



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
21.07.2021 Bulletin 2021/29

(51) Int Cl.:
B21D 5/01 (2006.01) B21C 37/08 (2006.01)

(21) Application number: **18933413.9**

(86) International application number:
PCT/JP2018/034145

(22) Date of filing: **14.09.2018**

(87) International publication number:
WO 2020/054051 (19.03.2020 Gazette 2020/12)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME KH MA MD TN

- **HINATA, Kosuke**
Tokyo 100-0011 (JP)
- **KAWANO, Tomohiro**
Tokyo 100-0011 (JP)
- **TAMURA, Yukuya**
Tokyo 100-0011 (JP)

(71) Applicant: **JFE Steel Corporation**
Tokyo 100-0011 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

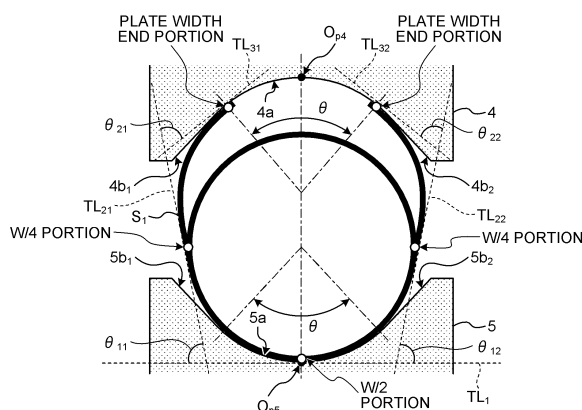
(72) Inventors:
• **HORIE, Masayuki**
Tokyo 100-0011 (JP)

(54) **STEEL PIPE MANUFACTURING METHOD AND PRESS DIE**

(57) A method of manufacturing a steel pipe includes performing bending three or more times on a plate material along a width direction, the plate material being subjected to edge bending at both ends in the width direction, to form a preform having a U-shaped cross section, then pressing the preform to form an open pipe having a seam gap portion in a longitudinal direction, and thereafter joining the seam gap portion to form a steel pipe. When a width of the plate material before the edge bending is a plate width W , the preform has a lightly bent portion having a small curvature compared with other

regions or an unbent portion not subjected to bending, of which center is positioned at a point away from a plate width end by $W/4$, and the pressing is performed to form the open pipe into a shape such that a range of 20 [%] or more of the plate width W of which center is positioned at a lowermost portion of the U-shaped cross section and a range of 10 [%] or more of the plate width W from the plate width end are inscribed in an arc with a diameter equal or substantially equal to an outer diameter of the steel pipe.

FIG.5



Description

Field

- 5 **[0001]** The present invention relates to a method of manufacturing a steel pipe and a press die for use in the method of manufacturing a steel pipe.

Background

- 10 **[0002]** UOE forming techniques are widely used to form steel pipes. In the UOE forming techniques, a steel plate is first press-bent into a U shape and then pressed into an O shape to form an open pipe, which is a tubular body having a seam gap portion between plate width ends opposed to each other in a circumferential direction. The seam gap portion of the open pipe is butted and joined by welding to form a steel pipe, which is then expanded such that the diameter of the steel pipe is increased. The UOE forming technique, however, requires a high press force in the process of pressing a steel plate into a U shape or an O shape to form an open pipe and inevitably requires the use of a large-scale press machine.

- 15 **[0003]** Then, in manufacturing a steel pipe, there is a technique for forming an open pipe with a reduced press force. For example, a press-bending process is in practical use, in which the edge portions in the width direction of a steel plate are bent to produce edge bent portions, and thereafter three-point press bending is performed multiple times with a punch supported on a punch support and a die to shape the steel plate into an approximately circular shape. The open amount of the seam gap portion of the open pipe formed by the press bending process is larger than the width of the punch support. If the open amount is too large, the force required for butting the plate width ends opposed to each other and closing the seam gap portion is increased in order to weld the seam gap portion. A larger facility is then required for closing the seam gap portion. In addition, after the seam gap portion with an excessively large open amount is welded, 20 the welded portion receives a force caused by springback to open the seam gap portion and tends to suffer a weld defect. If the force is too large, the welded portion is broken.

- 25 **[0004]** Techniques for reducing the open amount of the seam gap portion of an open pipe after press bending are disclosed in Patent Literatures 1 to 4. Patent Literature 1 discloses a technique for reducing the open amount of the seam gap portion of an open pipe by providing a pivotable coupling portion between the punch front end and the punch support to reduce the width of the punch support. Patent Literature 2 discloses a technique for reducing the open amount of the seam gap portion of an open pipe by providing gap holding means for restricting movement of a plate material in a direction orthogonal to the punch moving direction, and applying a large press in the final bending without the plate width end portions coming into contact with the punch support. Patent Literature 3 discloses a technique for reducing the open amount of the seam gap portion of an open pipe by measuring the gap between the plate width end portion and the punch support after the final pressing-down process and minimizing the gap. Patent Literature 4 discloses a technique for reducing the open amount of the seam gap portion of an open pipe irrespective of variation in shape produced in the press bending process, in which the amount of pressing-down by the punch in a final step is determined based on the point of time when the distance between the plate width ends becomes a predetermined value at the time of pressing-down in the final bending process.

- 30 **[0005]** Unfortunately, the techniques disclosed in Patent Literatures 1 to 4 fail to reduce the open amount of the seam gap portion of an open pipe to a width smaller than the width of the punch support. Then, the techniques for reducing the open amount of the seam gap portion by additionally processing the open pipe after press bending are disclosed in Patent Literatures 5 to 9. Patent Literature 5 discloses a technique of forming a pipe with a smaller load by hot-pressing a steel pipe after press bending. Patent Literature 6 discloses a technique of pressing, in which a distortion detector is disposed to detect a tilt or distortion of a pressing member attached to a slide, the pressing member is disposed so as to be able to tilt or translate in response to detection of a tilt or distortion by the distortion detector, and when the blank material is pressed into a pipe shape, the pressing member is tilted or translated for the amount of tilt or inclination of the pressing member so as to reduce the amount of distortion. Patent Literature 7 discloses a technique in which a slit tube having a non-circular preform is formed by shaping slightly, compared to other bending steps, in at least one bending step acting on the inner face of a plate material on the right and left sides with respect to the center defined by the longitudinal axis line of an upper-side tool going into the plate material progressively shaped, and the slit tube is then completed by properly in each case adding a pressing force acting on the areas previously shaped slightly at both sides of the center to the noncircular preform from outside. Patent Literature 8 discloses a technique in which, in a blank having a flat portion between portions bent into at least two pipe curvatures, plastic deformation is applied to at least one flat portion into a predetermined curvature to form a pipe with a closed slit portion. Patent Literature 9 discloses a method of forming a pipe with a closed slit portion. The method includes providing a lightly bent portion with a curvature slighter than other regions or providing a non-bent portion in which bending is omitted, to form a preformed body, and applying a bending force without constraining the lightly bent portion or the non-bent portion, in pressing the preformed body into 50
- 55

an open pipe. In applying the bending force, it is recommended that the preformed body is held in a die in a U-shaped posture with its opening portion facing upward, and is supported at its lowermost end.

[0006] Patent Literatures 10 and 11 disclose a method of manufacturing a UOE pipe having a product diameter in which the outer diameter of the product pipe is different from the diameter of an inner surface of an O-press die. The die disclosed in Patent Literature 10 is shaped such that only a part of the ellipse shape of the inner surface of the upper/lower die is notched. In FIG. 3(a) and FIG. 4(a) of Patent Literature 10 illustrating the effect of the die, an O pipe is in contact with the entire inner surface of the O-press die. Patent Literature 11 discloses a method using a die that has an inner surface having an arc with a radius larger than a product outer diameter and has an end surface ground in advance to provide a sufficiently large gap. After a material is fitted in the die and then subjected to predetermined compressing, the formed pipe is rotated by about 90 [°] and O-pressing is performed again to form a circular shape. In the first O-pressing step, the steel pipe is in intimate contact with the entire surface of the die.

Citation List

Patent Literature

[0007]

Patent Literature 1: Japanese Patent Application Laid-open No. 2004-82219

Patent Literature 2: Japanese Patent Application Laid-open No. 2011-56524

Patent Literature 3: WO2014/188468

Patent Literature 4: WO2014/192043

Patent Literature 5: Japanese Patent Application Laid-open No. 2005-324255

Patent Literature 6: Japanese Patent Application Laid-open No. 2005-21907

Patent Literature 7: Japanese Patent Application Laid-open No. 2012-250285

Patent Literature 8: United States Patent No. 4149399

Patent Literature 9: WO2016/084607

Patent Literature 10: Japanese Patent Application Laid-open No. 2003-39115

Patent Literature 11: Japanese Patent Application Laid-open No. 2002-178026

Summary

Technical Problem

[0008] Unfortunately, the technique disclosed in Patent Literature 5 incurs a significant cost increase if thermal energy consumption involved in heating is included. Moreover, in this technique, if a plate material produced through a thermo-mechanical processing step is used for achieving strength, toughness, and weldability, the characteristics of the material may be impaired. In the techniques disclosed in Patent Literatures 6 to 8, the blank material or the noncircular preform is formed separately on the right side and the left side. If the amount of deformation is different between the right and the left, a level difference (misalignment) may be produced at the seam gap portion or the slit portion serving as a welded portion. In these techniques, deformation into a desired shape in a single step causes local concentration of deformation, which may deteriorate the roundness of the steel pipe. For this reason, deformation in multiple steps is inevitable and poses a limit on efficient forming. In the technique disclosed in Patent Literature 9, since the radius of the lower die is larger than the pipe outer diameter, the lowermost portion of the preformed body in a U-shaped posture is bent back, causing a deformation that opens the gap portion. This may prevent reduction of the gap of the slit portion. The techniques disclosed in Patent Literatures 10 and 11 involve pressing in a state in which the O pipe is in intimate contact with the entire surface of the die, and require a high press force as described above and still inevitably require a large-scale press machine.

[0009] The present invention is made in view of the problems above. An object of the present invention is to provide a method of manufacturing a steel pipe for efficiently forming a steel pipe with high roundness and a press die.

Solution to Problem

[0010] To solve the problem and achieve the object, a method of manufacturing a steel pipe according to the present invention includes: performing bending three or more times on a plate material along a width direction, the plate material being subjected to edge bending at both ends in the width direction, to form a preform having a U-shaped cross section; pressing the preform to form an open pipe, the open pipe being a tubular body having a seam gap portion in a longitudinal direction; and joining the seam gap portion to form a steel pipe, wherein when a width of the plate material before the

edge bending is a plate width W, the preform has a lightly bent portion or an unbent portion of which center is positioned at a point away from a plate width end by W/4, the lightly bent portion having a small curvature compared with other regions, the unbent portion being not subjected to bending, and the pressing is performed to form the open pipe into a shape such that a range of 20 [%] or more of the plate width W of which center is positioned at a lowermost portion of the U-shaped cross section and a range of 10 [%] or more of the plate width W from the plate width end are inscribed in an arc with a diameter equal or substantially equal to an outer diameter of the steel pipe.

[0011] Moreover, in the method of manufacturing a steel pipe according to the present invention, where A denotes the range of 20 [%] or more of the plate width W of which center is positioned at the lowermost portion of the U-shaped cross section inscribed in an arc with a diameter equal or substantially equal to an outer diameter of the steep pipe, and B denotes a total range of 10 [%] or more of the plate width W from both plate width ends inscribed in an arc with a diameter equal or substantially equal to an outer diameter of the steel pipe, Expression (1) is satisfied,

$$2 |A-B| / (A+B) < 0.4 \quad (1)$$

where $|A-B|$ is an absolute value of A-B.

[0012] Moreover, in the method of manufacturing a steel pipe according to the present invention, when the preform is placed on a second die of a pair of dies such that a first die of the pair of dies is opposed to a U-shaped open side of the preform, and the preform is pressed while the preform is held between the pair of dies, the second die includes a pressing surface in such a manner that: in a state in which the preform is placed on the second die, the pressing surface is not in contact with the preform, excluding a range formed into a shape inscribed in an arc with a diameter equal or substantially equal to an outer diameter of the steel plate, with respect to the lowermost portion of the U-shaped cross section; and in a state in which pressing is completed, a part of the second die is not in contact with the open pipe, and the first die includes a pressing surface in such a manner that: in a state in which the preform is placed on the second die, the pressing surface is not in contact with the preform; and in a state in which pressing is completed, a part of the first die is not in contact with the open pipe.

[0013] Moreover, in the method of manufacturing a steel pipe according to the present invention, pressing is performed using a die having a radius of an arc portion within a range of ± 3.5 [%] with respect to a radius corresponding to an outer radius of the steel plate.

[0014] Moreover, in the method of manufacturing a steel pipe according to the present invention, in pressing of the preform, a center of a press die for use in pressing of the preform matches a center in a width direction of the preform.

[0015] Moreover, in the method of manufacturing a steel pipe according to the present invention, the preform is held in a U-shaped posture with a U-shaped open side facing upward.

[0016] Moreover, a press die for use in the method of manufacturing a steel pipe according to the present invention, includes: a pair of dies which are a pair of pressing bodies for holding the preform; and an arc portion formed in a surface of each die in contact with the preform such that an arc center is located at a position coincident with a bending center of the die, the arc portion having a radius within a range of ± 3.5 [%] with respect to a radius corresponding to an outer radius of the steel pipe, wherein the arc portion in each die has a central angle of 70 degrees or larger, and a total angle of the central angles of the arc portions of both dies is smaller than 360 degrees.

[0017] Moreover, in the press die according to the present invention, the central angles of the arc portions of both dies are equal to each other.

[0018] Moreover, in the press die according to the present invention, each die includes linear portions or small-curvature arc portions having a curvature smaller than the arc portion, the linear portions or the small-curvature arc portions being connected to both ends of the arc portion in an arc direction.

[0019] Moreover, in the method of manufacturing a steel pipe according to the present invention, the press die according to the present invention is used.

Advantageous Effects of Invention

[0020] The method of manufacturing a steel pipe and press die according to the present invention achieve the effect of efficiently forming a steel pipe with high roundness.

Brief Description of Drawings

[0021]

FIG. 1 is an external perspective view of a die and a punch for use in forming a preform having a U-shaped cross section through a press bending process according to an embodiment;

FIG. 2 is a diagram illustrating the procedure for forming a preform having a U-shaped cross section through a press bending process;

FIG. 3 is a cross-sectional view of the preform having a U-shaped cross section;

FIGS. 4(a) to 4(c) are diagrams schematically illustrating the process of forming an open pipe by performing O-

pressing on the preform;

FIG. 5 is an illustration of arc portions, linear portions, and central angles of an upper die and a lower die;

FIG. 6 is a graph illustrating the relation between the open amount of the seam gap portion of the open pipe and the constraining range, in conjunction with a press load;

FIGS. 7(a) to 7(c) are diagrams schematically illustrating a deformation state when the open pipe is formed using the upper die and the lower die with a constraining range of 0 degrees;

FIG. 8 is a graph illustrating the relation between the constraining range and the roundness of a steel pipe before pipe expanding when the seam gap portion of the open pipe is closed by welding;

FIG. 9 is a graph illustrating the relation between the constraining range and the press load;

FIG. 10 is a graph illustrating the result of the open amount of the seam gap portion of the open pipe when the individual constraining ranges of the upper die and the lower die are changed;

FIG. 11 is a graph illustrating the result of the roundness of a steel pipe before pipe expanding that is formed by closing the seam gap portion of the open pipe by welding when the individual constraining ranges of the upper die and the lower die are changed;

FIG. 12 is a graph illustrating the result of the press load when the individual constraining ranges of the upper die and the lower die are changed;

FIG. 13 is a graph illustrating the result of the open amount of the seam gap portion when the constraining range of the upper die and the constraining range of the lower die are the same and the length of a lightly bent portion or an unbent portion of the preform after press bending is changed;

FIG. 14 is a graph illustrating the result of the roundness of a steel pipe before pipe expanding when the constraining range of the upper die and the constraining range of the lower die are the same and the length of the lightly bent portion or the unbent portion of the preform after press bending is changed;

FIG. 15 is a graph illustrating the result of the press load when the constraining range of the upper die and the constraining range of the lower die are the same and the length of the lightly bent portion or the unbent portion of the preform after press bending is changed;

FIG. 16 is a graph illustrating the result of the open amount of the seam gap portion of the open pipe when the arc portion radiuses of the upper die and the lower die are changed; and

FIG. 17 is a graph illustrating the result of the press load when the arc portion radiuses of the upper die and the lower die are changed.

Description of Embodiments

[0022] An embodiment of a method of manufacturing a steel pipe and a press die for use in the method of manufacturing a steel pipe according to the present invention will be described below. FIG. 1 is an external perspective view of a die 1 and a punch 2 for use in forming a preform having a U-shaped cross section through a press bending process according to the present embodiment. The die 1 is disposed in a conveyance path including a plurality of conveyance rollers 3 for a plate material S and includes a pair of left and right rod-shaped members 1a and 1b for supporting the plate material S at two points along the plate material conveyance direction. A distance e between the rod-shaped members 1a and 1b in the plate material conveyance direction can be changed according to the size of a finished steel pipe.

[0023] The punch 2 is movable in a direction closer to or away from the die 1 and includes a downwardly projecting punch front end 2a for pressing a plate material S and a punch support 2b continuous to the back surface (upper end surface) of the punch front end 2a with the same width for supporting the punch front end 2a. The punch support 2b has an upper end coupled to not-illustrated driving means. The driving means applies a pressing force to the punch front end 2a.

[0024] FIG. 2 illustrates the procedure for forming a preform S_1 having a U-shaped cross section through a press bending process. This procedure specifically illustrates an example in which a plate material S subjected to edge bending in advance is bent and the plate material S is fed in order from the top to the bottom in the left column in FIG. 2, then from the top to the bottom in the middle column in FIG. 2, and finally to the right column in FIG. 2. The arrows given to the punch 2 and the plate material S in FIG. 2 indicate the direction in which the punch 2 or the plate material S moves in each stage.

[0025] To form a plate material S into a tubular shape using the plate material S as a starting material, first, edge bending is performed on the plate material S in advance. This edge bending is performed for a plate width end portion, which is relatively difficult to bend, compared with the bending performed on the plate material S using the die 1 and the punch 2. When edge bent portions are provided at the plate width end portions of the plate material S by the edge

bending, a steel plate with high roundness can be easily obtained, compared with when no edge bent portion is provided. The roundness of a steel pipe is an index representing how close to a circle the cross-sectional shape of the steel pipe is, and is a value indicated by a ratio obtained by dividing the difference between the maximum and the minimum of the amount of variation from an approximate arc on the entire circumference of a steel pipe by the steel pipe diameter. For example, a steel pipe having an outside diameter D is divided into 8 equal parts, 12 equal parts, 16 equal parts, or 24 equal parts in the circumferential direction of the pipe at any given pipe length, and the outside diameters at opposed positions are measured. When the maximum diameter and the minimum diameter of the measured outside diameters are $D_{\max}$ and $D_{\min}$, respectively, the roundness [%] is defined by $\{(D_{\max}-D_{\min})/D\} \times 100$. As the roundness is closer to zero, the cross-sectional shape of the steel pipe is closer to a perfect circle.

[0026] The plate material S provided with the edge bent portions is placed on the die 1 illustrated in FIG. 1. While the plate material S is intermittently conveyed at a predetermined feeding amount, bending is performed three or more times along the width direction of the plate material S through the procedure illustrated in FIG. 2 to form a preform S_1 having a U-shaped cross section as a whole.

[0027] FIG. 3 is a cross-sectional view of the preform S_1 having a U-shaped cross section. As illustrated in FIG. 3, when the width of the plate material S before edge bending is a plate width W , an unbent portion P not subjected to bending is provided at a part of the preform S_1 , in particular, such that a center of the unbent portion P is positioned at a $W/4$ portion that is a section $W/4$ away from each of the plate width ends. This unbent portion P can be provided by increasing the feeding amount of the plate material S and omitting the pressing by the punch 2. At a part of the preform S_1 , in particular, such that a center is positioned at the $W/4$ portion from each of the plate width ends, a lightly bent portion having a curvature smaller than other portions (with a slight curvature compared with other portions) may be provided instead of the unbent portion P . In this case, in the following description "unbent portion P " may read "lightly bent portion", if necessary. The lightly bent portion can be provided by applying a smaller amount of pressing by the punch 2 than on other portions.

[0028] The punch 2 illustrated in FIG. 1 and FIG. 2 has an I shape in which the width of the punch front end 2a in the plate material conveyance direction is equal to the width of the punch support 2b in the plate material conveyance direction. However, the shape of the punch 2 is not limited to this. For example, a punch 2 having an approximately inverse T shape may be used, in which the width of the punch front end 2a in the plate material conveyance direction is larger than the width of the punch support 2b in the plate material conveyance direction. If the width of the punch support 2b in the plate material conveyance direction is the same, the punch 2 having an approximately inverse T shape can press a larger area of the plate material S in a single press, compared with the punch 2 having an I shape, thereby reducing the number of times of pressing.

[0029] Once the plate material S is bent by press bending to form the preform S_1 having a U-shaped cross section, O-pressing is performed to press-bend the preform S_1 into an O shape using a press die that is a pair of dies including an upper die 4 and a lower die 5 as illustrated in FIG. 4, thereby forming an open pipe S_2 , which is a tubular body having a seam gap portion G between the plate width end portions opposed to each other in the circumferential direction.

[0030] The procedure for performing O-pressing on the preform S_1 to form the open pipe S_2 will now be described with reference to FIG. 4. First of all, as illustrated in FIG. 4(a), the preform S_1 is installed in the lower die 5 such that the upper die 4 and the U-shaped open side of the preform S_1 are opposed to each other (such that the U-shaped open side of the preform S_1 faces upward), and the preform S_1 is held between the upper die 4 and the lower die 5. In pressing of the preform S_1 , the bending center of the press die is aligned with the center in the width direction of the preform S_1 . The plate width end portions thus can be pressed evenly on the right and the left at the U-shaped open side of the preform S_1 .

[0031] As illustrated in FIG. 5, the surfaces of the upper die 4 and the lower die 5 that may be in contact with the preform S_1 have arc portions 4a and 5a, respectively, with a diameter equal or substantially equal to the outer diameter of the steel pipe to be formed and with a central angle θ . This range is pressed into a shape inscribed in the arc with a diameter equal or substantially equal to the outer diameter of the steel pipe. For example, the central angle θ of 360 degrees corresponds to a plate width of 100 [%] to be pressed into the inscribed shape. Hereinafter, the central angle θ of the arc portion 4a, 5a is referred to as a constraining range, and the value obtained by dividing this angle by 360 degrees is the range pressed into the shape inscribed in the arc with a diameter equal or substantially equal to the outer diameter of the steel pipe. The arc portion 4a has an arc center at a position coincident with the bending center O_{p4} of the upper die 4. The arc portion 5a has an arc center at a position coincident with the bending center O_{p5} of the lower die 5. The upper die 4 has linear portions 4b₁ and 4b₂ connected to respective both ends in the arc direction of the arc portion 4a. The lower die 5 has linear portions 5b₁ and 5b₂ connected to respective both ends in the arc direction of the arc portion 5a. In place of the linear portions 4b₁, 4b₂, 5b₁, and 5b₂, the upper die 4 and the lower die 5 may have small-curvature arc portions having a curvature smaller than that of the arc portions 4a and 5a. In the present invention, in view of enhancing the symmetry of the resultant steel pipe, it is preferable that the linear portions 4b₁, 4b₂, 5b₁, and 5b₂ or the small-curvature arc portions connected to the arc portions 4a and 5a are symmetric with respect to the bending centers O_{p4} and O_{p5} , that is, the centers of the arc portions 4a and 5a. It is preferable that pressing is performed using

a die having a radius of an arc portion within a range of ± 3.5 [%] relative to a radius corresponding to the outer radius of the steel pipe. The reason for this will be described later.

[0032] Subsequently, the preform S_1 held between the upper die 4 and the lower die 5 is pressed down by the upper die 4 and subjected to O-pressing as illustrated in FIG. 4(b). Here, the portions of the preform S_1 that are opposed to the arc portions 4a and 5a of the upper die 4 and the lower die 5 are constrained by the upper die 4 and the lower die 5, whereas the unbent portions P of the preform S_1 are not constrained by the upper die 4 and the lower die 5. Thus, the open pipe S_2 as illustrated in FIG. 4(c) can be formed with a pressing force smaller than the pressing force required when the entire circumference of the preform S_1 is constrained by the upper die 4 and the lower die 5.

[0033] In the method of manufacturing a steel pipe according to the present embodiment, using the press die including the upper die 4 and the lower die 5, the preform S_1 is pressed to form the open pipe S_2 into a shape such that a range of 20 [%] or more of the plate width W (equivalent to the central angle θ of 70 degrees or larger) of which center is positioned at the lowermost portion of the U-shaped cross section and a range of 10 [%] or more (equivalent to the central angle θ of 35 degrees or larger) of the plate width W from the plate width end are inscribed in the arc with a diameter equal or substantially equal to the outer diameter of the steel pipe.

[0034] In the present embodiment, in view of improving the resultant steel pipe shape, it is preferable that the range in which the open pipe S_2 is inscribed in the die is substantially the same on the upper die 4 side and the lower die 5 side. That is, when the range of 20 [%] or more of the plate width W of which center is positioned at the lowermost portion of the U-shaped cross section inscribed in the arc with a diameter equal or substantially equal to the outer diameter of the steel pipe is denoted by A, and the total range of 10 [%] or more of the plate width W from both plate width ends inscribed in the arc with a diameter equal or substantially equal to the outer diameter of the steel pipe is denoted by B, it is preferable that Expression (1) is satisfied:

$$2|A-B|/(A+B) < 0.4 \quad (1)$$

where $|A-B|$ is the absolute value of A-B.

[0035] The meaning of Expression (1) will be described in detail later.

[0036] In the method of manufacturing a steel pipe according to the present embodiment, in order to ensure that the open pipe S_2 is inscribed in the die in a predetermined range and to obtain a satisfactory shape, as illustrated in FIG. 5, it is preferable that, in the U-shaped cross section of the preform S_1 before pressing, the angles θ_{11} and θ_{12} between a tangent TL_1 at a W/2 portion that is a plate width center portion and tangents TL_{21} and TL_{22} at the W/4 portions is 35 degrees or larger and smaller than 90 degrees. Furthermore, it is preferable that, in the preform S_1 before pressing, the angles θ_{21} and θ_{22} between tangents TL_{31} and TL_{32} at the plate width end portions and tangents TL_{21} and TL_{22} at the W/4 portions is 35 degrees or larger and smaller than 90 degrees. In order to set the same inscribed range on the upper die 4 side and the lower die 5 side, it is preferable that the sum of the angles θ_{11} and θ_{12} between the tangent TL_1 and the tangents TL_{21} and TL_{22} is substantially equal to the sum of the angles θ_{21} and θ_{22} between the tangents TL_{31} and TL_{32} and the tangents TL_{21} and TL_{22} .

[0037] These angles need to be defined in consideration of a facility for bending into the U-shaped preform S_1 and the shape of a die for bending the U-shaped preform S_1 into the open pipe S_2 , for the following reasons. If these angles are too large, the distance between the plate width ends is small. If the distance is smaller than the width of the punch support 2b for bending into the U-shaped preform S_1 , it is impossible to obtain the U-shaped preform S_1 . On the other hand, if these angles are too small, the distance between the plate width ends of the U-shaped preform S_1 is large, so that when the U-shaped preform S_1 is placed on the die, the plate width ends are greater than the opening of the upper die 4 and the bending force is unable to be applied. In addition, the distance between the unbent portions P on the right and the left is excessively large to prevent proper placement in the lower die 5.

[0038] When the preform S_1 is placed on the lower die 5 that is the second die of a pair of dies such that the upper die 4 that is the first die of the pair is opposed to the U-shaped open side of the preform S_1 , and the preform S_1 is pressed while the preform S_1 is held between the upper die 4 and the lower die 5, the upper die 4 and the lower die 5 have the following pressing surfaces. That is, the lower die 5 has a pressing surface in such a manner that the pressing surface is not in contact with the preform S_1 , excluding the range of 20 [%] or more (equivalent to the central angle θ of 70 degrees or larger) of the plate width W of which center is positioned at the lowermost portion of the U-shaped cross section, in a state in which the preform S_1 is placed on the lower die 5, and that a part of the lower die 5 is not in contact with the open pipe S_2 in a state in which pressing is completed. The upper die 4 has a pressing surface in such a manner that the pressing surface is not in contact with the preform S_1 in a state in which the preform S_1 is placed on the lower die 5, and that a part of the upper die 4 is not in contact with the open pipe S_2 in a state in which pressing is completed.

[0039] In the present embodiment, it is preferable that, in pressing of the preform S_1 , the center of the press die for use in pressing of the preform S_1 matches the center in the width direction of the preform S_1 . This is because application of a symmetric force to the center in the width direction of the preform S_1 contributes to improvement in shape accuracy

of the resultant steel pipe.

[0040] In the present embodiment, it is preferable that the preform S_1 is held in a U-shaped posture with the U-shaped open side facing upward. This is because pressing in this posture facilitates the operation. Another reason is that if the U-shaped open side faces downward, the weight of the preform S_1 is exerted on the plate width end portions of the preform S_1 and may cause scratching at the plate width end portions or the die, and this should be avoided.

[0041] Here, in the present embodiment, when the open pipe S_2 is formed by performing O-pressing on the preform S_1 using the upper die 4 and the lower die 5, the pressing force is applied to a part $W/4$ away from the center of the unbent portion P toward the width end portion in the preform S_1 . The reason for this is as follows. When the entire preform S_1 is shaped into a circle, the bending moment is $M = F \cdot r \cdot \cos \phi$ (F : pressing force, r : radius of circle) at a position where the central angle is away from the pressed portion by an angle ϕ , and is largest at a position away from the pressed portion by 90 degrees, where the deformation is also largest. The pressing force is then applied to a position away from the center of the unbent portion P by 90 degrees, that is, by $1/4$ of the entire circumference, whereby the unbent portion P is effectively deformed. Here, the bending moment is largest at a position away from the position receiving the pressing force by 90 degrees and decreases as the distance from this position increases. Based on this, it is preferable to apply a pressing force to a section away from the center of the unbent portion P toward the plate width end portion by $W/4 \pm 0.07W$ in order to produce sufficient plastic deformation in the unbent portion P.

[0042] In the present embodiment, the center of the unbent portion P is provided at a section including the position away from the plate width end by $W/4$. The reason for this is as follows. Although it is preferable to apply a pressing force to a section away from the center of the unbent portion P toward the plate width end portion by $W/4$ as described above, the contact position between the upper die 4 and the preform S_1 changes, and the position receiving the pressing force also changes, because the shape of the preform S_1 changes in a stage of forming the preform S_1 into the open pipe S_2 . When the unbent portion P is provided at a section including the position away from the plate width end by $W/4$ in the preform S_1 , the portion receiving the pressing force is always the plate width end portion of the preform S_1 , so that the unbent portion P is most deformed. By doing so, it is possible to apply deformation to the unbent portion P in a single press, without changing the pressed position. Furthermore, it is preferable to provide the unbent portion P in a range of $W/4 \pm 0.07W$ from the position receiving the pressing force, that is, the plate width end of the preform S_1 .

[0043] Since the plate width end portions are in contact with the upper die 4 in the initial state of pressing as illustrated in FIG. 4(a) and FIG. 4(b), it is preferable that the unbent portion P is provided at a section including a section away from the plate width end of the preform S_1 by $W/4$.

[0044] FIG. 6 is a graph illustrating the relation between the open amount of the seam gap portion G of the open pipe S_2 and the constraining range, in conjunction with a press load. The relation between the open amount and the constraining range illustrated in FIG. 6 and the press load are those obtained when a steel pipe with a tensile strength of 630 [MPa], an outer diameter of 660.4 [mm], and a pipe thickness of 40.0 [mm] is formed by welding both edges of the open pipe S_2 and thereafter performing shape correction by pipe expanding at a pipe expanding ratio of 1 [%].

[0045] The preform S_1 after press bending is provided with an unbent portion P having a length of $W/12$ at a portion $W/4$ from each of the plate width ends on both sides. The angle θ_{11} , θ_{12} between the tangent at the plate width center portion and the $W/4$ portion that is a section away from the plate width end by $W/4$ is 75 degrees, and the angle θ_{21} , θ_{22} between the tangent at the plate width end portion and the tangent at the $W/4$ portion is 75 degrees. This preform S_1 is held between the upper die 4 and the lower die 5 having the same constraining range. The pressing amount is set such that the distance between the portions at $W/2$ of the open pipe S_2 is equal to the diameter before pipe expanding (the amount of pressing-down in O-pressing is set such that the longitudinal diameter agrees with the diameter before pipe expanding). As can be seen from FIG. 6, the larger the constraining range is, the smaller the open amount of the seam gap portion G of the open pipe S_2 is.

[0046] FIGS. 7(a) to 7(c) are diagrams schematically illustrating a deformation state when the open pipe S_2 is formed using the upper die 4 and the lower die 5 with a constraining range of 0 degrees. When the constraining range of the upper die 4 and the lower die 5 is 0 degrees, the arc portions 4a and 5a are arcs having a diameter 1.16 times as large as the steel pipe outer diameter such that the upper die 4 is in contact only with both edges of the preform S_1 and the lower die 5 is in contact only with the plate width center portion of the preform S_1 . As illustrated in FIG. 7(a), the diameter of the arc portion 5a of the lower die 5 is larger than the steel pipe diameter such that when the cross section of the preform S_1 is compared to a clock, the 6 o'clock portion alone is in contact with the lower die 5. Because of this, as illustrated in FIG. 7(b), the 6 o'clock portion of the preform S_1 and the vicinity thereof are bent back to conform to the arc portion 5a of the lower die 5 during O-pressing, and the radius of curvature becomes larger than the steel pipe diameter. As a result, after O-pressing, as illustrated in FIG. 7(c), the open amount of the seam gap portion G of the open pipe S_2 is large, in combination with the springback at the 3 o'clock portion and the 9 o'clock portion of the preform S_1 .

[0047] FIG. 8 is a graph illustrating the relation between the constraining range and the roundness of a steel pipe before pipe expanding when the seam gap portion G of the open pipe S_2 is closed by welding. As can be understood from FIG. 8, when the constraining range is 60 degrees, the roundness is worse than when the constraining range is 0 degrees. However, as the constraining range is increased, the roundness improves. When the constraining range is 70

degrees or larger, the roundness is better than when the constraining range is 0 degrees. It also can be understood that the roundness is most improved when the constraining range is 100 degrees to 110 degrees.

[0048] FIG. 9 is a graph illustrating the relation between the constraining range and the press load. As can be understood from FIG. 9, as the constraining range increases, the press load increases. Increasing the constraining range reduces the open amount of the seam gap portion G of the open pipe S₂, but the increased press load requires a larger size of press facility. It is therefore preferable to reduce the constraining range in a range in which a desired open amount is obtained. For example, the constraining range is set to 150 degrees or smaller in order to set the press load to 90 [%] or smaller of the press load required when the individual constraining ranges of the upper die 4 and the lower die 5 for constraining the entire circumference of the preform S₁ with the upper die 4 and the lower die 5 are 180 degrees.

[0049] FIG. 10 is a graph illustrating the result of the open amount of the seam gap portion G of the open pipe S₂ when the individual constraining ranges of the upper die 4 and the lower die 5 are changed. FIG. 11 is a graph illustrating the result of the roundness of the steel pipe before pipe expanding that is formed by closing the seam gap portion G of the open pipe S₂ by welding when the individual constraining ranges of the upper die 4 and the lower die 5 are changed. FIG. 12 is a graph illustrating the result of the press load when the individual constraining ranges of the upper die 4 and the lower die 5 are changed. In FIG. 10 to FIG. 12, the target steel pipe has a tensile strength of 630 [MPa], an outer diameter of 660.4 [mm], and a pipe thickness of 40.0 [mm], which are the same as those in FIG. 6, FIG. 8, and FIG. 9. The horizontal axis represents the average value of constraining ranges of the upper die 4 and the lower die 5, and different constraining ranges in the lower die 5 are represented by different symbols. In the figure, for example, "lower 60 degrees" means that the constraining range in the lower die 5 is 60 degrees.

[0050] As can be understood from FIG. 10, irrespective of the individual constraining ranges of the upper die 4 and the lower die 5, as the average value of constraining ranges of the upper die 4 and the lower die 5 increases, the open amount of the seam gap portion G of the open pipe S₂ decreases. As can be understood from FIG. 11, when the constraining range of one of the upper die 4 and the lower die 5 is smaller than 60 degrees, the roundness of the steel pipe is worse. Accordingly, although the individual constraining ranges of the upper die 4 and the lower die 5 may not necessarily be equal between the upper die 4 and the lower die 5, it is desirable that the constraining ranges of the upper die 4 and the lower die 5 both exceed 60 degrees in order to obtain a shape with satisfactory roundness of a steel pipe. It can also be understood from FIG. 12 that the larger the average value of constraining ranges of the upper die 4 and the lower die 5 is, the larger the press load is. Therefore, when the upper limit of permissible press load is set, the range of average value of applicable constraining ranges of the upper die 4 and the lower die 5 can be determined according to the upper limit value of press load.

[0051] In FIG. 11, when the difference between upper and lower constraining ranges is 30 degrees and the difference is 29 [%] of the average value of the upper and lower constraining ranges, namely, upper 90 degrees/lower 90 degrees, upper 90 degrees/lower 120 degrees, upper 120 degrees/lower 90 degrees, the roundness before pipe expanding after welding is as excellent as 1.5 [%] or less. On the other hand, when the difference between upper and lower constraining ranges is 30 degrees but the difference is as large as 40 [%] of the average value of the upper and lower constraining ranges, namely, upper 90 degrees/lower 60 degrees, the roundness before pipe expanding after welding is slightly poor, 2.0 [%]. In this way, reducing the difference between upper and lower constraining ranges can provide a satisfactory shape. That is, in the present invention, it is further preferable that the difference between upper and lower constraining ranges is set to less than 40 [%] of the average value of upper and lower constraining ranges, further preferably 30 [%] or less. It is preferable that the difference between upper and lower constraining ranges is less than 30 degrees. The relation of the difference between upper and lower constraining ranges and the average value of upper and lower constraining ranges can be said as follows. When the range of 20 [%] or more of the plate width W of which center is positioned at the lowermost portion of the U-shaped cross section inscribed in the arc with a diameter equal or substantially equal to the outer diameter of the steep pipe is denoted by A, and the total range of 10 [%] or more of the plate width W from both plate width ends inscribed in the arc with a diameter equal or substantially equal to the outer diameter of the steel pipe is denoted by B, it is preferable that Expression (1) is satisfied:

$$2|A-B|/(A+B) < 0.4 \quad (1)$$

where $|A-B|$ is the absolute value of A-B.

[0052] FIG. 13 is a graph illustrating the result of the open amount of the seam gap portion G when the constraining range of the upper die 4 and the constraining range of the lower die 5 are the same and the length L of the unbent portion P of the preform S₁ after press bending is changed. FIG. 14 is a graph illustrating the result of the roundness of the steel pipe before pipe expanding when the constraining range of the upper die 4 and the constraining range of the lower die 5 are the same and the length L of the unbent portion P of the preform S₁ after press bending is changed. FIG. 15 is a graph illustrating the result of the press load when the constraining range of the upper die 4 and the constraining range of the lower die 5 are the same and the length L of the unbent portion P of the preform S₁ after press bending is changed.

In FIG. 13 to FIG. 15, when the angle between the tangent at the plate width center portion and the tangent at the $W/4$ portion that is a section away from the plate width end by $W/4$ is θ_{11} , θ_{12} , and the angle between the tangent at the plate width end portion and the tangent at the $W/4$ portion is θ_{21} , θ_{22} , all of these angles are set to an equal value and changed in accordance with the width of the unbent portion P. The horizontal axis represents the average value of the constraining range of the upper die 4 and the constraining range of the lower die 5.

[0053] As can be understood from FIG. 13, irrespective of the length L of the unbent portion P of the preform S_1 and the angles of θ_{11} , θ_{12} , θ_{21} , and θ_{22} of the tangents, as the average value of the constraining range of the upper die 4 and the constraining range of the lower die 5 increases, the open amount of the seam gap portion G decreases. It is also understood that when the average value of the constraining range of the upper die 4 and the constraining range of the lower die 5 is the same, the longer the length L is and the smaller the angles θ_{11} , θ_{12} , θ_{21} , and θ_{22} of the tangents are, the smaller the open amount is. As can be understood from FIG. 14 and FIG. 15, when the average value of the constraining range of the upper die 4 and the constraining range of the lower die 5 is the same, there is no significant difference in roundness and press load of the steel pipe due to the length L of the unbent portion P of the preform S_1 and the angles θ_{11} , θ_{12} , θ_{21} , and θ_{22} of the tangents. In this way, when the average value of the constraining range of the upper die 4 and the constraining range of the lower die 5 is the same, the open amount of the seam gap portion G of the open pipe S_2 can be reduced by increasing the length L of the unbent portion P of the preform S_1 and reducing the angles θ_{11} , θ_{12} , θ_{21} , and θ_{22} of the tangents, without causing a difference in roundness or press load of the steel pipe due to the length L.

[0054] FIG. 16 is a graph illustrating the result of the open amount of the seam gap portion G of the open pipe S_2 when the arc portion radiuses of the upper die 4 and the lower die 5 are changed. FIG. 17 is a graph illustrating the result of the press load when the arc portion radiuses of the upper die 4 and the lower die 5 are changed. In FIG. 16 and FIG. 17, the central angles of the arc portions 4a and 5a of the upper die 4 and the lower die 5 are 45 degrees, and while the arc portion radiuses, which are the radiuses of the arc portions 4a and 5a, are changed, a steel pipe having a tensile strength of 630 MPa, an outer diameter of 660.4 [mm], and a pipe thickness of 40.0 [mm] is pressed down by O-pressing such that the longitudinal diameter agrees with the diameter before pipe expanding. In FIG. 16 and FIG. 17, the horizontal axis represents the ratio between the arc portion radius and the steel pipe outer radius (radius corresponding to the steel pipe outer diameter). When the arc portion radius is larger than the steel pipe outer radius, the ratio is greater than 1.0, and when the arc portion radius is smaller than the steel pipe outer radius, the ratio is smaller than 1.0.

[0055] As illustrated in FIG. 16, when the arc portion radius of the upper die 4 and the lower die 5 is equal to the steel pipe outer radius (the horizontal axis is 1.0 in FIG. 16), the open amount of the seam gap portion G is smallest. On the other hand, when the arc portion radius of the upper die 4 and the lower die 5 is larger than the steel pipe outer radius, bending-back deformation occurs at the 6 o'clock portion of the preform S_1 and the vicinity thereof as illustrated in FIG. 7, so that the open amount of the seam gap portion G increases as the arc portion radius of the upper die 4 and the lower die 5 increases. When the arc portion radius of the upper die 4 and the lower die 5 is smaller than the steel pipe outer radius, bending-back deformation occurs at portions where the arc portions 4a and 5a of the upper die 4 and the lower die 5 terminate, so that the open amount of the seam gap portion G increases as the arc portion radius decreases. In this way, although it is most preferable that the arc portion radius of the upper die 4 and the lower die 5 is equal to the steel pipe outer radius, the open amount of the seam gap portion G is kept to 40 [mm] or smaller when the arc portion radius of the upper die 4 and the lower die 5 is a radius equivalent to the steel pipe outer radius ± 3.5 [%].

[0056] However, as can be understood from FIG. 17, the press load increases as the arc portion radius decreases. In particular, when the arc portion radius is small, it is necessary to determine the radius considering the load of the press machine.

[Example 1]

[0057] A steel plate provided with a groove using an edge mirror and formed to have a plate width W of 1928 [mm] with a length of 1000 [mm], a plate thickness of 40 [mm], and a tensile strength of 635 [MPa] was subjected to edge bending, followed by press bending, to prepare a preform S_1 . Subsequently, O-pressing was performed on this preform S_1 with a press machine of 30 [MN] using the upper die 4 and the lower die 5 with various constraining ranges to form preforms A and B. Table 1 and Table 2 show the shapes of the preforms A and B. In Table 1 and Table 2, the initial alphabets A and B in the "No." column indicate the shapes of preforms (preforms A and B), and the numerals following the alphabets A, B, and C indicate a combination of the constraining ranges of the upper die 4 and the lower die 5.

[0058] Table 1 shows a preform A under Condition A in which an unbent portion was provided with a width of 160 [mm] ($W/12$) of which center is positioned at the $W/4$ portion from the plate width end, the angle θ_{21} , θ_{22} between the tangent at the plate width end portion and the tangent at the $W/4$ portion was 65 degrees, and the angle θ_{11} , θ_{12} between the tangent at the plate width center portion and the tangent at the $W/4$ portion was 73 degrees. Table 2 shows a preform B under Condition B in which an unbent portion was provided with a width of 321 [mm] ($W/6$) (the width twice that in Condition A) of which center is positioned at the $W/4$ portion from the plate width end, the angle θ_{21} , θ_{22} between the

tangent at the plate width end portion and the tangent at the W/4 portion was 59 degrees, and the angle θ_{11} , θ_{12} between the tangent at the plate width center portion and the tangent at the W/4 portion was 61 degrees. The preforms A and B are each symmetric with respect to a straight line connecting the center of the plate width end portion and the plate width 1/2, and Table 1 and Table 2 show the value of the portion at the plate width 1/2. The amount of pressing-down in O-

pressing was set such that the distance between the outer surface side of the W/2 portion and the outer surface side of the plate width end portion was 654 [mm].

[0059] After the open amount of the open pipe S_2 after O-pressing of the preforms A and B was measured, the seam gap portion G of the open pipe S_2 was welded to form a steel pipe having an outer diameter of 654 [mm]. Thereafter, the diameter of the steel pipe was measured at eight points at a pitch of 22.5 degrees in the circumferential direction, and the difference between the maximum diameter and the minimum diameter was obtained. Table 1 and Table 2 also show die shape (constraining range), press load, open amount, and roundness. Here, the roundness is a numeral obtained by dividing the difference between the maximum and the minimum by the steel pipe outer diameter (the average value of all the measured values of the diameter).

[0060] The welding machine used in this example failed to close the opening of the pipe having an open amount exceeding 40 [mm] after O-pressing. In this case, both ends and the center in the pipe axial direction were temporarily welded with the opening closed using another press machine, and thereafter the entire length of the seam gap portion G was normally welded. A roundness of 2.5 [%] before pipe expanding was considered acceptable. This is because if the roundness is equal to or lower than 2.5 [%] before pipe expanding, the roundness after pipe expanding is as satisfactory as 1.0 [%] or lower.

Table 1

No.	Shape of preform after press bending					Die shape			Result			Note
	Plate width [mm]		Angle of tangent [deg]		Constraining range [deg]			Press load [MN/m]	Open amount [mm]	Roundness [%]		
	Plate edge-side bent portion	Unbent portion	Plate width center-side bent portion	Plate edge-side bent portion	Upper die	Lower die	Upper and lower average					
A1						150	150	150	28	5	1.5	Example
A2						120	120	120	26	8	1.3	Example
A3						110	110	110	24	15	0.9	Example
A4						100	100	100	19	20	0.9	Example
A5						90	90	90	15	28	1.0	Example
A6						80	90	85	14	31	1.2	Example
A7						70	90	80	12	34	1.6	Example
A8	402	160	402	65	73	60	90	75	10	37	3.1	Comparative example
A9						80	80	80	12	35	1.5	Example
A10						70	70	70	9	38	2.4	Example
A11						90	60	75	10	36	3.0	Comparative example
A12						60	60	60	6	40	3.5	Comparative example
A13						0	90	45	6	45	3.3	Comparative example
A14						90	0	45	6	50	2.4	Comparative example
A15	60	0	30	5	52	*	Comparative example					
A16	0	0	0	5	60	*	Comparative example					

Table 2

No.	Shape of preform after press bending				Die shape			Result			Note		
	Plate width [mm]		Angle of tangent [deg]		Constraining range [deg]			Press load [MN/m]	Open amount [mm]	Roundness [%]			
	Plate edge-side bent portion	Unbent portion	Plate width center-side bent portion	Plate edge-side bent portion	Upper die	Lower die	Upper and lower average						
B1					61	59	150	150	150	28	1	1.5	Example
B2							120	120	120	26	4	1.4	Example
B3							110	110	110	24	11	1.0	Example
B4							100	100	100	19	16	0.9	Example
B5							90	90	90	15	24	0.9	Example
B6							80	90	85	14	27	1.1	Example
B7							70	90	80	12	30	1.6	Example
B8					61	59	60	90	75	10	33	3.0	Comparative example
B9							80	80	80	12	31	1.5	Example
B10							70	70	70	9	34	2.4	Example
B11							90	60	75	10	32	3.0	Comparative example
B12							60	60	60	6	36	3.5	Comparative example
B13							0	90	45	6	41	3.3	Comparative example
B14							90	0	45	6	46	2.4	Comparative example
B15							60	0	30	5	48	2.5	Comparative example
B16							0	0	0	5	56	*	Comparative example

[0061] In Nos. A1 to A7, A9, and A10 in Table 1 and Nos. B1 to B7, B9, and B10 in Table 2, which are in a range of examples of the present invention, the open amount is small, and the roundness is also satisfactory. In particular, the products with a constraining range of 90 degrees to 110 degrees have a roundness of 1.0 [%] or lower even without pipe expanding. The smaller the average value of constraining range is, the smaller the press load is.

[0062] By contrast, in Nos. A8 and A11 in Table 1 and Nos. B8 and B11 in Table 2, in which the constraining ranges of the upper die 4 and the lower die 5 are a combination of 60 degrees and 90 degrees, the open amount is small, but the roundness is bad. In Nos. A12 to A16 in Table 1 and Nos. B12 to B16 in Table 2, in which the average value of constraining ranges is 60 degrees or smaller, the open amount is large. In particular, in Nos. A15 and A16 in Table 1 and No. B16 in Table 2, it was impossible to measure the roundness, because the welded portion was broken after the seam gap portion G was welded.

[0063] In a product formed using the preform B having an unbent portion wider than that of the preform A, compared with a product formed using the preform A, the press load and the roundness are almost the same, but the open amount is small.

[0064] Although embodiments to which the present invention is applied have been described above, the present invention is not intended to be limited by the description and the drawings that are a part of the disclosure of the present invention according to the embodiments. In other words, all of other embodiments, examples, operating techniques, and the like carried out by those skilled in the art based on the embodiments are embraced in the scope of the present invention.

[Example 2]

[0065] A steel plate provided with a groove using an edge mirror and formed to have a width of 1639 [mm] with a length of 1000 [mm], a plate thickness of 31.8 [mm], and a tensile strength of 779 [MPa] was subjected to edge bending, followed by press bending, to prepare a preform S_1 . Subsequently, O-pressing was performed on this preform S_1 , using the upper die 4 and the lower die 5 with various constraining ranges with a press machine of 30 [MN] to form preforms A and B. Table 3 and Table 4 show the shapes of the preforms A and B. In Table 3 and Table 4, the initial alphabets A and B in the "No." column indicate the shapes of preforms (preforms A and B) and the numerals following the alphabets A and B each indicate a combination of the constraining ranges of the upper die 4 and the lower die 5.

[0066] Table 3 shows a preform A under Condition A in which an unbent portion was provided with a width of 137 [mm] ($W/12$) of which center is positioned at the $W/4$ portion from the plate width end, the angle θ_{21} , θ_{22} between the tangent at the plate width end portion and the tangent at the $W/4$ portion was 65 degrees, and the angle θ_{11} , θ_{12} between the tangent at the plate width center portion and the tangent at the $W/4$ portion was 72 degrees. Table 4 shows a preform B under Condition B in which an unbent portion was provided with a width of 273 [mm] ($W/6$) (the width twice that in Condition A) of which center is positioned at $W/4$ from the plate width end, the angle θ_{21} , θ_{22} between the tangent at the plate width end portion and the tangent at the $W/4$ portion was 59 degrees, and the angle θ_{11} , θ_{12} between the tangent at the plate width center and the tangent at the $W/4$ portion was 61 degrees. The preforms A and B are each symmetric with respect to a straight line connecting the center of the plate width end portion and the plate width $1/2$. Table 3 and Table 4 show the values of the portion at the plate width $1/2$. The amount of pressing-down in O-pressing was set such that the distance between the outer surface side of the $W/2$ portion and the outer surface side of the plate width end portion was 553 [mm].

[0067] Then, after the open amount of the open pipe S_2 after O-pressing of the preforms A and B was measured, the seam gap portion G of the open pipe S_2 was welded to form a steel pipe having an outer diameter of 553 [mm]. Thereafter, the diameter of the steel pipe was measured at eight points at a pitch of 22.5 degrees in the circumferential direction, and the difference between the maximum diameter and the minimum diameter was obtained. Table 3 and Table 4 also show die shape (constraining range), press load, open amount, and roundness. Here, the roundness is a numeral obtained by dividing the difference between the maximum and the minimum by the steel pipe outer diameter.

[0068] The welding machine used in this example failed to close the opening of the pipe having an open amount exceeding 40 [mm] after O-pressing. In this case, both ends and the center in the pipe axial direction were temporarily welded with the opening closed using another press machine, and thereafter the entire length of the seam gap portion G was normally welded. The roundness of 2.5 [%] before pipe expanding, which becomes 1.0 [%] or lower through pipe expanding, was considered acceptable.

Table 3

No.	Shape of preform after press bending				Die shape			Result			Note	
	Plate width [mm]		Angle of tangent [deg]		Constraining range [deg]			Press load [MN/m]	Open amount [mm]	Roundness [%]		
	Plate edge-side bent portion	Unbent portion	Plate width center-side bent portion	Plate edge-side bent portion	Upper die	Lower die	Upper and lower average					
A1	341	137	341	65	72	150	150	150	27	3	1.5	Example
A2						120	120	120	26	6	1.3	Example
A3						110	110	110	23	13	0.9	Example
A4						100	100	100	20	19	0.9	Example
A5						90	90	90	14	25	1.0	Example
A6						80	90	85	13	28	1.2	Example
A7						70	90	80	11	32	1.6	Example
A8	341	137	341	65	72	60	90	75	10	35	3.1	Comparative example
A9						80	80	80	11	33	1.5	Example
A10						70	70	70	9	36	2.4	Example
A11						90	60	75	10	34	3.0	Comparative example
A12	341	137	341	65	72	60	60	60	6	38	3.5	Comparative example
A13						0	90	45	5	43	3.3	Comparative example
A14						90	0	45	5	50	2.4	Comparative example
A15	341	137	341	65	72	60	0	30	4	54	*	Comparative example
A16						0	0	0	4	60	*	Comparative example

Table 4

No.	Shape of preform after press bending				Die shape			Result			Note	
	Plate width [mm]		Angle of tangent [deg]		Constraining range [deg]			Press load [MN/m]	Open amount [mm]	Roundness [%]		
	Plate edge-side bent portion	Unbent portion	Plate width center-side bent portion	Plate edge-side bent portion	Upper die	Lower die	Upper and lower average					
B1	273	273	273	59	61	150	150	150	27	0	1.5	Example
B2						120	120	120	26	3	1.4	Example
B3						110	110	110	23	9	1.0	Example
B4						100	100	100	20	13	0.9	Example
B5						90	90	90	14	22	0.9	Example
B6						80	90	85	13	25	1.1	Example
B7						70	90	80	11	28	1.6	Example
B8	273	273	273	59	61	60	90	75	10	30	3.0	Comparative example
B9						80	80	80	11	29	1.5	Example
B10						70	70	70	9	32	2.4	Example
B11						90	60	75	10	30	3.0	Comparative example
B12	273	273	273	59	61	60	60	60	6	34	3.5	Comparative example
B13						0	90	45	5	40	3.3	Comparative example
B14						90	0	45	5	44	2.4	Comparative example
B15	273	273	273	59	61	60	0	30	4	46	2.5	Comparative example
B16						0	0	0	4	53	*	Comparative example

[0069] In Nos. A1 to A7, A9, and A10 in Table 3 and Nos. B1 to B7, B9, and B10 in Table 4, which are in a range of examples of the present invention, the open amount is small, and the roundness is also satisfactory. In particular, the products with a constraining range of 90 degrees to 110 degrees have a roundness of 1.0 [%] or lower even without pipe expanding. The smaller the average value of constraining ranges is, the smaller the press load is.

[0070] By contrast, in Nos. A8 and A11 in Table 3 and Nos. B8 and B11 in Table 4, in which the constraining ranges of the upper die 4 and the lower die 5 are a combination of 60 degrees and 90 degrees, the open amount is small, but the roundness is bad. In Nos. A12 to A16 in Table 3 and Nos. B12 to B16 in Table 4, in which the average value of constraining ranges is 60 degrees or smaller, the open amount is large. In particular, in Nos. A15 and A16 in Table 3 and No. B16 in Table 4, it was impossible to measure the roundness, because the welded portion was broken after the seam gap portion G was welded.

[0071] In a product formed using the preform B having an unbent portion wider than that of the preform A, compared with a product formed using the preform A, the press load and the roundness are almost the same, but the open amount is small.

[Example 3]

[0072] A steel plate provided with a groove using an edge mirror and formed to have a plate width of 2687 [mm] with a length of 1000 [mm], a plate thickness of 50.8 [mm], and a tensile strength of 779 [MPa] was subjected to edge bending, followed by press bending, to prepare a preform S_1 . Subsequently, O-pressing was performed on this preform S_1 using the upper die 4 and the lower die 5 with various constraining ranges with a press machine of 30 [MN] to form preforms A and B. Table 5 and Table 6 show the shapes of the preforms A and B. In Table 5 and Table 6, the initial alphabets A and B in the "No." column indicate the shapes of preforms (preforms A and B), and the numerals following the alphabets A and B indicate a combination of the constraining ranges of the upper die 4 and the lower die 5.

[0073] Table 5 shows a preform A under Condition A in which an unbent portion was provided with a width of 224 [mm] ($W/12$) of which center is positioned at the $W/4$ portion from the plate width end, the angle θ_{21} , θ_{22} between the tangent at the plate width end portion and the tangent at the $W/4$ portion was 73 degrees, and the angle θ_{11} , θ_{12} between the tangent at the plate width center portion and the tangent at the $W/4$ portion was 72 degrees. Table 6 shows a preform B under Condition B in which an unbent portion was provided with a width of 448 [mm] ($W/6$) (the width twice that in Condition A) of which center is positioned at $W/4$ from the plate width end, the angle θ_{21} , θ_{22} between the tangent at the plate width end portion and the $W/4$ portion was 58 degrees, and the angle θ_{11} , θ_{12} between the tangent at the plate width center portion and the tangent at the $W/4$ portion was 59 degrees. The preforms A and B are each symmetric with respect to a straight line connecting the center of the plate width end portion and the plate width $1/2$, and Table 5 and Table 6 show the value of the portion at the plate width $1/2$. The amount of pressing-down in O-pressing was set such that the distance between the outer surface side of the $W/2$ portion and the outer surface side of the plate width end portion was 905 [mm].

[0074] After the open amount of the open pipe S_2 after O-pressing of the preforms A and B was measured, the seam gap portion G of the open pipe S_2 was welded to form a steel pipe having an outer diameter of 905 [mm]. Thereafter, the diameter of the steel pipe was measured at eight points at a pitch of 22.5 degrees in the circumferential direction, and the difference between the maximum diameter and the minimum diameter was obtained. Table 5 and Table 6 also show die shape (constraining range), press load, open amount, and roundness. Here, the roundness is a numeral obtained by dividing the difference between the maximum and the minimum by the steel pipe outer diameter.

[0075] The welding machine used in this example failed to close the opening of the pipe having an open amount exceeding 40 [mm] after O-pressing. In this case, both ends and the center in the pipe axial direction were temporarily welded with the opening closed using another press machine, and thereafter the entire length of the seam gap portion G was normally welded. The roundness of 2.5 [%] before pipe expanding, which becomes 1.0 [%] or lower through pipe expanding, was considered acceptable.

Table 5

No.	Shape of preform after press bending				Die shape			Result			Note	
	Plate width [mm]		Angle of tangent [deg]		Constraining range [deg]			Press load [MN/m]	Open amount [mm]	Roundness [%]		
	Plate edge-side bent portion	Unbent portion	Plate width center-side bent portion	Plate edge-side bent portion	Upper die	Lower die	Upper and lower average					
A1	560	224	560	73	72	150	150	150	29	7	1.4	Example
A2						120	120	120	27	10	1.3	Example
A3						110	110	110	25	17	1.0	Example
A4						100	100	100	20	21	1.0	Example
A5						90	90	90	26	29	0.9	Example
A6						80	90	85	14	33	1.0	Example
A7						70	90	80	12	35	1.4	Example
A8	560	224	560	73	72	60	90	75	10	39	3.2	Comparative example
A9						80	80	80	12	36	1.4	Example
A10						70	70	70	10	39	2.3	Example
A11						90	60	75	11	36	3.1	Comparative example
A12						60	60	60	6	40	3.4	Comparative example
A13						0	90	45	6	45	3.3	Comparative example
A14						90	0	45	6	50	2.4	Comparative example
A15	560	224	560	73	72	60	0	30	5	52	*	Comparative example
A16						0	0	0	5	60	*	Comparative example

Table 6

No.	Shape of preform after press bending				Die shape			Result			Note	
	Plate width [mm]		Angle of tangent [deg]		Constraining range [deg]			Press load [MN/m]	Open amount [mm]	Roundness [%]		
	Plate edge-side bent portion	Unbent portion	Plate width center-side bent portion	Plate edge-side bent portion	Upper die	Lower die	Upper and lower average					
B1	448	448	448	58	59	150	150	150	29	3	1.5	Example
B2						120	120	120	27	6	1.4	Example
B3						110	110	110	25	13	1.0	Example
B4						100	100	100	20	17	0.9	Example
B5						90	90	90	26	24	1.0	Example
B6						80	90	85	14	27	1.1	Example
B7						70	90	80	12	31	1.5	Example
B8	448	448	448	58	59	60	90	75	10	35	3.0	Comparative example
B9						80	80	80	12	32	1.4	Example
B10						70	70	70	10	35	2.4	Example
B11						90	60	75	11	32	3.0	Comparative example
B12						60	60	60	6	36	3.5	Comparative example
B13						0	90	45	6	41	3.3	Comparative example
B14						90	0	45	6	46	2.4	Comparative example
B15	448	448	448	58	59	60	0	30	5	48	2.5	Comparative example
B16						0	0	0	5	56	*	Comparative example

[0076] In Nos. A1 to A7, A9, and A10 in Table 5 and Nos. B1 to B7, B9, and B10 in Table 6, which are in a range of examples of the present invention, the open amount is small, and the roundness is also satisfactory. In particular, the products with a constraining range of 90 degrees to 110 degrees have a roundness of 1.0 [%] or lower even without pipe expanding. The smaller the average value of the constraining range is, the smaller the press load is.

[0077] By contrast, in Nos. A8 and A11 in Table 5 and Nos. B8 and B11 in Table 6, in which the constraining ranges of the upper die 4 and the lower die 5 are a combination of 60 degrees and 90 degrees, the open amount is small, but the roundness is bad. In Nos. A12 to A16 in Table 5 and Nos. B12 to B16 in Table 6, in which the average value of constraining ranges is 60 degrees or smaller, the open amount is large. In particular, in Nos. A15 and A16 in Table 5 and No. B16 in Table 6, it was impossible to measure the roundness, because the welded portion was broken after the seam gap portion G was welded.

[0078] In a product formed using the preform B having an unbent portion wider than that of the preform A, compared with a product formed using the preform A, the press load and the roundness are almost the same, but the open amount is small.

[Example 4]

[0079] To produce a steel pipe with a target outer diameter of 621 [mm] to 687 [mm], a steel plate provided with a groove using an edge mirror and formed to have a plate width of 1826 to 2032 [mm] with a length of 1000 [mm], a plate thickness of 40 [mm], and a tensile strength of 635 [MPa] was subjected to edge bending, followed by press bending, to prepare a preform S_1 . Subsequently, O-pressing was performed on this preform S_1 using a variety of the upper dies 4 and the lower dies 5 with an arc portion radius of 327 mm and a constraining range of 45 degrees, with a press machine of 30 [MN] to form preforms D1 to D11. Table 7 shows the bending conditions of the preforms D1 to D11. In the preforms D1 to D11, an unbent portion was provided with a width of $W/12$ of which center is positioned at the $W/4$ portion from the plate width end, in accordance with the initial plate width W , the angle θ_{21} , θ_{22} between the tangent at the plate width end portion and the tangent at the $W/4$ portion was 75 degrees, and the angle θ_{11} , θ_{12} between the tangent at the plate width center portion and the tangent at the $W/4$ portion was 75 degrees. In O-pressing, the pressing-down was performed such that the distance between the outer surface side of the $W/2$ portion and the outer surface side of the plate width end attained a value corresponding to the initial plate width W as shown in Table 7. Table 7 also shows the outer diameter of the steel pipe after pressing down with O-press.

[0080] The open amount of the open pipe S_2 after O-pressing of the preforms D1 to D11 was measured. Table 7 also shows the press load and the open amount as the results.

[Table 7]

[0081]

Table 7

No.	Target outer diameter [mm]	Plate width [mm]	Shape of preform after press bending					Die shape		Outer diameter [mm] after pressing down by O-press	Result	
			Plate width [mm]			Angle of tangent [deg]		Arc portion radius [mm]	Arc portion radius/steel pipe outer radius		Press load [MN/m]	Open amount [mm]
			Plate edge-side bent portion	Unbent portion	Plate width center-side bent portion	Plate edge-side bent portion	Plate width center-side bent portion					
D1	621	1826	380	152	380	75	75	0.95	621	17	51	
D2	628	1847	385	154	385			0.96	628	16	40	
D3	634	1867	389	156	389			0.97	634	16	35	
D4	641	1888	393	157	393			0.98	641	15	31	
D5	647	1908	398	159	398			0.99	647	15	28	
D6	654	1929	402	161	402			1.00	654	15	25	
D7	661	1949	406	162	406			1.01	661	15	27	
D8	667	1970	410	164	410			1.02	667	14	30	
D9	674	1991	415	166	415			1.03	674	14	35	
D10	680	2011	419	168	419			1.04	680	13	40	
D11	687	2032	423	169	423			1.05	687	12	53	

[0082] In No. D6 in Table 7 in which the ratio between the arc portion radius and the outer radius of the steel pipe is 1.00, the open amount is smallest, and as the steel pipe outer radius decreases or increases, the open amount increases. The open amount of 40 [mm] or smaller, which can be closed by the welding machine used in Example 1, was achieved in Nos. D2 to D10 in Table 7, and the ratio between the arc portion radius and the outer radius of the steel pipe is 0.96 to 1.04. The open amount of 50 [mm], which did not cause breakage of the welded portion in Example 1, was achieved also in Nos. D2 to D10 in Table 7, and the ratio between the arc portion radius and the outer radius of the steel pipe is 0.96 to 1.04.

[0083] Although the open amount that can be closed by welding the seam gap portion G and the open amount that does not cause breakage of the welded portion vary depending on the welding facility and the welding method, the guideline of the arc portion radii of the upper die 4 and the lower die 5 is 0.96 to 1.04 of the steel pipe outer radius.

[0084] According to the present invention, a method of manufacturing a steel pipe for efficiently forming a steel pipe with high roundness and a press die can be provided. Reference Signs List

[0085]

- 1 die
- 1a rod-shaped member
- 1b rod-shaped member
- 2 punch
- 2a punch front end
- 2b punch support
- 3 conveyance roller
- 4 upper die
- 4a arc portion
- 4b₁ linear portion or small-curvature arc portion
- 4b₂ linear portion or small-curvature arc portion
- 5 lower die
- 5a arc portion
- 5b₁ linear portion or small-curvature arc portion
- 5b₂ linear portion or small-curvature arc portion

Claims

1. A method of manufacturing a steel pipe, the method comprising:

performing bending three or more times on a plate material along a width direction, the plate material being subjected to edge bending at both ends in the width direction, to form a preform having a U-shaped cross section; pressing the preform to form an open pipe, the open pipe being a tubular body having a seam gap portion in a longitudinal direction; and joining the seam gap portion to form a steel pipe, wherein when a width of the plate material before the edge bending is a plate width W,

the preform has a lightly bent portion or an unbent portion of which center is positioned at a point away from a plate width end by W/4, the lightly bent portion having a small curvature compared with other regions, the unbent portion being not subjected to bending, and the pressing is performed to form the open pipe into a shape such that a range of 20 [%] or more of the plate width W of which center is positioned at a lowermost portion of the U-shaped cross section and a range of 10 [%] or more of the plate width W from the plate width end are inscribed in an arc with a diameter equal or substantially equal to an outer diameter of the steel pipe.

2. The method of manufacturing a steel pipe according to claim 1, wherein where A denotes the range of 20 [%] or more of the plate width W of which center is positioned at the lowermost portion of the U-shaped cross section inscribed in an arc with a diameter equal or substantially equal to an outer diameter of the steel pipe, and B denotes a total range of 10 [%] or more of the plate width W from both plate width ends inscribed in an arc with a diameter equal or substantially equal to an outer diameter of the steel pipe, Expression (1) is satisfied,

$$2 |A-B| / (A+B) < 0.4 \quad (1)$$

where $|A-B|$ is an absolute value of A-B.

3. The method of manufacturing a steel pipe according to claim 1 or 2, wherein
when the preform is placed on a second die of a pair of dies such that a first die of the pair of dies is opposed to a
U-shaped open side of the preform, and the preform is pressed while the preform is held between the pair of dies,
the second die includes a pressing surface in such a manner that:

in a state in which the preform is placed on the second die, the pressing surface is not in contact with the preform,
excluding a range formed into a shape inscribed in an arc with a diameter equal or substantially equal to an
outer diameter of the steel plate, with respect to the lowermost portion of the U-shaped cross section; and
in a state in which pressing is completed, a part of the second die is not in contact with the open pipe, and

the first die includes a pressing surface in such a manner that:

in a state in which the preform is placed on the second die, the pressing surface is not in contact with the preform;
and
in a state in which pressing is completed, a part of the first die is not in contact with the open pipe.

4. The method of manufacturing a steel pipe according to any one of claims 1 to 3, wherein pressing is performed
using a die having a radius of an arc portion within a range of ± 3.5 [%] with respect to a radius corresponding to
an outer radius of the steel plate.

5. The method of manufacturing a steel pipe according to any one of claims 1 to 4, wherein, in pressing of the preform,
a center of a press die for use in pressing of the preform matches a center in a width direction of the preform.

6. The method of manufacturing a steel pipe according to any one of claims 1 to 5, wherein the preform is held in a
U-shaped posture with a U-shaped open side facing upward.

7. A press die for use in the method of manufacturing a steel pipe according to any one of claims 1 to 6, the press die
comprising:

a pair of dies which are a pair of pressing bodies for holding the preform; and
an arc portion formed in a surface of each die in contact with the preform such that an arc center is located at
a position coincident with a pressing center of the die, the arc portion having a radius within a range of ± 3.5
[%] with respect to a radius corresponding to an outer radius of the steel pipe, wherein
the arc portion in each die has a central angle of 70 degrees or larger, and a total angle of the central angles
of the arc portions of both dies is smaller than 360 degrees.

8. The press die according to claim 7, wherein the central angles of the arc portions of both dies are equal to each other.

9. The press die according to claim 7 or 8, wherein each die includes linear portions or small-curvature arc portions
having a curvature smaller than the arc portion, the linear portions or the small-curvature arc portions being connected
to both ends of the arc portion in an arc direction.

10. The method of manufacturing a steel pipe according to any one of claims 1 to 6, wherein the press die according
to any one of claims 7 to 9 is used.

FIG.1

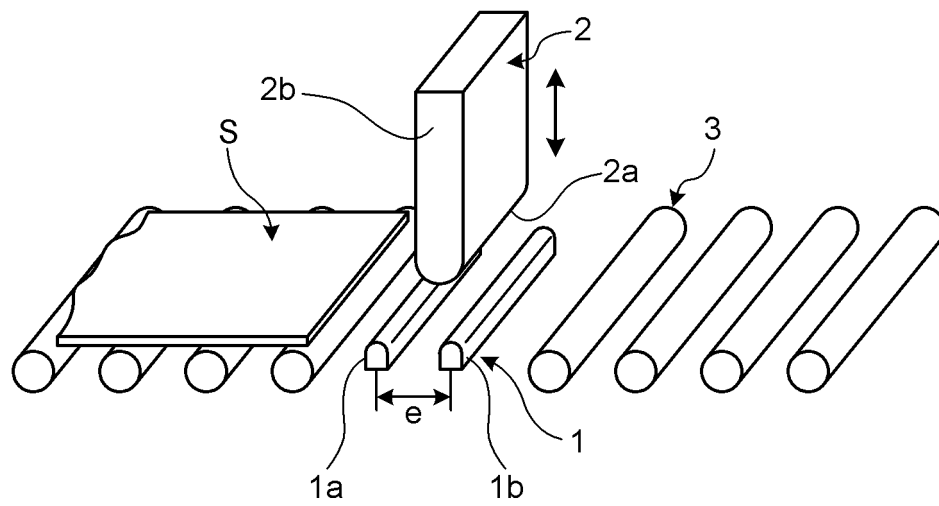


FIG.2

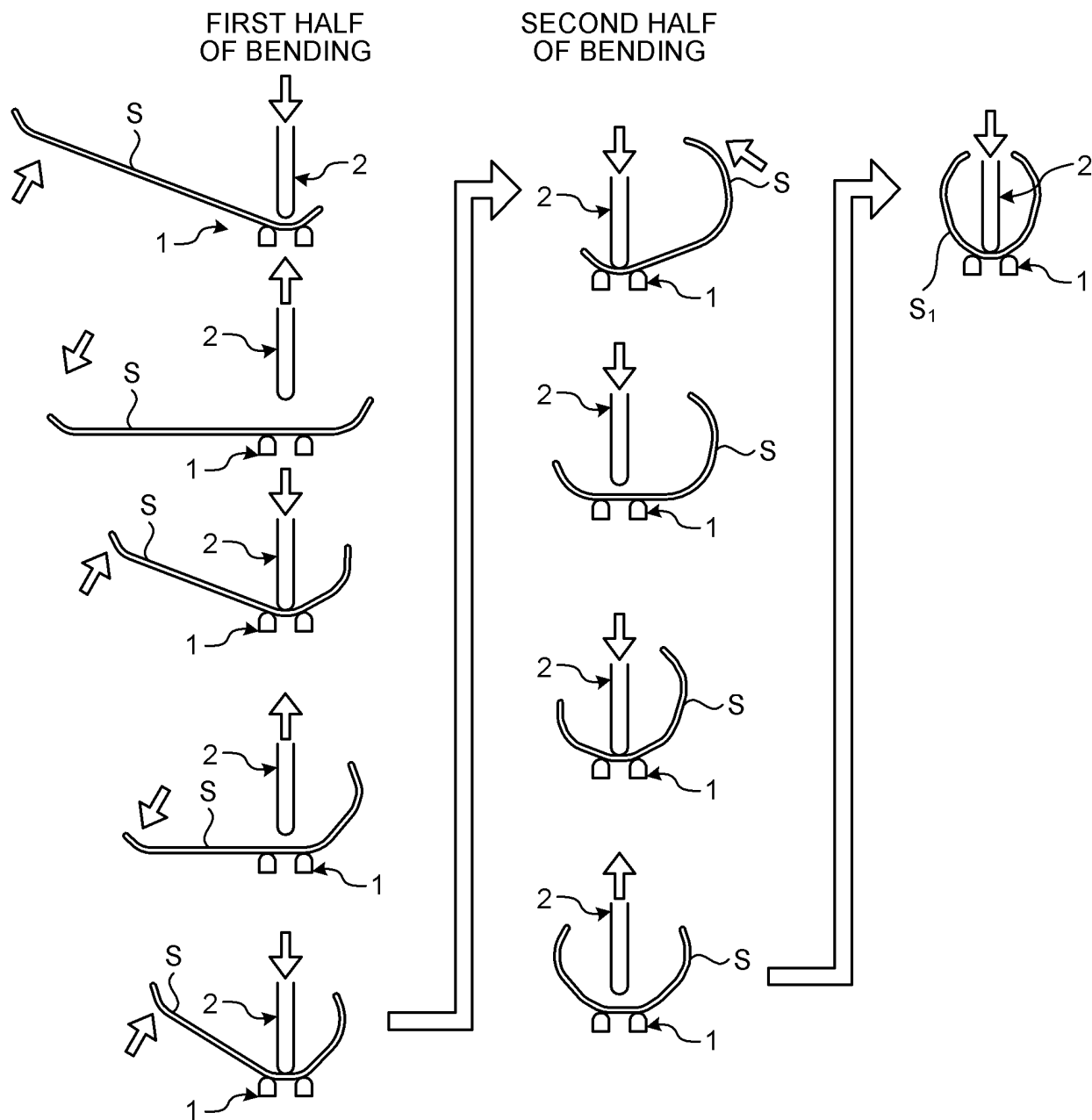


FIG.3

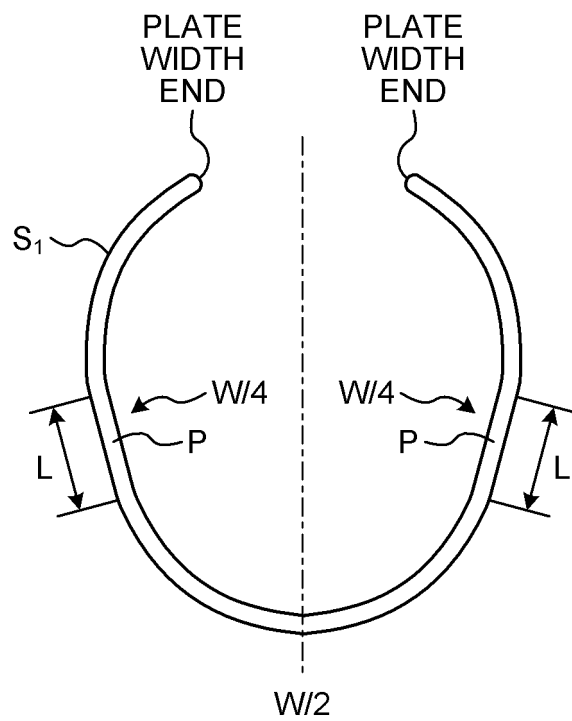


FIG.4

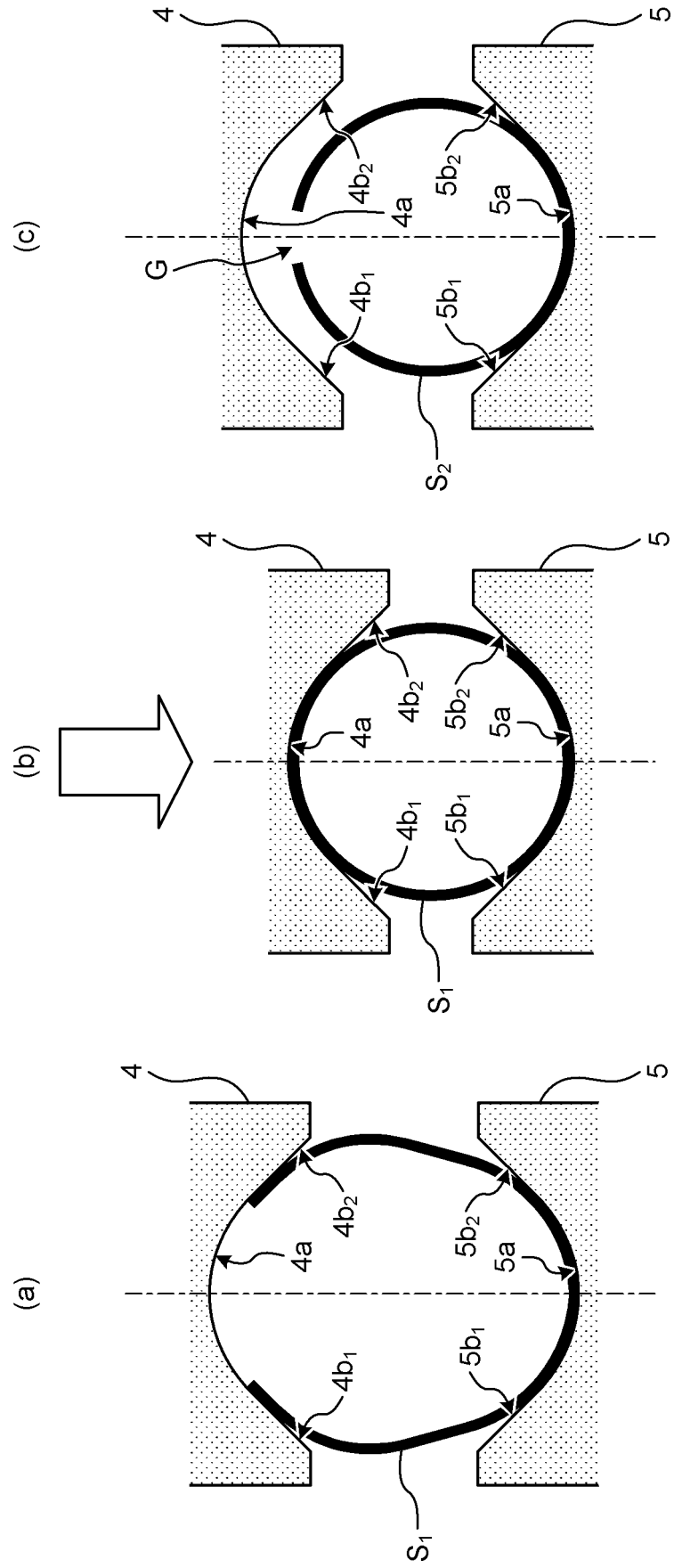


FIG.5

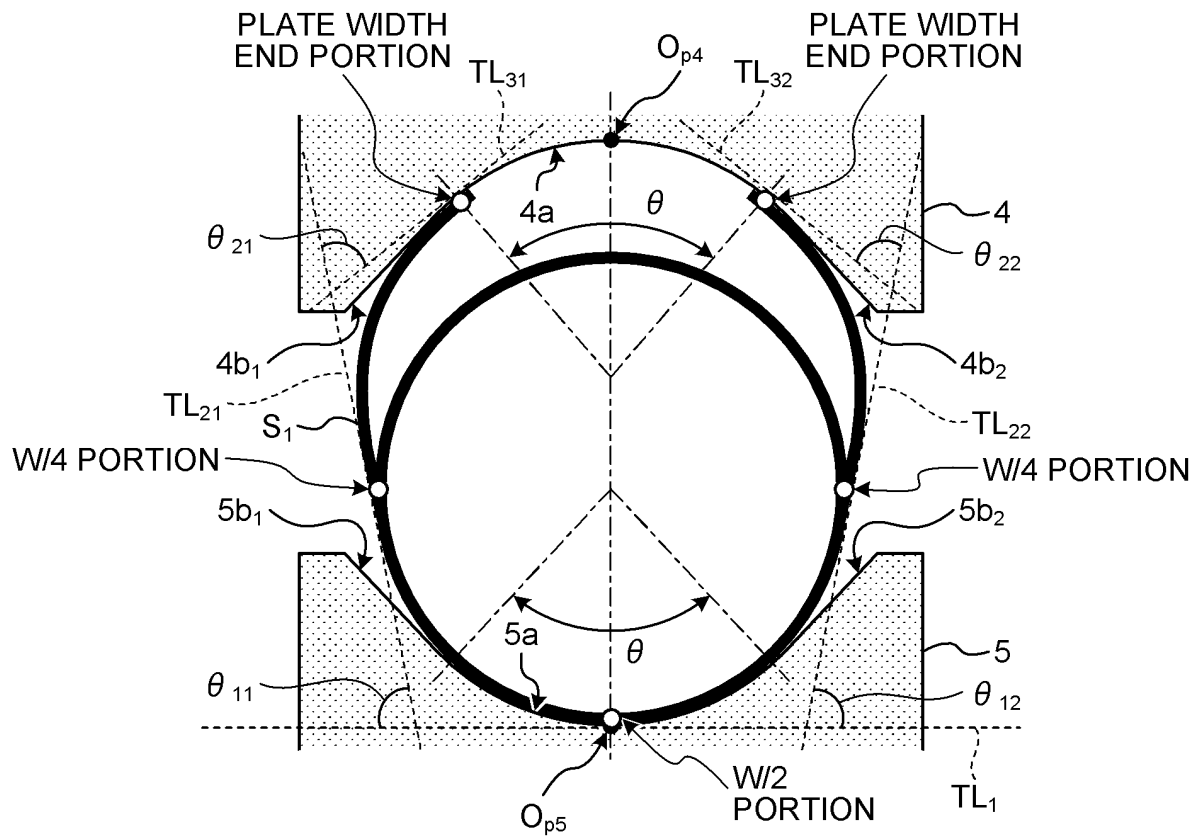


FIG.6

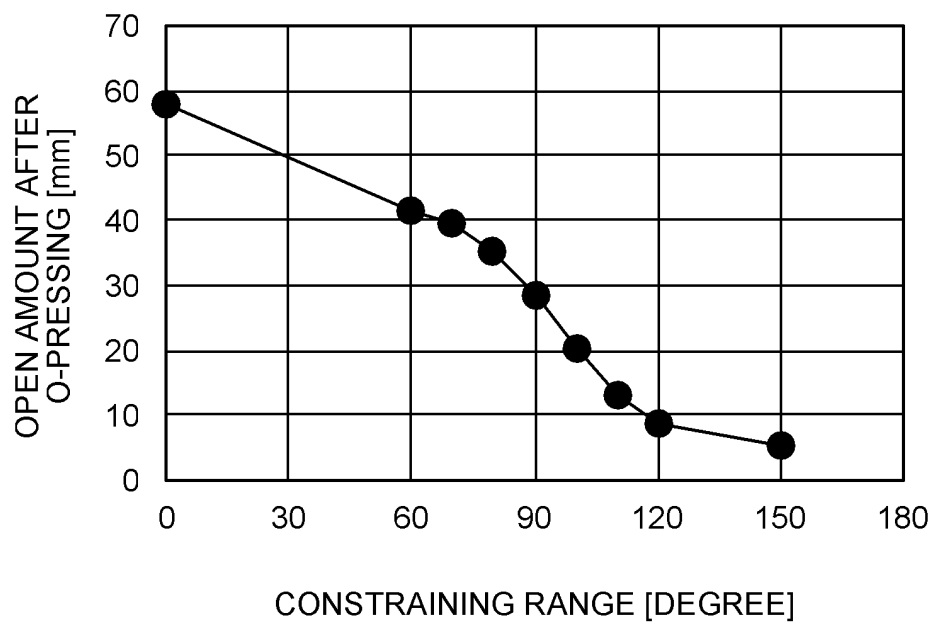


FIG.7

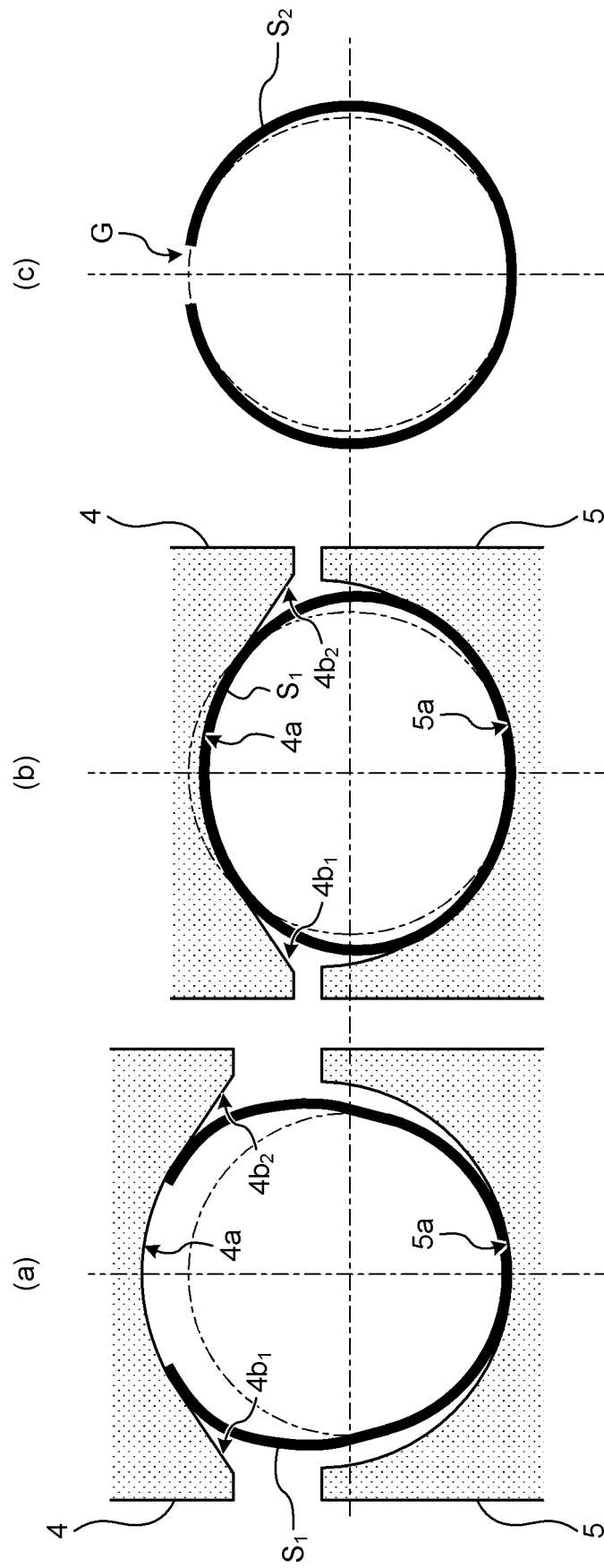


FIG.8

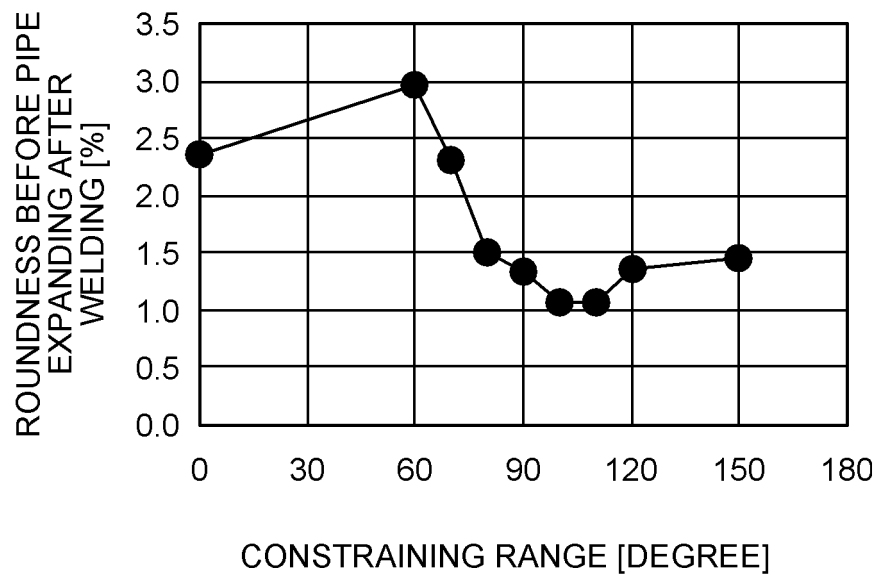


FIG.9

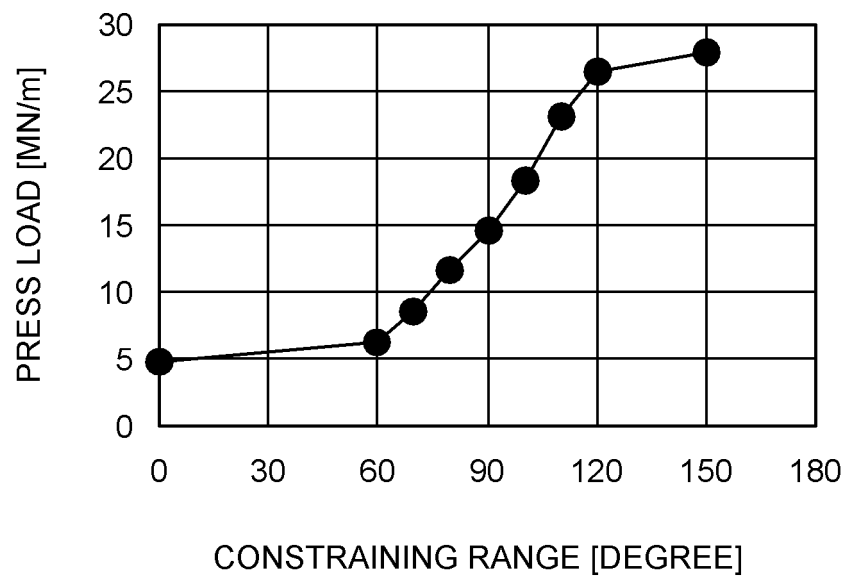


FIG.10

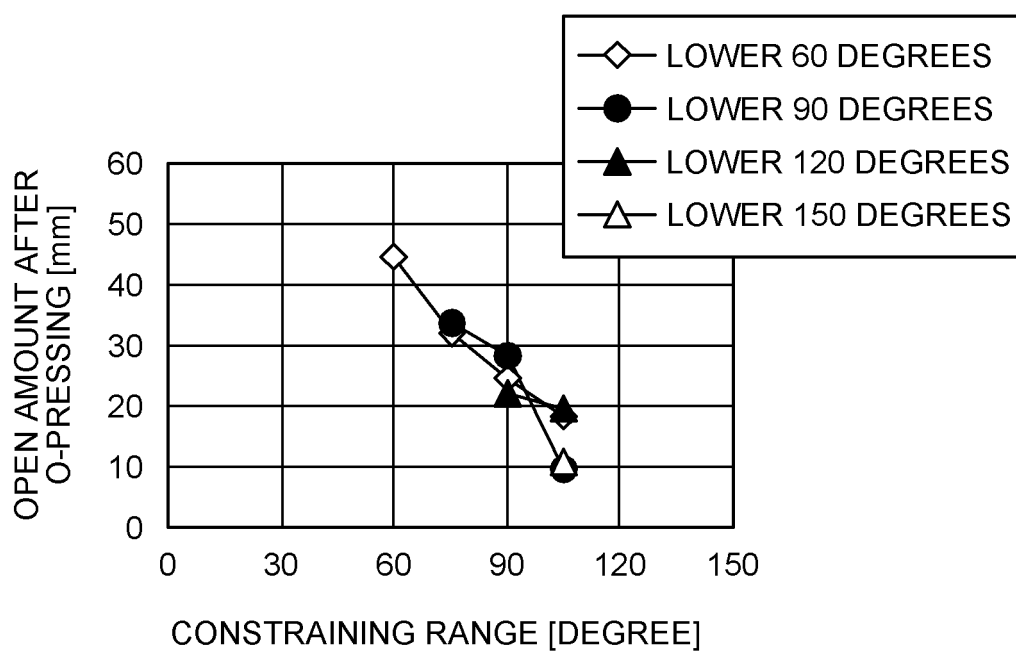


FIG.11

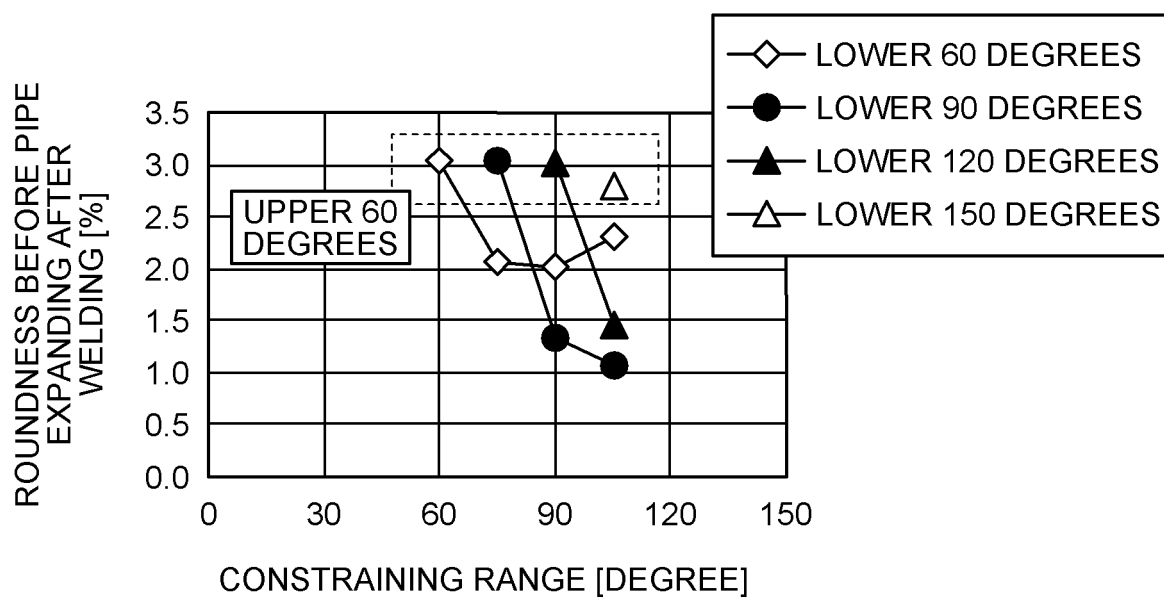


FIG.12

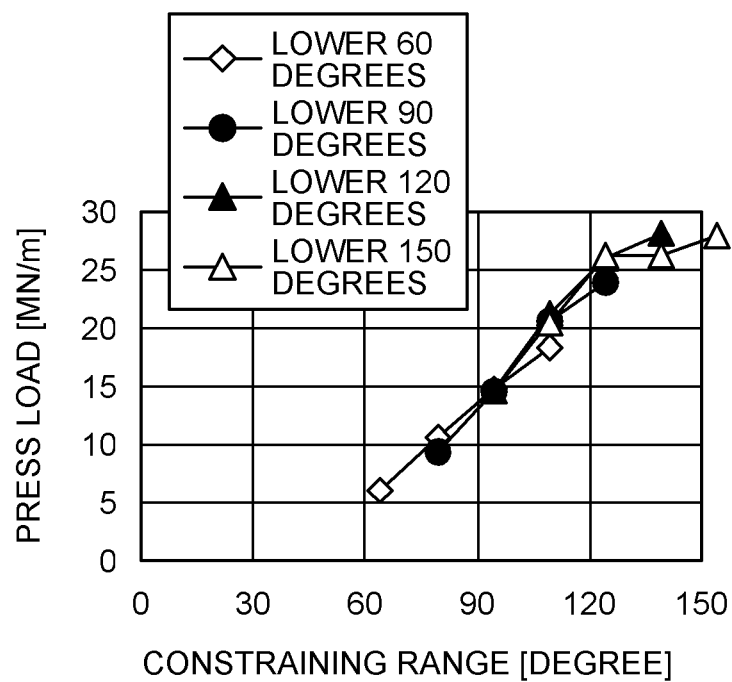


FIG.13

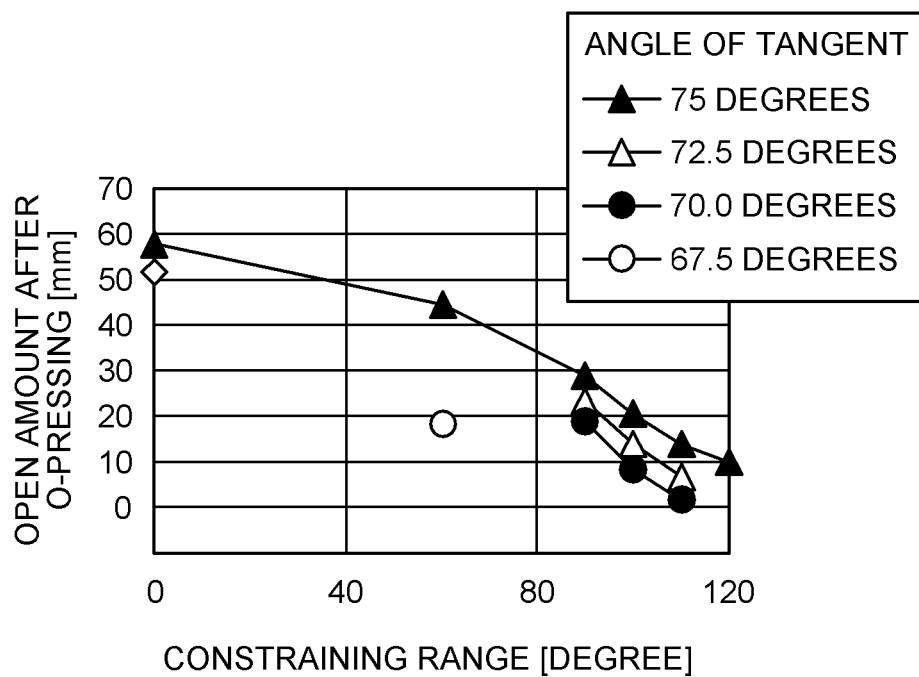


FIG.14

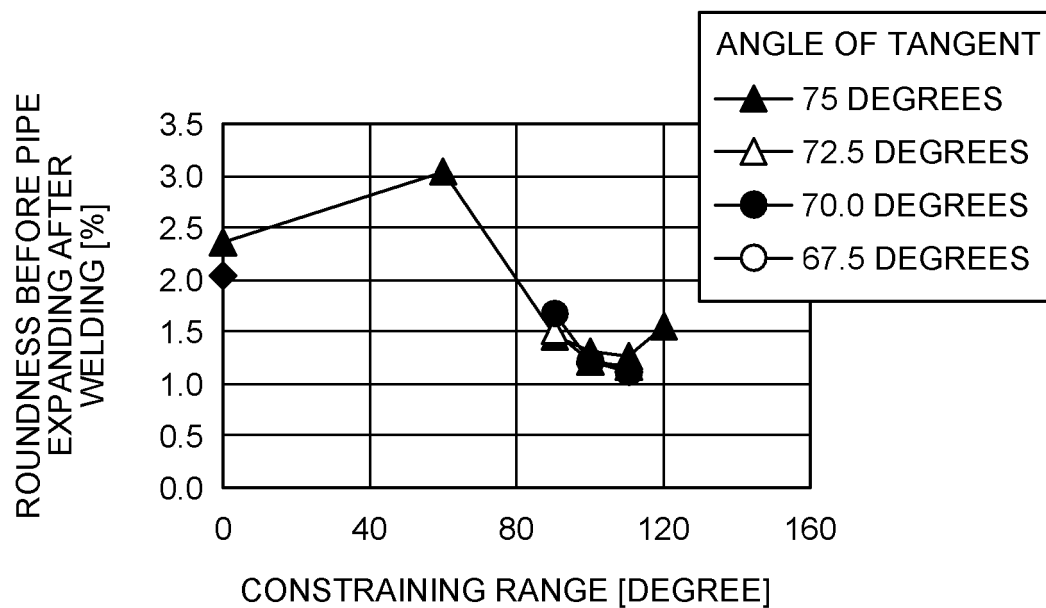


FIG.15

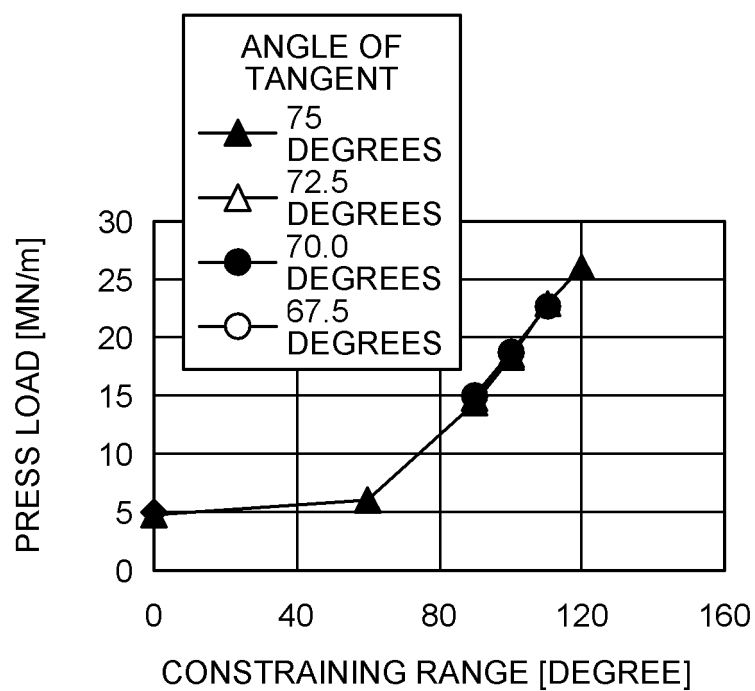


FIG.16

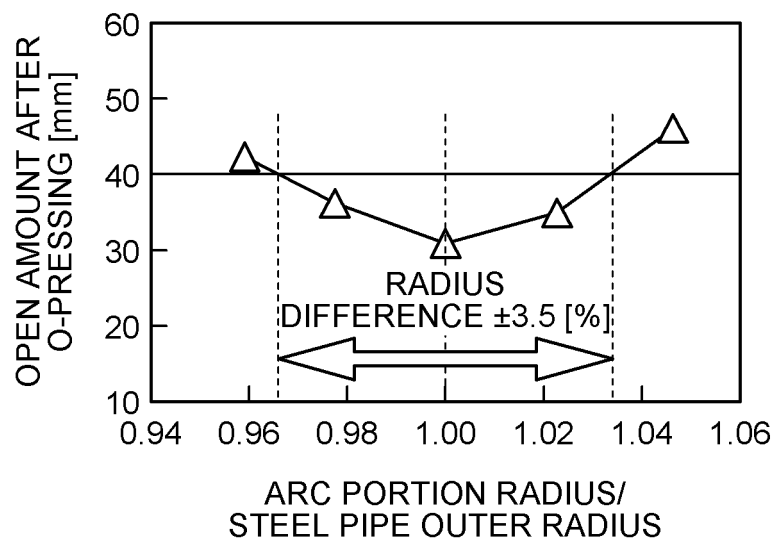
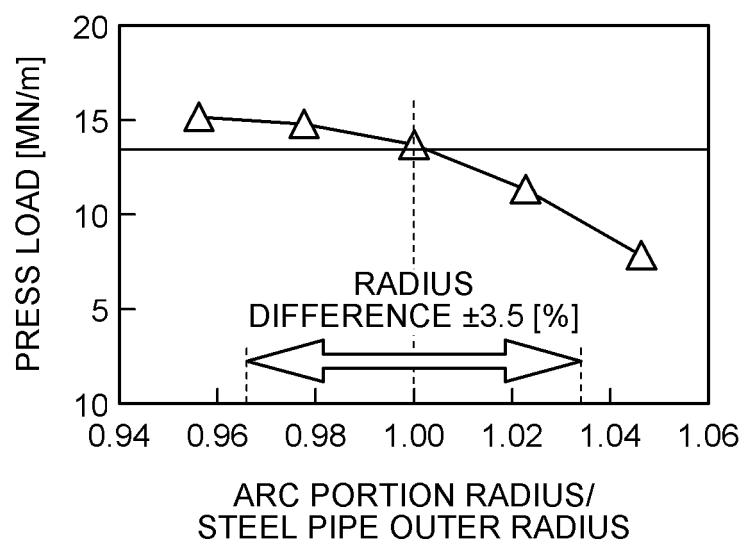


FIG.17



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/034145

A. CLASSIFICATION OF SUBJECT MATTER

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

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 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	WO 2016/084607 A1 (JFE STEEL CORP.) 02 June 2016, paragraphs [0030]-[0121], fig. 1-15 & EP 3225321 A1, paragraphs [0031]-[0118], fig. 1-15 & CA 2967914 A1 & KR 10-2017-0070155 A & CN 107000012 A & BR 112017010436 A2 & RU 2663674 C1	1-3, 5-6 4, 7-10
A	JP 2012-250285 A (SMS MEER GMBH) 20 December 2012, entire text, all drawings & EP 2529849 A2, entire text, all drawings & CN 102806245 A & RU 2012122452 A	1-10
A	JP 11-285729 A (SUMITOMO METAL INDUSTRIES, LTD.) 19 October 1999, entire text, all drawings (Family: none)	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"I"

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

07.12.2018

Date of mailing of the international search report

18.12.2018

Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/034145

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E, X	WO 2018/168563 A1 (JFE STEEL CORP.) 20 September 2018, paragraphs [0007]-[0081], fig. 1-17 (Family: none)	1-10

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

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2004082219 A [0007]
- JP 2011056524 A [0007]
- WO 2014188468 A [0007]
- WO 2014192043 A [0007]
- JP 2005324255 A [0007]
- JP 2005021907 A [0007]
- JP 2012250285 A [0007]
- US 4149399 A [0007]
- WO 2016084607 A [0007]
- JP 2003039115 A [0007]
- JP 2002178026 A [0007]