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(54) DIE FOR BENDING-PRESS FORMING

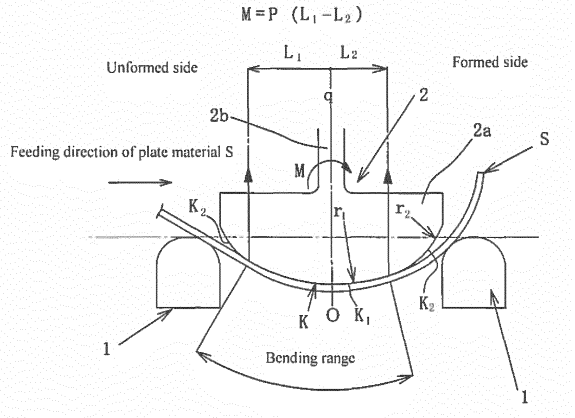
(57) [PROBLEM]

Disclosed is a bending-press forming punch which is hardly affected by the bending moment and can obtain a cylinder with good roundness.

[SOLUTION]

Provided is a bending-press forming punch which includes a pair of left and right dies 1 that are disposed at intervals along a widthwise direction of a plate material S to support the plate material S at two locations; and a punch 2 that is movable in a direction of getting close to or away from the dies 1 and sequentially presses the plate material S in the widthwise direction while interposing the plate material together with the dies 1 to perform the bending, wherein the punch 2 includes a punch head 2a having a working surface K which comes into direct contact with the plate material S to press the plate material S into a concave shape, and a punch supporter which is held by connection to the punch head 2a to support the punch head 2a. Moreover, the punch head 2a has a working surface K having a working surface center O which matches an axis q of the punch supporter 2b and being formed by a non-uniform circular arc in which a radius in a central region in the widthwise direction is a maximum radius.

FIG. 2



EP 3 127 624 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a bending-press forming punch which is suitable for efficiently producing a thick steel pipe of a large diameter, for example, used for a line pipe or the like, by successively pressing and bending a plate material along its feeding direction through a three-point bending-press.

BACKGROUND ART

[0002] As a technique of producing a thick steel pipe of a large diameter used for a line pipe or the like is widely used a so-called UOE forming technique of press-working a steel plate having a predetermined length, width and plate thickness into a U-shape, press-forming the steel plate into an O-shape, butt-jointing the end portions thereof by welding to form a steel pipe, and further expanding its diameter (so-called tube expansion) so as to enhance the roundness.

[0003] However, in the above UOE forming technique, a high press pressure is required in the process of forming the steel plate into a U-shape and an O-shape by press-working the steel plate, so that it has no choice but to use a large-scale press machine.

[0004] For this reason, studies have been made on the technique for reducing the pressing pressure in the production of this type of steel pipe.

[0005] As a prior art in this regard, a bending-press forming technique has been put into practical use which performs the bending (edge bending) of the end portions in a widthwise direction of the steel plate in advance, then, forms the steel plate into a substantially circular shape by performing three-point bending-press a plurality of times, and further corrects the shape to form a steel pipe.

[0006] FIG. 9 is a view illustrating an embodiment of performing such a bending-press forming. The reference number 101 in FIG. 9 indicates a die disposed within a conveying pathway of a plate material S. The die 101 includes a pair of left and right rod-shaped members 101a and 101b which support the plate material S at two points along the conveying direction, and a distance e between the left and right rod-shaped members can be changed depending on the size of the steel pipe to be formed. However, in the course of producing an open pipe by press-forming the plate material S, the distance e is not changed.

[0007] A punch 102 is movable in a direction which gets close to and away from the die 101. The punch 102 includes a punch head 102a having a downward convex working surface K which comes into direct contact with the plate material S to press the plate material S into a concave shape, and a punch supporter 102b which leads to the back of the punch head 102a and supports the punch head 102a. The maximum width of the punch head 102a is generally equal to the width (thickness) of the punch supporter 102b. Also, a roller 103 forms a conveying pathway of the plate material S.

[0008] In the bending applied with the three-point bending-press, it is common to empirically determine the number of times of bending and a punch to be used (in particular, a shape), in consideration of load and product shape during bending (for example, a working width of the punch is about 120 mm, and the number of times of bending is about 50 to 60).

[0009] In the bending method, it is difficult to perform the efficient production as the number of times of bending is increased. As a countermeasure for this problem, for example, Patent Document 1 discloses a method wherein press-forming of a steel plate is conducted in the widthwise direction by performing the bending on both end portions and a specific intermediate portion in the widthwise direction of the steel plate such that each of the straight portions of desired lengths remain and a portion between the straight portions is a circular arc portion, simultaneously welding a joint portion to form a semi-forming round steel pipe, and after heating the entire semi-forming round steel pipe, performing the hot-forming throughout the plurality of forming rolls in which the forming surface has a semicircular shape corresponding to the final radius to thereby adjust a shape.

[0010] However, according to the disclosure of Patent Document 1, a formed body after the press-forming has a shape close to a square, and it is essential to separately provide a process (hot) for correcting the shape, so that there is a problem of causing a significant increase in the production cost when including the consumption of thermal energy applied to the heating.

[0011] Also, in this method, when a plate material produced via a thermo-mechanical heat-treatment process is used as an original plate to combine strength, toughness and weldability, there is a risk of deteriorating its characteristics.

[0012] Meanwhile, Patent document 2 discloses a method of reducing the number of times of bending in three-point bending-press, while diminishing the stress acting on a connecting portion between a punch head and a bending board for supporting the punch head (corresponding to the punch supporter).

[0013] According to Patent document 2, since the working width of the punch head is wider than the width of the bending board, it is possible to reduce the number of times of bending in the three-point bending-press as compared to the case of the punch head as shown in FIG. 9. Moreover, since the punch head is rotatably attached to the bending board, only a small bending moment caused by the friction of the rotating part acts on the bending board, and thus, there

is an advantage that the load applied to the equipment is reduced. However, since the rotating support portion has a smaller width than that of the bending board, there is a concern that a large surface pressure acts on the site to cause wear and deformation of the rotating support portion, and there is a possibility that the rotation function cannot be maintained at an early stage.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0014]

Patent Document 1: JP-A-2005-324255

Patent Literature 2: JP-A-2004-82219

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0015] As described above, in the conventional techniques, it is not easy to simply expand the working width of the punch head used in the bending-press forming, and in order to prevent the excessive load from being applied to the connecting portion between the punch head and the punch supporter while expanding the working width of the punch head, it is useful to sufficiently increase the width (thickness) of the punch supporter.

[0016] However, from the viewpoint of improving the accuracy in the process after the bending-press forming in recent years, it is required to reduce the width (thickness) of the punch supporter of the punch used in the bending-press forming.

[0017] Also, in the case of forming the plate material into a cylindrical shape by the bending-press forming to make a tubular body, even if the tubular body is removed along a longitudinal direction when the tubular body as a material to be formed is extracted from the punch, it is not theoretically possible to provide an gap between the plate width end portions facing each other in the tubular body which has a smaller width than the width (thickness) of the punch supporter.

[0018] In the tubular body (hereinafter, such a pipe is also referred to as open pipe) in the form of having a gap in which the plate material is formed into a cylindrical shape and the plate width end portions facing each other are not welded, when welding the plate width end portions facing each other (hereinafter, such a site is also referred to as a seam portion), it is necessary to deform the I tubular body by applying force from the outside of the tubular body and to eliminate the gap by mutually butting the plate width end portions facing each other. Here, in the bending-press forming, as the gap between the plate width end portions is small, force required to butt the plate width end portions each other is small, and a bad shape such as roundness drop is also hard to occur. In this way, there has been an increasing demand for the technique of suppressing an increase in the width (thickness) of the punch supporter as much as possible while expanding the working width of the punch head in the bending-press forming.

[0019] Thus, an object of the present invention is to provide a bending-press forming punch capable of efficiently performing the bending, without causing wear and deformation of a punch or without impairing the product quality, in the production of the steel pipe from the plate material by the three-point bending-press.

MEANS FOR SOLVING PROBLEMS

[0020] The present invention provides a bending-press forming punch comprising dies that are disposed at intervals along a feeding direction of a plate material to support the plate material at two locations; and a punch that is movable in a direction of getting close to or away from the dies and sequentially presses the plate material supported by the dies along the feeding direction to perform bending, wherein the punch has a punch head that directly contacts with the plate material to press the plate material, and a punch supporter that is held by being connected to the back of the punch head and supports the punch head, and the punch head is provided with a working surface having a working surface center which matches an axis of the punch supporter and being formed by a non-uniform circular arc having a radius in a central region in the widthwise direction as a maximum radius.

[0021] In the bending-press forming punch having the above-described configuration, it is preferable as a specific means for solving the problems of the present invention that:

1) The non-uniform circular arc comprises a continuous circular arc or a discontinuous circular arc,
2) The non-uniform circular arc comprises an involute curve,
3) When the non-uniform circular arc comprises the continuous circular arc or the discontinuous circular arc, the

continuous circular arc and the discontinuous circular arc are constituted of a main circular arc having a radius corresponding to an inner diameter of a cylindrical body to be worked and laterally equivalent working widths (contact length) with respect to the working surface center, and a sub circular arc connecting with a width edge of the main circular arc and having a radius smaller than the radius,

4) Among the non-uniform circular arc, a circular arc primarily contributing to the bending has a working width of less than 0.90 times a feed pitch of the plate material, and

5) In the continuous circular arc and the discontinuous circular arc, the main circular arc has a working width of less than 0.90 times the feed pitch of the plate material.

EFFECTS OF THE INVENTION

[0022] According to the bending-press forming punch of the invention having the above-described configuration, the punch head is provided with a working surface having a working surface center which matches an axis of the punch supporter and being formed by a non-uniform circular arc having a radius in a central region in the widthwise direction as a maximum radius. Thus, even if a bending range of the plate material is increased, the width end of the working surface does not strongly come into contact with the plate material, and it is possible to suppress an occurrence of excessive bending moment which may cause deformation or damage to the punch. Moreover, since it is possible to bend the plate materials having the width wider than that of the conventional technique at a time, a steel pipe having good roundness can be obtained with the small number of times of bending. Furthermore, a process such as heating the plate material is not necessary, whereby it is possible to maintain the characteristics such as strength, toughness and weldability or the like obtained in the producing process of the plate material (original plate).

[0023] Furthermore, according to the bending-press forming punch of the invention, the non-uniform circular arc is the continuous circular arc or the discontinuous circular arc obtained by combining at least two arcs with different radii, so that the width end of the working surface of the punch head does not strongly come into contact with the plate material at the time of bending. Therefore, it is possible to avoid an excessive bending moment which causes the deformation and damage to the punch. Also, it is relatively easy to form a working surface.

[0024] According to the bending-press forming punch having the above configuration, the working surface of the punch head can be easily formed by making the non-uniform circular arc of an involute curve.

[0025] Further, according to the bending-press forming punch of the invention, the continuous circular arc and the discontinuous circular arc are constituted of a main circular arc having a radius corresponding to an inner diameter of a steel pipe to be worked and laterally equivalent working widths with respect to the working surface center, and a sub circular arc connecting with a width edge of the main circular arc and having a radius smaller than the radius of the main circular arc. Thus, it is possible to reduce unbalance of forces acting on the punch by decreasing a difference in the distances from a contact starting point between the plate material and the punch head to the punch head center through the unformed side and the formed side portion of the plate material, which can avoid an extreme load being applied to the connecting portion between the punch head and the punch supporter while ensuring a wide working width of the punch head.

[0026] According to the bending-press forming punch of the present invention having the above configuration, in the working surface formed with the non-uniform circular arc, the working width of a region in which a circular arc primarily contributing to bending is formed is set to less than 0.90 times the feed pitch of the plate material, whereby an excessive bending moment does not occur in the punch. Accordingly, the life of the punch is extended to enable the stable bending over the long period of time, and the roundness of the steel pipe can be enhanced. In particular, when the non-uniform circular arc is a continuous circular arc or a discontinuous circular arc and the continuous circular arc or the discontinuous circular arc is constituted of the main circular arc and the sub circular arc, since the main circular arc primarily contributes to the bending, it is possible to suppress an occurrence of excessive bending moment by setting the working width of the region formed with the main circular arc to be less than 0.90 times the feed pitch of the plate material.

BRIEF DESCRIPTION OF DRAWINGS

[0027]

FIG. 1 is a schematic view illustrating an embodiment of a bending-press forming punch according to the present invention.

FIG. 2 is a schematic view illustrating a deformed state of a plate material when being pressed using the bending-press forming punch illustrated in FIG. 1.

FIGs. 3(a) to 3(c) are schematic views illustrating another embodiment of the bending-press forming punch.

FIG. 4 is a schematic view illustrating a bending way using the bending-press forming.

FIG. 5 is a schematic view illustrating a deformation situation of the plate material when performing the bending-

press forming using a punch head having a uniform circular arc.

FIG. 6 is an explanation drawing of a working width n_i which contributes to the bending of the punch.

FIG. 7 is a schematic view illustrating a specific dimension of the punch head used in the example.

FIG. 8(a) is a schematic view illustrating a dial gauge used when evaluating the local roundness of the steel pipe, and FIG. 8(b) is a schematic view illustrating how to measure the local roundness.

FIG. 9 is a schematic view illustrating an example of the embodiment when performing a bending-press forming according to the conventional method.

EMBODIMENTS FOR CARRYING OUT THE INVENTION

[0028] Hereinafter, the present invention will be described more specifically with reference to the accompanying drawings.

[0029] FIG. 1 is a schematic view illustrating an embodiment of a bending-press forming punch according the present invention.

[0030] In the drawings, a die 1 is disposed within a conveying pathway of a plate material S. The die 1 includes a pair of left and right rod-shaped members 1a and 1b which support the plate material S at two locations along the feeding direction, and its distance e can be changed depending on the size of the steel pipe to be formed. However, in the course of producing a single open pipe by press-forming a plate material S, the distance e is not changed.

[0031] Also, a punch 2 is movable in a direction which gets come to and away from the die 1, The punch 2 includes a punch head 2a which has a downward convex working surface K coming into direct contact with the plate material S to press the plate material into a concave shape, and a punch supporter 2b which leads to the back of the punch head 2a and supports the punch head 2a. Also, rollers 3 form a conveying pathway of the plate material S.

[0032] A specific structure of the punch supporter 2b of the punch 2 is not illustrated, but its upper end portion is connected to a driving means such as a hydraulic cylinder so as to be able to apply the pressing force to the punch head 2a by the driving means.

[0033] A width (thickness) of the punch supporter 2b is appropriately designed by thickness and strength of the plate material S as a material to be formed and a shape of a tubular body to be formed. Also, since the punch supporter 2b may come into contact with the end portion of the plate material S, it is possible to provide a replaceable wearing plate on the surface of the punch supporter 2b. The wearing plate is preferable since it can be used for a long period of time without wearing the punch supporter 2b by appropriately exchanging it.

[0034] Moreover, as the main portions are illustrated in FIG. 2, the punch head 2a of the punch 2 has a working surface center O which matches an axis q of the punch supporter 2b, and a working surface K provided at its head is formed with a non-uniform circular arc which has a radius r_1 as a maximum radius in the central region in the widthwise direction (other regions have a radius r_2 which is smaller than the radius r_1).

[0035] Here, the non-uniform circular arc defined in the present invention refers to a circular arc provided by a combination as illustrated in FIGs. 3(a) to 3(c) in which at least two arcs having the different radii are combined with each other, that is, a circular arc which includes a circular arc of the radius r_1 positioned at the working surface center O (hereinafter, this circular arc is called a main circular arc K_1) and a circular arc having a smaller radius r_2 than that of the main circular arc K_1 (hereinafter, this circular arc is called a sub circular arc K_2). In FIGs. 3(a) to 3(c), (a) is a circular arc which has a common tangent at a connecting point between the main circular arc K_1 and the sub circular arc K_2 (when an angle formed by the tangent of the main circular arc K_1 and the tangent of the sub circular arc K_2 is 0°), and (b) is a circular arc in which the tangent of the main circular arc K_1 and the tangent of the sub circular arc K_2 are connected to each other while forming an angle (the angle is not 0°), and (c) is a circular arc in which an angle formed by the tangent of the main circular arc K_1 and the tangent of the sub circular arc K_2 is 0° but they are connected to each other via a step d. Hereinafter, the circular arc as illustrated in (a) will be referred to as a continuous circular arc (including a circular arc such as an involute curve or the like, in which a radius gradually is changed while having a common tangent), and the circular arcs as illustrated in (b) and (c) will be referred to as a discontinuous circular arc. The discontinuous circular arc also includes one in which the radius of the circular arc gradually is changed.

[0036] As described above, the punch 2 is basically configured to include the punch head 2a and the punch supporter 2b, but it is possible to interpose a spacer (not illustrated) between the punch head 2a and the punch supporter 2b. By interposing the spacer therebetween, for example, when finely adjusting a mounting angle of the punch head 2a to the punch supporter 2b, the mounting angle can be adjusted to an appropriate angle only by adjusting the shape of the spacer rather than the punch supporter 2b itself. Also, when the punch head 2a is divided in the longitudinal direction of the die 1, it is possible to improve the handling efficiency when storing the punch heads 2a or when mounting the punch heads 2a to the punch supporter 2b by holding the plurality of divided punch heads 2a with a single spacer. Since there are advantages as described above, it is preferable to interpose a spacer (not illustrated) between the punch head 2a and the punch supporter 2b.

[0037] To perform the bending of the plate material S by the bending press using a punch having the above-described

configuration, the plate material S is placed on the die 1, and in such a manner as illustrated in FIG. 4, the plate material S may be successively subjected to the three-point bending both on the left and right sides from the edge in the widthwise direction towards the center by the punch 2 while intermittently feeding the plate material S by a predetermined feed pitch. In addition, FIG. 4 is a schematic view illustrating a process of forming an open pipe as illustrated in the right lowest view, by performing the bending of the plate material S which has been subjected to edge bending (to be described below) in advance, from the top to the bottom of the left column, then, from the top to the bottom of the center column, and further from the top to the bottom of the right column, and by performing the feeding of the plate material S. In FIG. 4, open arrows assigned to the plate material S or the punch 2 indicate the directions of movement of the plate material S or the punch 2 in each process.

[0038] When performing the bending of the plate material S in the above-described manner (during pressing), the plate material S comes into contact with the die 1 in the state of being entirely inclined, and the plate material S is deformed in the state of left-right asymmetrical with respect to the working surface center O of the punch head 2a.

[0039] When the bending of the plate material S gradually progresses in this state, in order to maintain the state of contact between the punch 2 and the dies 1, the plate material S is greatly inclined on the unformed side rather than the center (working surface center O) in the widthwise direction of the punch head 2a (an bent angle of the plate material S with respect to the punch increases), and as illustrated in FIG. 5, a contact range (bending range) in which the punch head 2a comes into contact with the plate material S becomes wider on the unformed side than on the formed side.

[0040] Since the punch 2 receives the forming reaction force at both ends of the contact range, when there is a difference in distances (L_3, L_4) from the center (working surface center O) in the widthwise direction of the punch head 2a to both ends of the contact range, bending moment M (= P (L_3 - L_4)) acts on the connecting portion between the punch head 2a and the punch supporter 2b. In particular, in the three-point bending using a punch head with a working surface comprising a single circular arc, excessive bending moment acts. Accordingly, there is a concern that the punch head 2a or the punch supporter 2b may be deformed or damaged.

[0041] In the bending-press forming punch of the present invention, since the working surface K has the non-uniform circular arc and the radius of the sub circular arc K_2 is smaller than the radius of the main circular arc K_1 as illustrated in FIG. 2, it is possible to narrow the asymmetric range compared to a punch having a single working surface, and therefore, even when the bending of the plate material S progresses, the load in the width end region of the punch head 2a is not extremely increased, and as a result, an occurrence of the excessive bending moment can be suppressed.

[0042] In the present invention, in order to obtain a steel pipe with good roundness by the bending-press forming, the main circular arc K_1 formed on the working surface K has laterally equivalent contact lengths with respect to the working surface center O as a starting point.

[0043] Further, although the main circular arc K_1 and the sub circular arc K_2 are constituted of a continuous circular arc or a discontinuous circular arc, the number of circular arcs is not particularly limited.

[0044] Although the length (circumferential length) of the working surface K is determined by the size of the steel pipe to be manufactured and the number of times of pressing, the working width of the working surface K in the region formed by a circular arc primarily contributing to the bending is preferably less than 0.90 times the feed pitch of the plate material so as to diminish the bending moment occurring in the punch 2 and decrease the number of times of pressing to achieve the efficient bending (when the working width of the region formed with a circular arc primarily contributing to the bending is set to n_i and the feed pitch of the plate material S is set to δ, a ratio (n_i/δ) of the working width n_i and the feed pitch δ of the plate material S is less than 0.90 times). In the punch head 2a where the working surface K is formed with the main circular arc K_1 and the sub circular arc K_2, the main circular arc K_1 primarily contributes to the bending, so that the working width of the region formed by the main circular arc K_1 is set to less than 0.90 times the feed pitch δ of the plate material.

[0045] Here, when a target bending formation amount θ_i (a bending angle per time) is set around the working surface center O on the working surface K of the punch head 2a, the working width n_1 of the region formed with the circular arc primarily contributing to the bending refers to a length (length of a circular arc) on the working surface K corresponding to a range of the target bending formation amount θ_i as illustrated in FIG. 6. Also, when the number of times of bending is assumed to be N, since the plate material is bent into a pipe shape of 360° together with the edge bending, the target bending formation amount θ_i is (360° - 2 x edge bending angle)/N is a measure of the amount of the bending formation per time.

[0046] In the bending press using the punch 2 of the present invention, the number of times of bending N is normally not less than 3, so that 120° which is the value calculated when the edge bending angle is assumed to be 0° is sufficient as the target value of the amount of the bending formation per time. Accordingly, the bending formation amount on the working surface K of the punch 2 can be set not more than 120° (corresponding to not more than 60° on one side from the working surface center O of the punch 2), or may be further decreased to not more than 90° (corresponding to not more than 45° on one side from the working surface center O of the punch 2).

[0047] In general, when forming the plate material into a tubular shape by the bending-press forming, the edge bending (also referred to as crimping) is performed on the plate width end portions of the plate material prior to the bending-press

forming. This is implemented in order to ensure good roundness of the plate width end portions which are relatively hard to bend as compared to the case of performing the bending of the plate width central portion in the bending-press forming. Further, since the plate material has a pipe shape by performing the bending of 360° together with the subsequent bending-press forming, in the bending-press forming, the bending is applied except for the amount given by the edge bending. The bending formation amount (angle) θ_i per time in the bending press is (360° - 2 $\times$ edge bending angle)/N, and the range applied with the bending per time is the feed amount (feed pitch). In other words, the plate material is formed into a pipe shape by giving the bending formation amount θ_i every feed pitch.

[0048] At this time, when the plate material goes along the working surface K of the punch head 2a, the shape of the range of the bending formation amount (central angle) θ_i is transferred onto the punch head 2a to obtain the shape after the bending press. As the length (peripheral length (or circular arc length)) along the working surface K of the section of the bending formation amount θ_i approaches the feed pitch of the plate material, the portion to which the radius of curvature is given is widened, and the good roundness can be secured. However, when the bending range is widened, the position receiving the forming reaction force (bending reaction force) becomes remote from the working surface center O of the working surface K of the punch head 2a, and there is a problem of increasing the bending moment at the connecting portion between the punch supporter 2b and the punch head 2a. In order to reduce such problems, in the present invention, the working width n_i of the region formed with the circular arc primarily contributing to the bending is set to less than 0.90 times the feed amount (length) of the plate material.

[0049] Also, when bending the plate material S with the punch head 2a having a smaller radius than the radius of the product, the radius of curvature of the bent portion of the plate material S is also decreased. In this case, a bending forming portion having a radius of curvature locally smaller than that of other portions is also formed in the tubular body which is made of the plate, so that the shape is degraded if the portion remains in the product as it is. Since the radius of the sub circular arc K_2 of the working surface K is smaller than the radius of the main circular arc K_1, it is necessary to pay attention to the occurrence of such a failure. For that reason, the bending range of the sub circular arc K_2 is preferably set to not more than 15° at the central angle of the sub circular arc K_2.

[0050] When the length of the working surface coming into contact with the plate material is shortened, since the portion to which the curvature is not given (that is, flat portion) is increased and there is a risk of degradation of roundness, it is preferable to appropriately set the working width (distance) n_i of the region where the circular arc primarily contributing to the bending is formed, depending on the specifications (strength, thickness, size and shape) of the target product.

EXAMPLES

[0051] Nine steel plates (steel type: API grade. X80) having dimensions along the feeding direction of the plate material S of 3713 mm, a plate thickness of 25.4 mm and a tensile strength of 745 to 757 MPa are prepared, and the edge bending is performed so that both end portions of each steel plate has an angle of 16.9 degrees over the range of 215 mm by a punch having a radius of curvature of 380 mm.

[0052] Subsequently, the three-point bending is performed from each of both the left and right sides toward the center of the steel plate based on the conditions of a feed pitch 298 mm/time, a bending formation amount 29.6°/time and five times of press by using a position of one side 1492 mm from the center of the steel plate (the center of the dimension along the feeding direction) as the bending start point.

[0053] Then, one three-point bending is conducted on the steel plate subjected to the three-point bending at the center (11 times of bending in total), and the gap of the butted part of both ends of the steel plate is set to 125 mm, which is welded to form a steel pipe having an outer diameter of 1219 mm, and the quality of the obtained steel pipe and the stress acting on the punch supporter for supporting the punch head is investigated. The results are shown in Table 1 together with the results of the case of performing the bending using the punch head 2a provided with a working surface of a single circular arc.

[0054] Here, the bending is performed using a die where a radius of the head is set to 75 mm and a distance e (distance between centers) between the rod-shaped members 1a and 1b is set to 550 mm. Also, the punch head having the width of 400 mm is used, and the punch supporter having a width (thickness) of the body portion of 100 mm and a receiving portion of the width 400 mm to fix and hold the punch head to the tip is used for supporting it as illustrated in FIG. 7. A strain gauge is attached to an end portion (start site of R) of R having the radius of 50 mm provided in the connecting portion between the body portion and the receiving portion, thereby measuring the stress acting on the punch supporter 2b by the gauge.

[0055] In addition, the form of the working surface is a continuous circular arc in the item of Table 1 when performing the bending by the use of a punch head having a working surface in which the main circular arc and the sub circular arc are connected to each other with an angle of 0° formed between the tangent of the main circular arc and the tangent of the sub circular arc, at the position of the angle of 15° from the working surface center O of the punch head. The form of the working surface is an involute when performing the bending by the use of a punch head having a working surface in which the radius is gradually decreased as being remote from the working surface center O of the punch head by the

involute curve. In the case of the involute, the radius of the main circular arc indicates the value of the radius in the working surface center O (that is, the maximum value of the radius), and the radius of the sub circular arc indicates the position which is remote from the working surface center O by 1/2 of the bending formation amount θ_i: 29.6°, that is, the minimum value of the radius of the range primarily contributing to the bending, respectively. Moreover, the form of the working surface is a discontinuous circular arc when performing the bending by the use of a punch head having a working surface in which the main circular arc and the sub circular arc are connected to each other with a difference of 6° of the angles formed between the tangent of the main circular arc and the tangent of the sub circular arc at the positions of 15° from the working surface center 0 of the punch head 2a.

[0056] Also, in the ratio of the stress acting on the punch supporter to the fatigue limit stress in Table 1, the stress acting on the punch supporter indicates the largest value in the 11 times of bending. However, it is required to consider in the execution how much the stress acting on the punch supporter with respect to the fatigue limit stress is. Therefore, in Table 1 are shown values obtained by dividing the stress acting on the punch supporter by a basic allowable stress range in 2×10^6 times of stress repetition based on "Fatigue design guideline and commentary of steel structure (Hagane-Kouzou no Hirou Sekkei Shishin Dou Kaisetsu)" edited by Japanese Society of Steel Construction, regarding the punch supporter, that is, the ratio of stress acting on the punch supporter to the basic allowable stress range.

[0057] In the evaluation of punch head, a case where the stress acting on the punch supporter is lower than the fatigue limit stress, that is, a case where the ratio of the stress acting on the punch supporter to the fatigue limit stress is less than 1, is indicated by ◎ (excellent), a case where the ratio of stress is not more than 1.25 is indicated by ○ (allowable), and a case where the ratio is more than that value is indicated by × (unallowable). Here, the ratio 1.25 of the stress in which the number of times of stress repetition is not less than 1×10^6 is a threshold value. In the case of not more than the threshold value, since the repeated stress acts 10 times on the one pipe (the substantially symmetrical formation is obtained in the last 11-th time, and the stress due to the bending hardly acts and does not affect the fatigue life), it is possible to withstand the producing of 1×10^5 pipes (equivalent to 1219 km in the case the standard 40ft length), and there is no practical problem.

[0058] Further, the evaluation of the steel pipe in Table 1 is carried out for local roundness. The local roundness is measured by, for example, using a dial gauge 4 having a pair of leg portions 4a and 4b with an inter-leg distance of D as illustrated in FIG. 8(a), by contacting leg ends 4c, 4d of the leg portions 4a, 4b with the peripheral surface of the resultant steel pipe and simultaneously contacting a probe (not illustrated) provided at the tip of a spindle 4e with the peripheral surface of the steel pipe, and by reading a radial displacement from a virtual perfect circle as a target shape of the steel pipe. It means that the circle gets close to a perfect circle as the value is smaller. In this embodiment, it is an evaluation index of the variation of the shape between the portion which contacts with the punch head and the die and the portion which does not with the punch head and the die. Here, a dial gauge having an inter-leg distance D of 150 mm is used to measure the local roundness as illustrated in FIG. 8(b) along the circumferential direction of the peripheral surface of the steel pipe and obtain the maximum value of the measured local roundness. A case where the value is not more than the tolerance 2.0 mm of API-2B of the API standard as a typical standard of the steel pipe is indicated by ◎ (excellent), a case where the value is not more than the tolerance 3.2 mm of API-5L is indicated by ○ (good), and a case where the value exceeds that is indicated by × (unallowable) in Table 1.

[Table 1]

Punch No	Punch						Steel Pipe		Remarks
	Radius of main circular are (mm)	Radius of sub circular are (mm)	Ratio of stress acting on punch supporter to fatigue limit stress	Evaluation	Form of machining surface	n/δ	Maximum value of local roundness (mm)	Evaluation	
A	480	290	0 87	◎	continuous circular are	0.84	2.0	◎	Present invention
B	480	350	1.10	○	continuous circular are	0.84	1.9	◎	Present invention
C	480	400	1 25	○	continuous circular are	0.84	1.8	◎	Present invention
D	480	417	0.94	◎	involute	0.78	2.3	○	Present invention
E	480	433	1.02	○	involute	0.80	2.0	◎	Present invention
F	500	425	1.25	○	involute	0.81	1.7	◎	Present invention
G	480	340	0.97	◎	discountinuous circular are	0.84	2.2	○	Present invention
H	480	360	1.02	○	discountinuous circular are	0.84	2.1	○	Present invention
I	510	340	1.30	×	discountinuous circular are	090	2.1	○	Comparative example
J	480	-	1.37	×	single circular are	0.84	2.3	○	Comparative example
K	455	-	1.16	○	single circular are	0.80	3.1	×	Comparative example
L	420	-	0.97	◎	single circular are	0.74	3.5	×	Comparative example

[0059] As is apparent from Table 1, in the punch Nos. A to H suitable for the present invention, the ratio of stress applied to the punch supporter during bending is not more than 1.25, and the deformation and damage of the punch is not observed. In addition, it is confirmed that the local roundness of the steel pipe formed by the punch Nos. A to H is not more than 2.3 mm and sufficiently satisfies the standard API.

[0060] In particular, in a case where the working surface of the punch head is formed by a continuous circular arcs (Nos. A, B, C, E and F), the local roundness of the steel pipe is not more than 2.0 mm and satisfied the strict 2B standard in the API standard, and it is found clear that a steel pipe of high quality can be formed without adding extra processes.

[0061] When applying the continuous circular arc to the working surface of the punch head, in punch No. A having the smallest radius of the sub circular arc, the ratio of the stress in the connecting portion is the smallest as 0.87, and it is found that this is permanently usable for such a punch supporter.

[0062] In contrast, in punch No. I in which the ratio (n_i/δ) of the working width (n_i) of the region primarily contributing to the bending and the feed pitch (δ) of the plate material is 0.90, even in the case of the non-uniform circular arc, the ratio of stress applied to the punch supporter is large as 1.30, and there is a risk of deformation and damage of the punch.

[0063] Furthermore, in the bending using a punch having a punch head with a working surface of a single circular arc, in the case of applying punch No. J having the working surface with the radius of 480 mm, the ratio of the stress applied to the punch supporter is increased, and there is a risk of deformation or damage of the punch. Meanwhile, in the case of applying punch Nos. K and L having a working surface with a radius of 455 mm, or 420 mm, it is found that there is a tendency of deterioration of the local roundness of the steel pipe.

INDUSTRIAL APPLICABILITY

[0064] According to the present invention, it is possible to provide a bending-press forming punch in which impact on deformation and damage of the punch due to an occurrence of excessive bending moment is suppressed to stably and efficiently form the steel pipe with good roundness over long period of time.

DESCRIPTION OF REFERENCE SYMBOLS

[0065]

1, 101	die
1a, 101a	rod-shaped member
1b, 101b	rod-shaped member
2, 102	punch
2a, 102a	punch head
2b, 102b	punch supporter
3, 103	roller
4	dial gauge
4a	leg portion
4b	leg portion
4c	leg end
4d	leg end
4e	spindle
S	plate material
e	distance
K_1	main circular arc
K_2	sub circular are
r_1	radius
r_2	radius
O	working surface center
q	pressing axis

Claims

1. A bending-press forming punch comprising: dies that are disposed at intervals along a feeding direction of a plate material to support the plate material at two locations; and a punch that is movable in a direction of getting close to or away from the dies and sequentially presses the plate material supported by the dies along the feeding direction to perform bending,

characterized in that the punch has a punch head that directly contacts with the plate material to press the plate material, and a punch supporter that is connected to the back of the punch head and supports the punch head, and the punch head is provided with a working surface having a working surface center which matches an axis of the punch supporter and being formed by a non-uniform circular arc in which a radius in a central region in the widthwise direction is a maximum radius.

2. The bending-press forming punch according to claim 1, wherein the non-uniform circular arc is a continuous circular arc or a discontinuous circular arc obtained by combining at least two arcs having different radii.

3. The bending-press forming punch according to claim 1, wherein the non-uniform circular arc includes an involute curve.

4. The bending-press forming punch according to claim 2, wherein the continuous circular arc or the discontinuous circular arc includes a main circular arc which has a radius corresponding to an inner diameter of a steel pipe to be manufactured and has laterally identical working widths with respect to the working surface center, and a sub circular arc which leads to a width edge of the main circular arc and has a radius smaller than the radius.

5. The bending-press forming punch according to any one of claims 1 to 3, wherein a region of the non-uniform circular arc, in which a circular arc primarily contributing to the bending is formed, has a working width of less than 0.90 times a feed pitch of the plate material.

6. The bending-press forming punch according to claim 4, wherein a region of the continuous circular arc or the discontinuous circular arc, in which the main circular arc is formed, has a working width of less than 0.90 times the feed pitch of the plate material.

FIG. 1

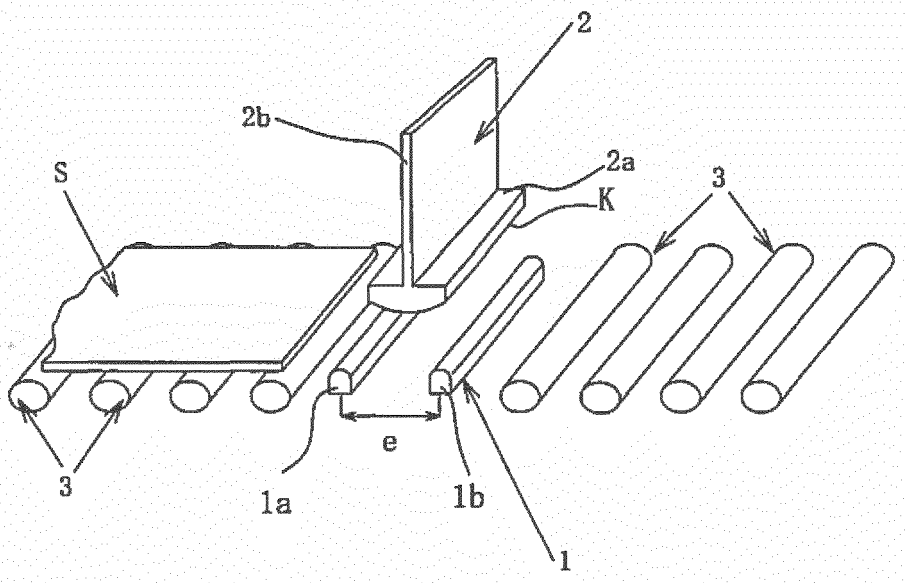

2
2b
2a
K
3
S
3
e
1a
1b
1

FIG. 2

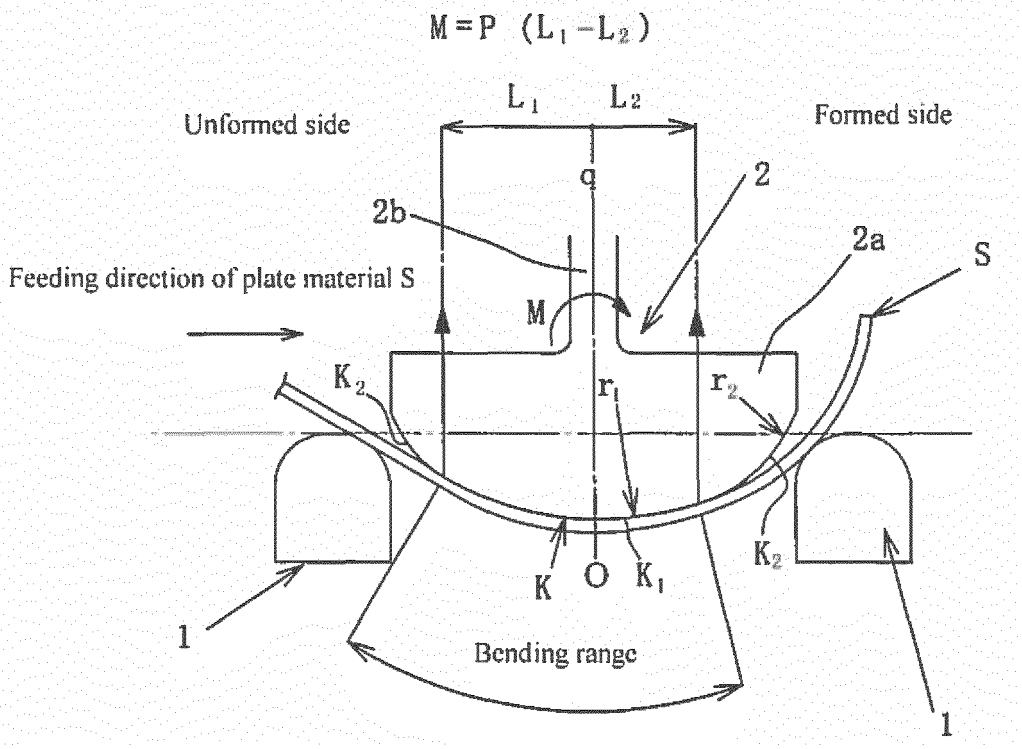

M=P (L1-L2)
L1
L2
Unformed side
Formed side
q
2
2b
2a
S
Feeding direction of plate material S
M
K2
r1
r2
K2
K
O
K1
1
Bending range
1

FIG. 3

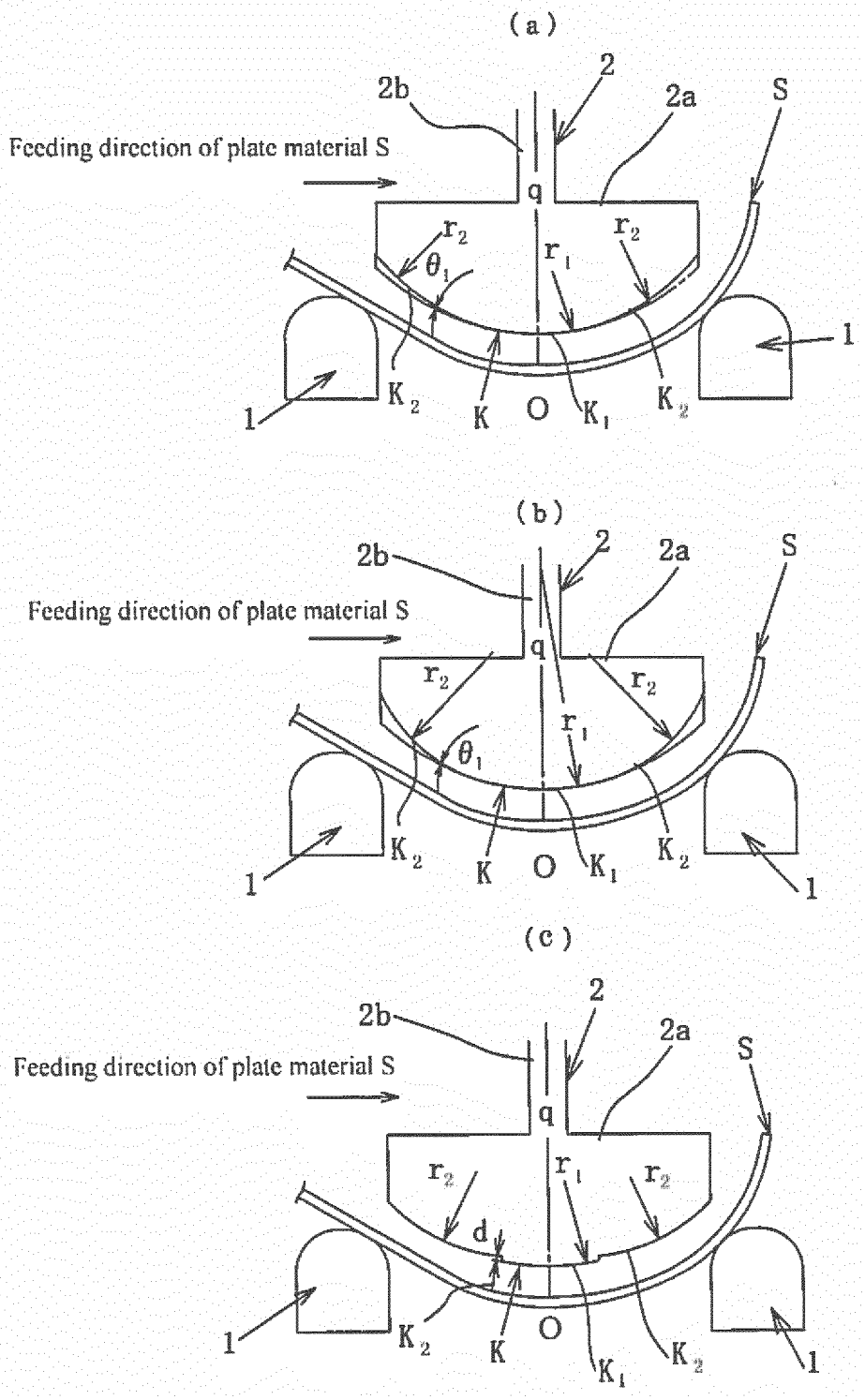

(a)
2b
2
2a
S
Feeding direction of plate material S
q
r2
θ1
r1
r2
1
K2
K
O
K1
K2
1
(b)
2b
2
2a
S
Feeding direction of plate material S
q
r2
r2
r1
θ1
K2
K
O
K1
K2
1
1
(c)
2b
2
2a
S
Feeding direction of plate material S
q
r2
r1
r2
d
1
K2
K
O
K1
K2
1

FIG. 4

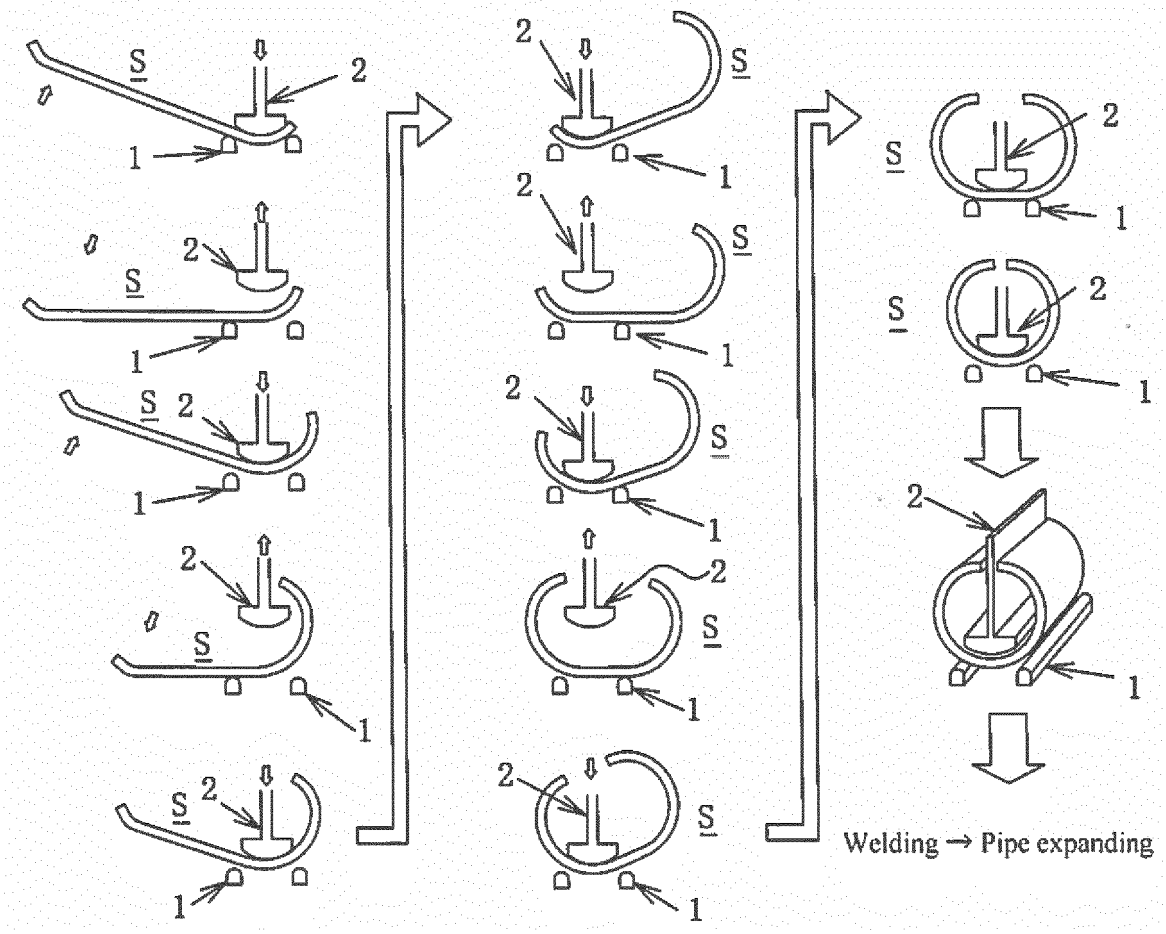


FIG. 5

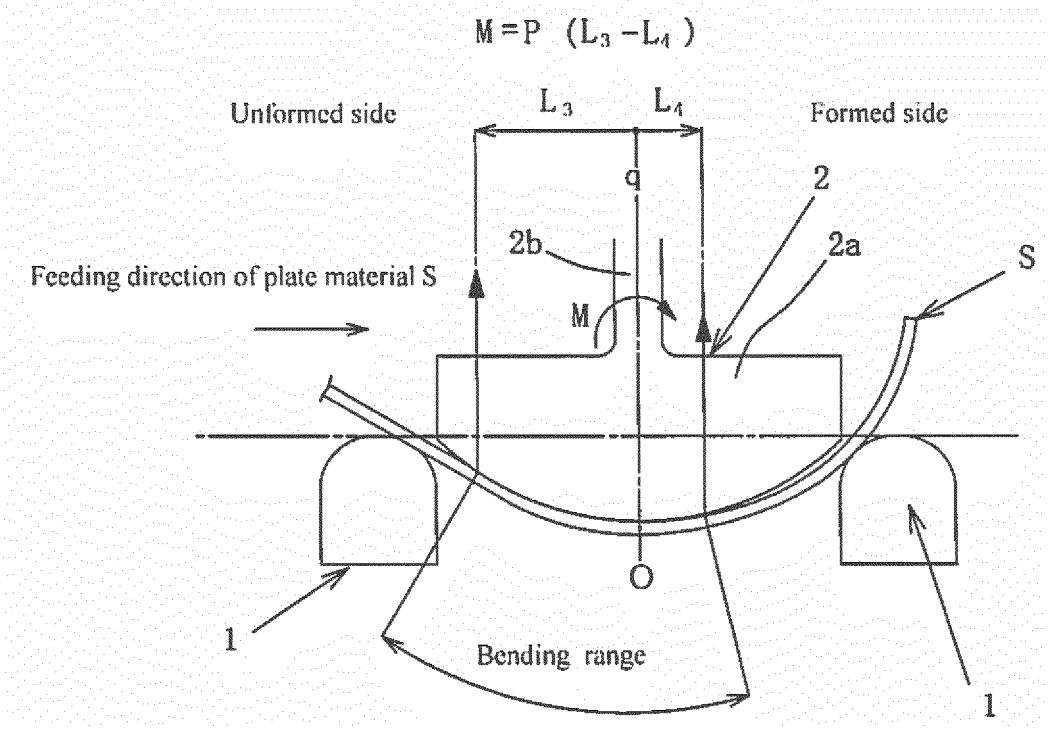

M = P (L3 − L4)
Unformed side
L3
L4
Formed side
q
2
2b
2a
S
Feeding direction of plate material S
M
O
1
Bending range
1

FIG. 6

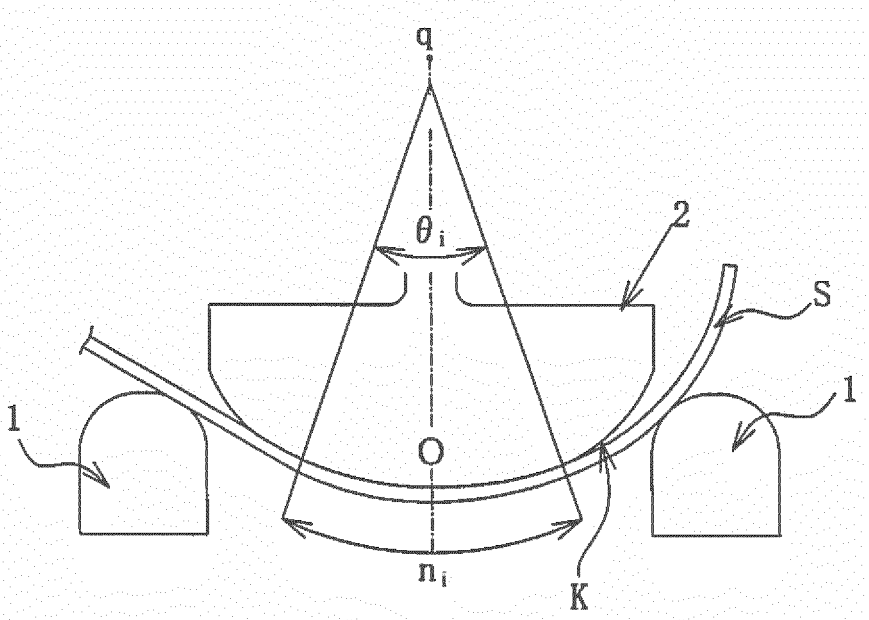


FIG. 7

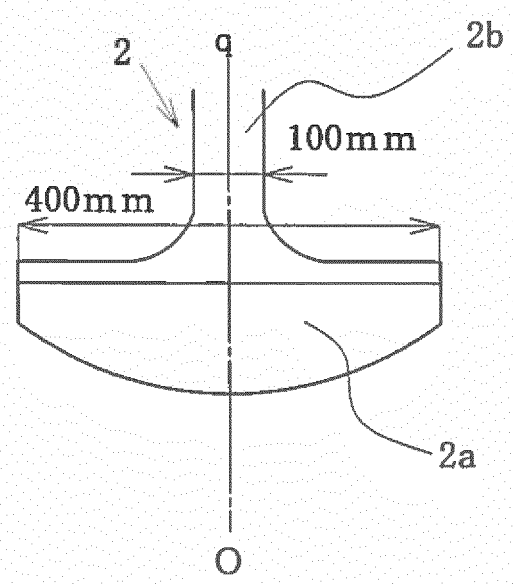


FIG. 8

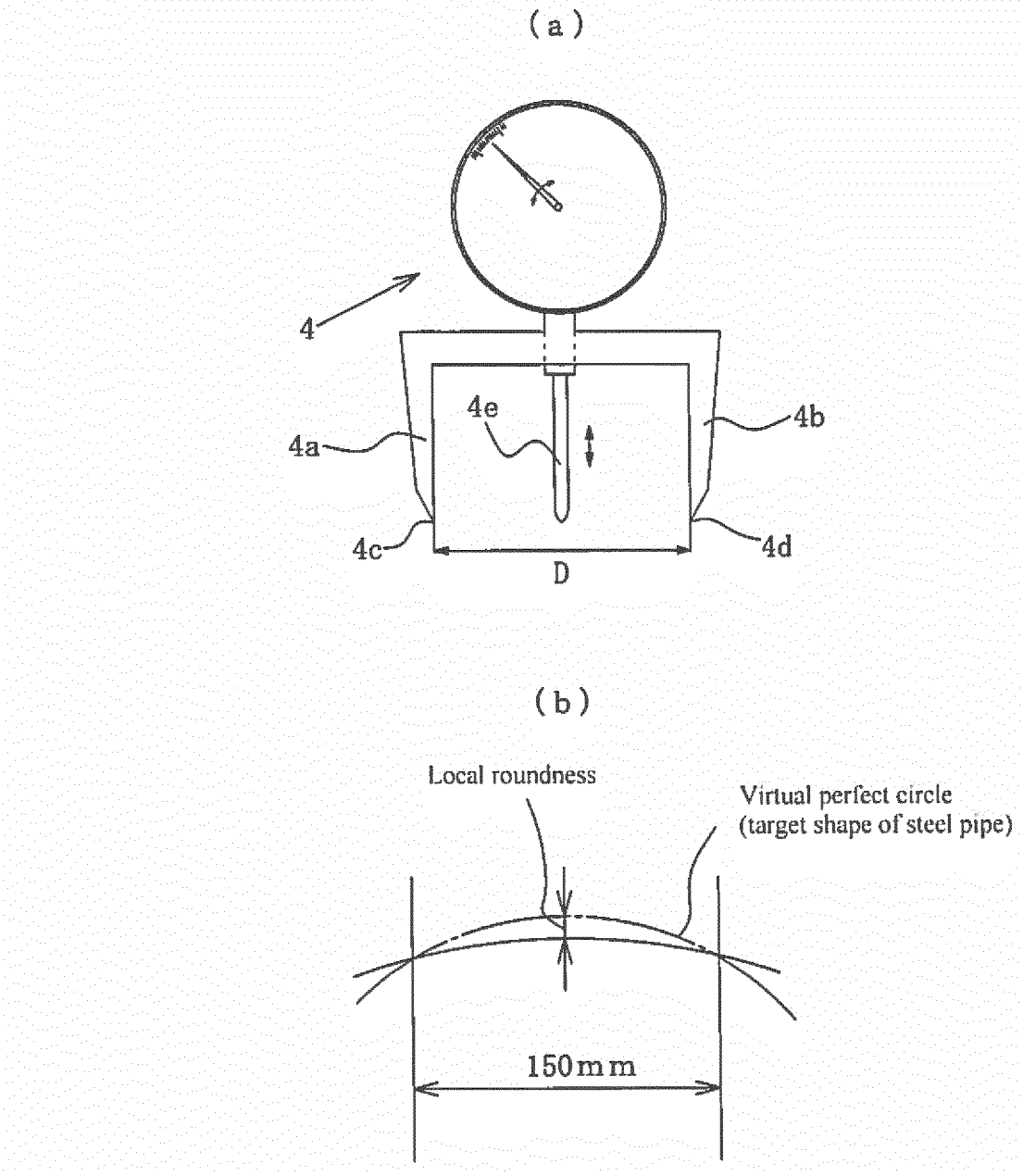
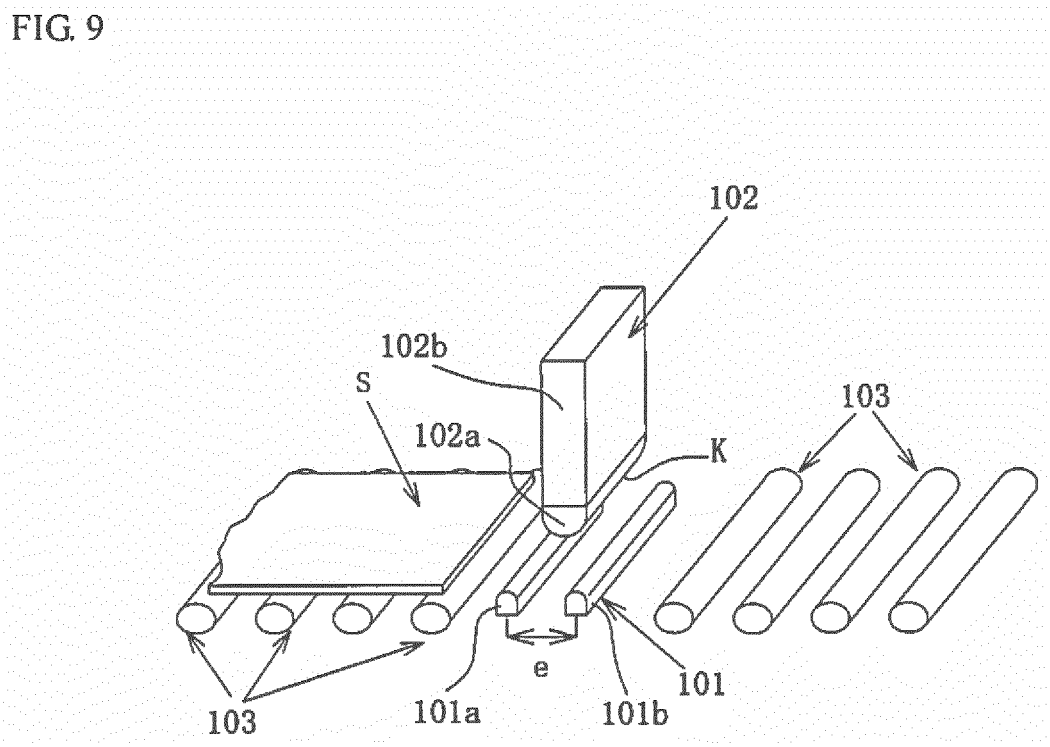

(a)
4
4e
4b
4a
4c
4d
D
(b)
Local roundness
Virtual perfect circle
(target shape of steel pipe)
150mm

FIG. 9



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/059833

A. CLASSIFICATION OF SUBJECT MATTER
B21D5/01(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)
B21D5/01, B21C37/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2015
Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015

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.
Y A	JP 2012-250285 A (SMS Meer GmbH), 20 December 2012 (20.12.2012), paragraph [0028]; fig. 1 & EP 2529849 A2 & CN 102806245 A & RU 2012122452 A	1-2,4-6 3
Y A	DE 19504736 A1 (MANNESMANN AG), 14 August 1996 (14.08.1996), specification, column 3, line 51 to column 5, line 20; fig. 2 (Family: none)	1-2,4-6 3
A	JP 2004-261845 A (JFE Steel Corp.), 24 September 2004 (24.09.2004), paragraphs [0056] to [0103]; fig. 1 to 9 (Family: none)	1-6

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

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"P" document published prior to the international filing date but later than the priority date claimed
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 May 2015 (20.05.15)	02 June 2015 (02.06.15)
Name and mailing address of the ISA/ Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/059833

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2005-324255 A (Nakajima Steel Pipe Co., Ltd.), 24 November 2005 (24.11.2005), paragraphs [0015] to [0018]; fig. 1 (Family: none)	1-6
A	JP 2004-82219 A (SMS Meer GmbH), 18 March 2004 (18.03.2004), paragraphs [0014] to [0017]; fig. 1 to 3 & US 2004/0055356 A1 & EP 1382402 A2 & DE 10232098 A1	1-6

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Patent documents cited in the description

- JP 2005324255 A **[0014]**
- JP 2004082219 A **[0014]**