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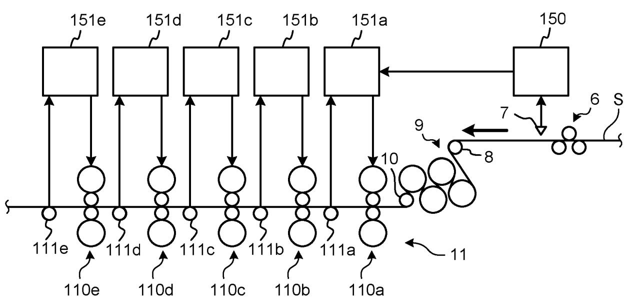
(54) COLD-ROLLING METHOD AND COLD-ROLLING EQUIPMENT

(57) A cold rolling method of the present invention includes: a calculation step of calculating a leveling amount of a rolling mill using an out-of-plane deformation amount of a steel sheet measured on an upstream side of the rolling mill; a control step of controlling leveling of the rolling mill based on the leveling amount calculated in the calculation step; and a cold rolling step of applying cold rolling on the steel sheet using the rolling mill controlled by the control step.

FIG.4



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Description

Field

[0001] The present invention relates to a cold rolling method and cold rolling equipment.

Background

[0002] In general, when a rolled material such as a cold-rolled thin steel sheet is cold-rolled, it is desirable to perform cold rolling in a state in which the sheet passing property of the rolled material is stabilized by improving the shape (or flatness) of the rolled material while maintaining good thickness accuracy in the longitudinal direction and the width direction of the rolled material. On the other hand, for the purpose of suppressing fuel consumption by weight reduction and the like, there is an increasing need for a difficult-to-roll material such as a thin hard material having a high load and a thin sheet thickness before rolling. During cold rolling of such a difficult-to-roll material, in order to suppress a rolling load, the difficult-to-roll material is thinned by hot rolling in the preceding process and then sent to the cold rolling process.

[0003] In recent years, many of the control factors of the cold rolling mill are automatically controlled by an actuator mounted on the cold rolling mill. As a method of automatically controlling the shape, shape feedback (FB) control is often used in which a shape meter is installed on the delivery side of the rolling mill, and leveling and bender of the rolling mill are automatically controlled using shape data of the shape meter. However, at the time of cold rolling of the difficult-to-roll material as described above, there is a case where the material is joined to the next coil in a state where the camber of the coil tip and tail end due to the shape defect at the time of hot rolling remains. When the camber or the shape defect sharply fluctuates along the coil longitudinal direction, variations with respect to roll deflection correction represented by a roll gap, leveling, a work roll bender or an intermediate roll shift of a cold rolling mill, and roll expansion by a thermal crown, as well as a rolling load (and an accompanying calculated forward slip or torque), cannot be absorbed by automatic control. For this reason, the shape of the rolled material after cold rolling is often poor, and sheet breakage frequently occurs during cold rolling. A weak point of the FB control is that it cannot cope with sudden fluctuations, and feed-forward (FF) control is also used to compensate for this.

[0004] Patent Literature 1 discloses an FF control method of predicting unilateral elongation or camber of a steel sheet on the entry side of a rolling mill from difference tension measured by a difference tensiometer on the upstream side of the rolling mill, and controlling leveling so as to correct the predicted unilateral elongation or camber. In addition, Patent Literature 2 discloses a method for suppressing a rollability defect by performing FF control on a bender of a rolling mill on the basis of a twist of steel sheet shape data of a cross-sectional profile meter on the upstream side of the rolling mill and a C-warping height. In addition, Patent Literature 3 discloses a method for suppressing rollability defect by stopping rolling when the twist of the steel sheet shape data of the cross-sectional profile meter on the upstream side of the rolling mill and the C-warping height are out of a predetermined range.

Citation List

Patent Literature

[0005]

Patent Literature 1: JP 2012-161806 A
Patent Literature 2: JP 2022-14800 A
Patent Literature 3: JP 2021-133411 A

Summary

Technical Problem

[0006] In the method disclosed in Patent Literature 1, the difference tension between the stands is measured, and the average unilateral elongation or camber between the stands is predicted from the difference tension.
Therefore, it does not matter if the change in the unilateral elongation or the camber is gentle, but in a case where the change is rapid as in the joint point, the unilateral elongation or the camber predicted from the difference tension and the unilateral elongation or the camber on the delivery side of the rolling mill are different, and thus, it is not possible to perform control well. This is because if the unilateral elongation or camber is too large, the steel sheet cannot be stuck to the roll, and the difference tension cannot be measured by the difference tensiometer. In the methods disclosed in Patent Literature 2 and Patent Literature 3, in order to calculate unilateral elongation or camber of a steel sheet having large unilateral

elongation or camber, a cross-sectional shape of the steel sheet is measured to calculate the twist and C-warping height of the cross section of the steel sheet. However, the twist and the C-warping height are only a part of the steel sheet shape information, and it is difficult to calculate accurate unilateral elongation or camber from the cross-sectional shape, so that it is not possible to perform control well.

[0007] The present invention has been made in view of the above problems, and an object of the present invention is to provide a cold rolling method and cold rolling equipment capable of performing cold rolling with high productivity and yield while securing stability of cold rolling even when cold rolling a difficult-to-roll material having a high load and a small sheet thickness before rolling.

Solution to Problem

[0008] To solve the problem and achieve the object, (1) a cold rolling method according to the present invention includes: a calculation step of calculating a leveling amount of a rolling mill using an out-of-plane deformation amount of a steel sheet measured on an upstream side of the rolling mill; a control step of controlling leveling of the rolling mill on a basis of the leveling amount calculated in the calculation step; and a cold rolling step of applying cold rolling to the steel sheet using the rolling mill controlled by the control step.

[0009] (2) Moreover, in the cold rolling method according to above (1), the out-of-plane deformation amount of the steel sheet may be an out-of-plane deformation amount measured on the upstream side of the rolling mill and immediately upstream or immediately downstream of a steering device that changes a conveying direction of the steel sheet.

[0010] (3) Moreover, in the cold rolling method according to above (1) or (2), when the out-of-plane deformation amount of the steel sheet measured on the upstream side of the rolling mill exceeds a threshold value, the cold rolling may not be performed on the steel sheet in the cold rolling step.

[0011] (4) Moreover, in the cold rolling method according to any one of above (1) to (3), in the calculation step, the leveling amount may be calculated using a value obtained as a result of applying a leveling amount calculation program to the out-of-plane deformation amount, and the leveling amount calculation program may be a machine-learned program using each out-of-plane deformation amount of a plurality of steel sheets as an input variable and each leveling amount obtained as a result of physical simulation with respect to each out-of-plane deformation amount as an objective variable.

[0012] (5) Moreover, in the cold rolling method according to any one of above (1) to (4), in the calculation step, the leveling amount may be calculated using an out-of-plane deformation amount of the steel sheet on the upstream side of the rolling mill and an out-of-plane deformation amount of the steel sheet measured on a downstream side of the rolling mill.

[0013] (6) Moreover, a cold rolling equipment according to the present invention includes: a rolling mill that applies cold rolling to a steel sheet; a shape measurement device that is disposed on an upstream side of the rolling mill and measures an out-of-plane deformation amount of the steel sheet; a calculation device that calculates a leveling amount of the rolling mill using the out-of-plane deformation amount of the steel sheet measured by the shape measurement device; and a control device that controls leveling of the rolling mill on a basis of the leveling amount calculated by the calculation device.

[0014] (7) Moreover, the cold rolling equipment according to above (6) may further include a steering device that is disposed on the upstream side of the rolling mill and changes a conveying direction of the steel sheet, wherein the out-of-plane deformation amount of the steel sheet may be an out-of-plane deformation amount measured on the upstream side of the rolling mill and immediately upstream or immediately downstream of the steering device.

[0015] (8) Moreover, in the cold rolling equipment according to above (6) or (7), when the out-of-plane deformation amount of the steel sheet measured on the upstream side of the rolling mill exceeds a threshold value, the rolling mill may not execute the cold rolling on the steel sheet.

[0016] (9) Moreover, in the cold rolling equipment according to any one of above (6) to (8), the calculation device may calculate the leveling amount using a value obtained as a result of applying a leveling amount calculation program to the out-of-plane deformation amount, and the leveling amount calculation program may be a machine-learned program using each out-of-plane deformation amount of a plurality of steel sheets as an input variable and each leveling amount obtained as a result of physical simulation with respect to each out-of-plane deformation amount as an objective variable.

[0017] (10) Moreover, in the cold rolling equipment according to any one of above (6) to (9), the calculation device may calculate the leveling amount using an out-of-plane deformation amount of the steel sheet on the upstream side of the rolling mill and an out-of-plane deformation amount of the steel sheet measured on a downstream side of the rolling mill.

Advantageous Effects of Invention

[0018] The cold rolling method and the cold rolling equipment according to the present invention have an effect of being able to perform cold rolling with high productivity and yield while securing stability of cold rolling even when cold rolling a difficult-to-roll material having a high load and a small sheet thickness before rolling.

Brief Description of Drawings

[0019]

FIG. 1 is an overall view illustrating a schematic configuration of a cold rolling line according to an embodiment.
FIG. 2 is a diagram illustrating an example of a method of measuring an out-of-plane deformation amount.
FIG. 3 is a diagram illustrating a measurement result of unilateral elongation or camber which is an out-of-plane deformation amount of a steel sheet measured by a shape measurement device installed on a delivery side of an entry-side looper.
FIG. 4 is an explanatory diagram of leveling control.
FIG. 5 is a diagram illustrating transition of true unilateral elongation or camber as a result of a simulation in which a steel sheet having unilateral elongation or camber is cold rolled.
FIG. 6 is a diagram illustrating transition of unilateral elongation or camber converted from difference tension as a result of simulation of cold rolling of a steel sheet having unilateral elongation or camber.
FIG. 7 is a diagram illustrating transition of true unilateral elongation or camber as a result of a simulation in which a steel sheet having unilateral elongation or camber is cold rolled when leveling FB control is performed.
FIG. 8 is a diagram illustrating transition of unilateral elongation or camber converted from difference tension as a result of a simulation in which a steel sheet having unilateral elongation or camber is cold rolled when leveling FB control is performed.
FIG. 9 is a diagram illustrating transition of true unilateral elongation or camber as a result of performing leveling FB control so as to reduce true unilateral elongation or camber on the delivery side of a first rolling mill by simulation.
FIG. 10 is a diagram illustrating transition of unilateral elongation or camber converted from the difference tension as a result of performing the leveling FB control so as to reduce the true unilateral elongation or camber on the delivery side of the first rolling mill by simulation.
FIG. 11 is a diagram illustrating transition of true unilateral elongation or camber as a result of simulation in which a steel sheet S having unilateral elongation or camber is cold rolled by performing leveling FF control and leveling FB control.
FIG. 12 is a diagram illustrating transition of unilateral elongation or camber converted from difference tension as a result of a simulation in which a steel sheet S having unilateral elongation or camber is cold rolled by performing leveling FF control and leveling FB control. Description of Embodiments

[0020] Hereinafter, embodiments of a cold rolling method and cold rolling equipment according to the present invention will be described. The cold rolling equipment according to an embodiment includes a rolling mill that applies cold rolling to a steel sheet, a shape measurement device that is disposed on an upstream side of the rolling mill and measures an out-of-plane deformation amount of the steel sheet, a calculation device that calculates a leveling amount of the rolling mill using the out-of-plane deformation amount of the steel sheet measured by the shape measurement device, and a control device that controls the leveling of the rolling mill on the basis of the leveling amount calculated by the calculation device. The cold rolling method applied to the cold rolling equipment according to the embodiment includes a calculation step of calculating the leveling amount of the rolling mill using the out-of-plane deformation amount of the steel sheet measured on the upstream side of the rolling mill, a control step of controlling the leveling of the rolling mill on the basis of the leveling amount calculated in the calculation step, and a cold rolling step of applying cold rolling to the steel sheet using the rolling mill controlled by the control step. Note that the present invention is not limited by the present embodiment.

[0021] FIG. 1 is an overall view illustrating a schematic configuration of cold rolling equipment 1 according to an embodiment. In the cold rolling equipment 1 according to the embodiment, a pay-off reel 2 for discharging the steel sheet S from the coil is installed at the most upstream portion. In addition, the cold rolling equipment 1 according to the embodiment is provided with a welding machine 3 that joins the tail end of the steel sheet S that has been delivered and the tip end of the steel sheet that has been delivered from the next coil, and a notcher 4 that cuts the steel sheet S in a semi-elliptical shape at the end of the welding line in order to suppress stress concentration. The cold rolling equipment 1 according to the embodiment is provided with an entry-side looper 5 for absorbing a line speed difference between the joining process and the rolling process. A steering device 6 having CPC meandering control is installed on a delivery side of the entry-side looper 5, and a shape measurement device 7 is installed immediately downstream of the steering device 6. The shape measurement device 7 may be disposed immediately upstream of the steering device 6. In the cold rolling equipment 1 according to the embodiment, a deflector steering roll 8 having CPC meandering control, a bridle roll group 9 for applying a tension step between a rolling process and an upstream process thereof, and a deflector steering roll 10 having CPC meandering control immediately downstream of the bridle roll group 9 are installed. In the cold rolling equipment 1, a 5-high continuous cold rolling mill 11 for rolling the steel sheet S is installed. In the cold rolling equipment 1, a bridle roll 12 for forming a tension step between a rolling step and a downstream step thereof, a cutting machine 13, and a tension reel 14 for winding the steel sheet S are installed.

[0022] At the tip end and the tail end of the steel sheet S delivered from the pay-off reel 2, there is a shape defective portion accompanied by unilateral elongation or camber derived from the hot rolling process. In addition, when the steel sheet S is not straight at the time of joining by the welding machine 3, the steel sheet S is welded in a "chevron" shape, and the unilateral elongation or camber is further increased. When such a shape defective portion is cold-rolled by the cold rolling mill 11, cracking occurs at the width end of the steel sheet S during the rolling process, and breaking occurs from the cracking as a starting point. In addition, when a difference tension between rolling mills (between stands) of the cold rolling mill 11 due to unilateral elongation or camber is applied to the steel sheet S, breaking occurs due to cracking, or breaking occurs even if the steel sheet S is not cracked. The difference tension refers to a tension difference between both ends in the width direction of the steel sheet S detected by a pressure detection unit such as a tensiometer disposed on the delivery side of the rolling mill.

[0023] Here, the geometry of the shape of the steel sheet S will be described. A shape defect occurs in the steel sheet S mainly due to unevenness in the width direction of elongation in the longitudinal direction in the rolling process. The shape defect is superposition such as unilateral elongation or camber or an edge wave (center buckle), and the shape defect that most greatly affects breakage during rolling is unilateral elongation or camber. In particular, in the case of a thin sheet, out-of-plane deformation derived from unilateral elongation or camber disappears when the thin sheet is cut, and it is difficult to measure the unilateral elongation or camber. On the other hand, the edge wave (center buckle) can be measured because out-of-plane deformation remains even in the case of a cut sheet.

[0024] When the steel sheet S is a curve, the geometric definition of the curvature κ of the unilateral elongation or the camber can be expressed by the following Formula (1).

$$\kappa = \cos\omega \frac{d^2 v}{dx^2} + \sin\omega \frac{d^2 w}{dx^2} \quad \cdots (1)$$

[0025] Here, in the above Formula (1), x is a line direction position, v is displacement in the width direction at the width center, w is displacement in the vertical direction at the width center, and ω is a twist angle. Since it is difficult to calculate the above Formula (1), it is considered as a longitudinal average of single elongation or camber. The average curvature K can be defined as the following Formula (2).

$$\mathrm{K}(x) = \frac{\int_x^{x+L} \kappa(\xi) d\xi}{L} \quad \cdots (2)$$

[0026] Here, in the above Formula (2), L is a length for averaging. When the above Formula (1) is substituted into the above Formula (2), the average curvature K can be expressed by the following Formula (3).

$$\mathrm{K}(x) = \frac{1}{L}\int_x^{x+L} \cos\omega \frac{d^2 v}{d\xi^2} d\xi + \frac{1}{L}\int_x^{x+L} \sin\omega \frac{d^2 w}{d\xi^2} d\xi \quad \cdots (3)$$

[0027] The first term on the right side of the above Formula (3) is an amount observed as meandering or skew. The second term on the right side of the above Formula (3) is an amount observed as out-of-plane deformation. From the above Formula (3), it can be seen that even if only meandering is observed, unilateral elongation or camber is not found. If meandering does not occur, the first term on the right side of the above Formula (3) becomes zero, and the average unilateral elongation or camber can be obtained only from the observation amount of out-of-plane deformation. Here, when the twist angle ω is small, the above Formula (3) becomes the following Formula (4).

$$\mathrm{K}(x) = \frac{1}{L}\int_x^{x+L} \frac{d^2 v}{d\xi^2} d\xi + \frac{1}{L}\int_x^{x+L} \omega \frac{d^2 w}{d\xi^2} d\xi \quad \cdots (4)$$

[0028] Further, the above Formula (4) can be modified to the following Formula (5).

$$\mathrm{K}(x) = \frac{1}{L}\int_x^{x+L} \frac{d^2 v}{d\xi^2} d\xi - \frac{1}{L}\int_x^{x+L} \frac{d\omega}{d\xi}\frac{dw}{d\xi} d\xi \quad \cdots (5)$$

[0029] Here, the observation amount of the out-of-plane deformation of the second term on the right side of the above Formula (5) will be considered. Assuming that the twist angle ω is small, the deflection W of the steel sheet S is expressed by the following Formula (6).

$$W(x,y) = w(x) + \omega(x)y \quad \cdots (6)$$

[0030] Here, in the above Formula (6), y is a position in the width direction. The length l of the steel sheet S along the bent curved surface can be expressed by the following Formula (7).

$$l(x,y) = \int_x^{x+L} \sqrt{1 + \left(\frac{dW}{d\xi}\right)^2}\, d\xi \quad \cdots (7)$$

[0031] Further, the elongation difference rate $\Delta\varepsilon_l$ can be defined as in the following Formula (8).

$$\Delta\varepsilon_l(x,y) = \frac{l(x,y) - l_0(x)}{l_0(x)} \quad \cdots (8)$$

[0032] Here, in the above Formula (8), l_0 is an average length in the width direction, and can be expressed by the following Formula (9).

$$l_0(x) = \frac{1}{b}\int_{-b/2}^{b/2} l(x,y)dy \quad \cdots (9)$$

[0033] Here, in the above Formula (9), b is a sheet width. When the above Formula (6) and the above Formula (7) are substituted into the above Formula (9), the following Formula (10) is established.

$$\begin{aligned} l_0(x) &= \frac{1}{b}\int_x^{x+L} d\xi \int_{-b/2}^{b/2} \sqrt{1 + \left(\frac{dW}{d\xi}\right)^2}\, dy \\ &= \frac{1}{b}\int_x^{x+L} d\xi \int_{-b/2}^{b/2} \sqrt{1 + \left(\frac{dw}{d\xi} + \frac{d\omega}{d\xi}y\right)^2}\, dy \end{aligned} \quad \cdots (10)$$

[0034] Here, when the deflection w and the twist angle ω are small, the above Formula (10) becomes the following Formula (11).

$$l_0(x) = \frac{1}{b}\int_x^{x+L} d\xi \int_{-b/2}^{b/2} \left(1 + \frac{1}{2}\left(\frac{dw}{d\xi} + \frac{d\omega}{d\xi}y\right)^2\right) dy \quad \cdots (11)$$

[0035] Further, when the above Formula (11) is further modified, the following Formula (12) is obtained.

$$l_0(x) = \int_x^{x+L} \left(1 + \frac{1}{2}\left(\frac{dw}{d\xi}\right)^2 + \frac{b^2}{24}\left(\frac{d\omega}{d\xi}\right)^2\right) d\xi \quad \cdots (12)$$

[0036] When the above Formula (6), the above Formula (7), and the above Formula (12) are substituted into the above Formula (8), the elongation difference rate $\Delta\varepsilon_l$ can be expressed by the following Formula (13).

$$\Delta\varepsilon_l(x,y)=\frac{1}{L}\int_x^{x+L}\left\{\frac{dw}{d\xi}\frac{d\omega}{d\xi}y+\frac{1}{2}\left(\frac{dw}{d\xi}\right)^2\left(y^2-\frac{b^2}{12}\right)\right\}d\xi \quad \cdots (13)$$

[0037] The curvature K_1 of the average unilateral elongation (average camber) converted from the elongation difference rate $\Delta\varepsilon_l$ can be defined as in the following Formula (14).

$$K_1(x)=-\frac{12}{b^3}\int_{-b/2}^{b/2}\Delta\varepsilon_l(x,y)ydy \quad \cdots (14)$$

[0038] Then, when the above Formula (13) is substituted into the above Formula (14), the following Formula (15) is obtained.

$$K_1(x)=-\frac{1}{L}\int_x^{x+L}\frac{dw}{d\xi}\frac{d\omega}{d\xi}d\xi \quad \cdots (15)$$

[0039] The above Formula (15) is the second term on the right side of the above Formula (5), and the above Formula (5) can be expressed as in the following Formula (16).

$$K(x)=\frac{1}{L}\int_x^{x+L}\frac{d^2v}{d\xi^2}d\xi+K_1(x) \quad \cdots (16)$$

[0040] From the measured value of the out-of-plane deformation amount or the gradient thereof measured by the shape measurement device 7, it is possible to calculate the curvature K_1 by using the above Formula (14). When there is no meandering of the steel sheet S and the first term on the right side of the above Formula (14) is zero, the curvature K_1 of the unique unilateral elongation or camber is the same as the measurable curvature K_1. Since it is difficult to measure the first term on the right side of the above Formula (16) related to the meandering of the above Formula (16), it is desirable to measure the out-of-plane deformation amount of the steel sheet S by the shape measurement device 7 at a place where the steel sheet S does not meander.

[0041] Here, the out-of-plane deformation amount is one of indices indicating camber and unilateral elongation of the steel sheet S. As a method of measuring the out-of-plane deformation amount, the following two methods are conceivable with reference to FIG. 2. FIG. 2 is a diagram illustrating an example of a method of measuring an out-of-plane deformation amount.

[0042] As a first method, as illustrated in FIG. 2(a), a normal force is applied to the steel sheet S to smooth the wrinkles by winding the steel sheet S around the roll 20 or pressing the steel sheet S, and the camber (unilateral elongation) of the steel sheet S in which the wrinkles are smoothed is measured.

[0043] As a second method, as illustrated in FIG. 2(b), the steel sheet S is straightened in the longitudinal direction (not meandering), and the camber (unilateral elongation) is converted from the height of the wrinkle of the steel sheet S.

[0044] In the first method, if the length of the steel sheet S in the longitudinal direction for smoothing wrinkles is short, it is difficult to perform measurement. Therefore, it is desirable to employ the second method, and in the present embodiment, the out-of-plane deformation amount is measured (converted) by the second method.

[0045] In the field of rolling, the shape of the asymmetric component is often expressed by the difference between the right and left sides (shape parameter) of the elongation difference rate distribution. A shape parameter λ_1 representing unilateral elongation or camber is defined as in the following Formula (17).

$$\lambda_1=3\int_{-1}^{1}\Delta\varepsilon_l\,(x,y')y'dy'\times 10^5 \quad \cdots (17)$$

[0046] The unit of the shape parameter λ_1 is an I-unit. Here, y' can be expressed by the following Formula (18).

$$y'=\frac{2}{b}y \quad \cdots (18)$$

[0047] Then, when the above Formula (18) and the above Formula (14) are substituted into the above Formula (17), the following Formula (19) is obtained.

$$\lambda_1 = \frac{12}{b^2}\int_{-b/2}^{b/2} \Delta\varepsilon_l(x,y)ydy \times 10^5 = -bK_1 \times 10^5 \quad \cdots (19)$$

[0048] As can be seen from the above Formula (19), the shape parameter λ_1 has a proportional relationship with the curvature K_1.

[0049] FIG. 3 is a diagram illustrating a measurement result of unilateral elongation or camber which is an out-of-plane deformation amount of the steel sheet S measured by the shape measurement device 7 installed on the delivery side of the entry-side looper 5. In FIG. 3, the horizontal axis represents time, and the vertical axis represents the shape parameter λ_1 defined by the above Formulae (17) and (19). In this case, the shape parameter λ_1 rapidly changes at the joining point. In the preceding material, there is no unilateral elongation or camber derived from the hot rolling process, and in the succeeding material, there is unilateral elongation or camber derived from the hot rolling process, and the size of the unilateral elongation or camber gradually decreases as the tip end is separated.

[0050] In order to detect the unilateral elongation or the camber by the shape measurement device 7, it is preferable that the steel sheet S does not meander, and in the present embodiment, the shape measurement device 7 is installed immediately downstream of the steering device 6. The shape measurement device 7 is a real-time 3D laser scanner that rotates a plurality of laser beams and measures a distance and a rotation angle between a rotation center and a surface of a steel sheet to measure a position of the surface of the steel sheet as a point cloud. The rotation cycle of the laser beam is, for example, 0.1 seconds. By using the 3D scanner as the shape measurement device 7, the shape measurement device 7 can be installed outside the line with a single sensor, so that there are few installation restrictions and maintenance is simple. In addition, since the surface of the steel sheet can be measured instantaneously, there are advantages that it is possible to perform measurement without depending on the line speed, with vibration resistance, and in a non-contact manner, and thus a large shape can be measured. Since the position of the point cloud has a measurement error and is an irregular point cloud, the measurement error is removed by the smoothing thin plate spline method to calculate the steel sheet curved surface W from the point cloud. Note that, since it takes time to calculate the smoothing thin plate spline method, it is preferable to use, for example, the technique disclosed in Japanese Patent Application Laid-Open No. 2017-49071 in order to increase the calculation speed. Then, the curvature K_1 is calculated from the above Formula (14) and the steel sheet curved surface W, and the shape parameter λ_1 is further calculated from the above Formula (19).

[0051] Here, when the unilateral elongation or camber as illustrated in FIG. 3 is present in the steel sheet S on the entry side of the rolling mill, the steel sheet S is broken by the cold rolling by the cold rolling mill 11. Since the shape measurement device 7 is installed on the upstream side of the cold rolling mill 11, information on the shape of the steel sheet S on the entry side of the rolling mill can be known before the cold rolling. The risk of the steel sheet S breaking can be predicted by the magnitude of the unilateral elongation or the camber obtained from the information. Therefore, when the unilateral elongation or camber on the entry side of the rolling mill is too large, it is possible to perform an operation so as not to perform rolling in order to prevent breakage of the steel sheet S. In the cold rolling equipment 1 according to the embodiment, the shape measurement device 7 measures, as the out-of-plane deformation amount of the steel sheet S, the unilateral elongation or the camber on the entry side of the rolling mill. When the measured out-of-plane deformation amount (unilateral elongation or camber) exceeds a preset threshold value, the cold rolling is not performed on the steel sheet S by the cold rolling mill 11. However, if rolling is not performed, the portion does not become a product, and thus the yield decreases.

[0052] Therefore, the leveling control will be described with reference to FIG. 4 in order to more actively utilize the information on the shape of the steel sheet S on the entry side of the rolling mill. In general, leveling FB control is performed in order to correct the unilateral elongation or the camber of the steel sheet S in the cold rolling mill 11. As illustrated in FIG. 4, in the cold rolling mill 11, a first shape meter roll 111a, a second shape meter roll 111b, a third shape meter roll 111c, a fourth shape meter roll 111d, and a fifth shape meter roll 111e are installed on the delivery sides of a first rolling mill 110a, a second rolling mill 110b, a third rolling mill 110c, a fourth rolling mill 110d, and a fifth rolling mill 110e, respectively. In the following description, the first rolling mill 110a, the second rolling mill 110b, the third rolling mill 110c, the fourth rolling mill 110d, and the fifth rolling mill 110e are also simply referred to as a rolling mill 110 unless otherwise distinguished. In addition, the first shape meter roll 111a, the second shape meter roll 111b, the third shape meter roll 111c, the fourth shape meter roll 111d, and the fifth shape meter roll 111e are also simply referred to as a shape meter roll 111 unless otherwise distinguished.

[0053] The shape meter roll 111 measures a contact force distribution between the shape meter roll 111 and the steel sheet S, and estimates unilateral elongation or camber, which is an out-of-plane deformation amount of the steel sheet S, from the contact force distribution. Although the measurement method of the shape meter roll 111 has high accuracy, it is necessary to bring the shape meter roll into contact with the steel sheet S. Therefore, it is difficult to measure a large shape defect. Therefore, merely estimating the unilateral elongation or the camber from the contact force distribution measured by the shape meter roll 111 may cause breakage due to the camber stress in rolling by the rolling mill 110.

[0054] The cold rolling mill 11 is provided with a first leveling control device 151a, a second leveling control device 151b, a third leveling control device 151c, a fourth leveling control device 151d, and a fifth leveling control device 151e respectively corresponding to the first rolling mill 110a, the second rolling mill 110b, the third rolling mill 110c, the fourth rolling mill 110d, and the fifth rolling mill 110e. In the following description, the first leveling control device 151a, the second leveling control device 151b, the third leveling control device 151c, the fourth leveling control device 151d, and the fifth leveling control device 151e are also simply referred to as a leveling control device 151 unless otherwise distinguished.

[0055] The leveling control device 151 calculates a leveling target value by multiplying a value obtained by time-integrating the unilateral elongation or the camber on the delivery side of the rolling mill by a gain. The leveling target value is equal to the pressing position difference between the left and right bearings of the backup roll of the rolling mill 110, and consequently, the pressing amount difference between one side in the sheet thickness direction and the other side in the sheet thickness direction (the pressing amount difference between the left and right of the steel sheet S) with the center portion of the steel sheet S in the sheet thickness direction as a boundary. Then, the leveling FB control is performed on the corresponding rolling mill 110 so as to obtain the calculated leveling target value. By performing such leveling FB control on the rolling mill 110, the contact force distribution on the shape meter roll 111 on the delivery side of the rolling mill becomes symmetric, and as a result, the unilateral elongation or the camber can be reduced. However, as a drawback of the leveling FB control, it is not possible to cope with a sudden disturbance, and it is not sufficient to cope with unilateral elongation or camber as illustrated in FIG. 3.

[0056] In the cold rolling equipment 1 according to the embodiment, the 5-high rolling mill 110 is provided in the cold rolling mill 11, but the rolling mill 110 to be controlled to the leveling target value may include at least the rolling mill 110 provided most upstream in the conveying direction of the steel sheet S. Therefore, in the cold rolling equipment 1 according to the embodiment, one or more rolling mills 110 including the rolling mill 110 (the first rolling mill 110a) provided on the most upstream side are targets of the leveling FB control.

[0057] FIG. 5 is a diagram illustrating transition of true unilateral elongation or camber as a result of a simulation in which a steel sheet S having unilateral elongation or camber is cold rolled. FIG. 6 is a diagram illustrating transition of the unilateral elongation or the camber converted from the difference tension as a result of the simulation in which the steel sheet S having the unilateral elongation or the camber is cold rolled. The unilateral elongation or the camber on the entry side of the first rolling mill is based on the unilateral elongation or the camber illustrated in FIG. 3.

[0058] As illustrated in FIG. 5, the true unilateral elongation or camber on the delivery side of the first rolling mill is smaller than the true unilateral elongation or camber on the entry side of the first rolling mill. This is considered to be because the rolling phenomenon itself has an action of reducing the unilateral elongation or the camber. However, as illustrated in FIG. 5, in a time (0 to 10 seconds) in which the true unilateral elongation or camber on the entry side of the first rolling mill rapidly changes, the magnitude of the true unilateral elongation or camber on the delivery side of the first rolling mill also increases.

[0059] The true unilateral elongation or camber on the delivery side of the first rolling mill illustrated in FIG. 5 is compared with the unilateral elongation or camber converted from the difference tension on the delivery side of the first rolling mill illustrated in FIG. 6. Then, it can be seen that, in the time (0 to 10 seconds) in which the true unilateral elongation or camber rapidly changes, the unilateral elongation or camber converted from the difference tension is different from the true unilateral elongation or camber. On the other hand, in a time (10 to 50 seconds) in which the change is relatively gentle, the both are relatively matched. Further, the unilateral elongation or camber converted from the difference tension on the delivery side of the first rolling mill and the unilateral elongation or camber converted from the difference tension in the first shape meter roll 111a illustrated in FIG. 6 relatively coincide with each other.

[0060] From the above, it can be seen that the unilateral elongation or camber converted from the difference tension in the first shape meter roll 111a disposed on the delivery side of the first rolling mill 110a does not necessarily coincide with the true unilateral elongation or camber. Therefore, it is not possible to observe true unilateral elongation or camber in the actual machine. Therefore, the results of a simulation in which the steel sheet S having unilateral elongation or camber in the case of performing the leveling FB control is cold rolled are illustrated in FIGS. 7 and 8.

[0061] FIG. 7 is a diagram illustrating transition of true unilateral elongation or camber as a result of a simulation in which a steel sheet S having unilateral elongation or camber is cold rolled in a case where the leveling FB control is performed. FIG. 8 is a diagram illustrating transition of the unilateral elongation or camber converted from the difference tension as a result of the simulation in which the steel sheet S having the unilateral elongation or camber is cold rolled when the leveling FB control is performed.

[0062] In the leveling FB control, the leveling of the first rolling mill 110a to the fifth rolling mill 110e is controlled so as to reduce the magnitude of the difference tension in each of the first shape meter roll 111a to the fifth shape meter roll 111e disposed on the delivery side of each of the first rolling mill 110a to the fifth rolling mill 110e. Therefore, the magnitude of the unilateral elongation or camber converted from the difference tension illustrated in FIG. 8 can be made significantly smaller than the magnitude of the unilateral elongation or camber converted from the difference tension illustrated in FIG. 6. On the other hand, the magnitude of the true unilateral elongation or camber on the delivery side of the first rolling mill illustrated in

FIG. 7 is smaller at the time (10 to 50 seconds) in which the true unilateral elongation or camber gently changes than the true unilateral elongation or camber on the delivery side of the first rolling mill illustrated in FIG. 5. However, in the time (0 to 10 seconds) in which the true unilateral elongation or camber rapidly changes, the time is substantially the same, and the leveling FB control cannot be performed.

[0063] Originally, it is desired to reduce the magnitude of the true unilateral elongation or camber on the delivery side of the first rolling mill, but it is not possible to observe them in an actual machine. Therefore, the results of performing the leveling FB control so as to reduce the true unilateral elongation or camber on the delivery side of the first rolling mill by simulation are illustrated in FIGS. 9 and 10.

[0064] FIG. 9 is a diagram illustrating transition of true unilateral elongation or camber as a result of performing the leveling FB control so as to reduce the true unilateral elongation or camber on the delivery side of the first rolling mill by simulation. FIG. 10 is a diagram illustrating transition of the unilateral elongation or camber converted from the difference tension as a result of performing the leveling FB control so as to reduce the true unilateral elongation or camber on the delivery side of the first rolling mill by simulation.

[0065] The leveling FB control in the present embodiment controls the leveling so as to reduce the magnitude of true unilateral elongation or camber on the delivery side of the first rolling mill. Therefore, the magnitude of the true unilateral elongation or camber on the delivery side of the first rolling mill illustrated in FIG. 9 can be made significantly smaller than the magnitude of the true unilateral elongation or camber on the delivery side of the first rolling mill illustrated in FIGS. 5 and 7. On the other hand, the magnitude of the unilateral elongation or camber converted from the difference tension illustrated in FIG. 10 is larger than the unilateral elongation or camber converted from the difference tension illustrated in FIG. 8. The true unilateral elongation or camber on the delivery side of the first rolling mill cannot be observed, but the unilateral elongation or camber on the entry side of the first rolling mill can be measured. Therefore, by using the simulation, it is possible to calculate the leveling amount that reduces the magnitude of the true unilateral elongation or camber on the delivery side of the first rolling mill from the unilateral elongation or camber on the entry side of the first rolling mill. Even in an actual machine, in principle, if simulation is performed at the time when the unilateral elongation or camber on the entry side of the first rolling mill is found, an appropriate leveling amount can be calculated in advance. Then, at the timing when the unilateral elongation or camber reaches the first rolling mill 110a, the leveling FF control is performed on the first rolling mill 110a of the actual machine with the calculated leveling amount. As a result, it is possible to reduce true unilateral elongation or camber on the delivery side of the first rolling mill.

[0066] Note that the simulation takes a calculation time. Therefore, the appropriate leveling amount can be obtained online by calculating the unilateral elongation or camber on the entry side of the first rolling mill and the appropriate leveling amount in a plurality of cases and performing machine learning so as to output the appropriate leveling amount from the unilateral elongation or camber on the entry side of the first rolling mill.

[0067] For example, a calculation device 150 illustrated in FIG. 4 calculates the leveling amount used for the leveling FF control of the first rolling mill 110a using a value obtained as a result of applying a leveling amount calculation program to the out-of-plane deformation amount (unilateral elongation or camber) on the entry side of the first rolling mill acquired from the shape measurement device 7. In addition, the leveling amount calculation program to be applied is machine-learned by using each out-of-plane deformation amount of the plurality of steel sheets as an input variable and each leveling amount obtained as a result of physical simulation for each out-of-plane deformation amount as an objective variable.

[0068] In practice, since there is a difference between the simulation and the actual machine, it is preferable to use the leveling FF control in combination with the leveling FB control instead of using the leveling FF control alone. Therefore, the results of a simulation in which the steel sheet S having unilateral elongation or camber is cold rolled by performing the leveling FF control and the leveling FB control are illustrated in FIGS. 11 and 12. In the first rolling mill 110a, the leveling FF control output and the leveling FB control output are added to each other to be the control output.

[0069] FIG. 11 is a diagram illustrating transition of true unilateral elongation or camber as a result of a simulation in which the steel sheet S having unilateral elongation or camber is cold rolled by performing the leveling FF control and the leveling FB control. FIG. 12 is a diagram illustrating transition of the unilateral elongation or camber converted from the difference tension as a result of a simulation in which the steel sheet S having the unilateral elongation or camber is cold rolled by performing the leveling FF control and the leveling FB control.

[0070] The true unilateral elongation or camber on the delivery side of the first rolling mill illustrated in FIG. 11 is smaller than the true unilateral elongation or camber on the delivery side of the first rolling mill illustrated in FIG. 7, but is larger than the true unilateral elongation or camber on the delivery side of the first rolling mill illustrated in FIG. 9. By adjusting the weighting of the leveling FF control and the leveling FB control, it is possible to adjust whether the true unilateral elongation or camber on the delivery side of the first rolling mill approaches the result of the leveling FF control or the result of the leveling FB control.

[0071] In the leveling control applied to the cold rolling equipment 1 according to the embodiment, the data processing of the shape measurement device 7, which is a shape meter disposed on the entry side of the first rolling mill 110a, is performed, and the unilateral elongation or camber on the entry side of the first rolling mill is calculated. Then, the leveling FF control output, which is appropriate leveling, is calculated from the calculated unilateral elongation or camber on the entry side of the first rolling mill using the machine learning program. The first leveling control device 151a calculates the leveling amount of the first rolling mill 110a using unilateral elongation or camber on the delivery side of the first rolling mill, which is the out-of-plane deformation amount of the steel sheet S measured by the first shape meter roll 111a. Then, the first leveling control device 151a performs leveling FB control for controlling the leveling of the first rolling mill 110a based on the calculated leveling amount. Furthermore, the first leveling control device 151a performs tracking of the steel sheet S from the line speed, weights and adds the leveling FF control output and the leveling FB control at the timing when the unilateral elongation or camber measured by the shape measurement device 7 reaches the first rolling mill 110a, and controls the leveling using the added value as a target value. Then, by performing such leveling control, it is possible to suppress the probability of breakage from 2[%] due to defective leveling control to 1[%].

Industrial Applicability

[0072] As described above, the present invention can provide a cold rolling method and cold rolling equipment capable of performing cold rolling with high productivity and yield while securing stability of cold rolling even when cold rolling a difficult-to-roll material having a high load and a small sheet thickness before rolling.

Reference Signs List

[0073]

1 COLD ROLLING EQUIPMENT
2 PAY-OFF REEL
3 WELDING MACHINE
4 NOTCHER
5 ENTRY-SIDE LOOPER
6 STEERING DEVICE
7 SHAPE MEASUREMENT DEVICE
8 DEFLECTOR STEERING ROLL
9 BRIDLE ROLL GROUP
10 DEFLECTOR STEERING ROLL
11 COLD ROLLING MILL
12 BRIDLE ROLL
13 CUTTING MACHINE
14 TENSION REEL
110 ROLLING MILL
110a FIRST ROLLING MILL
110b SECOND ROLLING MILL
110c THIRD ROLLING MILL
110d FOURTH ROLLING MILL
110e FIFTH ROLLING MILL
111 SHAPE METER ROLL
111a FIRST SHAPE METER ROLL
111b SECOND SHAPE METER ROLL
111c THIRD SHAPE METER ROLL
111d FOURTH SHAPE METER ROLL
111e FIFTH SHAPE METER ROLL
150 CALCULATION DEVICE
151 LEVELING CONTROL DEVICE
151a FIRST LEVELING CONTROL DEVICE
151b SECOND LEVELING CONTROL DEVICE
151c THIRD LEVELING CONTROL DEVICE
151d FOURTH LEVELING CONTROL DEVICE
151e FIFTH LEVELING CONTROL DEVICE

Claims

1. A cold rolling method comprising:

a calculation step of calculating a leveling amount of a rolling mill using an out-of-plane deformation amount of a steel sheet measured on an upstream side of the rolling mill;
a control step of controlling leveling of the rolling mill on a basis of the leveling amount calculated in the calculation step; and
a cold rolling step of applying cold rolling to the steel sheet using the rolling mill controlled by the control step.

2. The cold rolling method according to claim 1, wherein the out-of-plane deformation amount of the steel sheet is an out-of-plane deformation amount measured on the upstream side of the rolling mill and immediately upstream or immediately downstream of a steering device that changes a conveying direction of the steel sheet.

3. The cold rolling method according to claim 1 or 2, wherein, when the out-of-plane deformation amount of the steel sheet measured on the upstream side of the rolling mill exceeds a threshold value, the cold rolling is not performed on the steel sheet in the cold rolling step.

4. The cold rolling method according to claim 1 or 2, wherein

in the calculation step,
the leveling amount is calculated using a value obtained as a result of applying a leveling amount calculation program to the out-of-plane deformation amount, and
the leveling amount calculation program is a machine-learned program using each out-of-plane deformation amount of a plurality of steel sheets as an input variable and each leveling amount obtained as a result of physical simulation with respect to each out-of-plane deformation amount as an objective variable.

5. The cold rolling method according to claim 3, wherein

in the calculation step,
the leveling amount is calculated using a value obtained as a result of applying a leveling amount calculation program to an out-of-plane deformation amount of the steel sheet, and
the leveling amount calculation program is a machine-learned program using each out-of-plane deformation amount of a plurality of steel sheets as an input variable and each leveling amount obtained as a result of physical simulation with respect to each out-of-plane deformation amount as an objective variable.

6. The cold rolling method according to claim 1 or 2, wherein

in the calculation step,
the leveling amount is calculated using an out-of-plane deformation amount of the steel sheet on the upstream side of the rolling mill and an out-of-plane deformation amount of the steel sheet measured on a downstream side of the rolling mill.

7. The cold rolling method according to claim 3, wherein

in the calculation step,
the leveling amount is calculated using an out-of-plane deformation amount of the steel sheet on the upstream side of the rolling mill and an out-of-plane deformation amount of the steel sheet measured on a downstream side of the rolling mill.

8. The cold rolling method according to claim 4, wherein

in the calculation step,
the leveling amount is calculated using an out-of-plane deformation amount of the steel sheet on the upstream side of the rolling mill and an out-of-plane deformation amount of the steel sheet measured on a downstream side of the rolling mill.

9. The cold rolling method according to claim 5, wherein

in the calculation step,
the leveling amount is calculated using an out-of-plane deformation amount of the steel sheet on the upstream side of the rolling mill and an out-of-plane deformation amount of the steel sheet measured on a downstream side

of the rolling mill.

10. A cold rolling equipment comprising:

a rolling mill that applies cold rolling to a steel sheet;
a shape measurement device that is disposed on an upstream side of the rolling mill and measures an out-of-plane deformation amount of the steel sheet;
a calculation device that calculates a leveling amount of the rolling mill using the out-of-plane deformation amount of the steel sheet measured by the shape measurement device; and
a control device that controls leveling of the rolling mill on a basis of the leveling amount calculated by the calculation device.

11. The cold rolling equipment according to claim 10, further comprising

a steering device that is disposed on the upstream side of the rolling mill and changes a conveying direction of the steel sheet, wherein
the out-of-plane deformation amount of the steel sheet is an out-of-plane deformation amount measured on the upstream side of the rolling mill and immediately upstream or immediately downstream of the steering device.

12. The cold rolling equipment according to claim 10 or 11, wherein, when the out-of-plane deformation amount of the steel sheet measured on the upstream side of the rolling mill exceeds a threshold value, the rolling mill does not execute the cold rolling on the steel sheet.

13. The cold rolling equipment according to claim 10 or 11, wherein

the calculation device calculates the leveling amount using a value obtained as a result of applying a leveling amount calculation program to the out-of-plane deformation amount, and
the leveling amount calculation program is a machine-learned program using each out-of-plane deformation amount of a plurality of steel sheets as an input variable and each leveling amount obtained as a result of physical simulation with respect to each out-of-plane deformation amount as an objective variable.

14. The cold rolling equipment according to claim 12, wherein

the calculation device calculates the leveling amount using a value obtained as a result of applying a leveling amount calculation program to the out-of-plane deformation amount, and
the leveling amount calculation program is a machine-learned program using each out-of-plane deformation amount of a plurality of steel sheets as an input variable and each leveling amount obtained as a result of physical simulation with respect to each out-of-plane deformation amount as an objective variable.

15. The cold rolling equipment according to claim 10 or 11, wherein the calculation device calculates the leveling amount using an out-of-plane deformation amount of the steel sheet on the upstream side of the rolling mill and an out-of-plane deformation amount of the steel sheet measured on a downstream side of the rolling mill.

16. The cold rolling equipment according to claim 12, wherein the calculation device calculates the leveling amount using an out-of-plane deformation amount of the steel sheet on the upstream side of the rolling mill and an out-of-plane deformation amount of the steel sheet measured on a downstream side of the rolling mill.

17. The cold rolling equipment according to claim 13, wherein the calculation device calculates the leveling amount using an out-of-plane deformation amount of the steel sheet on the upstream side of the rolling mill and an out-of-plane deformation amount of the steel sheet measured on a downstream side of the rolling mill.

18. The cold rolling equipment according to claim 14, wherein the calculation device calculates the leveling amount using an out-of-plane deformation amount of the steel sheet on the upstream side of the rolling mill and an out-of-plane deformation amount of the steel sheet measured on a downstream side of the rolling mill.

FIG.1

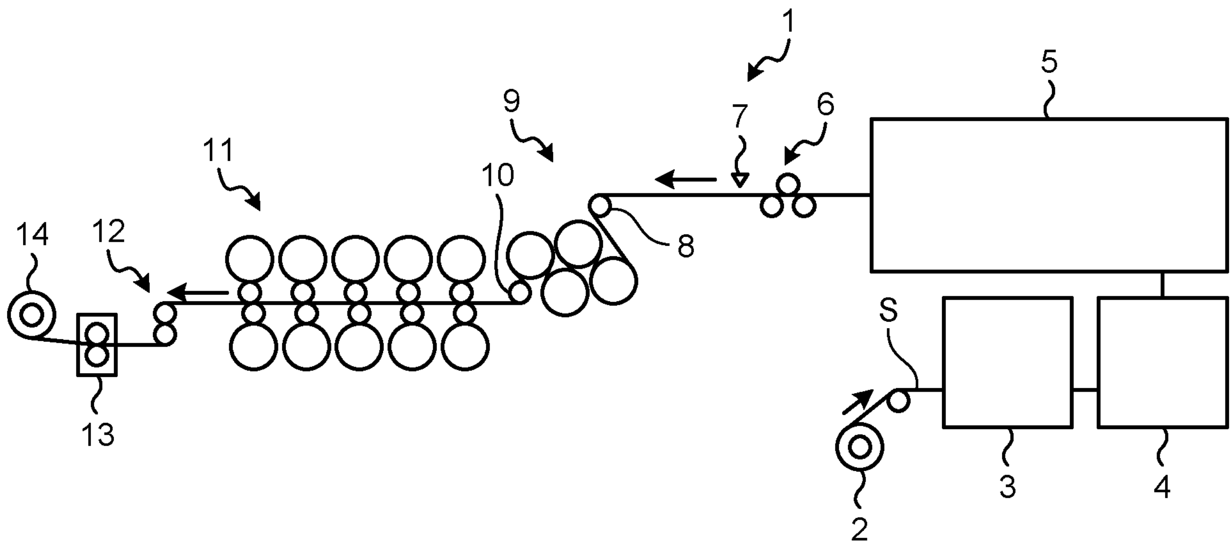


FIG.2

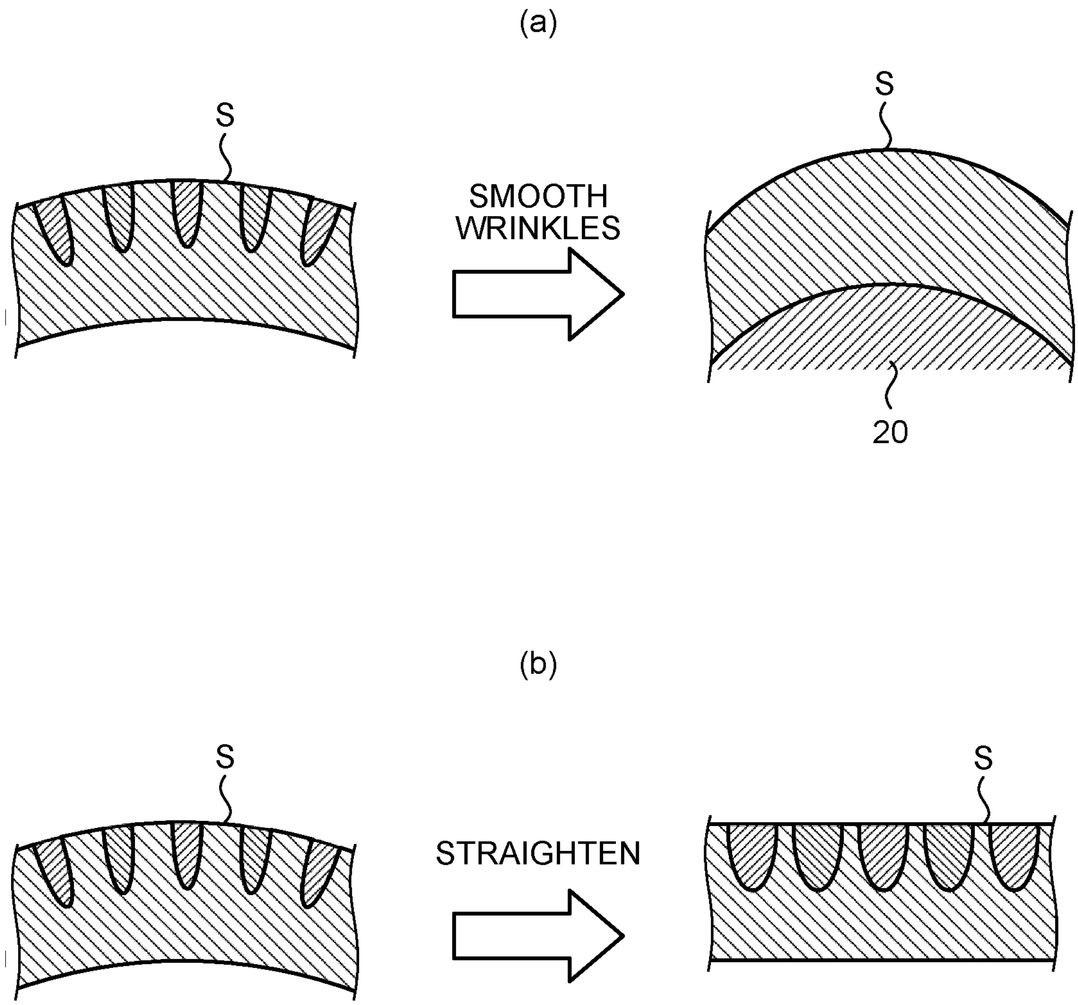


FIG.3

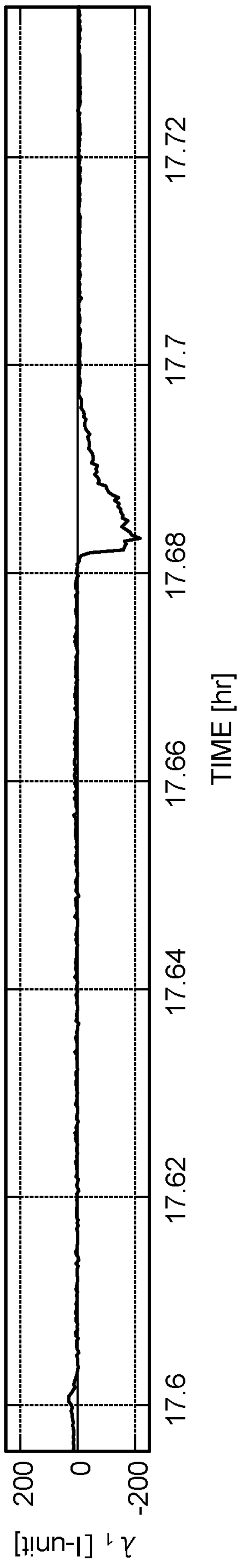


FIG.4

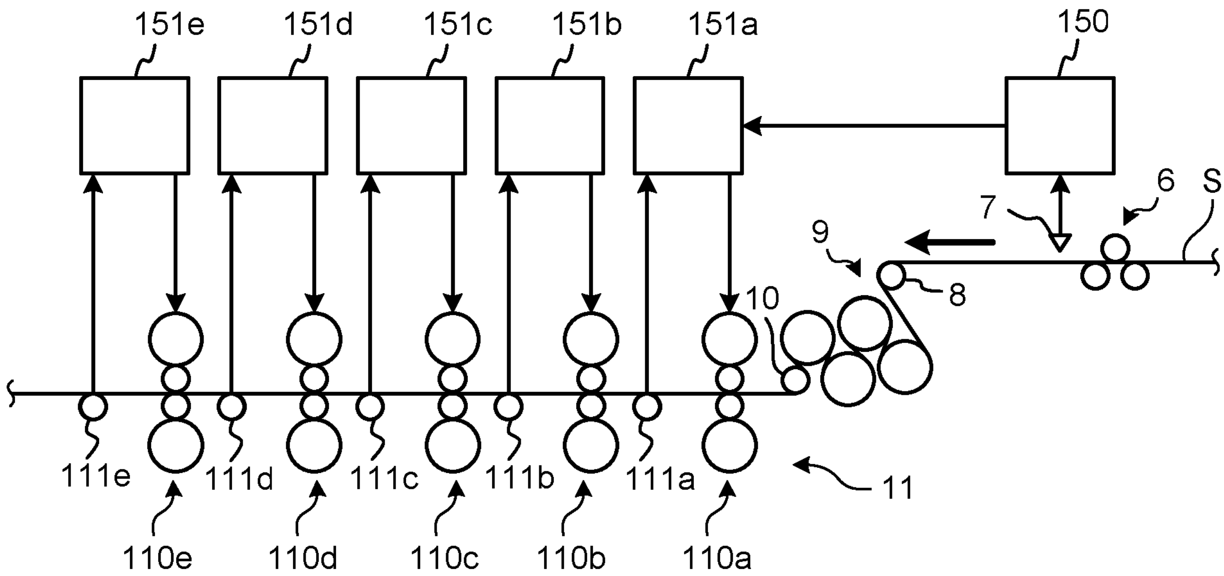

151e
151d
151c
151b
151a
150
7
6
S
9
10
8
111e
111d
111c
111b
111a
11
110e
110d
110c
110b
110a

FIG.5

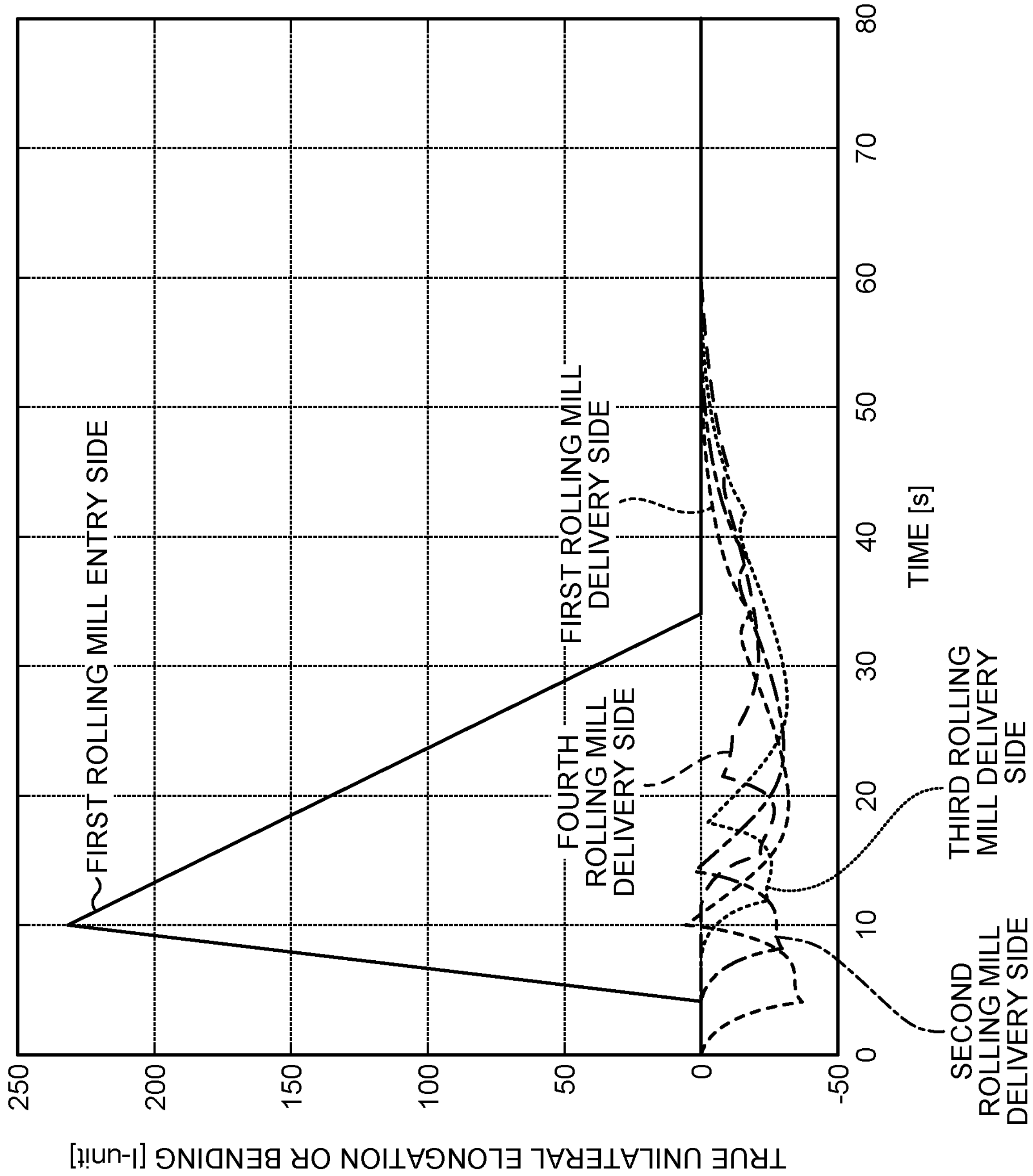

FIRST ROLLING MILL ENTRY SIDE
FIRST ROLLING MILL DELIVERY SIDE
FOURTH ROLLING MILL DELIVERY SIDE
THIRD ROLLING MILL DELIVERY SIDE
SECOND ROLLING MILL DELIVERY SIDE
TRUE UNILATERAL ELONGATION OR BENDING [I-unit]
TIME [s]
250
200
150
100
50
0
-50
0
10
20
30
40
50
60
70
80

FIG.6

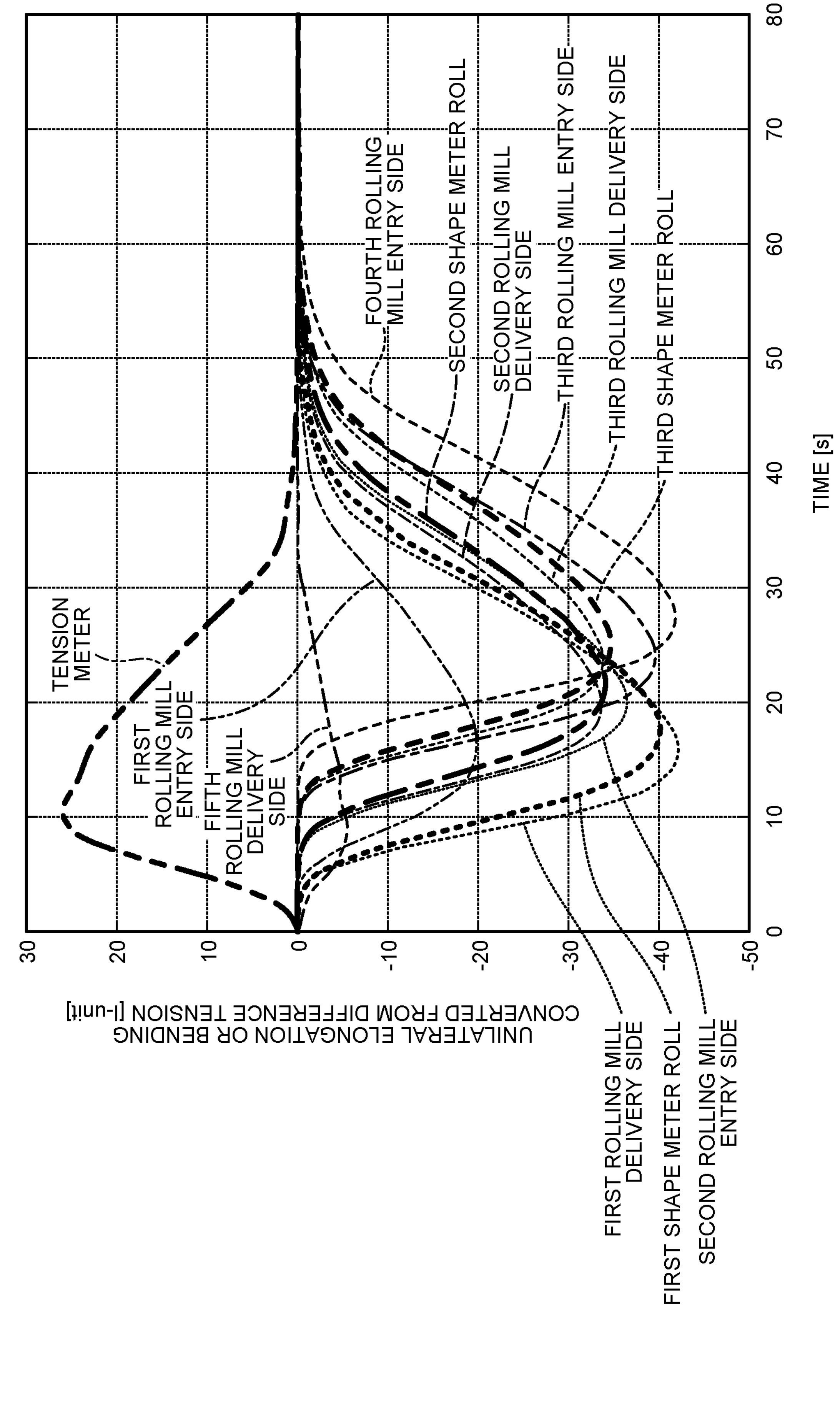

UNILATERAL ELONGATION OR BENDING
CONVERTED FROM DIFFERENCE TENSION [I-unit]
30
20
10
0
-10
-20
-30
-40
-50
0
10
20
30
40
50
60
70
80
TIME [s]
TENSION METER
FIRST ROLLING MILL ENTRY SIDE
FIFTH ROLLING MILL DELIVERY SIDE
FOURTH ROLLING MILL ENTRY SIDE
SECOND SHAPE METER ROLL
SECOND ROLLING MILL DELIVERY SIDE
THIRD ROLLING MILL ENTRY SIDE
THIRD ROLLING MILL DELIVERY SIDE
THIRD SHAPE METER ROLL
FIRST ROLLING MILL DELIVERY SIDE
FIRST SHAPE METER ROLL
SECOND ROLLING MILL ENTRY SIDE

FIG.7

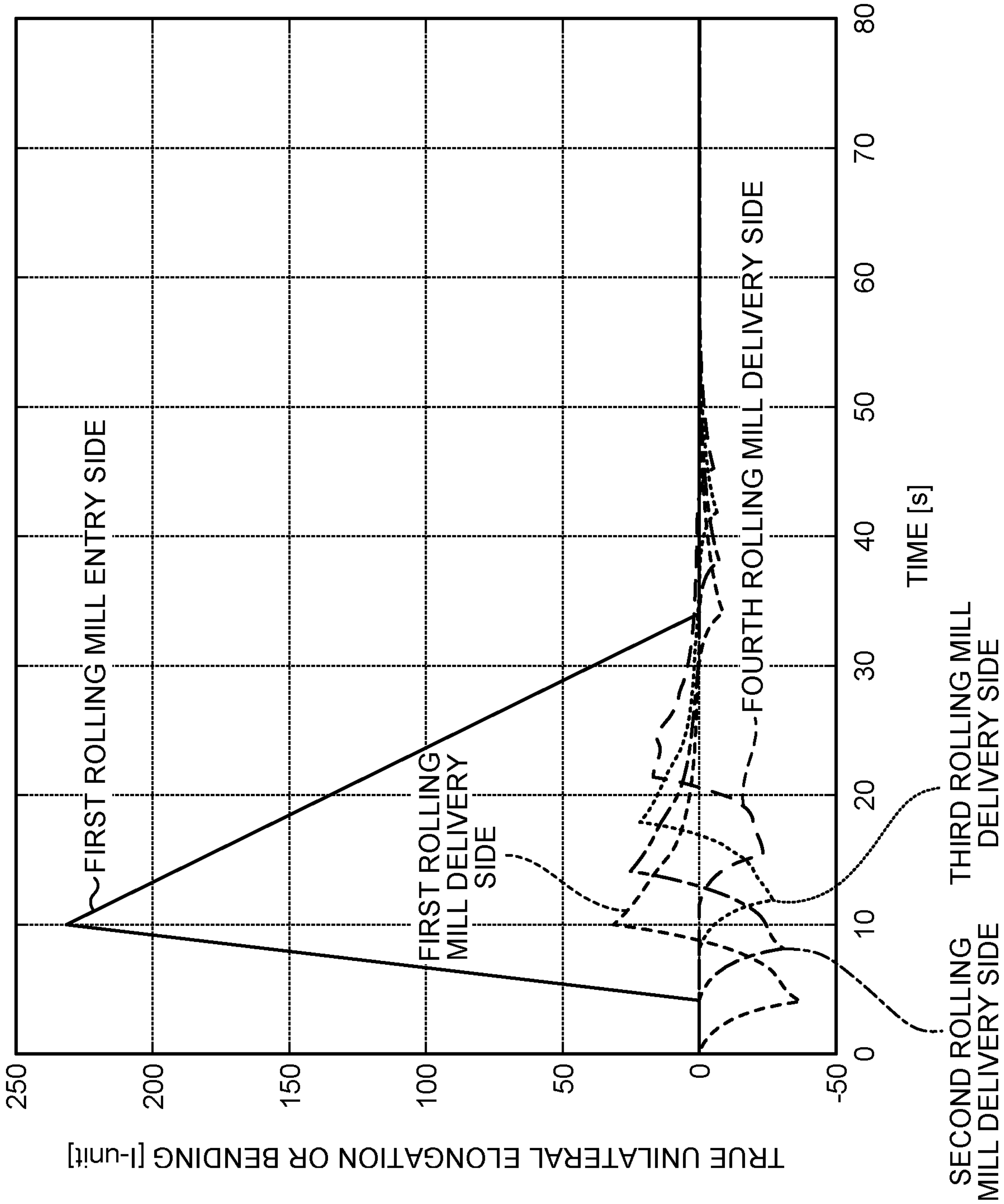
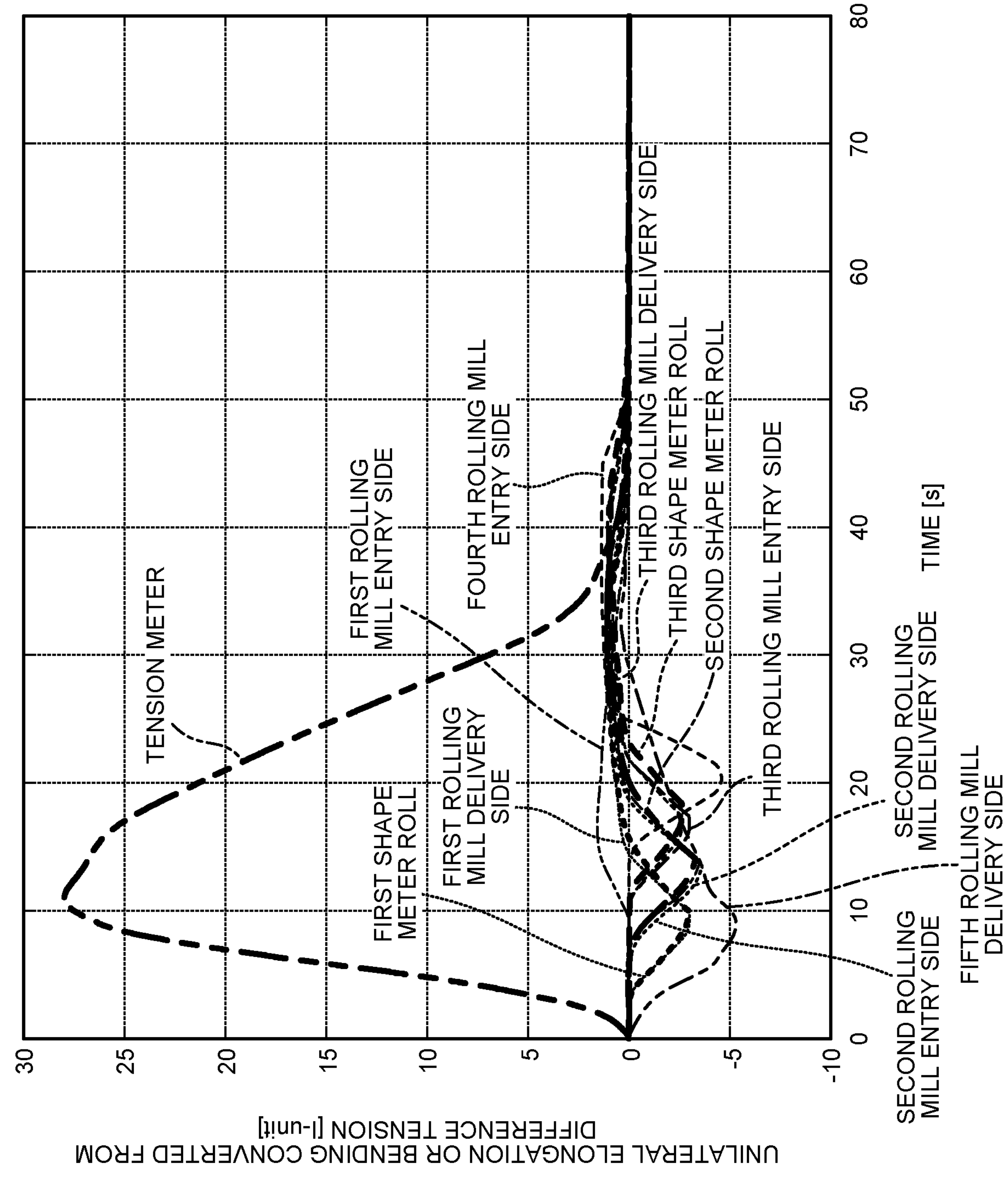

TRUE UNILATERAL ELONGATION OR BENDING [I-unit]
TIME [s]
250
200
150
100
50
0
-50
0
10
20
30
40
50
60
70
80
FIRST ROLLING MILL ENTRY SIDE
FIRST ROLLING MILL DELIVERY SIDE
SECOND ROLLING MILL DELIVERY SIDE
THIRD ROLLING MILL DELIVERY SIDE
FOURTH ROLLING MILL DELIVERY SIDE

FIG.8



TENSION METER
FIRST ROLLING MILL ENTRY SIDE
FOURTH ROLLING MILL ENTRY SIDE
THIRD ROLLING MILL DELIVERY SIDE
THIRD SHAPE METER ROLL
SECOND SHAPE METER ROLL
THIRD ROLLING MILL ENTRY SIDE
FIRST SHAPE METER ROLL
FIRST ROLLING MILL DELIVERY SIDE
SECOND ROLLING MILL DELIVERY SIDE
FIFTH ROLLING MILL DELIVERY SIDE
SECOND ROLLING MILL ENTRY SIDE
TIME [s]
UNILATERAL ELONGATION OR BENDING CONVERTED FROM DIFFERENCE TENSION [I-unit]
30
25
20
15
10
5
0
-5
-10
0
10
20
30
40
50
60
70
80

FIG.9

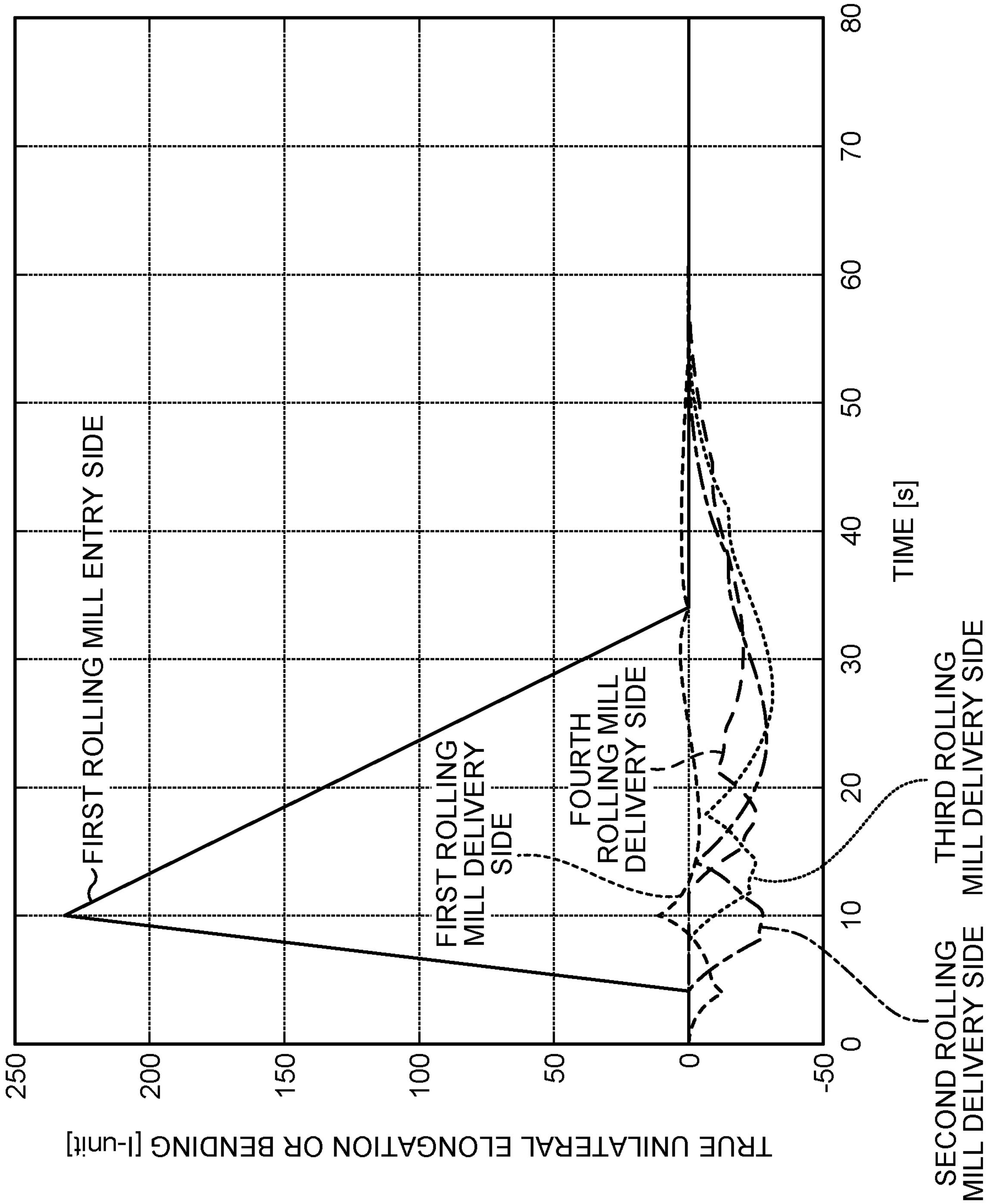

FIRST ROLLING MILL ENTRY SIDE
FIRST ROLLING MILL DELIVERY SIDE
FOURTH ROLLING MILL DELIVERY SIDE
SECOND ROLLING MILL DELIVERY SIDE
THIRD ROLLING MILL DELIVERY SIDE
TRUE UNILATERAL ELONGATION OR BENDING [I-unit]
TIME [s]
250
200
150
100
50
0
-50
0
10
20
30
40
50
60
70
80

FIG.10

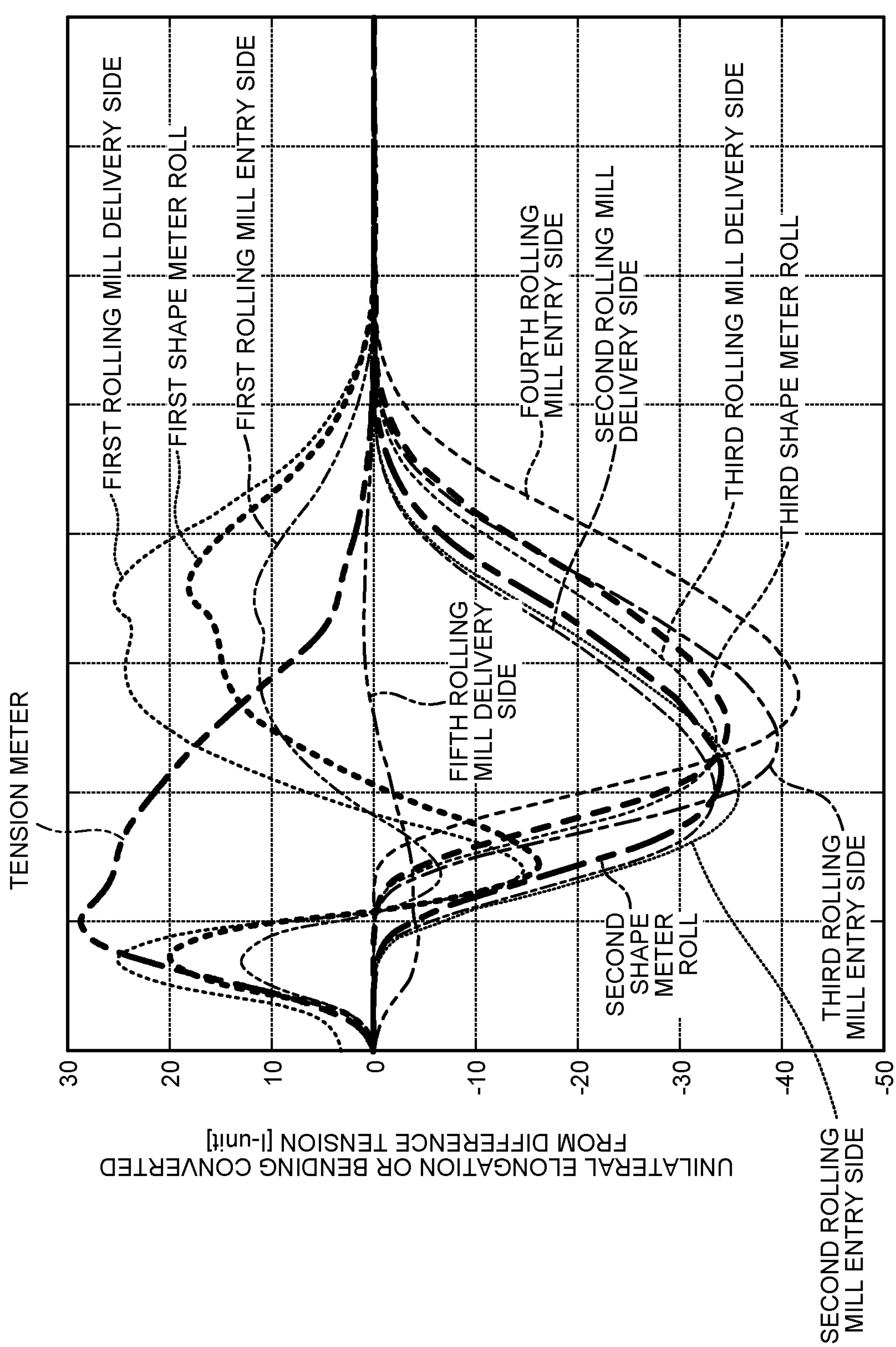

TENSION METER
FIRST ROLLING MILL DELIVERY SIDE
FIRST SHAPE METER ROLL
FIRST ROLLING MILL ENTRY SIDE
FOURTH ROLLING MILL ENTRY SIDE
SECOND ROLLING MILL DELIVERY SIDE
THIRD ROLLING MILL DELIVERY SIDE
THIRD SHAPE METER ROLL
FIFTH ROLLING MILL DELIVERY SIDE
SECOND SHAPE METER ROLL
THIRD ROLLING MILL ENTRY SIDE
SECOND ROLLING MILL ENTRY SIDE
UNILATERAL ELONGATION OR BENDING CONVERTED FROM DIFFERENCE TENSION [I-unit]
TIME [s]
30
20
10
0
-10
-20
-30
-40
-50
0
10
20
30
40
50
60
70
80

FIG.11

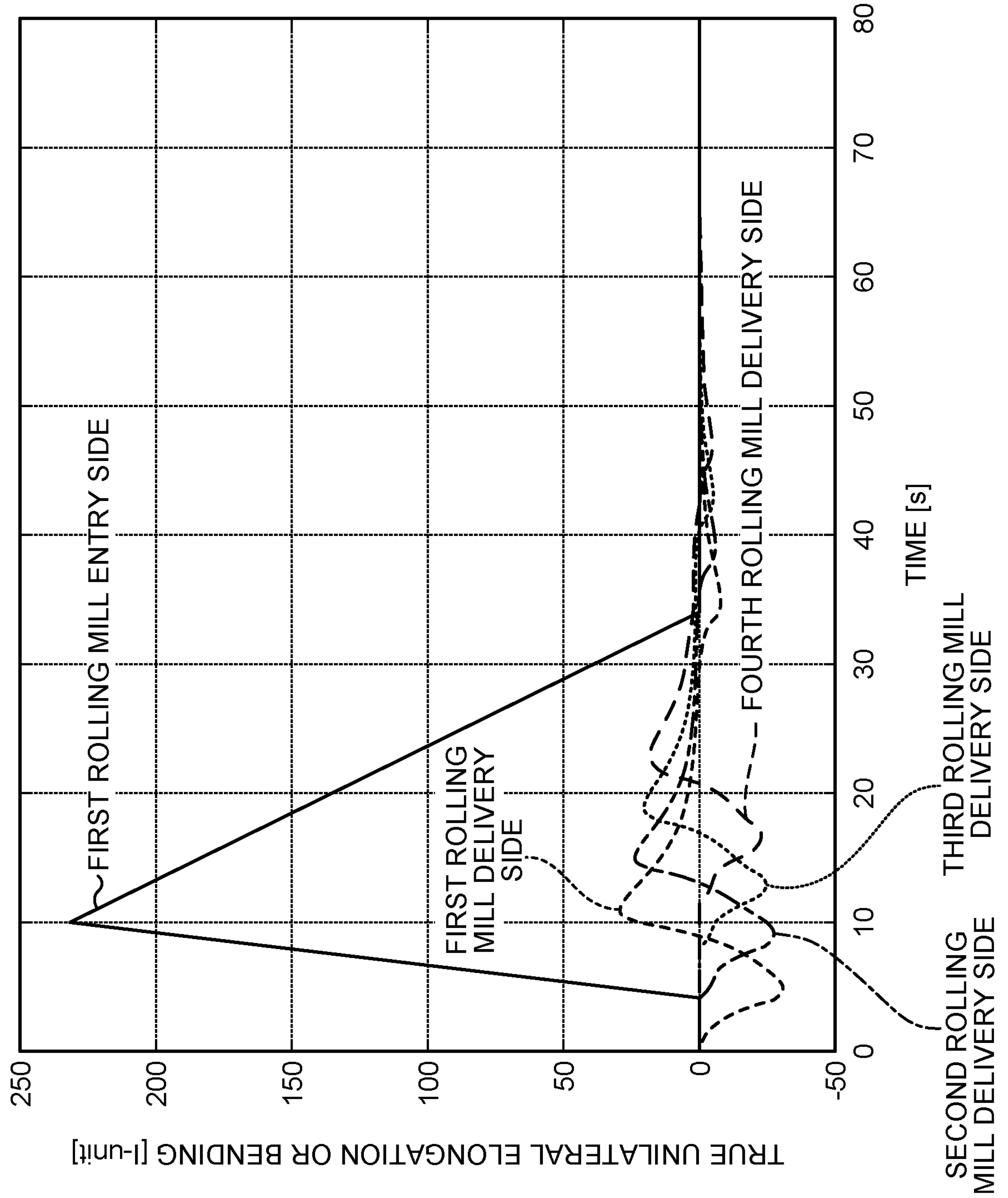
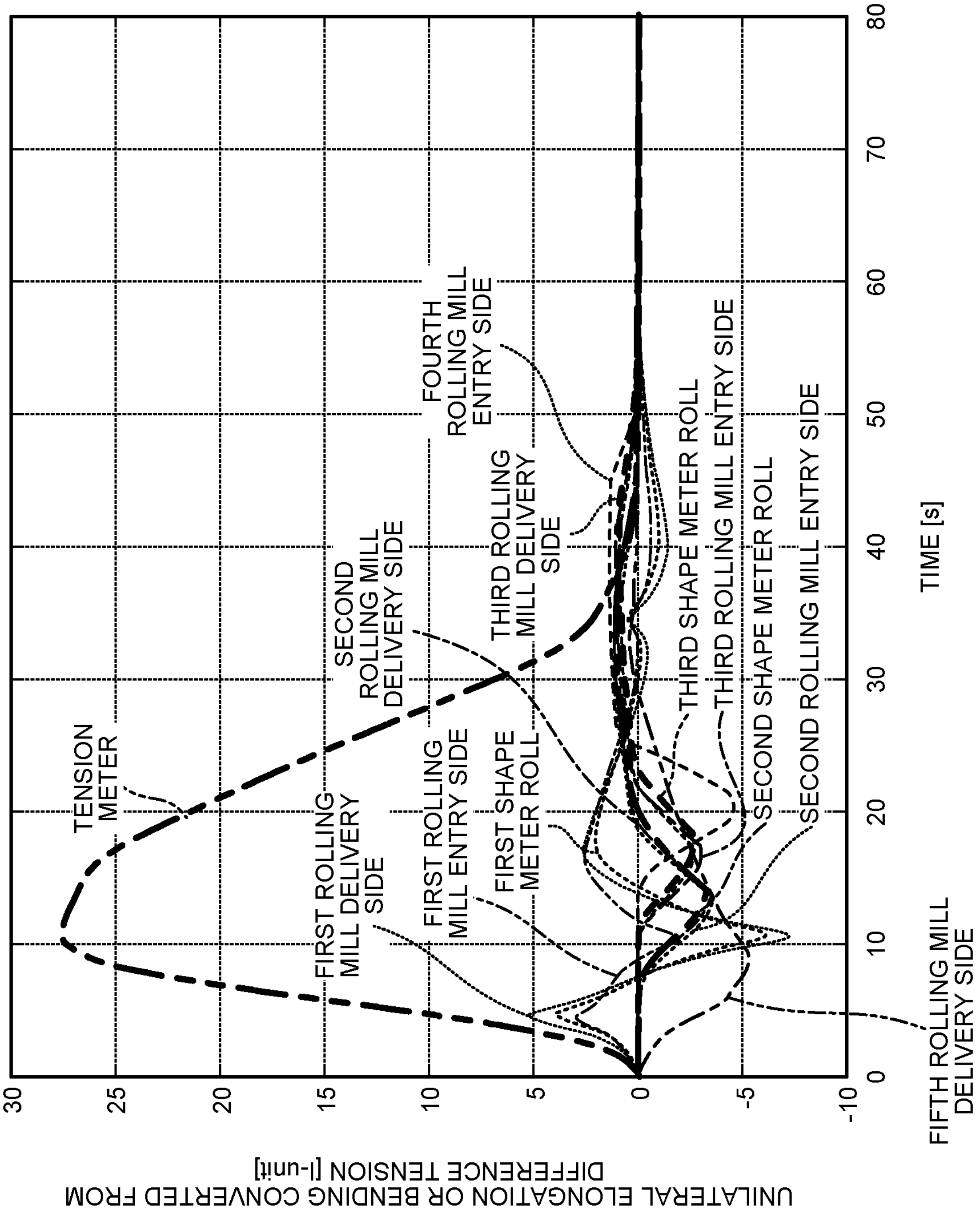

TRUE UNILATERAL ELONGATION OR BENDING [I-unit]
250
200
150
100
50
0
-50
TIME [s]
0
10
20
30
40
50
60
70
80
FIRST ROLLING MILL ENTRY SIDE
FIRST ROLLING MILL DELIVERY SIDE
SECOND ROLLING MILL DELIVERY SIDE
THIRD ROLLING MILL DELIVERY SIDE
FOURTH ROLLING MILL DELIVERY SIDE

FIG.12


TENSION METER
FIRST ROLLING MILL DELIVERY SIDE
FIRST ROLLING MILL ENTRY SIDE
FIRST SHAPE METER ROLL
SECOND ROLLING MILL DELIVERY SIDE
THIRD ROLLING MILL DELIVERY SIDE
FOURTH ROLLING MILL ENTRY SIDE
THIRD SHAPE METER ROLL
THIRD ROLLING MILL ENTRY SIDE
SECOND SHAPE METER ROLL
SECOND ROLLING MILL ENTRY SIDE
FIFTH ROLLING MILL DELIVERY SIDE
30
25
20
15
10
5
0
-5
-10
0
10
20
30
40
50
60
70
80
TIME [s]
UNILATERAL ELONGATION OR BENDING CONVERTED FROM DIFFERENCE TENSION [I-unit]

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/026602

A. CLASSIFICATION OF SUBJECT MATTER

B21B 37/58(2006.01)i; ***B21B 1/22***(2006.01)i; ***B21B 37/28***(2006.01)i; ***B21B 37/68***(2006.01)i; ***B21B 38/02***(2006.01)i; ***B21C 51/00***(2006.01)i
FI: B21B37/58 B; B21B1/22 J; B21B37/28 130; B21B37/68 Z; B21B38/02; B21C51/00 L

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)

B21B37/58; B21B1/22; B21B37/28; B21B37/68; B21B38/02; B21C51/00

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 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 62-68620 A (NIPPON KOKAN KK <NKK>) 28 March 1987 (1987-03-28) claims, p. 2, upper right column, line 3 to p. 4, upper right column, line 20, fig. 1-2	1, 10 2-9, 11-18
Y	JP 7-132310 A (MITSUBISHI HEAVY IND LTD) 23 May 1995 (1995-05-23) paragraphs [0002], [0009], fig. 1, 7, 11	2-9, 11-18
Y	JP 2012-161806 A (NIPPON STEEL CORP) 30 August 2012 (2012-08-30) paragraphs [0008], [0011], [0022]	6-9, 15-18

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

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
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"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
15 September 2023	**03 October 2023**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/026602

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 62-68620 A	28 March 1987	(Family: none)	
JP 7-132310 A	23 May 1995	(Family: none)	
JP 2012-161806 A	30 August 2012	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- JP 2012161806 A **[0005]**
- JP 2022014800 A **[0005]**
- JP 2021133411 A **[0005]**
- JP 2017049071 A **[0050]**