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(71) Applicant: **SUMITOMO METAL INDUSTRIES, LTD.**
Osaka-shi,
Osaka 541-0041 (JP)

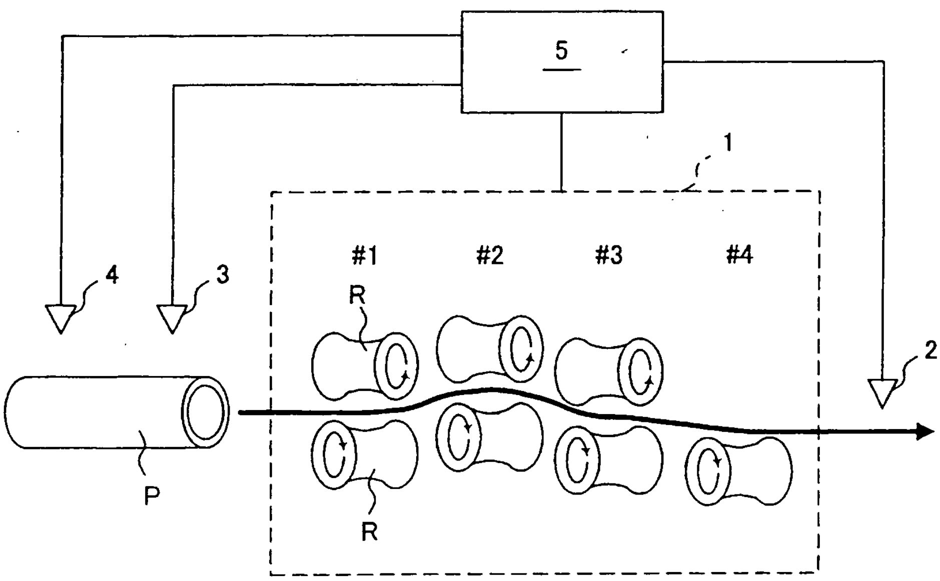
(72) Inventor: **KISHI, Masatomo**
c/o SUMITOMO METAL INDUSTRIES, LTD
Osaka-shi Osaka 5410041 (JP)

(74) Representative: **Jackson, Martin Peter**
J.A. Kemp & Co.,
14 South Square,
Gray's Inn
London WC1R 5JJ (GB)

(54) AUTOMATIC CONTROL METHOD OF ROLL TYPE PIPE CORRECTION MACHINE

(57) An automatic control method for a roll-type pipe straightener which can obtain a stable straightening effect is provided. When crushing a pipe using a straightener having at least three stands each having a pair of grooved rolls to perform straightening, automatic control is performed by first through fourth steps. First step: The relationship between the set value of the offset and the amount of bending of a pipe measured on the exit side of the straightener is previously calculated. Second step: The amount of bending of a pipe on the exit side of the straightener is measured. Third step: When the amount of bending measured in the second step is outside a target range, the amount of change of the offset to put the amount of bending of the pipe on the exit side of the straightener into the target range is calculated based on the relationship calculated in the first step. Fourth step: The set value of the offset when straightening the next pipe is determined based on the amount of change of the offset calculated in the third step.

Fig. 2



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Description

Technical Field

[0001] This invention relates to an automatic control method of a roll-type pipe straightener for straightening pipes such as steel pipes. In particular, it relates to an automatic control method for a roll-type pipe straightener which can obtain a stable straightening effect.

Background Art

[0002] Pipes manufactured by various pipe manufacturing methods are finished by various types of treatment to obtain a prescribed quality. Straightening is one such finishing process. It has the object of removing bends from a manufactured pipe to straighten the pipe as well as changing the external shape of the pipe from an elliptical shape to a perfectly circular shape.

[0003] In general, as shown in Figure 1, a roll-type pipe straightener which is used for straightening has at least three stands each equipped with a pair of opposing grooved rolls R,R. A roll-type pipe straightener offsets the pair of grooved rolls R,R in the #2 stand by a predetermined (amount of) offset with respect to the pairs of grooved rolls R,R in the #1 and #3 stands (the distance between the center of the grooves of the pair of grooved rolls R,R of the #2 stand and the center of the grooves of the pairs of grooved rolls R,R of the #1 and #3 stands), and the pipe P is crushed by the pairs of grooved rolls R,R in the #1 - #3 stands by a predetermined crushing amount (the difference between the target outer diameter D of the pipe P on the entrance side of the #1 - #3 stands and the spacing H between the groove bottom portions of the opposing pairs of grooved rolls R,R), thereby achieving straightening. The grooved roll R in the #4 stand functions as a guide roll.

[0004] The offset and the crushing amount of the grooved rolls in the #2 stand are important factors in determining the straightening effect of a pipe P. Thus far, various inventions related to setting the offset and the crushing amount have been disclosed.

[0005] For example, Patent Document 1 discloses an invention in which the load which develops on the grooved rolls in each stand is measured, and the offset and the crushing amount are set so that this load becomes a previously determined suitable value.

[0006] Patent Document 2 discloses an invention which predicts the amount of wear of grooved rolls and sets the offset, the crushing amount, and other factors in accordance with the predicted amount of wear.

[0007] Patent Document 3 discloses an invention in which the offset and the crushing amount are set based on a theoretical formula for the behavior in deformation of a pipe in a straightening process.

Patent Document 1: JP 2001-179340 A1
Patent Document 2: JP H02-207921 A1
Patent Document 3: JP H04-72619 B2

Disclosure of Invention

[0008] The inventions disclosed in Patent Documents 1 - 3 merely set the offset and the crushing amount based on a prediction that a good pipe straightening effect will be obtained, and they do not reflect the actual amount of bending or the ellipticity of a pipe on the exit side of a straightener. Therefore, the straightening effect with these inventions is not stable, and it is difficult to keep the amount of bending and the ellipticity within a target range.

[0009] At present, in order to incorporate the amount of bending and the ellipticity of a pipe on the exit side of a straightener into the inventions disclosed by Patent Documents 1 - 3, an operator visually ascertains the extent of bending or ellipticity of a pipe, and the offset and the crushing amount are manually set based on the experience and intuition of the operator. Since the offset and the crushing amount are manually set based on the experience and the intuition of the operator, the straightening effect remains unstable.

[0010] The present invention is an automatic control method for a roll-type pipe straightener which has at least 3 stands each provided with a pair of opposing grooved rolls and arranged such that the pair of grooved rolls in at least one stand are offset with respect to the pairs of grooved rolls in the other stands and which perform straightening by crushing a pipe with the pairs of grooved rolls in each of the stands. The method comprises the below-described step 1 (first step) through step 4 (fourth step). In this description, "automatic control" means control which is automatically carried out using a controller. Namely, the present invention automatically controls the following first through fourth steps using a controller.

[0011] In the first step, the relationship between the set value of the offset and the amount of bending of a pipe measured at least on the exit side of the roll-type pipe straightener is previously calculated. Namely, by measuring the amounts of bending r on the exit side of the roll-type pipe straightener for each of a plurality of pipes which were straightened using different settings for the offset δo, the relationship between these two parameters, i.e., the function f in the equation $\delta o = f(r)$ is calculated.

[0012] In the second step, the amount of bending of a pipe is measured at least on the exit side of the roll-type pipe straightener. Namely, the amount of bending r1 of the pipe P which was just straightened is measured.

[0013] In the third step, when the amount of bending r1 of the pipe on the exit side of the roll-type pipe straightener which was measured in the second step is outside a target range, based on the relationship $\delta o = f(r)$ calculated in the first step between the set value of the offset and the amount of bending of a pipe measured at least on the exit side of the roll-type pipe straightener, the change in the offset necessary to put the amount of bending of the pipe on the exit side of the roll-type pipe straightener inside the target range is calculated. Namely, if the target value of the amount of bending of the pipe (an arbitrary value within the target range) is r', the set value for the offset δo' which is required in order to obtain this target value r', is found by δo' = f(r'). Therefore, if the set value of the offset for the pipe which was just straightened is δo1, the necessary amount of change Δδo of the offset is calculated as Δδo = δo' - δo1.

[0014] In the fourth step, based on the amount of change Δδo of the offset calculated in the third step, the set value of the offset when straightening the next pipe P' is determined. Namely, if the set value of the offset when straightening the next pipe P' is δo2, it is determined by δo2 = δo1 + Δδo. At this time, in order to prevent divergence, Δδo may be multiplied by a slack coefficient in the range of 0 to 1.

[0015] In this manner, an automatic control method for a roll-type pipe straightener according to the present invention measures the amount of bending of a pipe on the exit side of a straightener and changes the offset when straightening the next pipe so that the measured value will be within a target range for the amount of bending. Namely, it performs feedback of the measured amount of bending of a pipe on the exit side of a straightener and changes the offset. Therefore, bending of the pipe can be stably straightened. "The amount of bending of a pipe" is defined by the amount of deviation of the center of the pipe cross section divided by the length of the pipe in the portion measured (mm/m). The amount of bending of a pipe can be measured by, for example, disposing an outer diameter gauge for measuring the outer diameter of a pipe in a plurality of radial directions on the exit side of a roll-type pipe straightener, calculating the position of the center of the pipe cross section based on the location of measurement of the outer diameter in each of the radial directions by the outer diameter gauge, and calculating the amount of variation of the center in the lengthwise direction of the pipe.

[0016] The amount of bending of a pipe on the exit side of a roll-type pipe straightener and therefore the necessary amount of variation of the offset varies in accordance with the amount of bending of the pipe on the entrance side of the roll-type pipe straightener. Namely, when the amount of bending on the entrance side of the roll-type pipe straightener is larger than for the previous pipe which was straightened, the offset is made larger than for the previous time. Conversely when the amount of bending on the entrance side is smaller than for the previous pipe to be straightened, the offset is made smaller than for the previous time. Therefore, in order to obtain a more stable straightening effect, preferably the amount of pipe bending on the entrance side of a roll-type pipe straightener is also measured, and this amount of bending is fed forward and used to change the offset.

[0017] Accordingly, in a preferred mode of the present invention, in a first step, the relationship among the set value of the offset and the measured amount of bending of a pipe on the entrance side and the exit side of a roll-type pipe straightener is previously calculated. Namely, the amounts of bending ri and ro on the entrance side and the exit side, respectively, of a roll-type pipe straightener are measured for a plurality of pipes which were straightened using different settings for the offset δo, and the function f in the equation δo = f(ri, ro) is previously calculated.

[0018] In a second step, the amount of bending ro1 on the exit side of the roll-type pipe straightener of the pipe P which was just straightened is measured, and the amount of bending ri2 on the entrance side of the roll-type pipe straightener of the next pipe to be straightened P' is measured.

[0019] In a third step, if the amount of bending ro1 which was measured in the second step on the exit side of the roll-type pipe straightener of the pipe P which was just straightened is outside a target range, based on the amount of bending ri2 on the entrance side of the roll-type pipe straightener of the next pipe to be straightened which was measured in the second step and the relationship δo = f(ri, ro) which was calculated in the first step among the set value of the offset and the amount of bending of the pipe measured on the entrance side and the exit side of the roll-type pipe straightener, the necessary change in the offset in order to put the amount of bending of the pipe on the exit side of the roll-type pipe straightener into the target range is calculated. Namely, the set value δo' of the offset which is required in order to obtain a target value ro' for the amount of bending of the pipe on the exit side of the roll-type pipe straightener is found from δo = f(ri2, ro'). Therefore, if the set value of the offset of the pipe which was just straightened is δo1, the necessary amount of change Δδo of the offset is calculated as Δδo = δo' - δo1.

[0020] The amount of bending of a pipe on the exit side of a roll-type pipe straightener and therefore the necessary amount of change of the offset also varies in accordance with the temperature of the pipe on the entrance side of the roll-type pipe straightener. Namely, when the temperature of a pipe on the entrance side of a roll-type pipe straightener is higher than the temperature of the previous pipe to be straightened, deformation becomes easier so the offset is made smaller than the previous time. Conversely, when the temperature of a pipe on the entrance side is lower than the temperature of the previous pipe to be straightened, the offset is made larger than the previous time. Therefore, in order to obtain a more stable straightening effect, preferably, the temperature of a pipe on the entrance side of a roll-type pipe straightener is measured, and the measured temperature is fed forward and used to change the offset.

[0021] Accordingly, in a preferred mode of the present invention, in a first step, the relationship among the set value of the offset, the amount of bending of a pipe measured on the exit side of a roll-type pipe straightener, and the temperature of a pipe measured on the entrance side of the roll-type pipe straightener is calculated. Namely, by measuring the amount of bending r on the exit side of the roll-type pipe straightener and the temperature T on the entrance side of the roll-type pipe straightener for a plurality of pipes which were straightened using different settings for the offset δo, the function f in the relationship δo = f(r, T) among them is previously calculated.

[0022] In a second step, the amount of bending r1 of the pipe P which was just straightened is measured on the exit side of the roll-type pipe straightener, and the temperature T2 of the next pipe to be straightened P' is measured on the entrance side of the roll-type pipe straightener.

[0023] In a third step, when the amount of bending r1 on the exit side of the roll-type pipe straightener of the pipe P which was just straightened which was measured in the second step is outside a target range, the necessary amount of change in the offset in order to put the amount of bending of the pipe on the exit side of the roll-type pipe straightener within the target range is calculated based on the pipe temperature T2 which was measured in the second step of the next pipe to be straightened P' on the entrance side of the roll-type pipe straightener and the relationship δo = f(r, T) which was calculated in the first step among the set value of the offset, the amount of bending of the pipe measured on the exit side of the roll-type pipe straightener, and the temperature of the pipe measured on the entrance side of the roll-type pipe straightener. Namely, the set value δo' of the target offset in order to obtain a target value r' for the amount of bending of the pipe on the exit side of the roll-type pipe straightener is found from δo' = f(r', T2). Accordingly, if the set value of the offset of the pipe which was just straightened is δo1, the necessary amount of change Δδo of the offset is calculated as Δδo = δo' - δo1.

[0024] The present invention also provides an automatic control method for a roll-type pipe straightener which has at least 3 stands each provided with a pair of opposing grooved rolls and which perform straightening by offsetting the pair of grooved rolls in at least one stand with respect to the pairs of grooved rolls in the other stands and crushing a pipe with the pairs of grooved rolls in each of the stands, the method comprising the below-described first through fourth steps.

[0025] In the first step, the relationship between the set value of the crushing amount and the ellipticity of a pipe measured at least on the exit side of a roll-type pipe straightener is previously calculated. Namely, the ellipticity ϕ on the exit side of the roll-type pipe straightener is measured for a plurality of pipes which were straightened using different settings for the crushing amount δc, and the function g in the relationship δc = g(ϕ) between these two parameters is previously calculated.

[0026] In the second step, the ellipticity of the pipe on the exit side of the roll-type pipe straightener is measured. Namely, the ellipticity ϕ1 of the pipe P which was just straightened is measured.

[0027] In the third step, when the ellipticity ϕ1 of the pipe on the exit side of the roll-type pipe straightener which was measured in the second step is outside a target range, based on the relationship δc = g(ϕ) calculated in the first step between the set value of the crushing amount and the ellipticity of the pipe measured at least on the exit side of the roll-type pipe straightener, the necessary change in the crushing amount in order to put the ellipticity of the pipe on the exit side of the roll-type pipe straightener into the target range is calculated. Namely, if the target value of the ellipticity of the pipe (an arbitrary value within the target range) is ϕ', the set value δc' of the crushing amount which is required in order to obtain this target value ϕ' is found from δc' = g(ϕ'). Therefore, if the set value of the ellipticity of the pipe which was just straightened is δc1, the necessary amount of change Δδc of the crushing amount is calculated as Δδc = δc' - δc1.

[0028] In the fourth step, based on the amount of change Δδc of the crushing amount calculated in the third step, the set value of the crushing amount when straightening the next pipe P' is determined. Namely, if the set value of the crushing amount when straightening the next pipe P' is δc2, it is calculated as δc2 = δc1 + Δδc. At this time, in order to prevent divergence, Δδc may be multiplied by a slack coefficient in the range from 0 to 1.

[0029] In this manner, an automatic control method for a roll-type pipe straightener according to the present invention measures the ellipticity of a pipe on the exit side of the straightener and changes the crushing amount when straightening the next pipe so that the measured value of ellipticity will be within a target range for the ellipticity. Namely, the actually measured ellipticity of a pipe on the exit side of the straightener is used as feedback to change the crushing amount, thereby making it possible to stably correct the ellipticity of a pipe.

[0030] The "ellipticity of a pipe" is defined as the maximum diameter minus the minimum diameter (mm) or as (maximum diameter - minimum diameter)/average diameter x 100 (%) in a pipe cross section. The ellipticity of a pipe can be measured by, for example, installing an outer diameter gauge for measuring the outer diameter of the pipe in a plurality of radial directions on the exit side of a roll-type pipe straightener, calculating the maximum diameter and the minimum diameter based on the outer diameter measured by the outer diameter gauge in each radial direction, and calculating the average diameter in the case of the latter definition of the ellipticity.

[0031] The ellipticity of a pipe on the exit side of a roll-type pipe straightener and therefore the necessary amount of change of the crushing amount varies in accordance with the ellipticity of the pipe on the entrance side of the roll-type pipe straightener. Namely, when the ellipticity on the entrance side of the roll-type pipe straightener is larger than for the previous pipe to be straightened, the crushing amount is made larger than for the previous time. Conversely, when the ellipticity on the entrance side is smaller than for the previous pipe to be straightened, the crushing amount is made smaller than for the previous time. Therefore, in order to obtain a more stable straightening effect, the ellipticity of a pipe is preferably measured also on the entrance side of the roll-type pipe straightener, and the measured ellipticity is fed forward and used to change the crushing amount.

[0032] Accordingly, in a preferred mode of the present invention, in a first step, the relationship among the set value of the crushing amount and the ellipticity of a pipe measured on the entrance side and the exit side of a roll-type pipe straightener is previously calculated. Namely, the values of ellipticity ϕi and ϕo on the entrance side and the exit side, respectively, of a roll-type pipe straightener are measured for a plurality of pipes which were straightened using different settings for crushing amounts δc, and the function g in the relationship $\delta c = g(\phi i, \phi o)$ is previously calculated.

[0033] In a second step, the ellipticity $\phi o1$ of the pipe P which was just straightened is measured on the exit side of the roll-type pipe straightener, and the ellipticity $\phi i2$ on the entrance side of the roll-type pipe straightener of the next pipe to be straightened P' is measured.

[0034] In a third step, when the ellipticity $\phi o1$ which was measured in the second step of the pipe P which was just straightened on the exit side of the roll-type pipe straightener is outside a target range, the necessary amount of change of the crushing amount in order to put the ellipticity of the pipe on the exit side of the roll-type pipe straightener into the target range is calculated based on the ellipticity $\phi i2$ which was measured in the second step of the next pipe to be straightened on the entrance side of the roll-type pipe straightener and the relationship $\delta c = g(\phi i, \phi o)$ calculated in the first step among the set value of the crushing amount and the ellipticity of the pipe measured on the entrance side and the exit side of the roll-type pipe straightener. Namely, the set value $\delta c'$ of the target crushing amount in order to obtain the target value $\phi o'$ of the ellipticity of the pipe on the exit side of the roll-type pipe straightener is found from $\delta c' = g(\phi i2, \phi o')$. If the set value of the crushing amount for the pipe which was just straightened is $\delta c1$, the necessary amount of change $\Delta\delta c$ of the crushing amount is calculated as $\Delta\delta c = \delta c' - \delta c1$.

[0035] The ellipticity of a pipe on the exit side of a roll-type pipe straightener and therefore the necessary amount of change of the crushing amount also varies in accordance with the temperature of the pipe on the entrance side of the roll-type pipe straightener. Namely, when the temperature on the entrance side of the roll-type pipe straightener is higher than for the previous pipe to be straightened, deformation takes place more easily, so the crushing amount is made smaller than for the previous time. Conversely, when the temperature on the entrance side is lower than for the previous pipe to be straightened, the crushing amount is made larger than for the previous time. Therefore, in order to more stably obtain a straightening effect, preferably the temperature of a pipe on the entrance side of the roll-type pipe straightener is measured, and the measured temperature is fed forward and used to change the crushing amount.

[0036] Accordingly, in a preferred mode of the present invention, in a first step, the relationship among the set value of the crushing amount, the ellipticity of a pipe measured on the exit side of a roll-type pipe straightener, and the temperature of a pipe measured on the entrance side of the roll-type pipe straightener is calculated. Namely, by measuring the ellipticity ϕ on the exit side of a roll-type pipe straightener of a plurality of pipes which were straightened using different set values of the crushing amount δc and measuring the temperature T of the pipes on the entrance side of the roll-type pipe straightener, the function g in the relationship $\delta c = g(\phi, T)$ is previously calculated.

[0037] In a second step, the ellipticity $\phi 1$ on the exit side of the roll-type pipe straightener of the pipe P which was just straightened is measured, and the temperature T2 on the entrance side of the roll-type pipe straightener of the next pipe to be straightened P' is measured.

[0038] In a third step, when the ellipticity $\phi 1$ on the exit side of the roll-type pipe straightener of the pipe P which was just straightened which was measured in the second step is outside a target range, the necessary amount of change of the crushing amount in order to put the ellipticity of the pipe on the exit side of the roll-type pipe straightener within the target range is calculated based on the temperature T2 which was measured in the second step of the next pipe to be straightened P' on the entrance side of the roll-type pipe straightener and the relationship $\delta c = g(\phi, T)$ calculated in the first step among the set value of the crushing amount, the ellipticity of the pipe measured on the exit side of the roll-type pipe straightener, and the temperature of the pipe measured on the entrance side of the roll-type pipe straightener. Namely, the set value $\delta c'$ of the target crushing amount for obtaining a target value ϕ' of the ellipticity of a pipe on the exit side of the roll-type pipe straightener is found from $\delta c' = g(\phi', T2)$. Therefore, if the set value of the crushing amount of the pipe which was just straightened is $\delta c1$, the necessary amount of change $\Delta\delta c$ of the crushing amount is calculated as $\Delta\delta c = \delta c' - \delta c1$.

[0039] According to the present invention, an automatic control method for a roll-type pipe straightener which can obtain a stable straightening effect can be provided.

Brief Description of the Drawings

[0040]

Figure 1 is an explanatory view schematically showing the typical structure of a roll-type pipe straightener.

Figure 2 is an explanatory view schematically showing the structure of an apparatus for applying an automatic control method for a roll-type pipe straightener according to an embodiment of the present invention.

Figure 3 is an explanatory view schematically showing the structure of the outer diameter gauge shown in Figure 2.

Figure 4 is a graph showing an example of the relationship between the offset of a pair of grooved rolls installed in the #2 stand and the amount of bending on the exit side of the pipe straightener which is calculated and stored by the arithmetic and control unit shown in Figure 2.

Figure 5 is a graph showing an example of the effects of an automatic control method according to an embodiment which controls the set value of the offset.

Figure 6 is a graph showing an example of the relationship between the crushing amount of a pair of grooved rolls in the #2 stand and the ellipticity on the exit side of the straightener which is calculated and stored by the arithmetic and control unit of Figure 2.

Figure 7 is a graph showing an example of the effects of an automatic control method according to an embodiment which controls the set value of the crushing amount.

Figure 8 is a graph showing an example of the effects of an automatic control method according to another embodiment which controls the set value of the offset.

Figure 9 is a graph showing an example of the effects of an automatic control method according to another embodiment which controls the set value of the crushing amount.

Figure 10 is a graph showing an example of the effects of an automatic control method according to still another embodiment of the present invention which controls the set value of the offset.

Figure 11 is a graph showing an example of the effects of an automatic control method according to yet another embodiment of the present invention which controls the set value of the crushing amount.

List of reference symbols:

[0041]

1: roll-type pipe straightener
2, 3: outer diameter gauge
4: radiation thermometer
5: arithmetic and control unit
P: pipe
R: grooved roll

Best Mode for Carrying Out the Invention

[0042] Below, the best mode for carrying out the present invention will be explained in detail while referring to the attached drawings.

[0043] Figure 2 is a figure schematically showing the structure of an apparatus for applying an automatic control method for a roll-type pipe straightener according to the present invention.

[0044] As shown in Figure 2, this embodiment of an automatic control method is applied to a roll-type pipe straightener 1 (referred to below, for convenience, as a "straightener" for short) which has at least 3 stands (in the illustrated example, a total of 3 stands comprising #1 - #3 stands) each equipped with a pair of opposing grooved rolls R, R in which the pair of grooved rolls R, R in at least one of the stands (the #2 stand in the illustrated example) are offset with respect to the pairs of grooved rolls R, R in the other stands (the #1 - #3 stands in the illustrated example). The straightener straightens a pipe P by crushing it with the pairs of grooved rolls in each of the #1 - #3 stands.

[0045] An outer diameter gauge 2 for measuring the outer diameter of the pipe P after straightening in a plurality of radial directions is provided on the exit side of the straightener 1.

[0046] Figure 3 is a schematic view schematically showing the structure of the outer diameter gauge 2 according to this embodiment. As shown in Figure 3, the outer diameter gauge 2 according to this embodiment comprises a light projecting portion 21 which is constituted by a laser light source and a scanning optical system so as to project a laser beam at the pipe P while scanning (in parallel to the direction shown by the hollow arrow in the figure) and a light receiving portion 22 which is disposed opposite the light projecting portion 21 on the opposite side of the pipe P and which is constituted by a condensing optical system and a photoelectric element so as to receive the laser beam. The outer diameter of the pipe P is calculated by converting the time for which the laser beam is blocked by the pipe P into dimensions.

[0047] In Figure 3, for convenience, the outer diameter gauge 2 is constructed so as to have only one pair of a light projecting portion 21 and a light receiving portion 22, but in actuality, the gauge has a plurality of pairs of a light projecting portion 21 and a light receiving portion 22 having different light axes for the light projecting portion 21 and the light receiving portion 22 (the direction in which the laser beam is projected and received) for each pair in order to make it possible to measure the outer diameter of the pipe P in a plurality of radial directions.

[0048] The outer diameter gauge 2 calculates the midpoint between the positions where the outer diameter was measured by each pair of the light projecting portion 21 and the light receiving portion 22 (the positions corresponding to both ends of a pipe in the cross section of the pipe P where the outer diameter was measured, which are the locations of points a1 and a2 in Figure 3) and calculates the location of the center of the cross section of the pipe P by geometric calculation.

[0049] In this embodiment, in a preferred mode, in order to measure the outer diameter of the pipe P before straightening on the entrance side of the straightener 1 in a plurality of radial directions and to calculate the location of the center of the cross section of the pipe P before straightening, an outer diameter gauge 3 having the same structure as outer diameter gauge 2 is provided. In a preferred mode, a radiation thermometer 4 is provided for measuring the temperature of the pipe P on the entrance side of the straightener 1.

[0050] Output signals from the outer diameter gauges 2 and 3 (the measured value of the outer diameter of the pipe P and the measured value of the location of the center of the cross section) and the temperature measured by the radiation thermometer 4 are input to an arithmetic and control unit 5, which calculates the set value of the offset and the set value of the crushing amount when straightening the next pipe P. The arithmetic and control unit 5 then controls the positions of the pairs of grooved rolls R, R of the straightener 1 so that the set value of the offset and the set value of the crushing amount which were calculated are obtained. Below, the arithmetic operation performed in the arithmetic and control unit 5 will be explained in more detail.

[0051] First, the arithmetic operation of the set value of the offset when straightening the next pipe P will be explained. The arithmetic and control unit 5 previously calculates the relationship between the set value of the offset of the pair of grooved rolls R, R in the #2 stand and the amount of bending of the pipe P measured on the exit side of the straightener 1. Namely, by measuring the amount of bending r on the exit side of the straightener 1 for a plurality of pipes P which were straightened using different set values for the offset δo for the #2 stand, the function f in the relationship $\delta o = f(r)$ between these two parameters is calculated and stored. The amount of bending r is measured by calculating the amount of variation in the lengthwise direction of the pipe P of the location of the center of the cross section of the pipe P which was input by the outer diameter gauge 2.

[0052] The relationship between the offset δo and the amount of bending r on the exit side of the straightener 1 actually varies in accordance with the skew angle of the pair of grooved rolls R, R in the #2 stand, the number of pipes P being straightened, the outer diameter and the wall thickness of the pipes P, and the like. Therefore, a plurality of functions fl ... fn corresponding to the values of these various parameters is calculated and stored. For example, by learning of a nonlinear model such as a neural network using a large number of combinations of input and output data with the amount of bending r on the exit side of the straightener 1 and each of the above-described parameters as input data and the offset δo as output data, a nonlinear model is identified which, in response to input of the amount of bending r on the exit side of the straightener 1 and each of the above-described parameters, outputs the corresponding offset δo.

[0053] Figure 4 is a graph showing an example of a relationship which is calculated by and stored in the arithmetic and control unit 5 between the offset δo (mm) of the pair of grooved rolls R, R in the #2 stand and the amount of bending r (mm) on the exit side of the straightener 1. In the example shown in Figure 4, the relationship is given by $r = a \times \delta o^2 + b \times \delta o + c$, wherein a, b, and c can be found to be a = 0.0813, b = -1.009, and c = 3.6924 by the least squares method, for example.

[0054] As shown in Figure 4, if the offset δo is too much smaller than a suitable offset (in the vicinity of 6 mm in the example shown in Figure 4), the amount of straightening of bends becomes insufficient. On the other hand, if it becomes too much larger than a suitable offset, buckling develops and bends cannot be straightened.

[0055] Next, the arithmetic and control unit 5 measures the amount of bending r1 on the exit side of the straightener 1 of the pipe P which was just straightened. When the measured amount of bending r1 is outside a target range (such as when the amount of bending in the example shown in Figure 4 is larger than 0.6 mm/m), as stated above, the necessary amount of change of the offset in order to put the amount of bending of the pipe on the exit side of the straightener 1 into the target range is calculated based on the previously calculated relationship $\delta o = f(r)$ between the set value of the offset and the amount of bending of the pipe measured on the exit side of the straightener 1. Namely, if the target value of the amount of bending of the pipe is r' (for example, in the example shown in Figure 4, an amount of bending r' of 0.6 mm/m is made a target value), the set value $\delta o'$ of the offset which is required in order to obtain this target value r' is found by $\delta o' = f(r')$. Therefore, if the set value of the offset of the pipe P which was just straightened is $\delta o1$, the necessary amount of change $\Delta\delta o$ of the offset is calculated as $\Delta\delta o = \delta o' - \delta o1$.

[0056] Finally, the arithmetic and control unit 5 determines the set value of the offset when straightening the next pipe P' based on the amount of change $\Delta\delta o$ of the offset calculated as described above. Namely, if the set value of the offset when straightening the next pipe P' is $\delta o2$, it is determined as $\delta o2 = \delta o1 + \Delta\delta o$. In order to prevent divergence, $\Delta\delta o$ may be multiplied by a slack coefficient in the range of 0 to 1.

[0057] Figure 5 is a graph showing an example of the effects of an automatic control method of this embodiment. Figure 5(a) shows the variation in the amount of bending of a pipe on the exit side of a straightener 1, and Figure 5(b) shows the variation in the set value of the offset in the #2 stand. In the example shown in Figure 5, an automatic control method according to the present embodiment is applied to the fifth and subsequent straightened pipes. The target value of the amount of bending is made 0.5 mm/m, and the above-described slack coefficient is set to 0.5.

[0058] As shown in Figure 5, the amount of bending of the fifth and subsequent straightened pipes was gradually improved, and it reached the target value of 0.5 mm/m with the eighth straightened pipe. Therefore, the set value of the offset was fixed for subsequent pipes.

[0059] Next, arithmetic operation of the set value of the crushing amount when straightening the next pipe P will be explained. The arithmetic and control unit 5 previously calculates the relationship between the set value of the crushing amount of the pairs of grooved rolls in each of the #1 - #3 stands and the ellipticity of the pipe P measured on the exit side of the straightener 1. Namely, by measuring the ellipticity ϕ on the exit side of the straightener 1 of a plurality of straightened pipes P set to different crushing amounts δc in each of the #1 - #3 stands, the function g in the relationship between these two parameters $\delta c = g(\phi)$ is previously calculated and stored. The ellipticity ϕ in this embodiment is a value calculated by averaging the value (maximum diameter - minimum diameter)/average diameter x 100 (%) in a pipe cross section in different lengthwise positions at the portion of the pipe P (a location 50% along the overall length) which is calculated based on the outer diameter of the pipe P in a plurality of radial directions input from the outer diameter gauge 2.

[0060] The relationship between the crushing amount δc and the ellipticity ϕ on the exit side of the straightener 1 actually varies with the skew angle of the pairs of grooved rolls R, R in each stand, the number of pipes P which were straightened, and the outer diameter and the wall thickness of the pipes P, and the like. Therefore, a plurality of functions gl ... gn corresponding to each of these parameters is calculated and stored. For example, by learning of a nonlinear model such as a neural network using a large number of combinations of input and output data with the ellipticity ϕ on the exit side of the straightener 1 and each of the above-described parameters as input data and the crushing amount δc as output data, a nonlinear model is identified which, in response to input of the ellipticity ϕ on the exit side of the straightener 1 and each of the above-described parameters, outputs the corresponding crushing amount δc.

[0061] Figure 6 is a graph showing an example of a relationship between the crushing amount δc (mm) of the pair of grooved rolls R, R in the #2 stand and the ellipticity ϕ (%) on the exit side of the straightener 1 which is calculated by and stored in the arithmetic and control unit 5. In the example shown in Figure 6, the relationship is given by $\phi = a \times \delta c^2 + b \times \delta c + c$, wherein a, b, and c can be found to be a = 0.0348, b = -0.4909, and c = 2.1251 by the least squares method, for example.

[0062] As shown in Figure 6, when the crushing amount δc is too much smaller than an appropriate crushing amount (in the vicinity of 7 mm in the example shown in Figure 6), the correction of the ellipticity becomes insufficient, while if it becomes too much larger than a suitable crushing amount, the outer surface becomes rectangular and ellipticity cannot be corrected.

[0063] Next, the arithmetic and control unit 5 measures the ellipticity $\phi 1$ of the pipe P which was just straightened on the exit side of the straightener 1. When the measured ellipticity $\phi 1$ is outside a target range (such as when the ellipticity is greater than 0.4% in the example shown in Figure 6), as described above, based on the previously calculated relationship $\delta c = g(\phi)$ between the set value of the crushing amount and the ellipticity of the pipe measured on the exit side of the straightener 1, the amount of change of the crushing amount necessary to put the ellipticity of the pipe on the exit side of the straightener 1 into the target range is calculated. Namely, if the target value of the ellipticity of the pipe is ϕ' (for example, 0.4% is made a target value for the ellipticity in the example shown in Figure 6), the set value $\delta c'$ of the crushing amount which is required in order to obtain the target value ϕ' is found from $\delta c' = g(\phi')$. If the set value of the crushing amount of the pipe P which was just straightened is $\delta c1$, the necessary amount of change $\Delta\delta c$ of the crushing amount is calculated as $\Delta\delta c = \delta c' - \delta c1$.

[0064] Finally, based on the amount of change $\Delta\delta c$ of the crushing amount calculated as described above, the arithmetic and control unit 5 determines the set value of the crushing amount when straightening the next pipe P'. Namely, if the set value of the crushing amount when straightening the next pipe P' is $\delta c2$, it is determined as $\delta c2 = \delta c1 + \Delta\delta c$. At this time, in order to prevent divergence, $\Delta\delta c$ may be multiplied by a slack coefficient in the range of 0 to 1.

[0065] Figure 7 is a graph showing an example of the effects of an automatic control method of this embodiment. Figure 7(a) shows the variation in the ellipticity of a pipe on the exit side of a straightener 1, and Figure 7 (b) shows the variation in the set value of the crushing amount in the #2 stand. In the example shown in Figure 7, an automatic control method according to this embodiment is applied to the fifth and subsequent straightened pipes. The target value of the ellipticity is set to 0.4%, and the above-mentioned slack coefficient is set to 0.5. As shown in Figure 7, the ellipticity gradually was improved for the fifth and subsequent straightened pipes, and the target value of 0.4% was reached for the eighth straightened pipe. Therefore, the crushing amount was fixed from that point.

[0066] In this embodiment, as a preferred mode, the output signal of the outer diameter gauge 3 (the measured value of the outer diameter of the pipe P and the measured value of the location of the center of the cross section of the pipe on the entrance side of the straightener 1) is input to the arithmetic and control unit 5 in the manner described above. Accordingly, the arithmetic and control unit 5 can calculate the set value of the offset and the set value of the crushing amount when straightening the next pipe P using the output signal from the outer diameter gauge 3.

[0067] The arithmetic operation for calculating the set value of the offset when straightening the next pipe P using the output signal from the outer diameter gauge 3 will be explained. In this case, the arithmetic and control unit 5 previously calculates the relationship among the set value of the offset of the pair of grooved rolls R, R in the #2 stand and the amount of bending of the pipe P measured on the entrance side and the exit side of the straightener 1. Namely, by measuring the amount of bending ri and ro on the entrance side and the exit side, respectively, of the straightener 1 for a plurality of pipes P which were straightened using different set values for the offset δo for the #2 stand, the function f in the relationship $\delta o = f(ri, ro)$ among these parameters is previously calculated and stored.

[0068] The relationship between the offset δo and the amount of bending ro on the exit side of the straightener 1 actually varies with the skew angle of the pair of grooved rolls R, R in the #2 stand, the number of straightened pipes P, and the outer diameter and wall thickness of the pipes P, and the like. Therefore, a plurality of functions fl ... fn corresponding to these parameters is calculated and stored in the same manner as described above.

[0069] Next, the arithmetic and control unit 5 measures the amount of bending ro 1 of the pipe P which was just straightened on the exit side of the straightener 1, and it also measures the amount of bending ri2 on the entrance side of the straightener of the next pipe to be straightened P'. When the measured amount of bending ro 1 is outside a target range, as described above, based on the previously calculated relationship $\delta o = f(ri, ro)$ among the set value of the offset and the amount of bending measured on the entrance side and the exit side of the straightener 1, the amount of change of the offset necessary to put the amount of bending of the pipe on the exit side of the straightener 1 into the target range is calculated. Namely, if the target value of the amount of bending of the pipe is ro', the target for the set value δo' of the offset in order to obtain this target value ro' is found as $\delta o' = f(ri2, ro')$. Therefore, if the set value of the offset of the pipe P which was just straightened is δo1, the necessary amount of change Δδo of the offset is calculated as $\Delta\delta o = \delta o' - \delta o1$.

[0070] Finally, based on the amount of change Δδo of the offset which was calculated in the above-described manner, the arithmetic and control unit 5 determines the set value of the offset when straightening the next pipe P'. Namely, if the set value of the offset when straightening the next pipe P' is δo2, it is calculated as $\delta o2 = \delta o1 + \Delta\delta o$. At this time, in order to prevent divergence, Δδo may be multiplied by a slack coefficient in the range of 0 to 1.

[0071] Figure 8 is a graph showing an example of the effects of this automatic control method. Figure 8(a) shows the variation in the amount of bending of a pipe on the exit side of the straightener 1, and Figure 8(b) shows the variation in the set value of the offset in the #2 stand. In the example shown in Figure 8, in the same manner as for the example shown in Figure 5, a preferred control method according to this embodiment is applied to the fifth and subsequent straightened pipes. The target value of the amount of bending is set to 0.5 mm/m, and the above-described slack coefficient is set to 0.5. As shown in Figure 8, the amount of bending rapidly was improved for the fifth and subsequent straightened pipes, and the target value of 0.5 mm/m was reached on the sixth straightened pipe. Therefore, the set value of the offset was fixed from that point. Namely, the amount of bending can be more rapidly improved than in the example shown in Figure 5.

[0072] Next, the arithmetic operation for calculating the set value of the crushing amount when straightening the next pipe P by also using the output signal of outer diameter gauge 3 will be explained. In this case, the arithmetic and control unit 5 previously calculates the relationship among the set value of the crushing amount of the pair of grooved rolls R, R in each of the #1 - #3 stands and the ellipticity of the pipe P measured on the entrance side and the exit side of the straightener 1. Namely, by measuring the ellipticity ϕi and ϕo on the entrance side and the exit side, respectively, of the straightener 1 for a plurality of pipes P which were straightened with the crushing amount δc set to different amounts for each of the #1 - #3 stands, the function g in the relationship $\delta c = g(\phi i, \phi o)$ among these parameters is previously calculated and stored.

[0073] The relationship between the crushing amount δo and the ellipticity ϕo on the exit side of the straightener 1 actually depends on the skew angle of the pair of grooved rolls R, R in each of the #1 - #3 stands, the number of pipes P which were straightened, and the outer diameter and wall thickness of the pipes P, and the like. Therefore, a plurality of functions gl ... gn corresponding to the values of each of these parameters is calculated and stored in the same manner as described above.

[0074] Next, the arithmetic and control unit 5 measures the ellipticity ϕo1 on the exit side of the straightener 1 of the pipe P which was just straightened and the ellipticity ϕi2 of the next pipe to be straightened P' on the entrance side of the straightener. When the measured ellipticity ϕo1 is outside a target range, as described above, based on the previously calculated relationship $\delta c = g(\phi i, \phi o)$ among the set value of the crushing amount and the ellipticity of the pipe measured on the entrance side and the exit side of the straightener 1, the amount of change of the crushing amount necessary to put the ellipticity of the pipe on the exit side of the straightener 1 into the target range is calculated. Namely, if the target value of the ellipticity is ϕo', the set value δc' of the target crushing amount in order to obtain this target value ϕo' is found as $\delta c' = g(\phi i2, \phi o')$. Therefore, if the set value of the crushing amount of the pipe P which was just straightened is δc1, the necessary amount of change Δδc of the crushing amount is calculated as $\Delta\delta c = \delta c' - \delta c1$.

[0075] Finally, based on the amount of change Δδc of the crushing amount which was calculated as described above, the arithmetic and control unit 5 determines the set value of the crushing amount when straightening the next pipe P'. Namely, if the set value of the crushing amount when straightening the next pipe P' is δc2, it is calculated as $\delta c2 = \delta c1 + \Delta\delta o$. At this time, in order to prevent divergence, Δδo may be multiplied by a slack coefficient in the range of 0 to 1.

[0076] Figure 9 is a graph showing an example of the effects of this automatic control method. Figure 9(a) shows the variation in the ellipticity of pipes on the exit side of the straightener 1, and Figure 9(b) shows the variation in the set value of the crushing amount in the #2 stand. In the example shown in Figure 9, in the same manner as in the example shown in Figure 7, a preferred automatic control method according to this embodiment is applied to the fifth and subsequent straightened pipes. The target value of the ellipticity is set to 0.4%, and the above-mentioned slack coefficient is set to 0.5. As shown in Figure 9, the ellipticity of the fifth and subsequent straightened pipes was rapidly improved and reached the target value of 0.4% for the sixth straightened pipe. Therefore, the set value of the crushing amount was fixed from that point. Namely, the ellipticity can be improved more rapidly than with the example shown in Figure 7.

[0077] As a preferred mode in this embodiment, the temperature measured by the radiation thermometer 4 is input to the arithmetic and control unit 5 as described above. Accordingly, the arithmetic and control unit 5 can calculate the set value of the offset and the set value of the crushing amount when straightening the next pipe P using the temperature measured by the radiation thermometer 4.

[0078] The arithmetic operation for calculating the set value of the offset when straightening the next pipe using the temperature measured by the radiation thermometer 4 merely uses the temperature T of the pipe P measured on the entrance side of the straightener 1 in place of the amount of bending ri measured on the entrance side of the above-described straightener 1 and is otherwise the same. Therefore, a detailed description of the arithmetic operation will be omitted, and only an example of the effects will be described.

[0079] Figure 10 is a graph showing an example of the effects of this control method. Figure 10(a) shows the variation in the amount of bending of pipes on the exit side of a straightener 1, and Figure 10(b) shows the variation in the set value of the offset in the #2 stand. In the example shown in Figure 10, in the same manner as in the example of Figure 5, a preferred automatic control method according to this embodiment is applied to the fifth and subsequent straightened pipes. The target value of the amount of bending is 0.5 mm/m, and the above-mentioned slack coefficient is set to 0.5. As shown in Figure 10, the amount of bending for the fifth and subsequent straightened pipes was rapidly improved and reached the target value of 0.5 mm/m for the seventh straightened pipe. Therefore, the set value of the offset was fixed from that point. Namely, it is possible to more rapidly improve the amount of bending than in the example shown in Figure 5.

[0080] The arithmetic operations for calculating the set value of the crushing amount when straightening the next pipe P also using the temperature measured by the radiation thermometer 4 are otherwise the same except that the temperature T of the pipe P measured on the entrance side of the straightener 1 is used instead of the above-mentioned ellipticity ϕi measured on the entrance side of the straightener 1. Therefore, a detailed explanation of the arithmetic operations will be omitted, and only an example of the effects will be described.

[0081] Figure 11 is a graph showing an example of the effects of this automatic control method. Figure 11(a) shows the variation in the ellipticity of pipes on the exit side of a straightener 1, and Figure 11(b) shows the variation in the set value of the crushing amount in the #2 stand. In the example shown in Figure 11, in the same manner as in the example shown in Figure 7, a preferred automatic control method according to this embodiment is applied to the fifth and subsequent straightened pipes. The target value of the ellipticity is made 0.4% and the above-mentioned slack coefficient is set to 0.5. As shown in Figure 11, the ellipticity was rapidly improved for the fifth and subsequent straightened pipes and reached the target value of 0.4 on the seventh straightened pipe. Therefore, the set value of the crushing amount was fixed from that point. Namely, it is possible to improve the ellipticity more rapidly than with the example shown in Figure 7.

Claims

1. An automatic control method for a roll-type pipe straightener which has at least 3 stands each provided with a pair of opposing grooved rolls and arranged such that the pair of grooved rolls in at least one of the stands have a predetermined offset with respect to the pairs of grooved rolls in the other stands and which crushes a pipe by the pairs of grooved rolls in each stand to perform straightening, **characterized by** comprising the following steps:

    a first step of previously calculating the relationship between the set value of the offset and the amount of bending of a pipe measured at least on the exit side of the roll-type pipe straightener,
    a second step of measuring the amount of bending of a pipe at least on the exit side of the roll-type pipe straightener,
    when the amount of bending of the pipe measured in the second step is outside a target range, a third step of calculating the amount of change of the offset necessary to put the amount of bending of the pipe on the exit side of the roll-type pipe straightener into the target range based on the relationship calculated in the first step, and
    a fourth step of determining the set value of the offset when straightening the next pipe based on the amount of change of the offset calculated in the third step.

2. An automatic control method for a roll-type pipe straightener which has at least 3 stands each provided with a pair of opposing grooved rolls and arranged such that the pair of grooved rolls in at least one of the stands have a predetermined offset with respect to the pairs of grooved rolls in the other stands and which crushes a pipe by the pairs of grooved rolls in each stand to perform straightening, **characterized by** comprising the following steps:

    a first step of previously calculating the relationship among the set value of the offset and the amount of bending of a pipe measured on the entrance side and the exit side of the roll-type

pipe straightener,
a second step of measuring the amount of bending of the pipe which was just straightened on the exit side of the roll-type pipe straightener and measuring the amount of bending of the next pipe to be straightened on the entrance side of the roll-type pipe straightener,
when the amount of bending measured in the second step of the pipe which was just straightened on the exit side of the roll-type pipe straightener is outside a target range, a third step of calculating the amount of change of the offset necessary to put the amount of bending of the pipe on the exit side of the roll-type pipe straightener into the target range based on the relationship calculated in the first step, and
a fourth step of determining the set value of the offset when straightening the next pipe based on the amount of change of the offset calculated in the third step.

3. An automatic control method for a roll-type pipe straightener which has at least 3 stands each provided with a pair of opposing grooved rolls and arranged such that the pair of grooved rolls in at least one of the stands have a predetermined offset with respect to the pairs of grooved rolls in the other stands and which crushes a pipe by the pairs of grooved rolls in each stand to perform straightening, **characterized by** comprising the following steps:

a first step of previously calculating the relationship among the set value of the offset, the amount of bending of a pipe measured on the exit side of the roll-type pipe straightener, and the temperature of the pipe measured on the entrance side of the roll-type pipe straightener,
a second step of measuring the amount of bending of the pipe which was just straightened on the exit side of the roll-type pipe straightener and measuring the temperature of the next pipe to be straightened on the entrance side of the roll-type pipe straightener,
when the amount of bending measured in the second step of the pipe which was just straightened on the exit side of the roll-type pipe straightener is outside a target range, a third step of calculating the amount of change of the offset necessary to put the amount of bending of the pipe on the exit side of the roll-type pipe straightener into the target range based on the temperature measured in the second step of the next pipe to be straightened on the entrance side of the roll-type pipe straightener and the relationship calculated in the first step among the set value of the offset, the amount of bending of a pipe measured on the exit side of the roll-type pipe straightener, and the temperature of the pipe measured on the entrance side of the roll-type pipe straightener, and
a fourth step of determining the set value of the offset when straightening the next pipe based on the amount of change of the offset calculated in the third step.

4. An automatic control method for a roll-type pipe straightener which has at least 3 stands each provided with a pair of opposing grooved rolls and arranged such that the pair of grooved rolls in at least one of the stands have a predetermined offset with respect to the pairs of grooved rolls in the other stands and which crushes a pipe by the pairs of grooved rolls in each stand to perform straightening, **characterized by** comprising the following steps:

a first step of previously calculating the relationship between the set value of the crushing amount and the ellipticity of a pipe measured at least on the exit side of the roll-type pipe straightener,
a second step of measuring the ellipticity of a pipe at least on the exit side of the roll-type pipe straightener,
when the ellipticity of the pipe measured in the second step is outside a target range, a third step of calculating the amount of change of the crushing amount necessary to put the ellipticity of the pipe on the exit side of the roll-type pipe straightener into the target range based on the relationship calculated in the first step between the set value of the crushing amount and the ellipticity of a pipe measured at least on the exit side of the roll-type pipe straightener, and
a fourth step of determining the set value of the crushing amount when straightening the next pipe based on the amount of change of the crushing amount calculated in the third step.

5. An automatic control method for a roll-type pipe straightener which has at least 3 stands each provided with a pair of opposing grooved rolls and arranged such that the pair of grooved rolls in at least one of the stands have a predetermined offset with respect to the pairs of grooved rolls in the other stands and which crushes a pipe by the pairs of grooved rolls in each stand to perform straightening, **characterized by** comprising the following steps:

a first step of previously calculating the relationship among the set value of the crushing amount and the ellipticity of a pipe measured on the entrance side and the exit side of the roll-type pipe straightener,
a second step of measuring the ellipticity of a pipe which was just straightened on the exit side of the roll-type pipe straightener and measuring

the ellipticity of the next pipe to be straightened on the entrance side of the roll-type pipe straightener,

when the ellipticity which was measured in the second step of the pipe which was just straightened on the exit side of the roll-type pipe straightener is outside a target range, a third step of calculating the amount of change of the crushing amount necessary to put the ellipticity of the pipe on the exit side of the roll-type pipe straightener into the target range based on the ellipticity measured in the second step of the next pipe to be straightened on the entrance side of the roll-type pipe straightener and the relationship calculated in the first step among the set value of the crushing amount and the ellipticity of the pipe measured on the entrance side and the exit side of the roll-type pipe straightener, and

a fourth step of determining the set value of the crushing amount when straightening the next pipe based on the amount of change in the crushing amount calculated in the third step.

6. An automatic control method for a roll-type pipe straightener which has at least 3 stands each provided with a pair of opposing grooved rolls and arranged such that the pair of grooved rolls in at least one of the stands have a predetermined offset with respect to the pairs of grooved rolls in the other stands and which crushes a pipe by the pairs of grooved rolls in each stand to perform straightening, **characterized by** comprising the following steps:

a first step of previously calculating the relationship among the set value of the crushing amount, the ellipticity of a pipe measured on the exit side of the roll-type pipe straightener, and the temperature of the pipe measured on the entrance side of the roll-type pipe straightener,

a second step of measuring the ellipticity of a pipe which was just straightened on the exit side of the roll-type pipe straightener and measuring the temperature of the next pipe to be straightened on the entrance side of the roll-type pipe straightener,

when the ellipticity measured in the second step of the pipe which was just straightened on the exit side of the roll-type pipe straightener is outside a target range, a third step of calculating the amount of change of the crushing amount necessary to put the ellipticity of the pipe on the exit side of the roll-type pipe straightener into the target range based on the temperature measured in the second step of the next pipe to be straightened on the entrance side of the roll-type pipe straightener and the relationship calculated in the first step among the set value of the crushing amount, the ellipticity of a pipe measured on the exit side of the roll-type pipe straightener, and the temperature of the pipe measured on the entrance side of the roll-type pipe straightener, and

a fourth step of determining the set value of the crushing amount when straightening the next pipe based on the amount of change of the crushing amount calculated in the third step.

Fig. 1

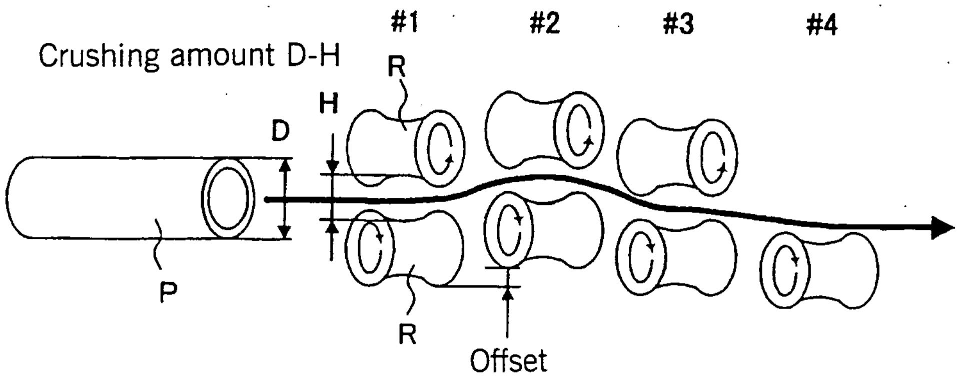


Fig. 2

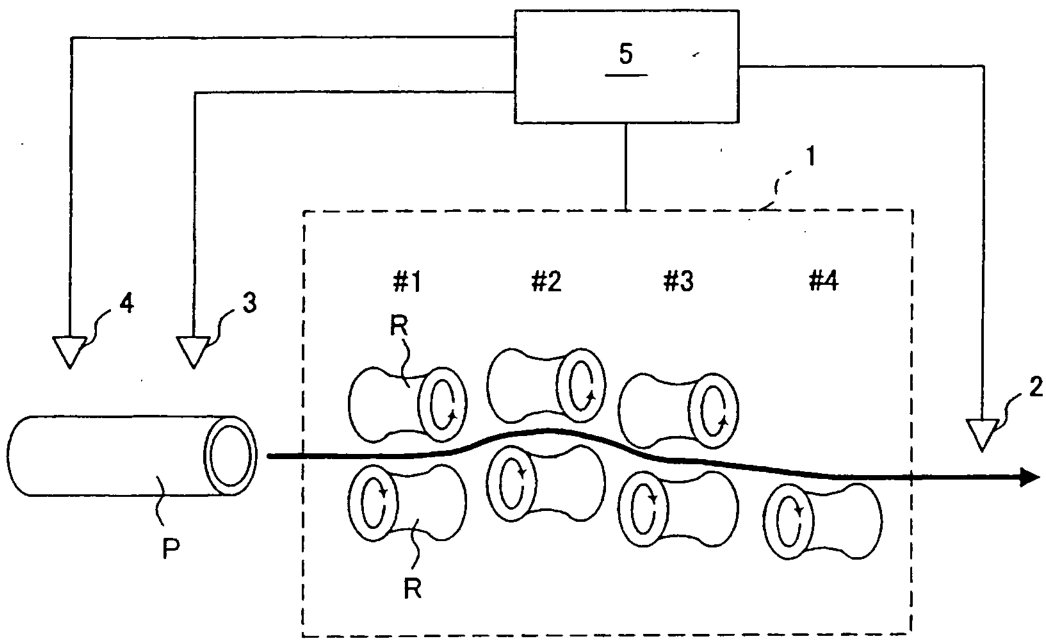


Fig. 3

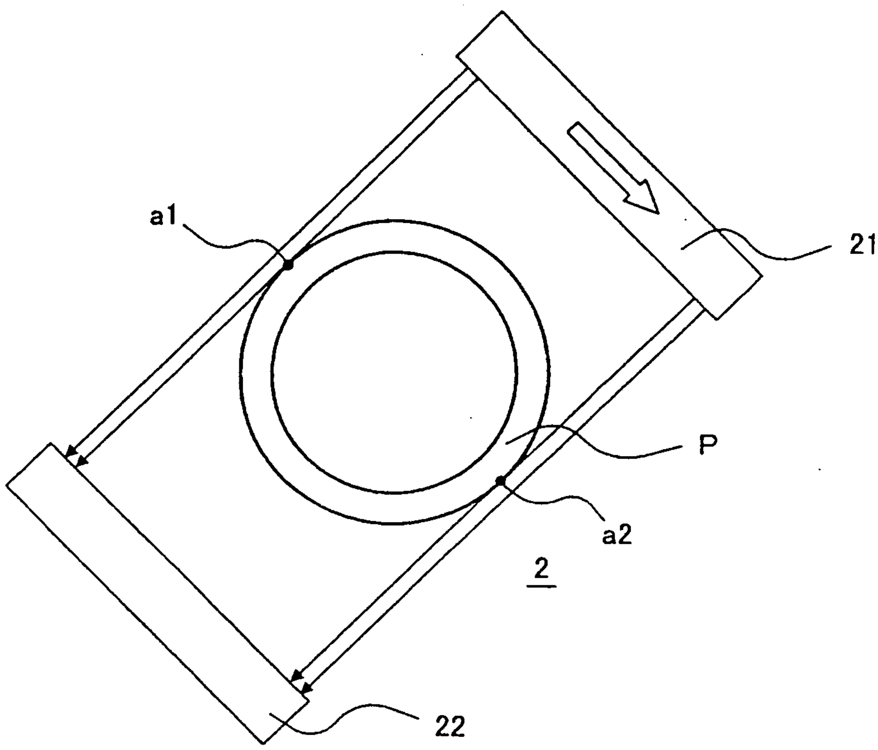

a1
21
P
a2
2
22

Fig. 4

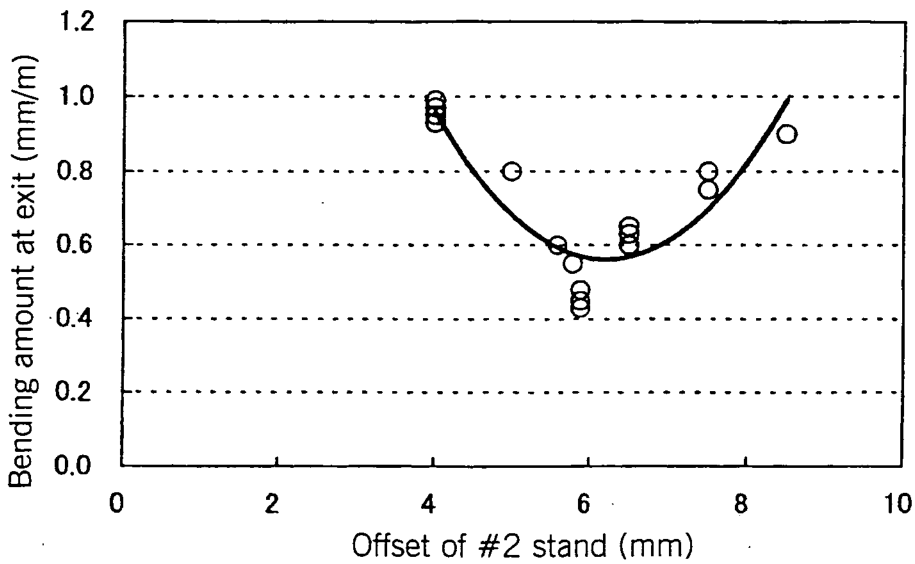
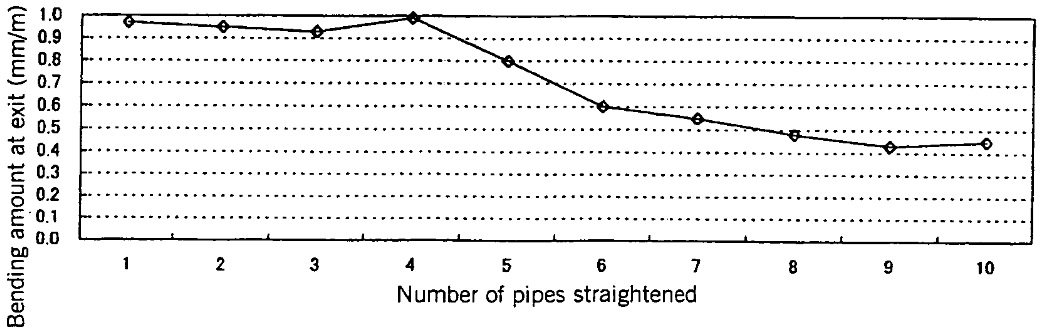

1.2
1.0
0.8
0.6
0.4
0.2
0.0
Bending amount at exit (mm/m)
0
2
4
6
8
10
Offset of #2 stand (mm)

Fig. 5

(a)


Bending amount at exit (mm/m)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
6
7
8
9
10
Number of pipes straightened

(b)

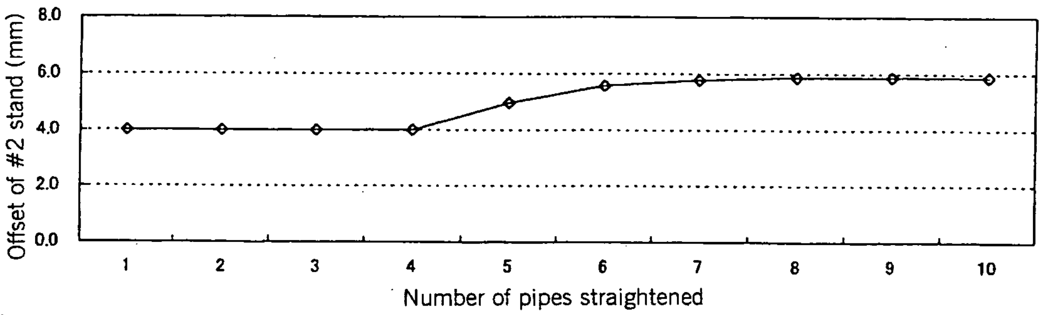

Offset of #2 stand (mm)
8.0
6.0
4.0
2.0
0.0
1
2
3
4
5
6
7
8
9
10
Number of pipes straightened

Fig. 6

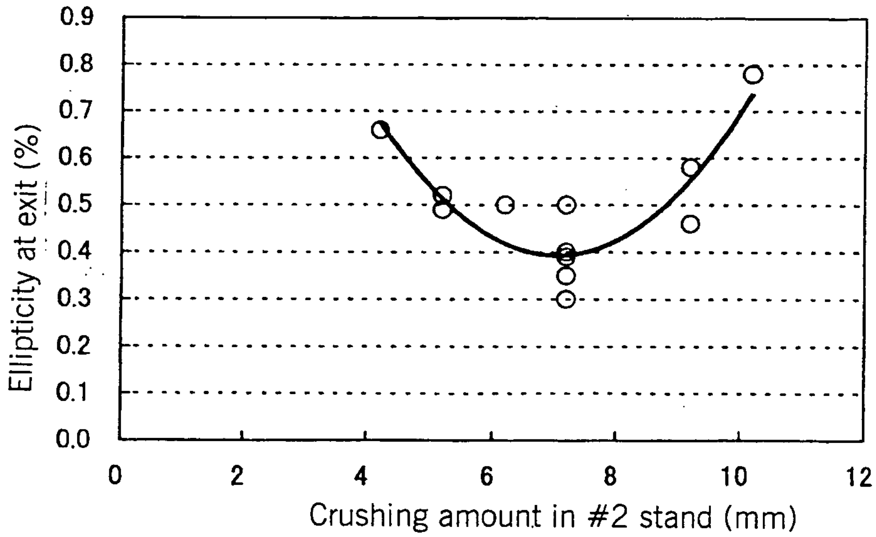

Ellipticity at exit (%)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
Crushing amount in #2 stand (mm)

Fig. 7

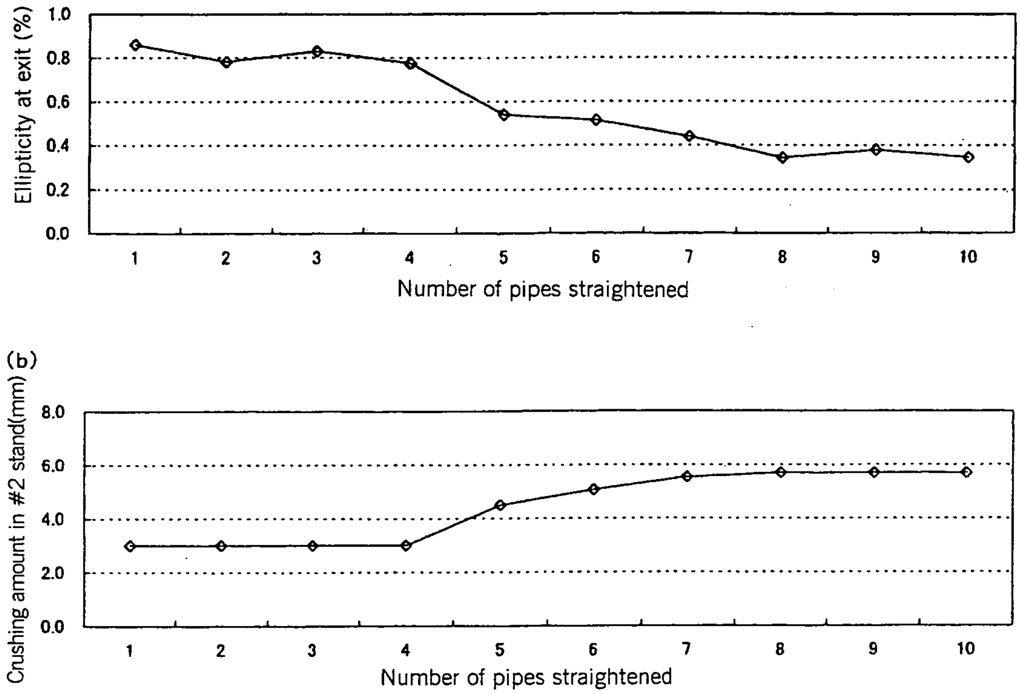

Ellipticity at exit (%)
1.0
0.8
0.6
0.4
0.2
0.0
1 2 3 4 5 6 7 8 9 10
Number of pipes straightened
(b)
Crushing amount in #2 stand(mm)
8.0
6.0
4.0
2.0
0.0
1 2 3 4 5 6 7 8 9 10
Number of pipes straightened

Fig. 8

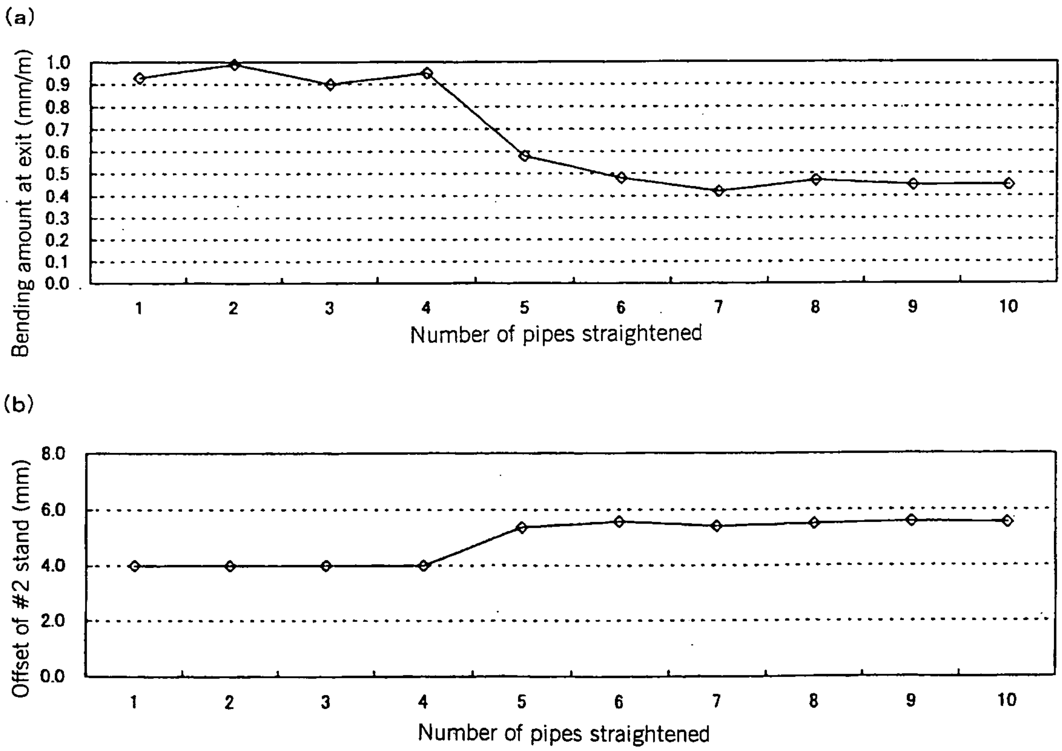

(a)
Bending amount at exit (mm/m)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3 4 5 6 7 8 9 10
Number of pipes straightened
(b)
Offset of #2 stand (mm)
8.0
6.0
4.0
2.0
0.0
1 2 3 4 5 6 7 8 9 10
Number of pipes straightened

Fig. 9

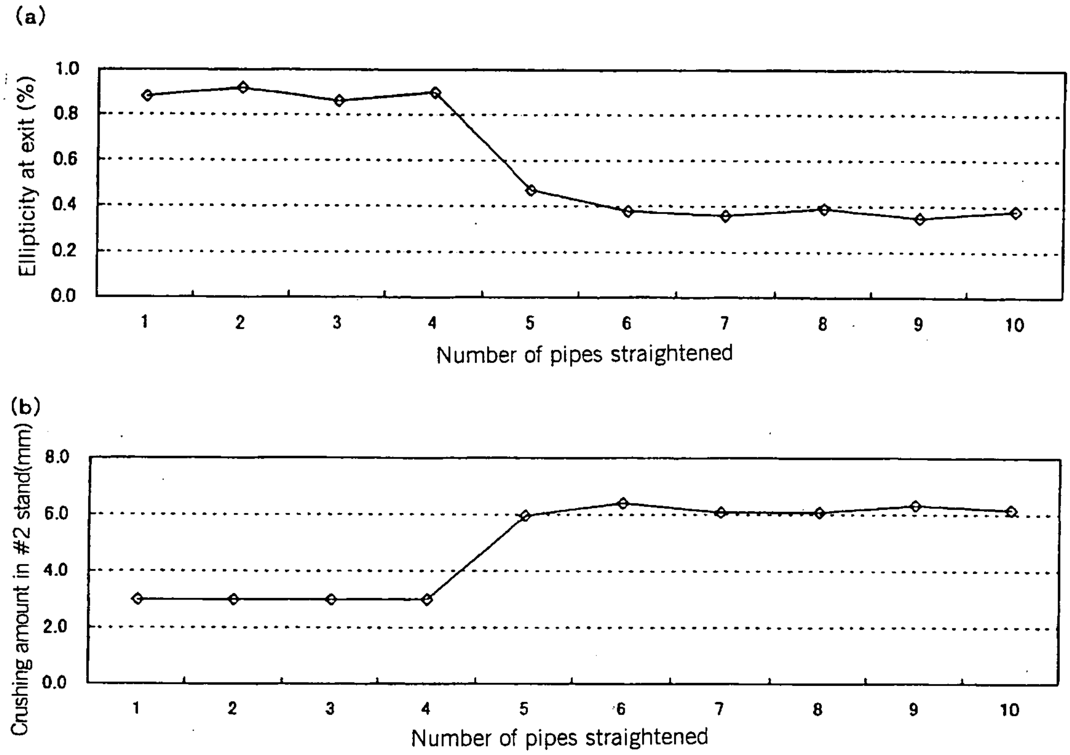

(a)
Ellipticity at exit (%)
1.0
0.8
0.6
0.4
0.2
0.0
1 2 3 4 5 6 7 8 9 10
Number of pipes straightened
(b)
Crushing amount in #2 stand(mm)
8.0
6.0
4.0
2.0
0.0
1 2 3 4 5 6 7 8 9 10
Number of pipes straightened

Fig. 10

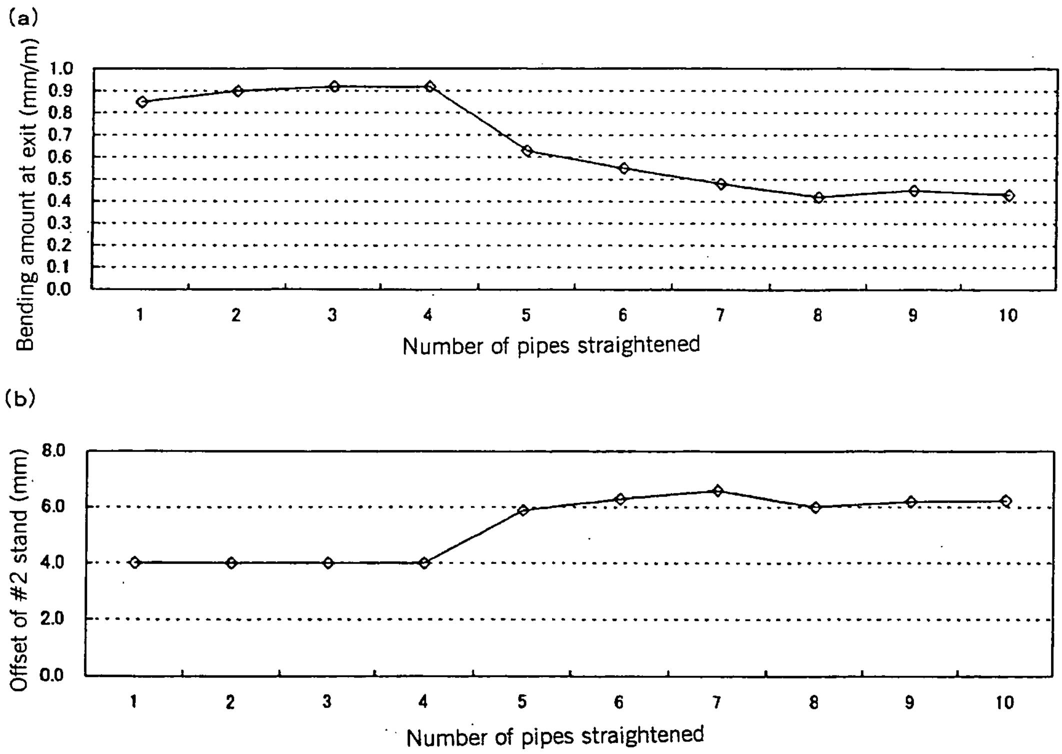
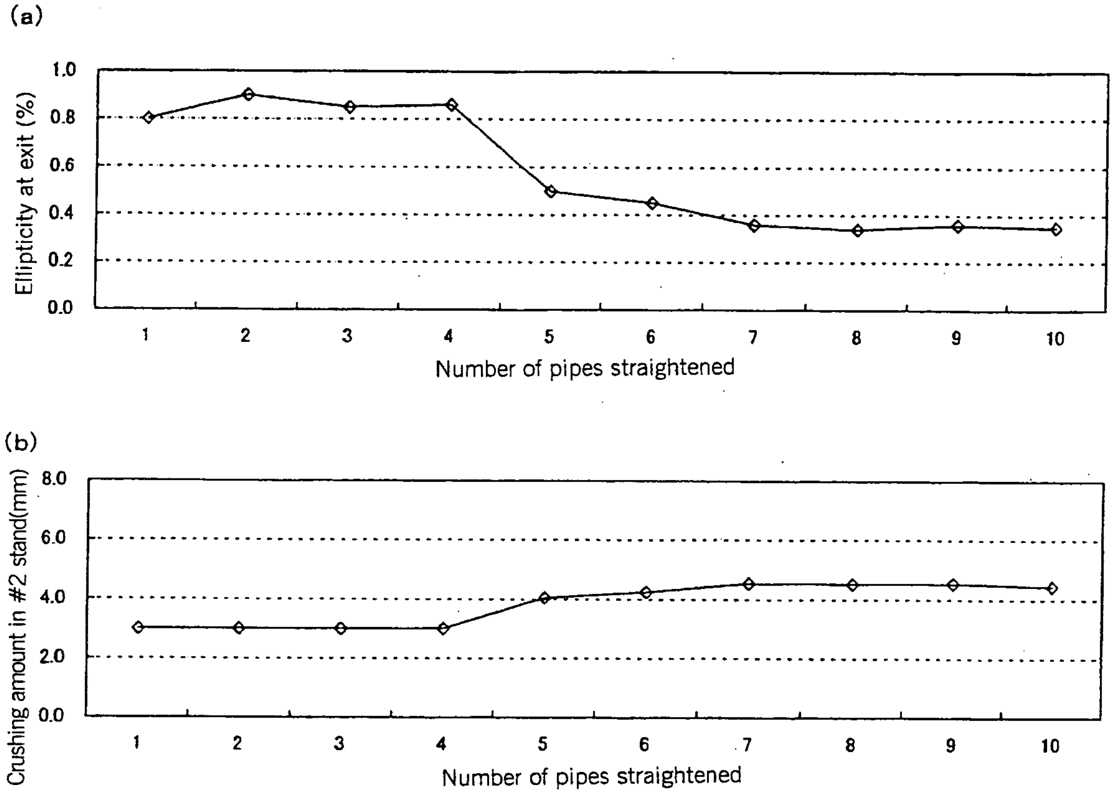

(a)
Bending amount at exit (mm/m)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1 2 3 4 5 6 7 8 9 10
Number of pipes straightened
(b)
Offset of #2 stand (mm)
8.0
6.0
4.0
2.0
0.0
1 2 3 4 5 6 7 8 9 10
Number of pipes straightened

Fig. 11


(a)
Ellipticity at exit (%)
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
6
7
8
9
10
Number of pipes straightened
(b)
Crushing amount in #2 stand(mm)
8.0
6.0
4.0
2.0
0.0
1
2
3
4
5
6
7
8
9
10
Number of pipes straightened

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2006/306678

A. CLASSIFICATION OF SUBJECT MATTER
B21D3/02(2006.01), ***B21D3/14***(2006.01)

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)
B21D3/02(2006.01), ***B21D3/14***(2006.01)

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	1996-2006
Kokai Jitsuyo Shinan Koho	1971-2006	Toroku Jitsuyo Shinan Koho	1994-2006

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 2001-179340 A (Sumitomo Metal Industries, Ltd.), 03 July, 2001 (03.07.01), Full text (Family: none)	1-6
Y	JP 6-114442 A (JGC Corp.), 26 April, 1994 (26.04.94), Par. No. [0010]; Figs. 3, 4 (Family: none)	1-6
Y	JP 6-88084 B2 (Hitachi, Ltd.), 09 November, 1994 (09.11.94), Page 2, right column, lines 17 to 42; Figs. 7, 8 (Family: none)	1-6

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

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Date of the actual completion of the international search
15 June, 2006 (15.06.06)

Date of mailing of the international search report
27 June, 2006 (27.06.06)

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Patent documents cited in the description

- JP 2001179340 A **[0007]**
- JP H02207921 A **[0007]**
- JP H0472619 B **[0007]**