(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 834 956 A1

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

(43) Date of publication:
16.06.2021 Bulletin 2021/24

(21) Application number: **19848710.0**

(22) Date of filing: **06.08.2019**

(51) Int Cl.:
B21D 3/10 *(2006.01)*

(86) International application number:
PCT/JP2019/030998

(87) International publication number:
WO 2020/032070 (13.02.2020 Gazette 2020/07)

(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

(30) Priority: **09.08.2018 JP 2018150091**

(71) Applicant: **NIPPON STEEL CORPORATION**
Chiyoda-ku
Tokyo 100-8071 (JP)

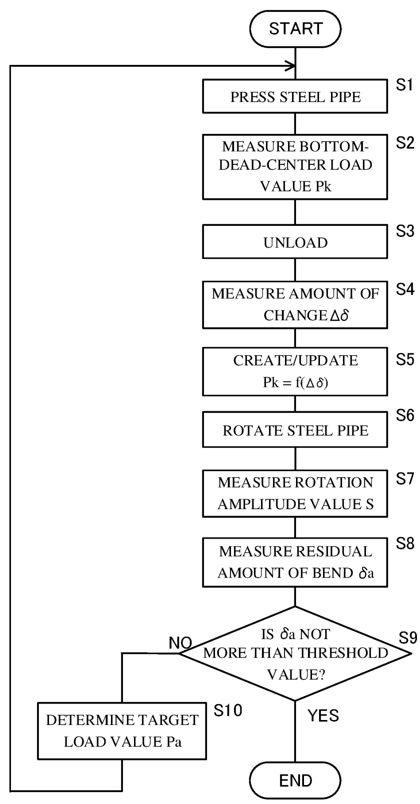
(72) Inventors:
- **KURODA, Koichi**
  Tokyo 100-8071 (JP)
- **OTAO, Shuji**
  Tokyo 100-8071 (JP)

(74) Representative: **Zimmermann & Partner Patentanwälte mbB**
Postfach 330 920
80069 München (DE)

(54) BEND CORRECTION METHOD

(57) There is provided a method for bend straightening in which a steel pipe having a bend is placed in a state where the steel pipe is convex upward, the steel pipe is pressed from above by a press unit at a target load value, whereby the steel pipe is straightened, the method including: (a) a step of measuring a bottom-dead-center load value Pk when the press unit is at a bottom dead center in the pressing; (b) a step of measuring an amount of change $\Delta\delta$ in amount of bend between an amount of bend of the steel pipe before the pressing in the step (a) and an amount of bend of the steel pipe after the pressing in the step (a); (c) a step of repeating the step (a) and the step (b) a plurality of times to create a relational expression $Pk = f(\Delta\delta)$; and (d) a step of determining a target load value for next pressing from the relational expression $Pk = f(\Delta\delta)$.

Fig.5



Printed by Jouve, 75001 PARIS (FR)

Description

TECHNICAL FIELD

[0001] The present invention relates to a method for bend straightening.

BACKGROUND ART

[0002] Steel materials such as pipes and bar materials come to have bends in their producing process. Patent Document 1 and Patent Document 2 disclose straightening methods for straightening bends of a pipe or a bar material. Figure 7 is a graph used for describing a principle of a conventional method for bend straightening.

[0003] The straightening methods described in Patent Documents 1 and 2 present a method in which a load and a deflection in press straightening are measured continuously over time, and the load is removed when a limit within which the load increases in proportion to the deflection is exceeded and a value of (deflection - straightening load × proportionality coefficient) reaches a preset amount of straightening. In other words, in the straightening method, a bend of a pipe is straightened by measuring an amount of bend in advance before applying the straightening load, determining a deflection δ_1 of a material in pressing for giving unbending deformation necessary to straighten the bend by a predetermined method, performing press bending until the deflection δ_1 is reached, and then removing the load.

[0004] A concept of determining the deflection δ_1 will be described below. First, an initial bend δ_0 of a material placed on two supports separated by a span L is measured before straightening. As one of methods for the measurement, while the material placed on the two supports is rotated about its axis, an amplitude of a mid-span portion of the material is measured with a measuring instrument such as a dial gauge installed below the material. Half of the amplitude of the mid-span portion is considered to be a target value δ_0 for an amount of the bending by which the bend straightening is to be performed.

[0005] To perform the bend straightening, the material is placed on the supports such that a direction of the bend of the material becomes a vertically upward direction, and a center portion of the material is bent downward with a press head attached to an end of a hydraulic cylinder. Regarding a relation between a load P applied at that time and a bending displacement δ of the material, deformation of the material is in an elasticity region in an initial stage being a beginning of pressing, where a P-δ curve has an inclination of $\lambda 1$. As the press bending proceeds with the load P gradually increasing, the deformation of the material, which is in the deform plastically region with the inclination $\lambda 1$ in the beginning, reaches a plastic deformation region, the increase in the load P slows down, and a plastic bending of the material progresses. Then, when the bending displacement δ reaches the deflection δ_1 of the press bending determined beforehand, pressing operation is stopped, and the load is removed. When the load is removed, the elastic deformation given to the material by the working load before the unloading is released, and after the load is completely removed, the plastic bending δ_0 as permanent deformation remains. This enables unbending by the same amount as the initial amount of bend, and the bend straightening can be achieved.

[0006] Patent Documents 1 and 2 are characterized in that a bending amount δ_1 up to a pressing bottom dead center position described above is determined with consideration given to a difference between the inclination $\lambda 1$ in the elasticity region when a bending load is applied initially and an inclination $\lambda 2$ when the load is removed after the pressing bottom dead center position is reached and the elastic deformation is released, that is at so-called spring back, on a load-displacement curve. In other words, an amount of pressing operation is determined, focusing on the fact that the inclination in loading and the inclination in unloading are λ_1 and λ_2, respectively, both of which do not match in general. The present inventors consider that a reason for this is due to Bauschinger effect and residual stress associated with a history of a straightened material.

LIST OF PRIOR ART DOCUMENTS

PATENT DOCUMENT

[0007]

Patent Document 1: JP63-199025A
Patent Document 2: JP10-5872A

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0008] According to these Patent Documents 1 and 2, the press bending amount δ_1 is determined with reference to behavior of the relationship between the load and the displacement illustrated in Figure 7. This is effective in a case where behavior of the plastic deformation is clear, for example, in a case where a large bend is to be straightened. However, the present inventors found that the following problem occurs if the methods described in Patent Documents 1 and 2 are used in a case where a minute bend is to be straightened.

[0009] In other words, even when a bend is straightened by the methods described in Patent Documents 1 and 2, it was difficult to perform straightening with high accuracy by performing pressing operation only once. For example, a straightening level of 0.5 mm to 1 mm per 1 m is often required as a product specification; however, it is difficult to achieve such a straightening level by performing the pressing operation according to the method described in Patent Documents 1 and 2 once, due to the Bauschinger effect described above and subtle fluctuations in properties of a material and a machine and additionally various unevenness factors including backlash of a device and stiffness of the device. This makes it difficult to apply techniques of prior art to press straightening performed in an actual operation site, which brings about a situation where the press straightening still has to depend on a pressing operation by a skilled worker.

[0010] The present inventors conducted detailed studies about a flaw of prior art and found that the straightening with high accuracy to perform needs slight adjustment in amount of bend in its final stage, that is, finish straightening; however, this case requires straightening working in a light load region where no clear transition to the plasticity region can be read even when a load-displacement curve is observed by on-line measurement. In other words, as illustrated in Figure 8, in a case where such minute bending is performed, transition to the plastic deformation region is observed in the press loading, as described in Patent Documents 1 and 2, and it was found that the finish straightening by the minute bending deformation, which is an objective, can be realized by, for example, operation of performing the unloading in the light load region, which is seemingly considered as the elastic deformation region, rather than the pressing operation that enters a region beyond a point B illustrated in Figure 7. Figure 8 is a diagram illustrating relation between load and amount of bend in pressing operation with various amounts of press stroke.

[0011] Is was further found that, in such a light-load deformation region, the inclination λ_2 at the unloading is not constant and subtly changes depending on a level of a value of a pressing-bottom-dead-center load value at start of the unloading, as described in Patent Documents 1 and 2. In Figure 8, pressing bottom dead center positions B3 and B4 correspond to a case where press working is performed beyond the point B in Figure 7. Pressing bottom dead center positions B1 and B2 correspond to press working in the light load region that is seemingly considered as the elastic deformation region. Here, inclinations at times of unloading at B1, B2, B3, and B4 are illustrated as $\lambda 21$, $\lambda 22$, $\lambda 23$, and $\lambda 24$; $\lambda 23$ and $\lambda 24$ are equal to each other as in prior art, while $\lambda 21$ and $\lambda 22$ in the light load region are different from each other. Therefore, a concept of prior art, in which an operation amount of the press working is determined by estimating the inclination $\lambda 2$ at the unloading with reference to a shape of the load-displacement curve in the pressing operation, cannot possibly realize the finish straightening. Hence, in a pressing operating region that is seemingly considered as the elasticity region, the present inventors conducted detailed studies about a relation between bottom dead center load P in the pressing operation and change $\Delta\delta$ in amount of bend of a pipe after unloading and determined, based on a database of the studies, to perform the unloading after performing the pressing operation until a pressing load P at which $\Delta\delta$ provides a target straightening amount δ_0 described above.

[0012] In addition, the present inventors found that determining an operation amount of pressing control to be a target load value to be applied to a steel material in a region that is not used in conventional practice makes the pressing control easy, which can increase an accuracy of the bend straightening as compared with the case of Patent Documents 1 and 2 where a displacement of the steel material in pressing is determined as the operation amount of the pressing control.

[0013] An objective of the present invention is to provide a method for bend straightening that includes determining a target load value, and performing pressing control using the target load value to increase the accuracy of the bend straightening.

SOLUTION TO PROBLEM

[0014] The present invention is a method for bend straightening in which a pipe body having a bend is placed in a state where the pipe body is convex upward, the pipe body is pressed from above by a press unit at a target load value, whereby the pipe body is straightened, the method including: (a) a step of measuring a bottom-dead-center load value when the press unit is at a bottom dead center in the pressing; (b) a step of measuring an amount of change in amount of bend between an amount of bend of the pipe body before the pressing in the step (a) and an amount of bend of the pipe body after the pressing in the step (a); (c) a step of repeating the step (a) and the step (b) a plurality of times to create a relation between the bottom-dead-center load value and the amount of change in the amount of bend; and (d) a step of determining a target load value for next pressing from the relation.

ADVANTAGEOUS EFFECTS OF INVENTION

[0015] According to the present invention, the bottom-dead-center load value and the amount of change in amount of bend are collected to create a relation between the bottom-dead-center load value and the amount of change in amount of bend, and from the relation, the target load value used for pressing the pipe body is determined. In addition, by using the target load value as an operation amount of pressing control, the pressing control can be made easy to perform, and an accuracy of bend straightening can be increased.

BRIEF DESCRIPTION OF DRAWINGS

[0016]

[Figure 1] Figure 1 is a diagram used for describing a press straightener that performs press straightening on a steel pipe.
[Figure 2] Figure 2 is a diagram used for describing an amount of bend of a steel pipe.
[Figure 3] Figure 3 is a diagram used for describing the rotation amplitude value measured by the displacement gauge.
[Figure 4] Figure 4 is a graph used for describing a relational expression $Pk = f(\Delta\delta)$.
[Figure 5] Figure 5 is a flowchart illustrating a procedure of a method for bend straightening.
[Figure 6] Figure 6 is a table showing experimental results obtained by performing the method for bend straightening using the relational expression $Pk = f(\Delta\delta)$.
[Figure 7] Figure 7 is a graph used for describing a conventional method for bend straightening.
[Figure 8] Figure 8 is a diagram illustrating a relation between load and amount of bend in pressing operation with various amounts of press stroke.

DESCRIPTION OF EMBODIMENTS

[0017] A method for bend straightening to be described below is a method for straightening a steel pipe being a pipe body by pressing a bend portion that occurs in the steel pipe using a press straightener.
[0018] Figure 1 is a diagram used for describing a press straightener 1 that performs press straightening on a steel pipe 100.
[0019] The steel pipe 100 that is to be subject to the press straightening by the press straightener 1 has, for example, a curve-like bend. The bend of the steel pipe 100 occurs in, for example, hot or cold working in a producing process of the steel pipe 100.
[0020] The press straightener 1 includes a two-point support 2. The two-point support 2 supports the steel pipe 100 at two points, with its axis direction set to be a horizontal direction. The steel pipe 100 is placed on the two-point support 2 to be convex upward.
[0021] The press straightener 1 includes a press unit 3. The press unit 3 includes a press cylinder 31 and a press plate 32. The press unit 3 presses the steel pipe 100 placed on the two-point support 2 to apply a load to the steel pipe 100.
[0022] The press cylinder 31 includes a rod not illustrated, which has a rod end provided with the press plate 32. The press cylinder 31 is coupled to a hydraulic unit 33 and expands and contracts the rod via working of the hydraulic unit 33 to perform ascending and descending operation of the press plate 32 and the pressing control on the steel pipe 100.
[0023] The press plate 32 ascends and descends via the expansion and contraction of the press cylinder 31. By the rod of the press cylinder 31 expanding, the press plate 32 presses the steel pipe 100 placed on the two-point support 2 from above, applying the load to the steel pipe 100.
[0024] The press cylinder 31 is provided with a load cell 34. The load cell 34 measures a load value P with which the press plate 32 presses the steel pipe 100. During the pressing by the press plate 32, the load cell 34 measures the load value P as appropriate and outputs a value of the measurement to a controller 10 described below.
[0025] The press straightener 1 is provided with a displacement gauge 4. The displacement gauge 4 measures an amount of bend δ of the steel pipe 100 being pressed by the press unit 3.
[0026] Figure 2 is a diagram used for describing the amount of bend δ of the steel pipe 100. The amount of bend δ is an amount of displacement from a reference level that is set at support points of the steel pipe 100 provided by the two-point support 2.
[0027] The displacement gauge 4 measures an amount of bend δ of the steel pipe 100 by the press unit 3 with respect to the axis direction of the steel pipe 100. The displacement gauge 4 outputs a value of the measurement to the controller 10 described below. The displacement gauge 4 may be of a contact type that comes in contact with the steel pipe 100

to measure the amount of bend δ or may be of a noncontact type that measures the amount of bend δ without contact with the steel pipe 100.

[0028] The press straightener 1 includes a pair of rotating rollers 51 and the displacement gauge 4. The pair of rotating rollers 51 rotates while sandwiching one end of the steel pipe 100 to hold the steel pipe 100. The press straightener 1 causes the press unit 3 to press the steel pipe 100, lifts up the steel pipe 100 from the two-point support 2 after unloading, and causes the pair rotating rollers 51 to rotate the steel pipe 100.

[0029] The displacement gauge 4 measures a rotation amplitude value S of the steel pipe 100 rotated by the pair rotating rollers 51. The rotation amplitude value S is measured by the displacement gauge 4, and half of the rotation amplitude value can be measured as a residual amount of bend δa of the steel pipe 100 after the pressing. The displacement gauge 4 is, for example, a dial gauge.

[0030] Figure 3 is a diagram used for describing the rotation amplitude value S measured by the displacement gauge 4.

[0031] When the pressing by the press unit 3 starts, the steel pipe 100 deforms elastically, and as the pressing further continues, the steel pipe 100 deforms plastically. When the steel pipe 100 is unloaded being bent in the plastic deformation region, the steel pipe 100 maintains its bent state. In the state where the steel pipe 100 is deformed plastically after the unloading, the amount of bend δ from the reference level described above is the residual amount of bend δa.

[0032] The displacement gauge 4 measures the rotation amplitude value S of the steel pipe 100 rotated by the pair rotating rollers 51 when the steel pipe 100 is bent downward. In other words, the residual amount of bend δa of the steel pipe 100 after the pressing is obtained by halving the rotation amplitude value S measured by the displacement gauge 4.

[0033] Return to Figure 1. The press straightener 1 includes the controller 10. The controller 10 is, for example, a control circuit using a PC or the like. The controller 10 drives and controls the hydraulic unit 33 to press the steel pipe 100. The controller 10 drives and controls the pair of rotating rollers 51 to rotate the steel pipe 100 about a rotation axis Ax.

[0034] The controller 10 acquires results of the measurement from the load cell 34 and the displacement gauge 4.

[0035] The controller 10 uses the value of the measurement by the load cell 34 to perform feedback control on the hydraulic unit 33 and perform the pressing control on the press unit 3. In the pressing, the controller 10 measures a bottom-dead-center load value Pk when the press unit 3 is at its bottom dead center. When the press unit 3 is at its bottom dead center refers to when the rod (not illustrated) of the press cylinder 31 is at its bottom dead center.

[0036] From the value of the measurement by the displacement gauge 4, the controller 10 measures an amount of change $\Delta\delta$ between the amount of bend δ of the steel pipe 100 before the pressing and the amount of bend δ of the steel pipe 100 after the pressing. Here, after the pressing means a state where the load of the pressing is removed, and no load is applied to the steel pipe 100 by the press unit 3.

[0037] In addition, the controller 10 measures the residual amount of bend δa of the steel pipe 100 from the rotation amplitude value S measured by the displacement gauge 4, as described with reference to Figure 3.

[0038] The controller 10 collects pluralities of bottom-dead-center load values Pk and amounts of change $\Delta\delta$ to create $Pk = f(\Delta\delta)$, a relational expression of Pk-$\Delta\delta$.

[0039] Figure 4 is a graph used for describing the relational expression $Pk = f(\Delta\delta)$. In Figure 4, black dots each indicate a bottom-dead-center load value Pk and an amount of change $\Delta\delta$ measured in one press. Figure 4 illustrates data in a case where carbon steel pipes each of which has an outer diameter of 34 mm and a wall thickness of 2.6 mm are supported at a press span of 1500 mm and pressed by the press unit 3. The press span is a distance between the two support points with which the two-point support 2 supports the steel pipe 100.

[0040] In Figure 4, for example, in a case where the steel pipe 100 is pressed with a bottom-dead-center load value Pk of 2.9 [kN], the amount of change $\Delta\delta$ in the amount of bend δ of the steel pipe 100 before and after the pressing is about 0.4 [mm]. In this case, the steel pipe 100 is deformed plastically.

[0041] In contrast, for example, in a case where the steel pipe 100 is pressed with a bottom-dead-center load value Pk of 2.7 [kN], the amount of change $\Delta\delta$ in the amount of bend δ of the steel pipe 100 before and after the pressing is about 0 [mm]. In this case, the steel pipe 100 is deformed elastically.

[0042] After collecting the pluralities of bottom-dead-center load values Pk and amounts of change $\Delta\delta$ measured, the controller 10 creates $Pk = f(\Delta\delta)$, the relational expression of Pk-$\Delta\delta$. The relational expression $Pk = f(\Delta\delta)$ is a regression formula that is acquired from a plurality of data items, as illustrated as a solid line in Figure 4. The relational expression $Pk = f(\Delta\delta)$ is expressed by Formula (1) shown below.

$$Pk = a\cdot\Delta\delta^4 + b\cdot\Delta\delta^3 + c\cdot\Delta\delta^2 + d\cdot\Delta\delta + e \qquad (1)$$

where a = -0.0269, b = 0.174, c = -0.416, d = 0.467, e = 2.77. Note that Formula (1) is updated whenever a bottom-dead-center load value Pk and an amount of change $\Delta\delta$ are measured.

[0043] From the relational expression $Pk = f(\Delta\delta)$ shown by Formula (1) and the residual amount of bend δa of the steel pipe 100, the controller 10 determines a load value for the next pressing (hereinafter, referred to as target load value Pa). Using the relational expression $Pk = f(\Delta\delta)$ makes it possible to determine a load value necessary to perform the bend straightening by deforming the steel pipe 100 plastically by the residual amount of bend δa. For example, in a case where the residual amount of bend δa of the steel pipe 100 is about 1.8 mm, a load value necessary to deform the steel pipe 100 plastically by about 1.8 mm is about 3.0 kN (see Figure 4). The controller 10 sets a target load value Pa at about 3.0 kN to press the steel pipe 100.

[0044] When performing the pressing at the target load value Pa, the controller 10 performs feedback control on the hydraulic unit 33 to press the steel pipe 100 with reference to the result of the measurement by the load cell 34. The controller 10 then repeats the pressing of the steel pipe 100 until the residual amount of bend δa becomes not more than a threshold value, so as to straighten the steel pipe 100. The threshold value is preferably 1 mm, more preferably 0.5 mm.

[0045] A method for bend straightening performed by the press straightener 1 will be described below in detail. Figure 5 is a flowchart illustrating a procedure of the method for bend straightening.

[0046] First, the controller 10 causes the press unit 3 to press the steel pipe 100 (S1). Specifically, the controller 10 operates the hydraulic unit 33 to expand the rod of the press cylinder 31. The controller 10 then uses the press plate 32 to press the steel pipe 100 placed on the two-point support 2. At this time, the controller 10 controls the hydraulic unit 33 such that the load value P becomes the target load value Pa while acquiring the result of the measurement by the load cell 34.

[0047] In a case where step S1 is performed first in the production or the relational expression Pk = f(Δδ) described above is not created with high accuracy because the database is built insufficiently, that is, in a case where the target load value Pa is not determined strictly from the relational expression Pk = f(Δδ), the controller 10 may start the operation based on a material strength level of the material and a simple elastic bending deformation prediction formula. Alternatively, the pressing may be performed according to an empirical rule of a worker or a load value determined by another method.

[0048] Next, the controller 10 measures the bottom-dead-center load value Pk (S2). Thereafter, the controller 10 performs unloading (S3) and measures the amount of change Δδ (S4). The amount of change Δδ is measured as the difference between the amount of bend δ of the steel pipe 100 before the pressing and the amount of bend δ of the steel pipe 100 after the pressing, as described above.

[0049] In step S5, from the bottom-dead-center load value Pk and the amount of change Δδ, the controller 10 creates the relational expression Pk = f(Δδ). At this time, in a case where the relational expression Pk = f(Δδ) has not been created, the controller 10 repeats step S1 to step S4 a plurality of times to collect pluralities of bottom-dead-center load values Pk and amounts of change Δδ, and then create the relational expression Pk = f(Δδ). In contrast, in a case where the relational expression Pk = f(Δδ) has already been created, the controller 10 uses the bottom-dead-center load value Pk measured in step S2 and the amount of change Δδ measured in step S4 to update the relational expression Pk = f(Δδ).

[0050] Subsequently, the controller 10 controls the rotation of the pair of rotating rollers 51 to rotate the steel pipe 100 (S6). The controller 10 causes the displacement gauge 4 to measure the rotation amplitude value S (S7). The controller 10 determines the residual amount of bend δa of the steel pipe 100 from the measured rotation amplitude value S (S8).

[0051] The controller 10 determines whether the residual amount of bend δa of the steel pipe 100 after the straightening is not more than the threshold value (e.g., 1 mm or 0.5 mm) (S9). When the residual amount of bend δa is not more than the threshold value (S9: YES), the controller 10 determines that the steel pipe 100 is straight. The method for bend straightening is thus finished.

[0052] When the residual amount of bend δa is more than the threshold value (S9: NO), the controller 10 determines that the steel pipe 100 is not straight. The controller 10 then determines the target load value Pa from the relational expression Pk = f(Δδ) and the residual amount of bend δa (S10). Specifically, the controller 10 substitutes the residual amount of bend δa for Δδ in Formula (1) to calculate the load value Pk. The controller 10 determines the calculated load value Pk as the target load value Pa.

[0053] The controller 10 returns to step S1 to press the steel pipe 100 with the determined target load value Pa. In a case where the steel pipe 100 is convex downward before being pressed in step S1, the steel pipe 100 is rotated to be convex upward.

[0054] By repeating the process described above, the bend of the steel pipe 100 is straightened, and the steel pipe 100 becomes straight. Since the relational expression Pk = f(Δδ) is updated whenever necessary, a reliability of the target load value Pa determined from the relational expression Pk = f(Δδ) increases as the pressing for the bend straightening is repeated. As a result, an accuracy of the bend straightening increases.

[0055] Figure 6 is a table showing experimental results obtained by performing the method for bend straightening using the relational expression Pk = f(Δδ). In Figure 6, "Path" means the process for performing the pressing by the press unit 3. "Path No" of "1" means that the steel pipe 100 is pressed once, and "Path No" of "2" means that the steel pipe 100 is pressed twice. "Actual load value" is a load value P measured by the load cell 34 when the controller 10 controls the hydraulic unit 33 to perform the pressing with the "Target load value Pa".

[0056] In the method for bend straightening of the present embodiment, the pressing control is performed using only the target load value Pa without measuring the amount of bend of the steel pipe 100 being pressed. Furthermore, as shown in Figure 6, the actual load value substantially matches the target load value Pa. In other words, in the present embodiment, the pressing control is performed accurately. As a result, as read from Figure 6, the amount of bend δ of the steel pipe 100 is 0.5 mm or less at fourth pressing. As seen from the above, the method for bend straightening of the present embodiment provides results of high accuracy.

[0057] As described above, in conventional practice, the bend straightening is performed while observing a displacement of a steel pipe being pressed in the plastic deformation region using the inclination $\lambda 2$ of an unload curve created in the plastic deformation region, as illustrated in Figure 7; in contrast, in the present embodiment, the relation expressed by Formula (1) shown above is created in (the region where the load increases with the inclination $\lambda 1$), which is seemingly observed as the elastic deformation region immediately after starting the press loading illustrated in Figure 7. Then, in the region, the bend straightening is performed at the target load value Pa determined from the relation expressed by Formula (1). Using the load value as a control parameter dispenses with the observation of the displacement of the steel pipe being pressed in the bend straightening as in conventional practice, and the pressing control can be performed with high accuracy even when an amount of bend displacement is small. In particular, the present embodiment is effective when a quality level of 1 mm to 0.5 mm or less per length of 1 m in terms of the bend displacement is required.

REFERENCE SIGNS LIST

[0058]

1	press straightener
2	two-point support
3	press unit
4	displacement gauge
10	controller
31	press cylinder
32	press plate
33	hydraulic unit
34	load cell
51	rotating roller
100	steel pipe

Claims

1. A method for bend straightening in which a pipe body having a bend is placed in a state where the pipe body is convex upward, the pipe body is pressed from above by a press unit at a target load value, whereby the pipe body is straightened, the method comprising:

(a) a step of measuring a bottom-dead-center load value when the press unit is at a bottom dead center in the pressing;
(b) a step of measuring an amount of change in amount of bend between an amount of bend of the pipe body before the pressing in the step (a) and an amount of bend of the pipe body after the pressing in the step (a);
(c) a step of repeating the step (a) and the step (b) a plurality of times to create a relation between the bottom-dead-center load value and the amount of change in the amount of bend; and
(d) a step of determining a target load value for next pressing from the relation.

2. The method for bend straightening according to claim 1, further comprising:

(e) a step of measuring the bottom-dead-center load value when the press unit is at the bottom dead center in a case where the pressing is performed at the target load value determined in the step (d);
(f) a step of measuring an amount of change in amount of bend between an amount of bend of the pipe body before the pressing in the step (e) and an amount of bend of the pipe body after the pressing in the step (e); and
(g) a step of updating the relation using the bottom-dead-center load value measured in the step (e) and the amount of change in the amount of bend measured in the step (f).

3. The method for bend straightening according to claim 1 or claim 2, further comprising
(h) a step of measuring a residual amount of bend of the pipe body after the pressing, wherein
in the step (d), the target load value is determined from the relation and the residual amount of bend.

4. The method for bend straightening according to claim 3, wherein in the step (h), after the pressing, the pipe body is rotated about an axis direction, a rotation amplitude value of the pipe body is measured, and from the rotation amplitude value, the residual amount of bend is measured.

5. The method for bend straightening according to any one of claim 1 to claim 4, wherein the steps (a) to (d) are repeated until an amount of bend of the pipe body after the pressing is equal to or less than a threshold value.

6. The method for bend straightening according to any one of claim 1 to claim 5, wherein the pipe body is a steel pipe.

Fig.1

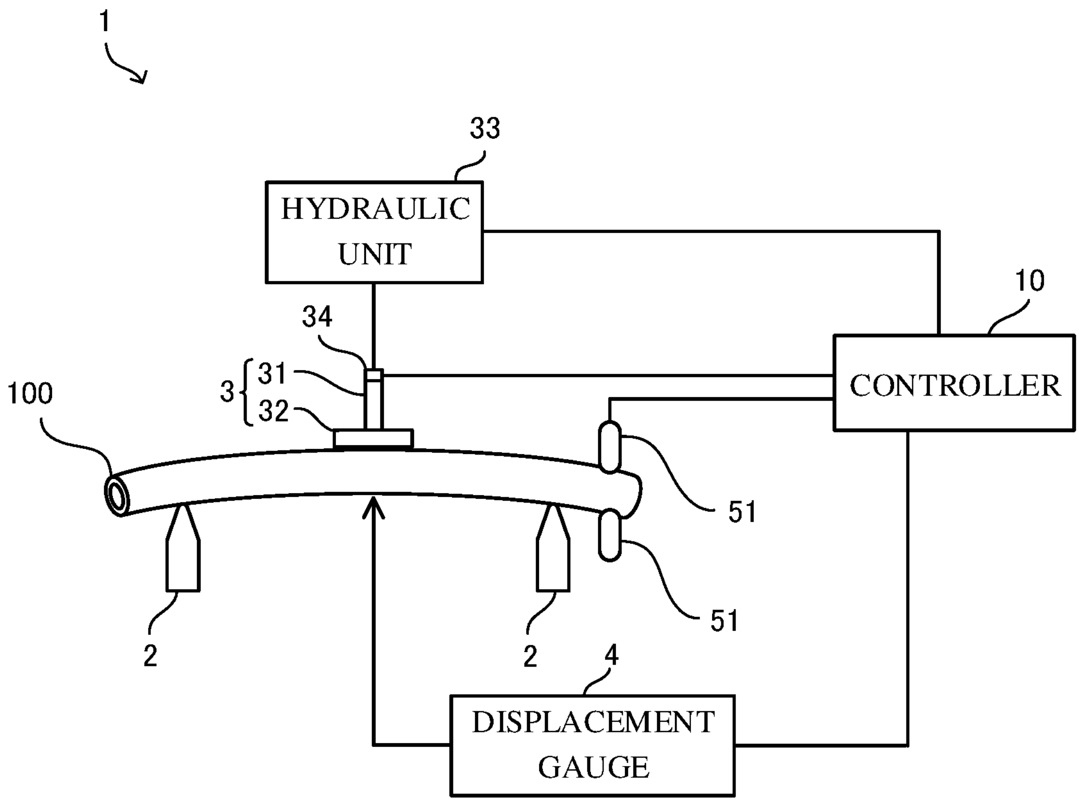

1
33
HYDRAULIC UNIT
10
34
3
31
32
100
CONTROLLER
51
51
2
2
4
DISPLACEMENT GAUGE

Fig.2

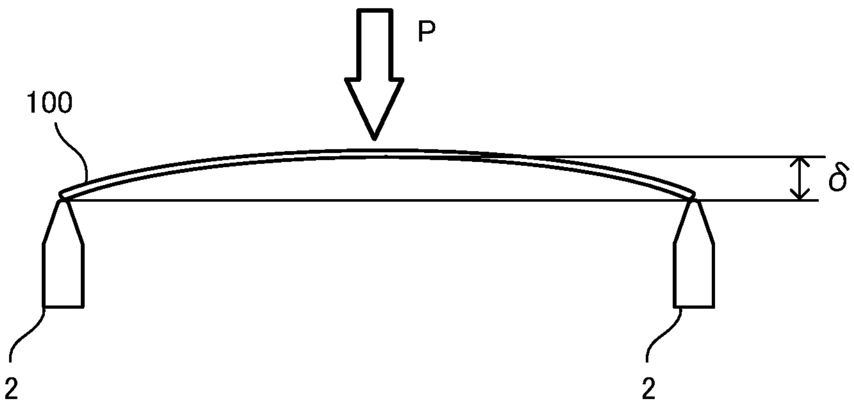


Fig.3

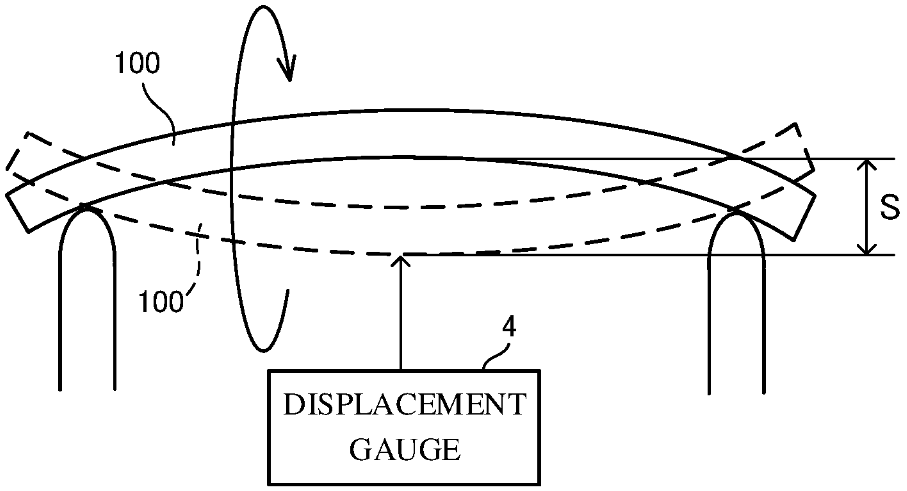


Fig.4

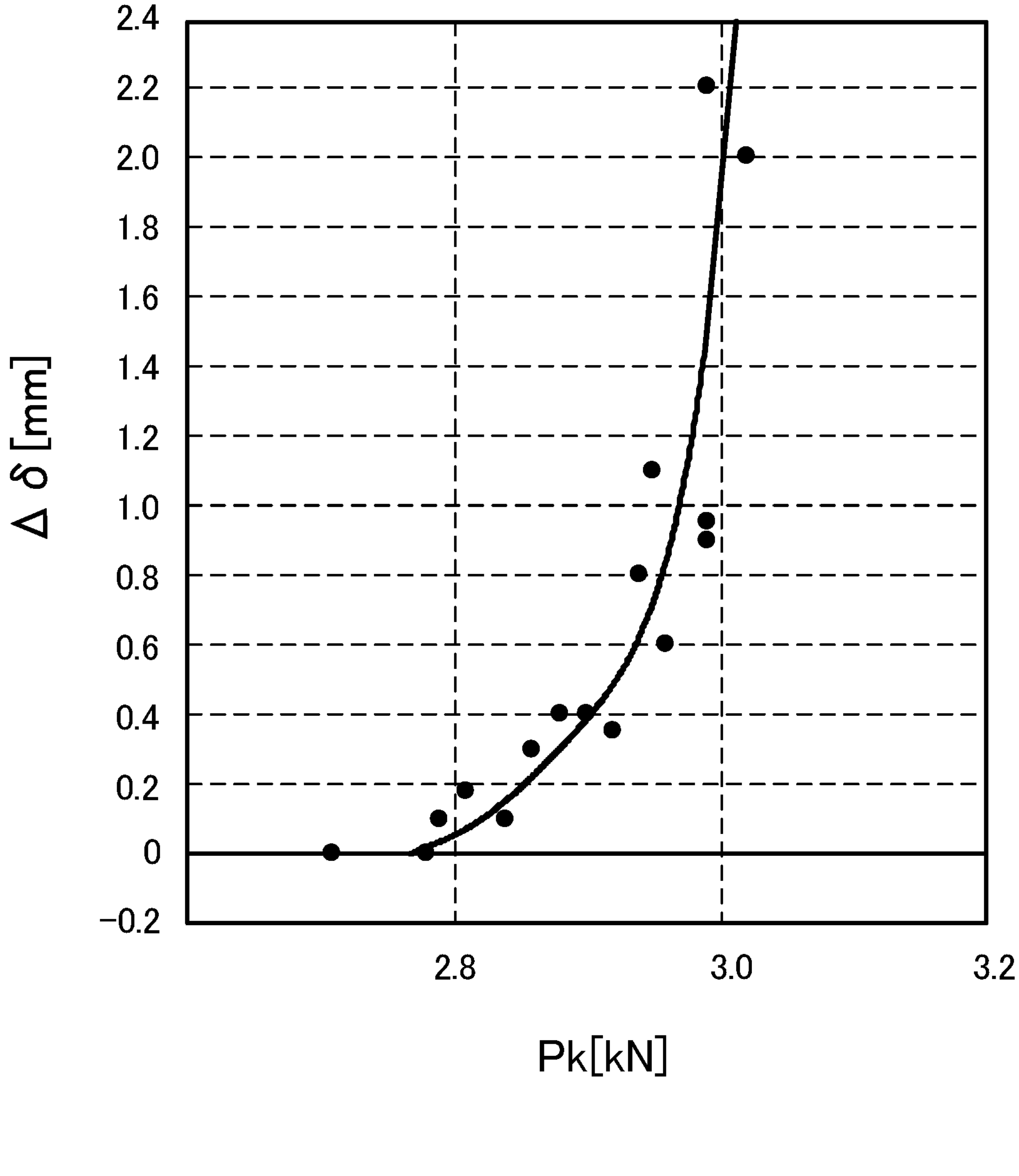


Fig.5

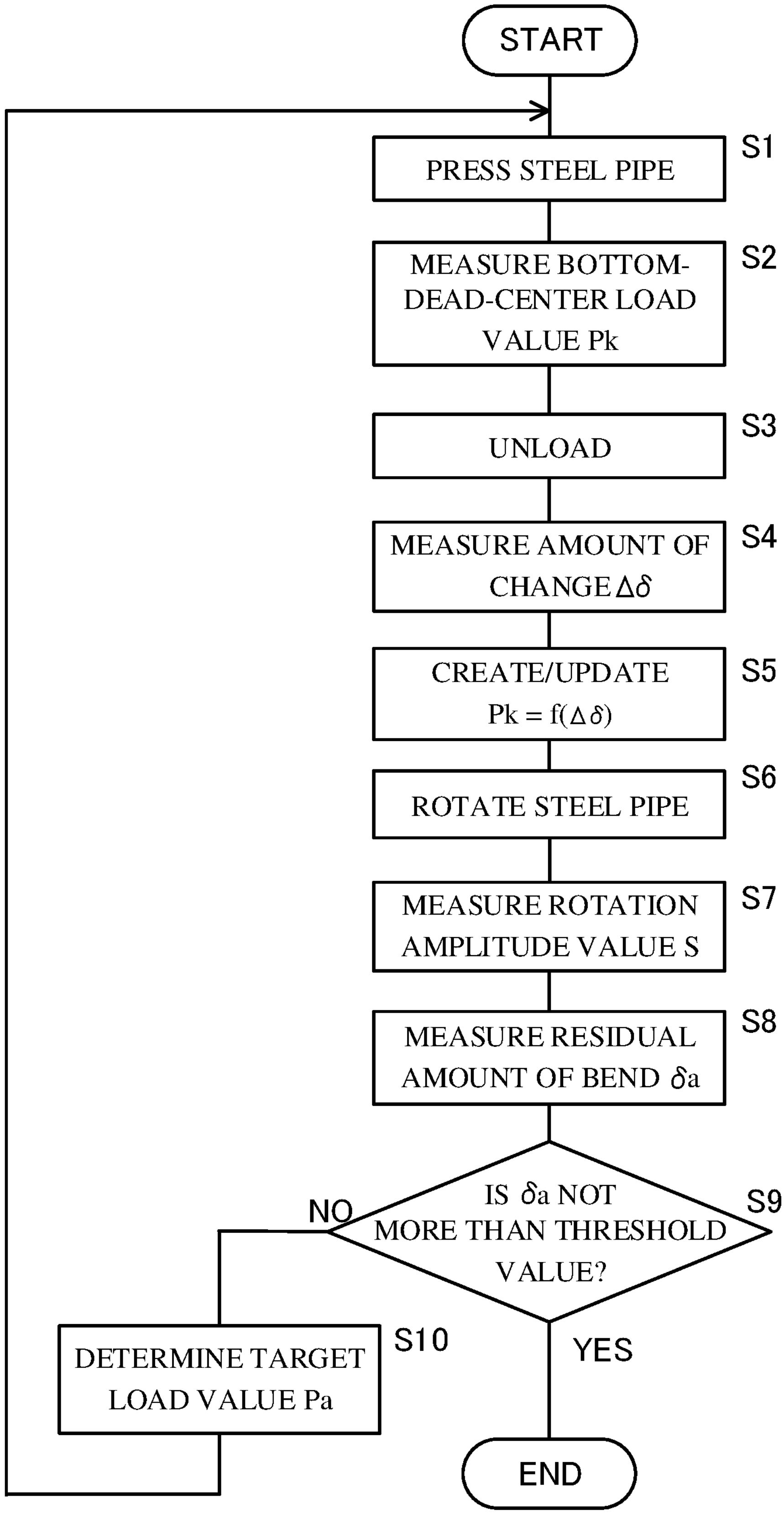

START
PRESS STEEL PIPE
S1
MEASURE BOTTOM-DEAD-CENTER LOAD VALUE Pk
S2
UNLOAD
S3
MEASURE AMOUNT OF CHANGE Δδ
S4
CREATE/UPDATE Pk = f(Δδ)
S5
ROTATE STEEL PIPE
S6
MEASURE ROTATION AMPLITUDE VALUE S
S7
MEASURE RESIDUAL AMOUNT OF BEND δa
S8
IS δa NOT MORE THAN THRESHOLD VALUE?
S9
NO
YES
DETERMINE TARGET LOAD VALUE Pa
S10
END

Fig.6

Path No	Target load value Pa [kN]	Actual load value [kN]	Amount of bend displacement δ [mm]		
			Before straightening	After straightening	Amount of change
1	3.01	3.00	2.5	1.5	1.0
2	2.99	2.99	1.5	1.0	0.5
3	2.97	2.97	1.0	0.6	0.4
4	2.93	2.93	0.6	0.3	0.3

Fig.7

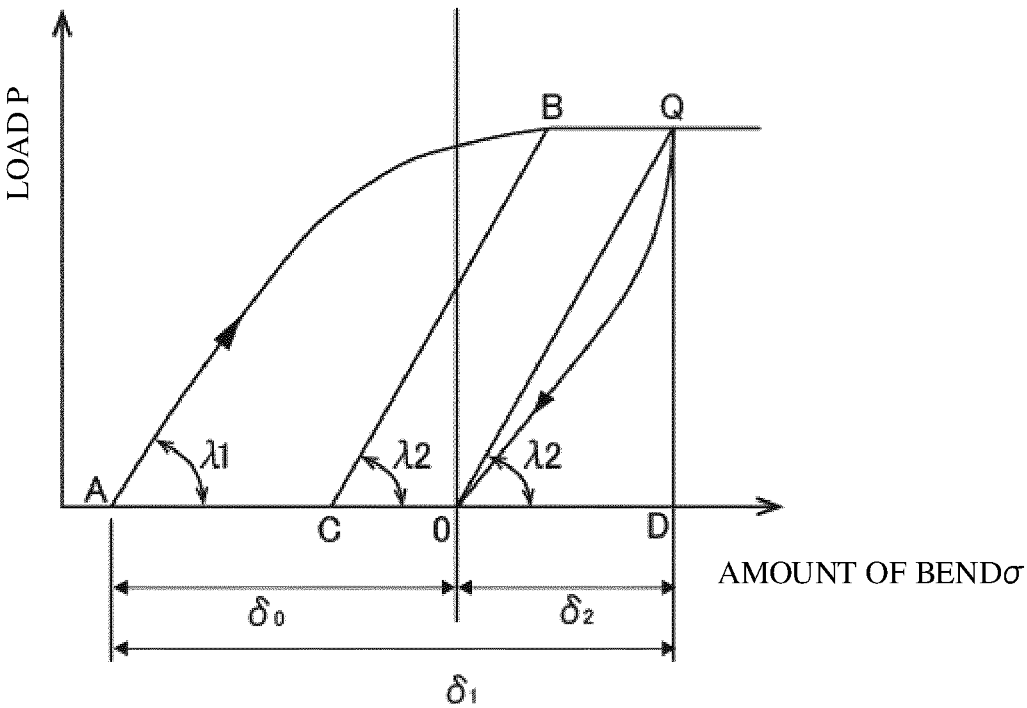
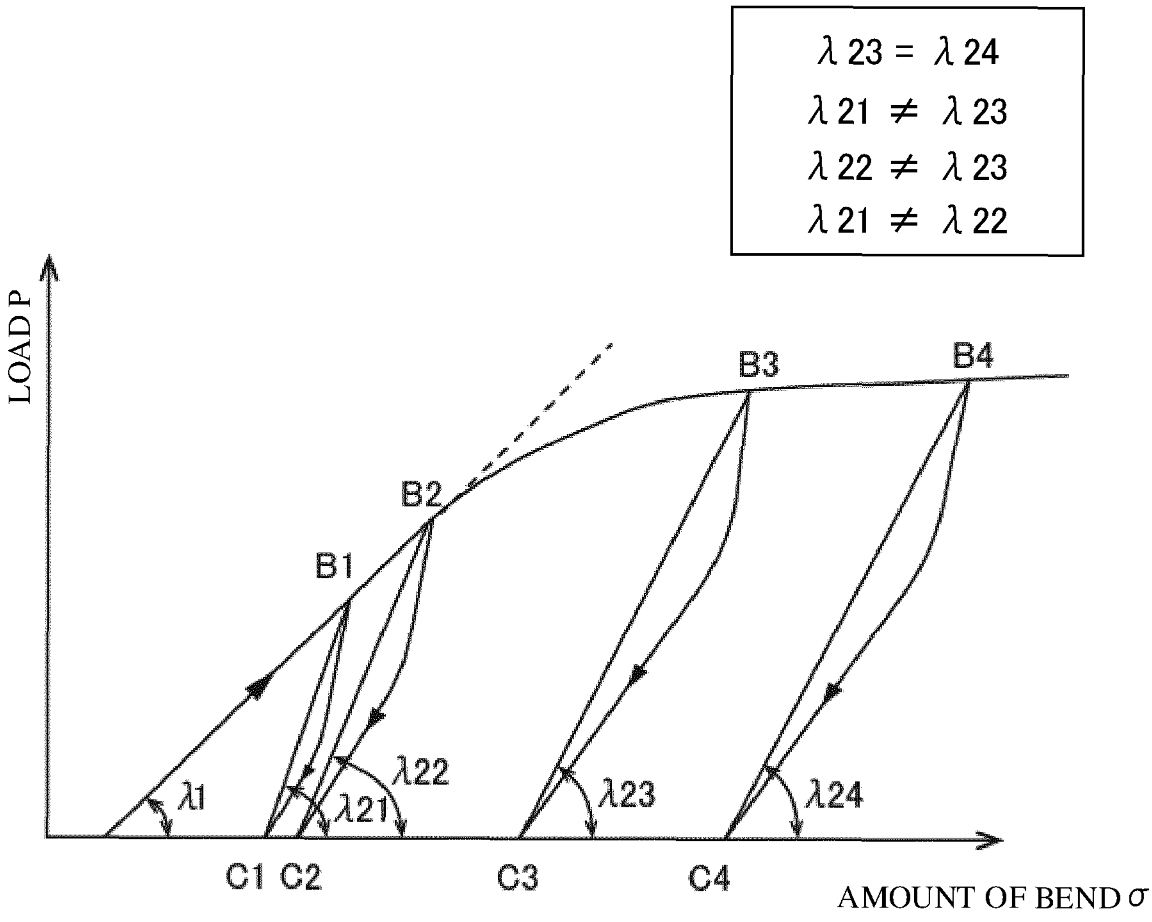


Fig.8


λ23 = λ24
λ21 ≠ λ23
λ22 ≠ λ23
λ21 ≠ λ22
LOAD P
B1
B2
B3
B4
λ1
λ21
λ22
λ23
λ24
C1 C2
C3
C4
AMOUNT OF BEND σ

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/030998

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. B21D3/10(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. B21D3/10, B21D7/00

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2019
Registered utility model specifications of Japan	1996-2019
Published registered utility model applications of Japan	1994-2019

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2-192820 A (SUMITOMO METAL INDUSTRIES, LTD.) 30 July 1990, page 3, upper left column, line 7 to page 3, upper right column, line 5, page 3, lower left column, line 5 to lower left column, line 11, page 5, lower right column, line 2, fig. 1 (Family: none)	1-6
Y	JP 49-130303 A (TOYOTA MOTOR INDUSTRY CO., LTD.) 13 December 1974, page 2, upper left column, line 12 to page 3, lower right column, line 2, fig. 1-6 (Family: none)	1-6

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
28 October 2019 (28.10.2019)	05 November 2019 (05.11.2019)

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

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

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/030998

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 63-144822 A (NIPPON STEEL CORP.) 17 June 1988, page 2, upper left column, line 16 to page 10, upper right column, line 20, fig. 1-8 (Family: none)	1-6
A	JP 63-199026 A (TOYOTA CENTRAL R&D LABS., INC.) 17 August 1988, page 4, upper right column, line 3 to page 13, lower right column, line 11, fig. 1-10 (Family: none)	1-6

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 63199025 A **[0007]**
- JP 10005872 A **[0007]**