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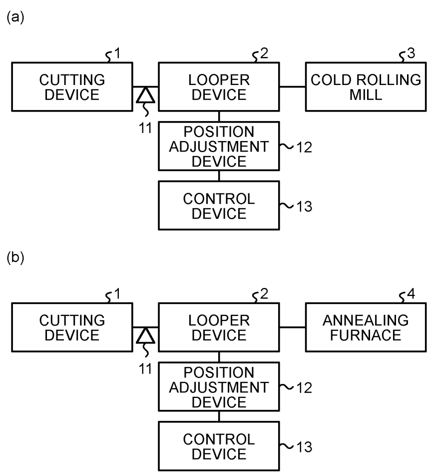
(54) **MEANDERING CONTROL METHOD, MEANDERING CONTROL APPARATUS, AND MANUFACTURING METHOD FOR STEEL SHEET**

(57) A meandering control method for a steel sheet according to the present invention includes: a measurement step of measuring an out-of-plane deformation amount of the steel sheet on an upstream side of a steering device that changes a conveyance direction of the steel sheet; a calculation step of calculating an average curvature of the steel sheet using the out-of-plane deformation amount of the steel sheet measured in the measurement step; and a control step of calculating an off-center amount of the steel sheet in the steering device using the average curvature of the steel sheet calculated in the calculation step, and controlling a winding position of the steel sheet relative to the steering device based on the calculated off-center amount.

FIG.1

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## Description

Field

**[0001]** The present invention relates to a meandering control method, a meandering control apparatus, and a manufacturing method for a steel sheet.

Background

**[0002]** In general, a large number of deflector rolls are installed in a continuous steel sheet manufacturing device for the purpose of changing a traveling direction of a steel sheet. By installing the deflector roll, the continuous steel sheet manufacturing device is formed compactly, thereby reducing construction costs. On the other hand, an adverse effect caused by installing the deflector roll is that meandering of the steel sheet occurs due to frictional force of the deflector roll. Therefore, a center position control (CPC) meandering control device is generally used to suppress the meandering of the steel sheet due to the frictional force of the deflector roll. However, the CPC meandering control device may not be usable due to restriction on costs and installation places. For example, in a horizontal looper device, it is difficult to install the CPC meandering control device on the deflector roll on a moving looper car due to restriction on costs and electronic components. Therefore, a deflector crown roll having a convex roll profile is used for the deflector roll in which the CPC meandering control device cannot be installed. By forming the roll profile as a convex shape, frictional force becomes centering force, and meandering of the steel sheet can be suppressed to some extent although not as much as the CPC meandering control device. In addition, since only the roll profile is processed into the convex shape, there are almost no restrictions on costs and installation places, and the roll profile can be frequently used.

**[0003]** In recent years, with an increase in high-tensile steel sheet or the like, a shape defect is likely to occur at a tip end portion or a tail end portion of a coil of a hot-rolled steel sheet manufactured in a hot-rolling step as an upstream step, and a situation in which meandering of the steel sheet cannot be suppressed at a joint portion between the steel sheets having such a shape defect has frequently occurred. If the meandering of the steel sheet cannot be suppressed, the steel sheet is rolled out and comes into contact with a peripheral frame, which causes a serious trouble such as breakage and results in incapacity of operation. Therefore, it is difficult to newly install the CPC meandering control device in an existing facility, and thus, meandering countermeasures by a crown roll such as adjusting the convex shape of the crown roll are taken. However, if the convex shape of the crown roll is too high, the steel sheet and the roll surface cannot be brought into contact with each other on the entire surface, and as a result, a contact defect or the like may occur, so that an effect of suppressing meandering by the crown roll is limited. In addition, since it is known that the shape defect at the tip end portion or the tail end portion of the coil causes meandering, the portions are usually removed, but costs increase due to the addition of a removal step, and removal of the tip end portion and the tail end portion are directly linked to reduction in the yield. Therefore, to reduce $CO_2$, it is needless to say that it is better not to perform the removal step as possible. In addition, a method of suppressing the meandering of the steel sheet by a guide roll in contact with an end portion of the steel sheet in the width direction has also been proposed, but in such method, large collision force that suppresses the meandering of the steel sheet is generated in the guide roll, and defects such as chipping of the end portion of the steel sheet in the width direction may occur by the collision force.

**[0004]** From such a background, Patent Literature 1 proposes a meandering control method of suppressing meandering of a steel strip by predicting a meandering amount of the steel strip from a real-time simulation of the meandering amount of the steel strip on the upstream side of a steering device and movement of the steel sheet and controlling the steering device based on the predicted meandering amount.

Citation List

Patent Literature

**[0005]** Patent Literature 1: JP 2018-192490 A

Summary

Technical Problem

**[0006]** However, in the meandering control method described in Patent Literature 1, the meandering amount on the upstream side of the steering device used for predicting the meandering amount of the steel strip is a part of shape information of the steel strip, and is insufficient as information for suppressing the meandering of the steel strip. In addition, in the meandering control method described in Patent Literature 1, the lack of information is to be complemented by real-time simulation, but there is no description on a simulation method, and the meandering control method has not been put to practical use.

**[0007]** The present invention has been made in view of the above problems, and an object thereof is to provide a meandering control method and a meandering control apparatus for a steel sheet capable of suppressing meandering of a steel sheet having a shape defect. Another object of the present invention is to provide a manufacturing method for a steel sheet capable of manufacturing a steel sheet having a good yield by suppressing meandering of a steel sheet having a shape defect.

Solution to Problem

**[0008]** To solve the problem and achieve the object, a meandering control method for a steel sheet according to the present invention includes: a measurement step of measuring an out-of-plane deformation amount of the steel sheet on an upstream side of a steering device that changes a conveyance direction of the steel sheet; a calculation step of calculating an average curvature of the steel sheet using the out-of-plane deformation amount of the steel sheet measured in the measurement step; and a control step of calculating an off-center amount of the steel sheet in the steering device using the average curvature of the steel sheet calculated in the calculation step, and controlling a winding position of the steel sheet relative to the steering device based on the calculated off-center amount.

**[0009]** Moreover, the measurement step may include a step of measuring the out-of-plane deformation amount of the steel sheet on a delivery side of a cutting device installed on the upstream side of the steering device, the cutting device being configured to cut an end portion of the steel sheet in a width direction.

**[0010]** Moreover, a meandering control apparatus for a steel sheet according to the present invention includes: a steering device that changes a conveyance direction of the steel sheet; a measurement device that measures an out-of-plane deformation amount of the steel sheet on an upstream side of the steering device; a position adjustment device that adjusts a winding position of the steel sheet relative to the steering device; and a control device that controls the position adjustment device, wherein the control device calculates an average curvature of the steel sheet using the out-of-plane deformation amount of the steel sheet that is measured by the measurement device, calculates an off-center amount of the steel sheet in the steering device using the calculated average curvature of the steel sheet, and controls the position adjustment device based on the calculated off-center amount.

**[0011]** Moreover, the measurement device may be installed on a delivery side of a cutting device installed on the upstream side of the steering device, the cutting device being configured to cut an end portion of the steel sheet in a width direction.

**[0012]** Moreover, a manufacturing method for a steel sheet according to a first mode of the present invention includes: a storage step of storing the steel sheet in a looper device while suppressing the meandering of the steel sheet using the method of controlling the meandering of the steel sheet according to the present invention; and a cold rolling step of cold-rolling the steel sheet stored in the looper device.

**[0013]** Moreover, a manufacturing method for a steel sheet according to a second mode of the present invention includes: a storage step of storing the steel sheet in a looper device while suppressing the meandering of the steel sheet using the method of controlling the meandering of the steel sheet according to the present invention; and an annealing step of annealing the steel sheet stored in the looper device.

Advantageous Effects of Invention

**[0014]** A meandering control method and a meandering control apparatus for a steel sheet according to the present invention can suppress meandering of a steel sheet having a shape defect. Further, according to a manufacturing method for a steel sheet of the present invention, it is possible to manufacture a steel sheet having a good yield by suppressing meandering of a steel sheet having a shape defect.

Brief Description of Drawings

**[0015]**

FIG. 1 is a block diagram illustrating a configuration of a manufacturing line of a steel sheet to which a meandering control method and a meandering control apparatus for a steel sheet according to an embodiment of the present invention are applied.
FIG. 2 is a schematic diagram illustrating a configuration of a looper device illustrated in FIG. 1.
FIG. 3 is a diagram illustrating an example of shape data of the steel sheet measured by a measurement device.
FIG. 4 is a diagram illustrating an example of a relationship between a maximum bending of a joint portion of the steel sheet and an occurrence state of a defect.

FIG. 5 is a diagram illustrating an example of a method of measuring an out-of-plane deformation amount. Description of Embodiments

**[0016]** Hereinafter, a meandering control method, a meandering control apparatus, and a manufacturing method for a steel sheet according to an embodiment of the present invention will be described with reference to the drawings.

[Concept]

**[0017]** First, a concept of the present invention will be described.

**[0018]** A shape defect of a steel sheet occurs mainly due to widthwise nonuniformity of elongation in the longitudinal direction in a rolling process. The shape defect of the steel sheet is superposition such as bending (one-side elongation) and edge wave/center buckle, and the shape defect that most greatly affects the meandering of the steel sheet is bending. In particular, in the case of a thin plate, out-of-plane deformation derived from bending disappears when the thin plate is formed into a cut plate, and it becomes difficult to measure bending. On the other hand, the edge wave/center buckle can be measured because the out-of-plane deformation remains even in the cut plate.

**[0019]** If the shape of the steel sheet is a curved surface shape in which the cross section in the width direction is a straight line, geometric definition of a curvature $\kappa$ of the bending is described as in the following Mathematical Formula (1). In Mathematical Formula (1), x represents a longitudinal position of the steel sheet, v represents displacement of the steel sheet in the width direction from the center position of the steel sheet in the width direction, w represents displacement of the steel sheet in the vertical direction from the center position of the steel sheet in the width direction, and $\omega$ represents a twist angle of the steel sheet.

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

**[0020]** Since it is difficult to observe the curvature $\kappa$ shown in Mathematical Formula (1), the bending of the steel sheet in the longitudinal direction is considered as an average value (average bending), and an average curvature K is defined as in Mathematical Formula (2) shown below. In Mathematical Formula (2), L represents a length of the steel sheet for averaging.

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

**[0021]** Accordingly, by substituting Mathematical Formula (1) into Mathematical Formula (2), the average curvature K is expressed as the following Mathematical Formula (3). The first term on the right side of Mathematical Formula (3) is an amount observed as meandering or skewing of the steel sheet, and the second term on the right side is an amount observed as out-of-plane deformation of the steel sheet. From Mathematical Formula (3), it can be seen that, even if only the meandering of the steel sheet is observed, the bending (average curvature K) of the steel sheet deeply related to the meandering of the steel sheet is not found. On the other hand, if meandering of the steel sheet does not occur, a value of the first term on the right side becomes zero, so that the average curvature K can be obtained from an observation amount of the out-of-plane deformation (second term on the right side). In a thin plate, when meandering occurs, the out-of-plane deformation of the thin plate is often accompanied.

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

**[0022]** When the twist angle $\omega$ of the steel sheet is small, Mathematical Formula (3) can be approximated as the following Mathematical Formula (4), and Mathematical Formula (4) can be transformed as the following Mathematical Formula (5).

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

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

**[0023]** When the twist angle ω of the steel sheet is small, the deflection W of the steel sheet can be expressed by the following Mathematical Formula (6). In Mathematical Formula (6), y represents the position of the steel sheet in the width direction.

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

**[0024]** Further, a length 1(x, y) of the steel sheet along the bent curved surface can be expressed by the following Mathematical Formula (7).

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

**[0025]** Further, an elongation difference rate $\Delta\varepsilon_1(x, y)$ of the steel sheet can be defined as the following Mathematical Formula (8).

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

**[0026]** In Mathematical Formula (8), $l_0(x)$ represents the average length of the steel sheet in the width direction, and is expressed as the following Mathematical Formula (9). In Mathematical Formula (9), b represents the sheet width of the steel sheet.

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

**[0027]** Therefore, by substituting Mathematical Formula (6) and Mathematical Formula (7) into Mathematical Formula (9), Mathematical Formula (10) shown below is obtained.

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

**[0028]** When the deflection W and the twist angle ω of the steel sheet are small, Mathematical Formula (10) can be approximated as Mathematical Formula (11) shown below, and Mathematical Formula (12) shown below is obtained by deforming Mathematical Formula (11).

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

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

**[0029]** When Mathematical Formula (6), Mathematical Formula (7), and Mathematical Formula (12) are substituted into Mathematical Formula (8), the elongation difference rate $\Delta\varepsilon_1(x, y)$ of the steel sheet is expressed by the following Mathematical Formula (13).

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

**[0030]** The curvature $K_1$ of the average bending converted from the elongation difference rate $\Delta\varepsilon_1(x, y)$ of the steel sheet is defined by the following Mathematical Formula (14) .

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

**[0031]** By substituting Mathematical Formula (13) into Mathematical Formula (14), the following Mathematical Formula (15) is obtained.

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

**[0032]** Therefore, since Mathematical Formula (15) corresponds to the second term on the right side of Mathematical Formula (5), Mathematical Formula (5) can be modified as Mathematical Formula (16) shown below.

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

**[0033]** According to the above description, when the meandering of the steel sheet does not occur and the first term on the right side of Mathematical Formula (16) becomes zero, it can be seen that the average curvature K of the average bending can be obtained from the curvature $K_1$. The curvature $K_1$ can be calculated by substituting measured values of the out-of-plane deformation amount of the steel sheet and the gradient thereof into Mathematical Formula (14). Therefore, in the present invention, the out-of-plane deformation amount of the steel sheet and the gradient thereof are measured at a position at which the meandering of the steel sheet does not occur, the average curvature K of the steel sheet is calculated from the measured value, the off-center amount of the steel sheet in the steering device (the positional deviation direction and positional deviation amount of the center position in width direction of the steel sheet relative to the center position in the width direction of the steering device when the steel sheet reaches the steering device) is calculated from the calculated average curvature K, and the winding position of the steel sheet relative to the steering device is controlled based on the calculated off-center amount. The same control may be performed by measuring the meandering amount and the out-of-plane deformation amount of the steel sheet at a position at which the meandering of the steel sheet occurs, and calculating the average curvature K of the steel sheet using the measured meandering amount and out-of-plane deformation amount of the steel sheet. Accordingly, it is possible to suppress meandering of a steel sheet having a shape defect. In addition, by manufacturing the steel sheet using such meandering control method, it is possible to suppress the meandering of the steel sheet having the shape defect and to manufacture a steel sheet having a good yield.

**[0034]** Hereinafter, a description will be given as to a meandering control method, a meandering control apparatus, and a manufacturing method for a steel sheet according to an embodiment of the present invention, which is conceived based on the above concept. Note that the out-of-plane deformation amount is one of indices indicating bending and one-side elongation of a steel sheet S. As a method of measuring the out-of-plane deformation amount, methods illustrated in FIGS. 5(a) and 5(b) can be considered. The method illustrated in FIG. 5(a) is a method of winding the steel sheet S around a roll 20 or pressing the steel sheet S to apply normal force to the steel sheet S to elongate a wrinkle, and measuring bending (one-side elongation) of the steel sheet S in which the wrinkle is elongated. On the other hand, the method illustrated in FIG. 5(b) is a method of straightening the steel sheet S in the longitudinal direction (not meandering) and converting the bending (one-side elongation) of the steel sheet S from a height of the wrinkle of the steel sheet S. In the method illustrated in FIG. 5(a), when the length of the steel sheet S in which the wrinkle is elongated in the longitudinal direction is short, it is difficult to measure the out-of-plane deformation amount. Therefore, it is desirable to employ the method illustrated in FIG. 5(b), and in the present embodiment, the out-of-plane deformation amount is measured (converted) using the method illustrated in

FIG. 5(b).

[Configuration of Manufacturing Line]

**[0035]** First, with reference to FIGS. 1 and 2, a description will be given as to a configuration of a manufacturing line of the steel sheet to which the meandering control method and the meandering control apparatus for the steel sheet according to the embodiment of the present invention are applied.

**[0036]** FIGS. 1(a) and 1(b) are block diagrams illustrating a configuration of a manufacturing line of the steel sheet to which the meandering control method and the meandering control apparatus for the steel sheet according to the embodiment of the present invention are applied. As illustrated in FIG. 1(a), the manufacturing line of the steel sheet to which the meandering control method and the meandering control apparatus for the steel sheet according to the embodiment of the present invention are applied includes a cutting device 1 that cuts an end portion of the steel sheet in the width direction, a looper device 2 that stores the steel sheet having the end portion in the width direction cut by the cutting device 1, and a cold rolling mill 3 that cold-rolls the steel sheet stored in the looper device 2. As illustrated in FIG. 1(b), an annealing furnace 4 for annealing the steel sheet stored in the looper device 2 may be disposed instead of the cold rolling mill 3.

**[0037]** FIG. 2 is a schematic diagram illustrating a configuration of the looper device 2 illustrated in FIGS. 1(a) and 1(b). As illustrated in FIG. 2, in the present embodiment, the looper device 2 includes a horizontal looper including a deflector roll. A free looper FL is disposed at the most upstream portion of the looper device 2, the cutting device 1 (not illustrated) is disposed downstream of the free looper FL, a bridle roll BR is disposed downstream of the cutting device 1, and a first deflector roll #1DEF is disposed downstream of the bridle roll BR. A first steering roll #1STR also having a deflector function is disposed downstream of the deflector roll #1DEF. The steering roll #1STR includes a CPC meandering control device. On the downstream side of the steering roll #1STR, a looper car #1LP car including a second deflector roll is disposed. The looper car #1LP car adjusts the length of the steel sheet S between the rolls by moving in the left-right direction of the drawing.

**[0038]** A second steering roll #2STR also having a deflector function is disposed on the downstream side of the looper car #1LP car. The steering roll #2STR includes the CPC meandering control device. On the downstream side of the steering roll #2STR, a looper car #2LP car including a third deflector roll is disposed. The looper car #2LP car adjusts the length of the steel sheet S between the rolls by moving in the left-right direction of the drawing. A third steering roll #3STR also having a deflector function is disposed on the downstream side of the looper car #2LP car. The steering roll #3STR includes the CPC meandering control device.

**[0039]** Between the deflector roll #1DEF and the looper car #1LP car and between the steering roll #2STR and the looper car #2LP car, support rolls that support the weight of the steel sheet S are disposed at a pitch of 2.5 m. Between the looper car #1LP car and the steering roll #2STR and between the looper car #2LP car and the steering roll #3STR, separator rolls having a function of supporting the weight of the steel sheet S and opening and closing when the steel sheet S passes through the looper car are installed at a pitch of 15 m. Although not illustrated, a guide vertical roll is installed at a predetermined pitch in the vicinity of the support roll for suppressing meandering.

[Configuration of Meandering control apparatus for Steel Sheet]

**[0040]** Next, a configuration of the meandering control apparatus for the steel sheet according to the embodiment of the present invention will be described with reference to FIG. 1.

**[0041]** As illustrated in FIGS. 1(a) and 1(b), the meandering control apparatus for the steel sheet according to the embodiment of the present invention includes a measurement device 11, a position adjustment device 12, and a control device 13.

**[0042]** The measurement device 11 is configured with a profilometer such as a three-dimensional laser scanner, and is disposed on the upstream side of a steering device that changes a conveyance direction of the steel sheet. Specifically, in the present embodiment, the measurement device 11 is disposed on the downstream side of the cutting device 1 and on the upstream side of the looper device 2 (steering roll). The measurement device 11 measures shape data of the steel sheet including the out-of-plane deformation amount of the steel sheet, and outputs an electric signal indicating the measured shape data to the control device 13. The location of the measurement device 11 is not limited to the position on the downstream side of the cutting device 1 and on the upstream side of the looper device 2, and may be disposed at any position as long as the steel sheet does not meander or the meandering amount of the steel sheet can be regarded as zero. For example, the measurement device 11 may be disposed at a position at which the meandering amount of the steel sheet has a size that does not affect the measurement of the shape data of the steel sheet (for example, the meandering amount of the steel sheet in the width direction is within $\pm 20$ mm). Further, when the cutting device 1 is not disposed, the measurement device 11 may be disposed on the upstream side of the looper device 2.

**[0043]** The position adjustment device 12 adjusts the winding position of the steel sheet relative to the steering roll in the looper device 2 according to a control signal output from the control device 13. An operator may manually adjust the winding position of the steel sheet relative to the steering roll.

**[0044]** The control device 13 is configured by an information processing device such as a computer, and controls the entire operation of the meandering control apparatus for the steel sheet by executing a computer program stored in advance. In the present embodiment, the control device 13 calculates an average curvature of the steel sheet using the out-of-plane deformation amount of the steel sheet measured by the measurement device 11, calculates an off-center amount of the steel sheet in the steering roll using the calculated average curvature of the steel sheet, and controls the position adjustment device 12 based on the calculated off-center amount. FIG. 3 is a diagram illustrating an example of the shape data of the steel sheet measured every 0.1 seconds by the measurement device 11. Since the shape data illustrated in FIG. 3 includes an error, the measurement device 11 may smooth the shape data to calculate a mathematical formula representing the curved surface of the steel sheet, and calculate the average curvature of the steel sheet using the calculated mathematical formula.

**[0045]** As is apparent from the above description, the meandering control apparatus for the steel sheet according to the embodiment of the present invention measures the out-of-plane deformation amount of the steel sheet on the upstream side of the steering device that changes the conveyance direction of the steel sheet, calculates the average curvature of the steel sheet using the measured out-of-plane deformation amount of the steel sheet, calculates the off-center amount of the steel sheet in the steering device using the calculated average curvature of the steel sheet, and controls the winding position of the steel sheet relative to the steering device based on the calculated off-center amount. Accordingly, it is possible to suppress meandering of a steel sheet having a shape defect. In addition, by manufacturing the steel sheet using such meandering control method, it is possible to suppress the meandering of the steel sheet having the shape defect and to manufacture a steel sheet having a good yield.

[First Example]

**[0046]** In the present example, whether there is a defect in a steel sheet was evaluated when meandering control according to the present invention was performed (example) and when the meandering control according to the present invention was not performed (comparative example and reference example) on a plurality of steel sheets having different shapes. The evaluation results are shown in Table 1 below. In the example, the winding position of the steel sheet relative to the steering roll #1STR illustrated in FIG. 2 was controlled. As shown in Table 1, it was confirmed that occurrence of defects in the steel sheet due to the meandering of the steel sheet can be suppressed by executing the meandering control of the present invention. In addition, it was confirmed that, when there is no bending in the steel sheet, the steel sheet does not meander even if meandering control is not performed, and therefore no defect occurs in the steel sheet (reference example). Additionally, it was confirmed that, even when there is bending in the steel sheet, if a difference between a sheet width and a line width of the steel sheet is 0.4 m or more, the steel sheet does not collide with a guide vertical roll even if the steel sheet meanders, and therefore no defect occurs in the steel sheet (reference example).

Table 1

| Sheet width (m) | Line width (m) | Bending (1/m) | Edge wave/center buckle (elongation difference rate) | Meandering amount (m) | Off-center amount (m) | Whether there is defect | Remarks |
|---|---|---|---|---|---|---|---|
| 1.0 | 1.65 | 0 | 0 | 0 | 0 | No | Reference example |
| 1.3 | 1.65 | 0 | 0 | 0 | 0 | No | Reference example |
| 1.0 | 1.65 | 0.005 | 0 | 0 | 0 | No | Reference example |
| 1.1 | 1.65 | 0.005 | 0 | 0 | 0 | No | Reference example |
| 1.2 | 1.65 | 0.005 | 0 | 0 | 0 | No | Reference example |
| 1.3 | 1.65 | 0.005 | 0 | 0 | 0 | Yes | Comparative example |
| 1.3 | 1.65 | 0.005 | 0 | 0 | -0.05 | No | Example |

(continued)

| Sheet width (m) | Line width (m) | Bending (1/m) | Edge wave/center buckle (elongation difference rate) | Meandering amount (m) | Off-center amount (m) | Whether there is defect | Remarks |
|---|---|---|---|---|---|---|---|
| 1.3 | 1.65 | -0.005 | 0 | 0 | 0 | Yes | Comparative example |
| 1.3 | 1.65 | -0.005 | 0 | 0 | 0.05 | No | Example |
| 1.3 | 1.65 | 0.005 | 0.002 (edge) | 0 | 0 | No | Comparative example |
| 1.3 | 1.65 | 0.005 | 0.002 (edge) | 0 | -0.05 | No | Example |
| 1.3 | 1.65 | 0.005 | -0.002 (center) | 0 | 0 | Yes | Comparative example |
| 1.3 | 1.65 | 0.005 | -0.002 (center) | 0 | -0.05 | No | Example |
| 1.0 | 1.45 | 0 | 0 | 0 | 0 | No | Reference example |
| 1.1 | 1.45 | 0 | 0 | 0 | 0 | No | Reference example |
| 1.0 | 1.45 | 0.005 | 0 | 0 | 0 | No | Reference example |
| 1.2 | 1.45 | 0.005 | 0 | 0 | 0 | Yes | Comparative example |
| 1.2 | 1.45 | 0.005 | 0 | 0 | -0.05 | No | Example |

[Second Example]

**[0047]** In the present example, a relationship between the maximum bending of a joint portion of the steel sheet and occurrence of defects was evaluated. The evaluation results are illustrated in FIG. 4. In FIG. 4, a horizontal axis represents a sheet width, a vertical axis represents the maximum bending of the steel sheet, a white circle represents a joint portion without defects, and a black circle represents a joint portion with defects. As illustrated in FIG. 4, it was confirmed that three defects occur in 52 joint portions, and defects occur when both the sheet width and the bending are large. In addition, the positive and negative of the bending represented the occurrence direction of the defect, and the occurrence of the defect and the direction thereof was able to be predicted by a value of the bending. Therefore, if the bending and the sheet width are larger than a predetermined value, when the steel sheet is intentionally off-centered in the direction opposite to the occurrence direction of the defect predicted from the bending by the downstream steering roll, the occurrence of defects derived from the bending can be suppressed.

**[0048]** Although the embodiments to which the invention made by the present inventors is applied have been described above, the present invention is not limited by the description and drawings configuring a part of the disclosure of the present invention according to the present embodiments. That is, other embodiments, examples, operation techniques, and the like made by those skilled in the art based on the present embodiment are all included in the scope of the present invention.

Industrial Applicability

**[0049]** According to the present invention, it is possible to provide a meandering control method and a meandering control apparatus for a steel sheet capable of suppressing meandering of the steel sheet having a shape defect. Further, according to the present invention, it is possible to provide a manufacturing method for the steel sheet capable of manufacturing the steel sheet having a good yield by suppressing meandering of the steel sheet having the shape defect.

Reference Signs List

**[0050]**

1 CUTTING DEVICE

2 LOOPER DEVICE

3 COLD ROLLING MILL

4 ANNEALING FURNACE

11 MEASUREMENT DEVICE

12 POSITION ADJUSTMENT DEVICE

13 CONTROL DEVICE

S STEEL SHEET

**Claims**

**1.** A meandering control method for a steel sheet, the method comprising:

a measurement step of measuring an out-of-plane deformation amount of the steel sheet on an upstream side of a steering device that changes a conveyance direction of the steel sheet;
a calculation step of calculating an average curvature of the steel sheet using the out-of-plane deformation amount of the steel sheet measured in the measurement step; and
a control step of calculating an off-center amount of the steel sheet in the steering device using the average curvature of the steel sheet calculated in the calculation step, and controlling a winding position of the steel sheet relative to the steering device based on the calculated off-center amount.

**2.** The meandering control method for the steel sheet according to claim 1, wherein the measurement step includes a step of measuring the out-of-plane deformation amount of the steel sheet on a delivery side of a cutting device installed on the upstream side of the steering device, the cutting device being configured to cut an end portion of the steel sheet in a width direction.

**3.** A meandering control apparatus for a steel sheet, the apparatus comprising:

a steering device that changes a conveyance direction of the steel sheet;
a measurement device that measures an out-of-plane deformation amount of the steel sheet on an upstream side of the steering device;
a position adjustment device that adjusts a winding position of the steel sheet relative to the steering device; and
a control device that controls the position adjustment device,
wherein the control device

calculates an average curvature of the steel sheet using the out-of-plane deformation amount of the steel sheet that is measured by the measurement device,
calculates an off-center amount of the steel sheet in the steering device using the calculated average curvature of the steel sheet, and
controls the position adjustment device based on the calculated off-center amount.

**4.** The meandering control apparatus for the steel sheet according to claim 3, wherein the measurement device is installed on a delivery side of a cutting device installed on the upstream side of the steering device, the cutting device being configured to cut an end portion of the steel sheet in a width direction.

**5.** A manufacturing method for a steel sheet, the method comprising:

a storage step of storing the steel sheet in a looper device while suppressing the meandering of the steel sheet using the method of controlling the meandering of the steel sheet according to claim 1 or 2; and
a cold rolling step of cold-rolling the steel sheet stored in the looper device.

**6.** A manufacturing method for a steel sheet, the method comprising:

a storage step of storing the steel sheet in a looper device while suppressing the meandering of the steel sheet using the method of controlling the meandering of the steel sheet according to claim 1 or 2; and
an annealing step of annealing the steel sheet stored in the looper device.

FIG.1

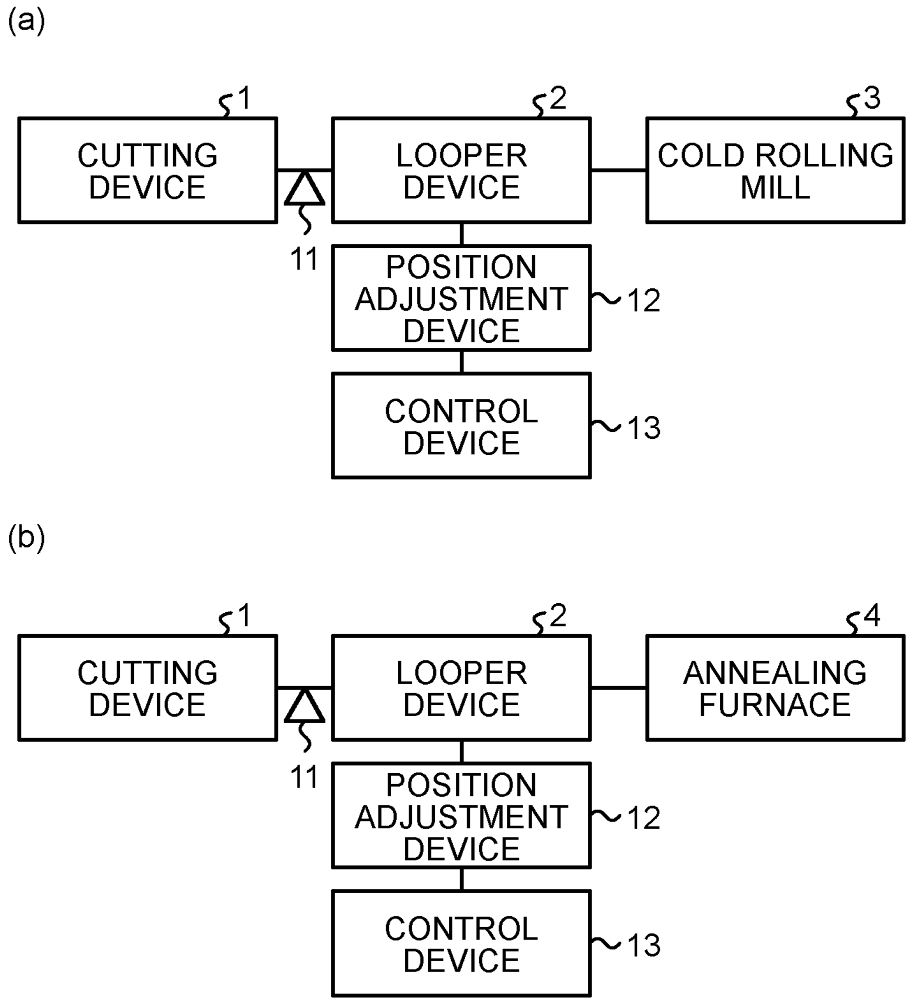

(a)
1
2
3
CUTTING DEVICE
LOOPER DEVICE
COLD ROLLING MILL
11
POSITION ADJUSTMENT DEVICE
12
CONTROL DEVICE
13
(b)
1
2
4
CUTTING DEVICE
LOOPER DEVICE
ANNEALING FURNACE
11
POSITION ADJUSTMENT DEVICE
12
CONTROL DEVICE
13

FIG.2

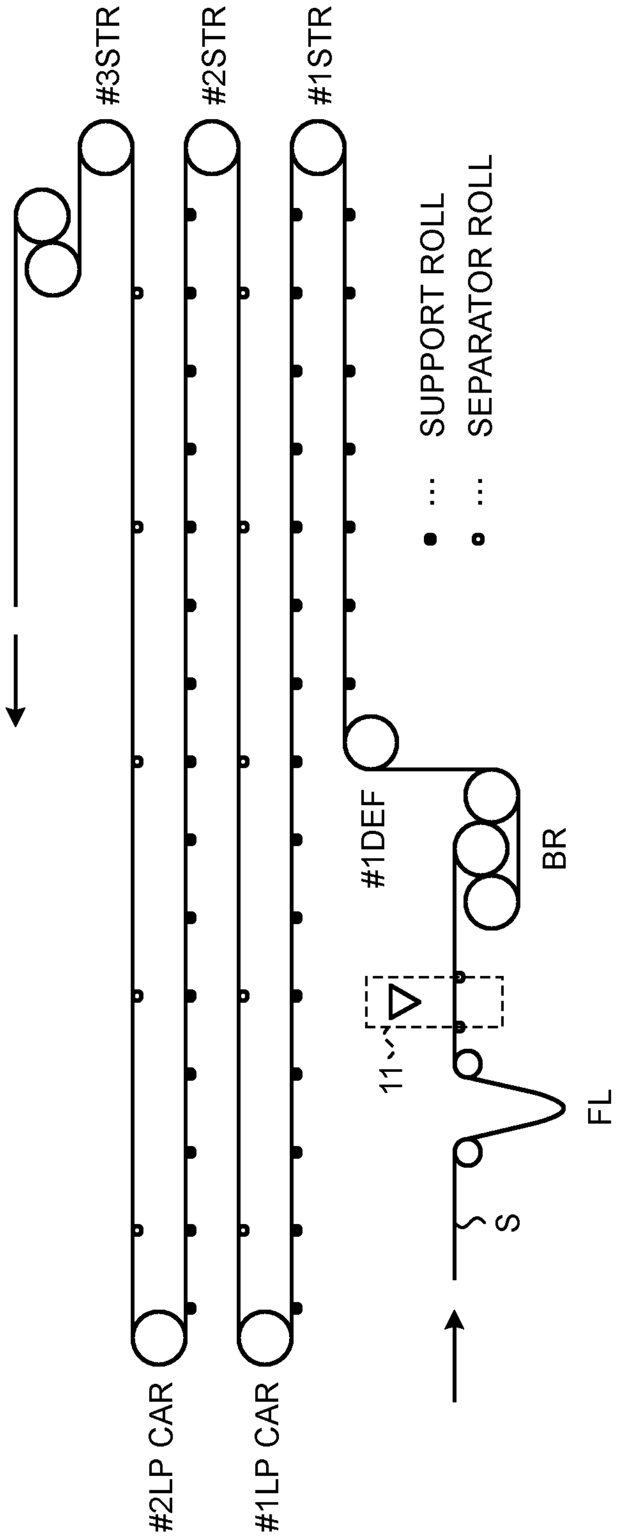

#3STR
#2STR
#1STR
... SUPPORT ROLL
... SEPARATOR ROLL
#1DEF
BR
11
FL
S
#2LP CAR
#1LP CAR

FIG.3

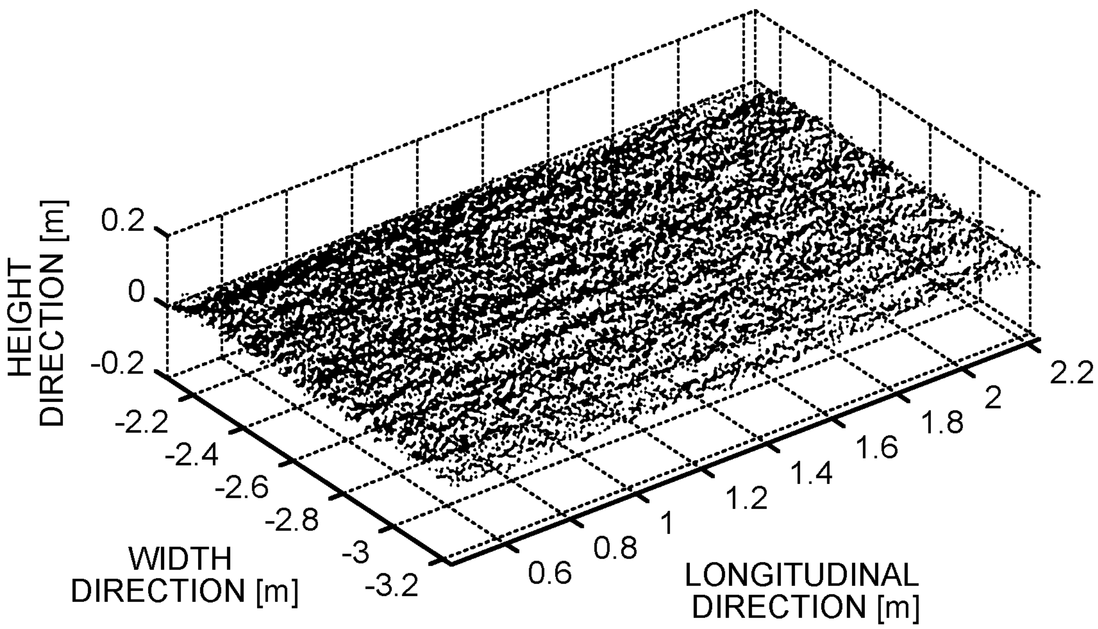

HEIGHT DIRECTION [m]
0.2
0
-0.2
-2.2
-2.4
-2.6
-2.8
-3
-3.2
WIDTH DIRECTION [m]
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
LONGITUDINAL DIRECTION [m]

FIG.4

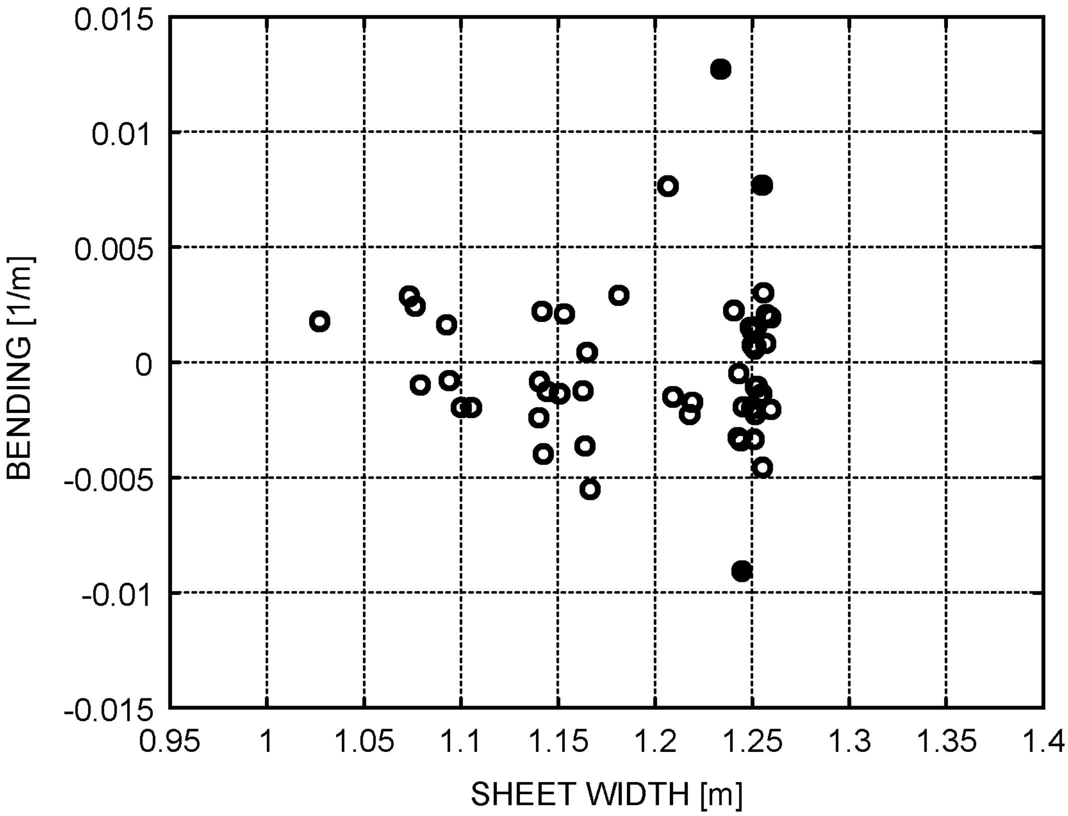
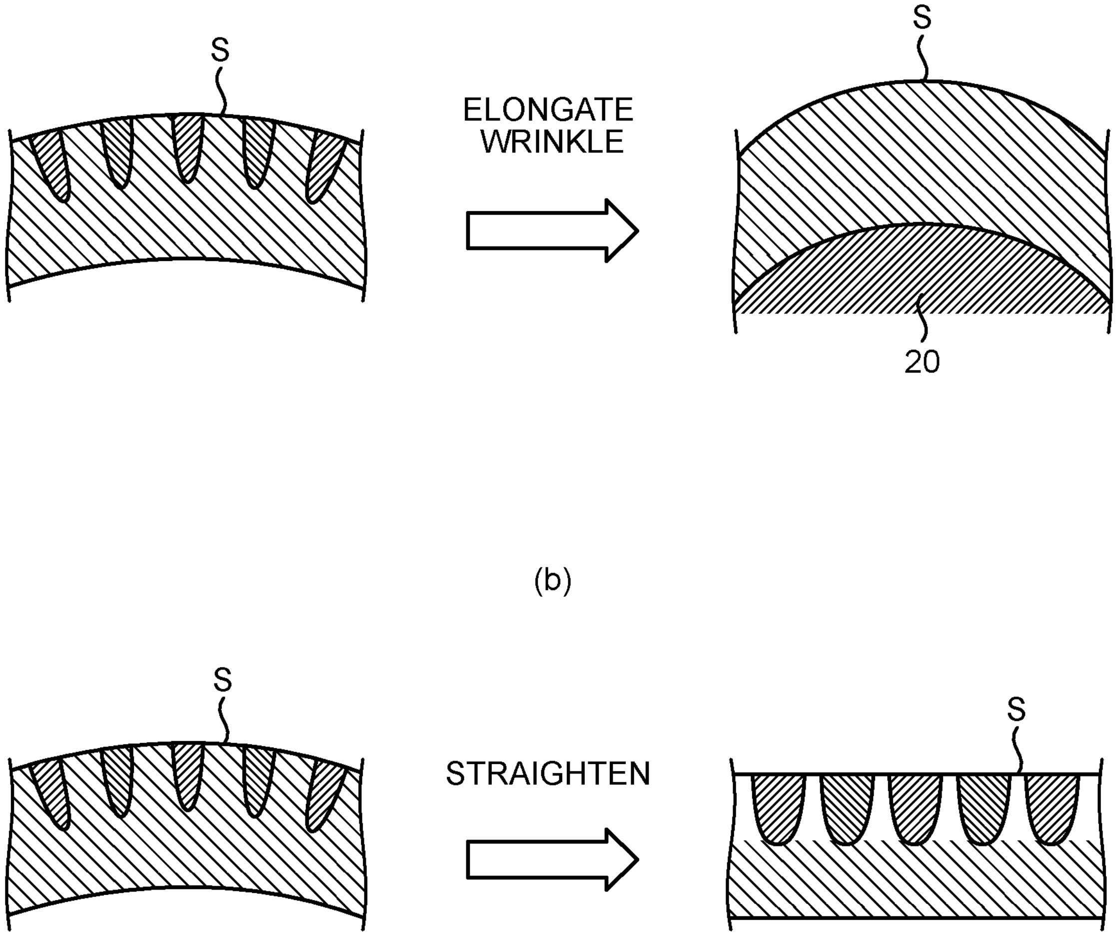

0.015
0.01
0.005
0
-0.005
-0.01
-0.015
BENDING [1/m]
0.95
1
1.05
1.1
1.15
1.2
1.25
1.3
1.35
1.4
SHEET WIDTH [m]

FIG.5

(a)



## INTERNATIONAL SEARCH REPORT

International application No.
**PCT/JP2023/000975**

**A. CLASSIFICATION OF SUBJECT MATTER**

***B21B 39/14***(2006.01)i; ***B65H 23/038***(2006.01)i
FI: B21B39/14 J; B65H23/038 Z

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)

B21B39/14; B65H23/038

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. |
|---|---|---|
| A | JP 2021-194704 A (JFE STEEL CORPORATION) 27 December 2021 (2021-12-27) entire text | 1-6 |
| A | JP 2017-192943 A (JFE STEEL CORPORATION) 26 October 2017 (2017-10-26) entire text | 1-6 |
| A | JP 2007-46131 A (NIPPON STEEL CORPORATION) 22 February 2007 (2007-02-22) entire text | 1-6 |
| A | JP 2014-223973 A (NIPPON STEEL & SUMIKIN ENGINEERING COMPANY, LIMITED) 04 December 2014 (2014-12-04) entire text | 1-6 |
| A | KR 10-2004-0027080 A (POSCO) 01 April 2004 (2004-04-01) entire text | 1-6 |

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

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| **22 March 2023** | **04 April 2023** |

| Name and mailing address of the ISA/JP | Authorized officer |
|---|---|
| **Japan Patent Office (ISA/JP)**<br>**3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915**<br>**Japan** | Telephone No. |

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

**INTERNATIONAL SEARCH REPORT**
**Information on patent family members**

International application No.
**PCT/JP2023/000975**

| Patent document cited in search report | Publication date (day/month/year) | Patent family member(s) | Publication date (day/month/year) |
|---|---|---|---|
| JP 2021-194704 A | 27 December 2021 | (Family: none) | |
| JP 2017-192943 A | 26 October 2017 | (Family: none) | |
| JP 2007-46131 A | 22 February 2007 | (Family: none) | |
| JP 2014-223973 A | 04 December 2014 | (Family: none) | |
| KR 10-2004-0027080 A | 01 April 2004 | (Family: none) | |

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

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- JP 2018192490 A **[0005]**