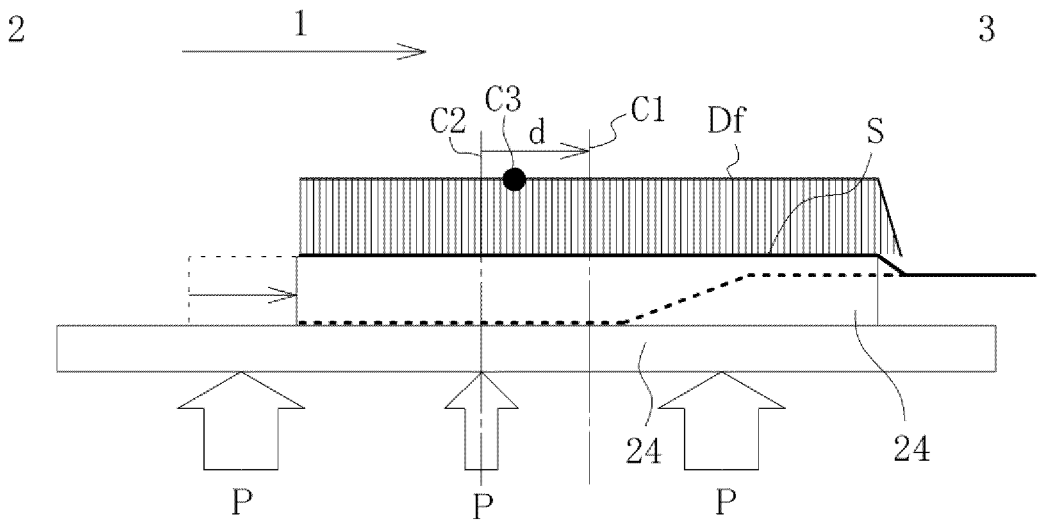


FIG. 12

(a)



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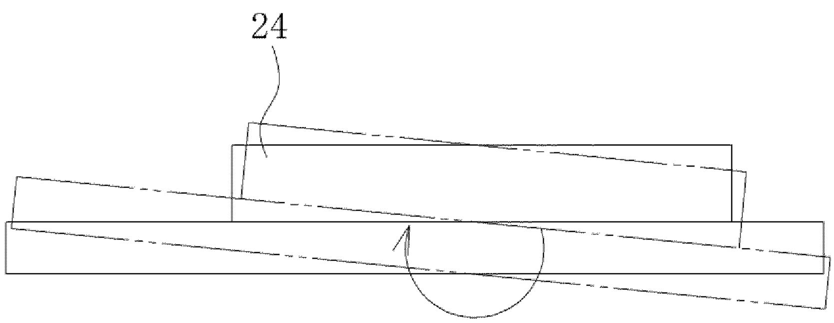


FIG. 13

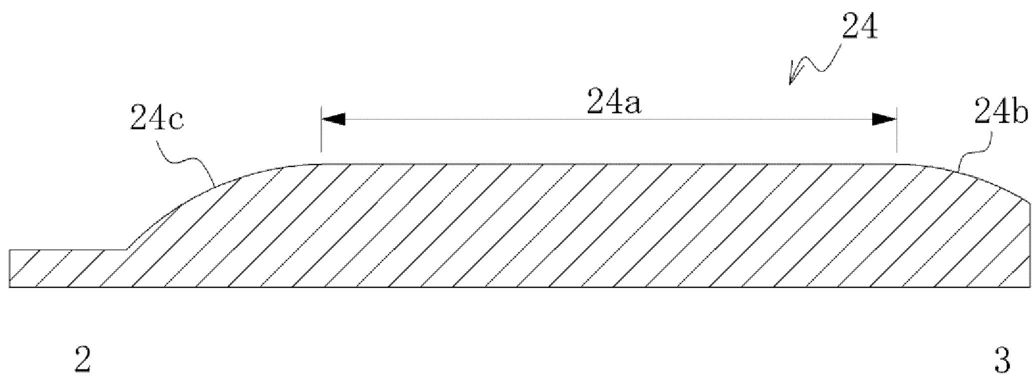


FIG. 14

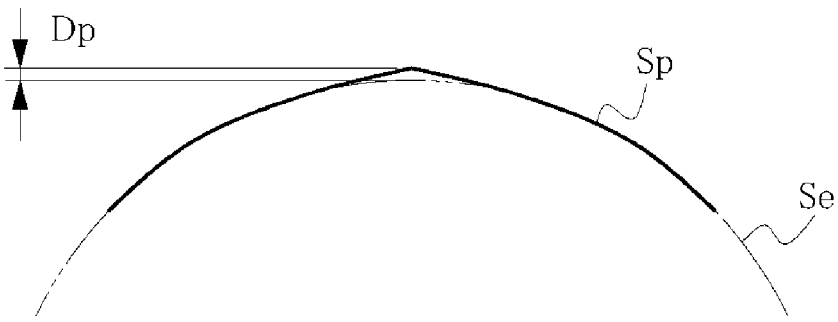
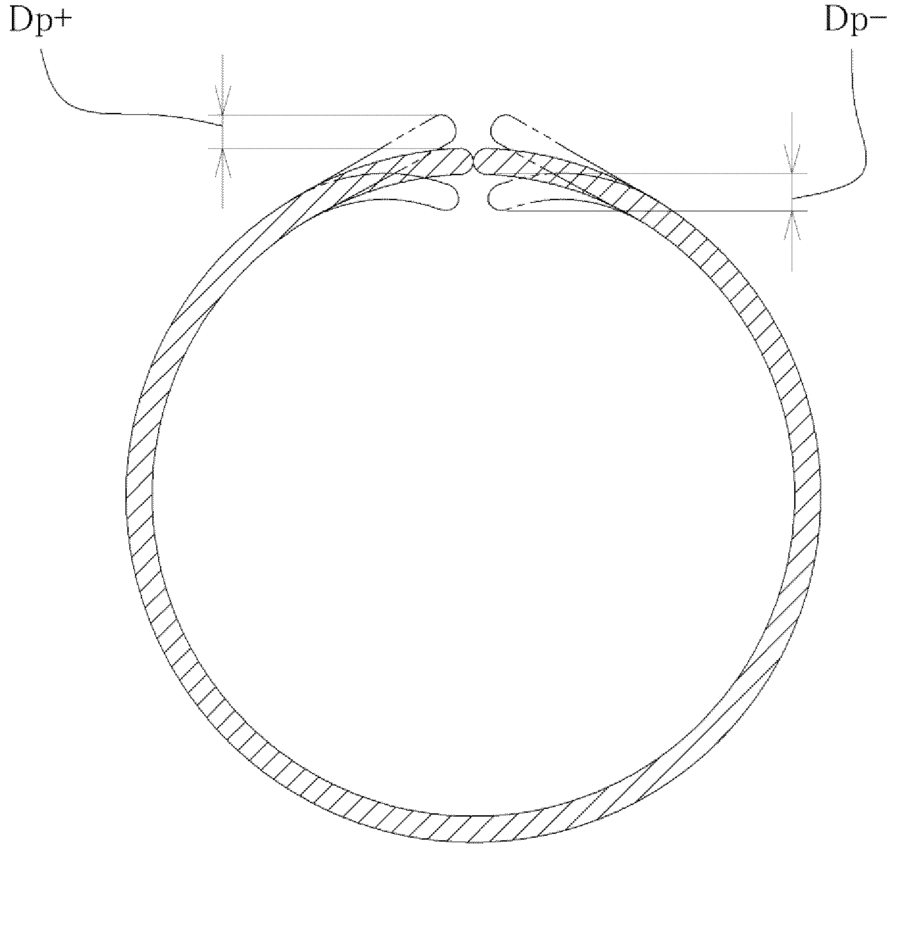


FIG. 15



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/008297

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)	1-9
A	JP 58-81517 A (NIPPON STEEL CORP.) 16 May 1983 (Family: none)	1-9
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)	1-9

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

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27.03.2019	09.04.2019

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

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

REFERENCES CITED IN THE DESCRIPTION

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- JP 2008119710 A **[0006]**
- JP 2009006358 A **[0006]**
- JP H0732049 A **[0006]**
- JP 2007245218 A **[0006]**