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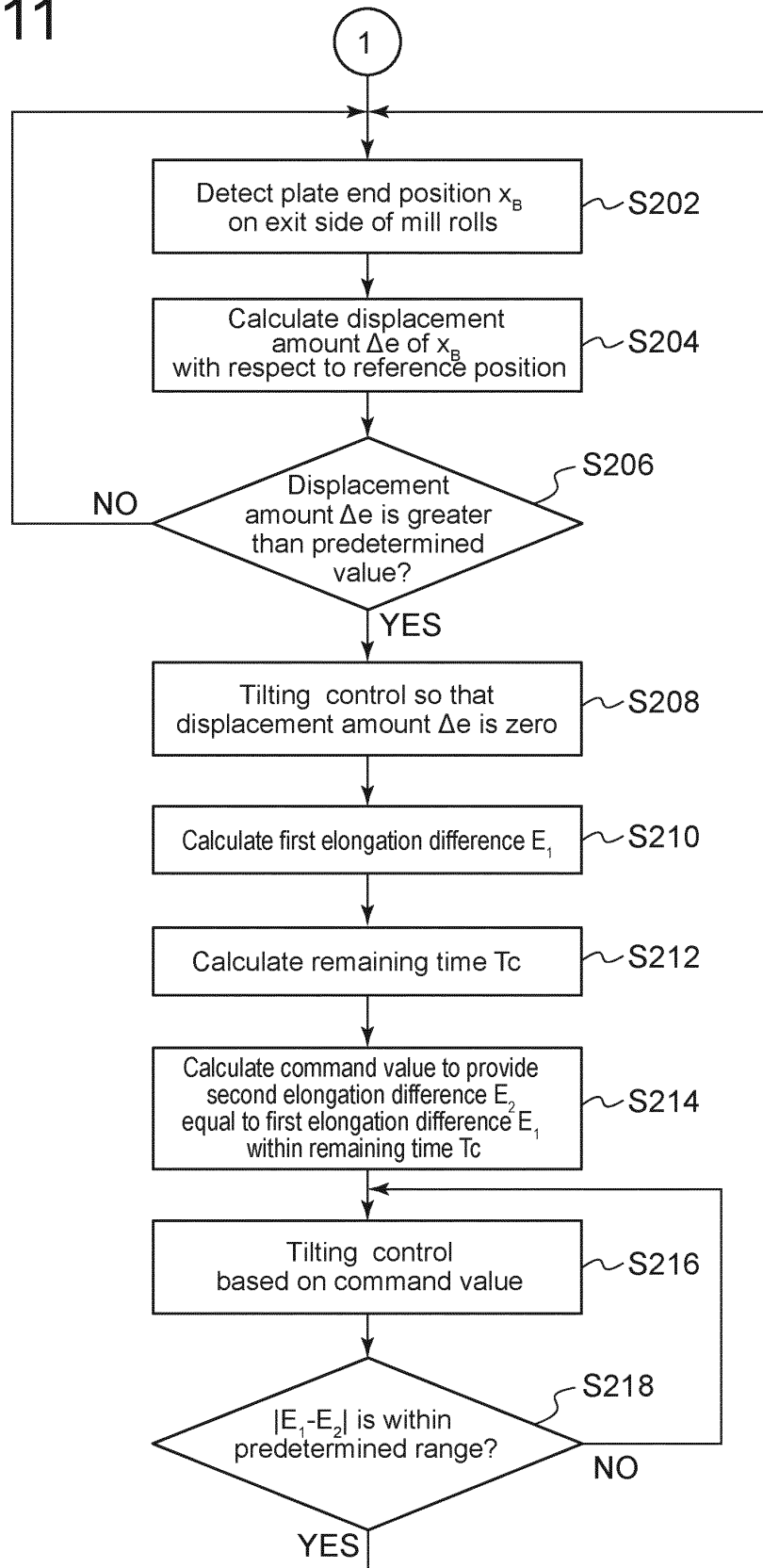
(54) **METHOD OF OPERATING ROLLING DEVICE, CONTROL DEVICE FOR ROLLING DEVICE, AND ROLLING EQUIPMENT**

(57) A method for operating a rolling mill device including a pair of mill rolls disposed on opposite sides of a metal plate includes: a detection step of detecting a plate end position in a plate width direction of the metal plate at a position on an exit side of the pair of mill rolls while rolling the metal plate by the pair of mill rolls in a state where an exit-side tension applied to the metal plate is zero; a first tilting step of performing, when a detection result of the plate end position in the detection step is deviated from a reference position to one side in the plate

width direction, a roll tilting control of the pair of mill rolls so that an outgoing direction of the metal plate from the mill rolls is along a conveying direction of the metal plate in the rolling mill device; and a second tilting step of performing a roll tilting control of the pair of mill rolls after the first tilting step so that the outgoing direction of the metal plate from the mill rolls is displaced to the other side in the plate width direction with respect to the conveying direction, and then the outgoing direction of the metal plate returns to the conveying direction.

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FIG. 11



Description

TECHNICAL FIELD

[0001] The present disclosure relates to a method for operating a rolling mill device, a control device for a rolling mill device, and a rolling mill device.

BACKGROUND

[0002] In the rolling of a metal plate using a rolling mill that includes a pair of mill rolls, before the tip end portion of the metal plate is wound by a winding device, the metal plate may be rolled in a state where no tension is applied to the metal plate on the exit side of the rolling mill (tip end tension-free rolling).

[0003] For example, Patent Document 1 describes that, using a rolling mill device that includes a rolling mill (mill rolls) and a tension reel (winding device) disposed on the exit side of the rolling mill, rolling is performed before the tension is established on the exit side of the rolling mill by winding a rolled material (metal plate) with the tension reel. In addition, Patent Document 1 describes the installation of a meandering detector upstream of the tension reel on the exit side of the rolling mill, and the tilting control of the rolling mill on the basis of the offset amount (the difference between the axial center position of the mill rolls and the widthwise center position of the rolled material) detected by the meandering detector. This is intended to improve yield by suppressing meandering and one-sided elongation that can occur due to rolling in a state where no exit-side tension is applied.

Citation List

Patent Literature

[0004] Patent Document 1: JPH11-179414A

SUMMARY

Problems to be Solved

[0005] When a metal plate is rolled in a tip end tension-free state where no exit-side tension is applied to the metal plate, an elongation difference occurs between opposite end portions of the rolled metal plate in the plate width direction, which can cause a phenomenon (tip end bending) in which the direction of the tip end portion of the metal plate is turned in the plate width direction with respect to the conveying direction of the rolling mill on the exit side (downstream side) of the rolling mill. When such tip end bending of the metal plate occurs, the outgoing direction of the metal plate can be brought in line with the conveying direction of the rolling mill by operating the rolling mill so that the plate end position in the plate width direction deviated from a specified position returns

to the specified position using a plate end position detector installed on the exit side of the rolling mill. However, such an operating method may not be able to correct the state where the direction of the tip end portion of the metal plate is bent with respect to the conveying direction, and when the tip end portion of the metal plate is bent, the front edge of the metal plate is oblique to the rotation axis of the winding device, so that the winding device may not be able to wind the metal plate properly.

[0006] In view of the above, an object of at least one embodiment of the present invention is to provide a method for operating a rolling mill device, a control device for a rolling mill device, and a rolling mill facility whereby it is possible to appropriately wind by a winding device a metal plate that has been rolled with no tension applied to the tip end.

Solution to the Problems

[0007] A method for operating a rolling mill device according to at least one embodiment of the present invention is a method for operating a rolling mill device including a pair of mill rolls disposed on opposite sides of a metal plate, comprising: a detection step of detecting a plate end position in a plate width direction of the metal plate at a position on an exit side of the pair of mill rolls while rolling the metal plate by the pair of mill rolls in a state where an exit-side tension applied to the metal plate is zero; a first tilting step of performing, when a detection result of the plate end position in the detection step is deviated from a reference position to one side in the plate width direction, a roll tilting control of the pair of mill rolls so that an outgoing direction of the metal plate from the mill rolls is along a conveying direction of the metal plate in the rolling mill device; and a second tilting step of performing a roll tilting control of the pair of mill rolls after the first tilting step so that the outgoing direction of the metal plate from the mill rolls is displaced to the other side in the plate width direction with respect to the conveying direction, and then the outgoing direction of the metal plate returns to the conveying direction.

Advantageous Effects

[0008] At least one embodiment of the present invention provides a method for operating a rolling mill device, a control device for a rolling mill device, and a rolling mill facility whereby it is possible to appropriately wind by a winding device a metal plate that has been rolled in a state where no tension is applied to the tip end.

BRIEF DESCRIPTION OF DRAWINGS

[0009]

FIG. 1 is a schematic configuration diagram of a rolling mill facility equipped with a control device according to an embodiment.

FIG. 2 is a schematic configuration diagram of a rolling mill facility equipped with a control device according to an embodiment.

FIG. 3 is a schematic configuration diagram of a controller constituting the control device according to an embodiment.

FIG. 4 is a flowchart showing an example of the method for operating a rolling mill device according to an embodiment.

FIG. 5A is a schematic diagram showing the state of a metal plate and mill rolls at the time of start of the tip end tension-free rolling of the metal plate.

FIG. 5B is a schematic diagram showing the state of a metal plate and mill rolls at the time of start of the tip end tension-free rolling of the metal plate.

FIG. 5C is a schematic diagram showing the state of a metal plate and mill rolls at the time of start of the tip end tension-free rolling of the metal plate.

FIG. 6 is a diagram for describing determination by a determination part whether the tip end tension-free rolling can be started.

FIG. 7 is a diagram for describing determination by a determination part whether the tip end tension-free rolling can be started.

FIG. 8 is a schematic partial cross-sectional view of a metal plate rolled by the rolling mill facility according to an embodiment, in a cross-section including the plate width direction and the longitudinal direction of the metal plate.

FIG. 9 is a graph showing an example of a graph representing a relationship between time and roll-to-roll gap.

FIG. 10 is a graph showing an example of a graph representing a relationship between time and roll-to-roll gap.

FIG. 11 is a flowchart showing an example of the method for operating a rolling mill device according to an embodiment.

FIG. 12A is a diagram showing a state transition of a metal plate when the rolling mill device is operated according to the flowchart shown in FIG. 11.

FIG. 12B is a diagram showing a state transition of a metal plate when the rolling mill device is operated according to the flowchart shown in FIG. 11.

FIG. 12C is a diagram showing a state transition of a metal plate when the rolling mill device is operated according to the flowchart shown in FIG. 11.

FIG. 12D is a diagram showing a state transition of a metal plate when the rolling mill device is operated according to the flowchart shown in FIG. 11.

FIG. 13 is a graph for describing an example of a method of calculating a first elongation difference and a second elongation difference of a metal plate.

FIG. 14 is a flowchart showing an example of the method for operating a rolling mill device according to an embodiment.

FIG. 15A is a diagram showing a state transition of a metal plate when the rolling mill device is operated

according to the flowchart shown in FIG. 14.

FIG. 15B is a diagram showing a state transition of a metal plate when the rolling mill device is operated according to the flowchart shown in FIG. 14.

FIG. 15C is a diagram showing a state transition of a metal plate when the rolling mill device is operated according to the flowchart shown in FIG. 14.

FIG. 15D is a diagram showing a state transition of a metal plate when the rolling mill device is operated according to the flowchart shown in FIG. 14.

FIG. 16 is a flowchart showing an example of the method for operating a rolling mill device according to an embodiment.

FIG. 17 is a flowchart showing an example of the method for operating a rolling mill device according to an embodiment.

DETAILED DESCRIPTION

[0010] Embodiments of the present invention will now be described in detail with reference to the accompanying drawings. It is intended, however, that unless particularly identified, dimensions, materials, shapes, relative positions, and the like of components described in the embodiments shall be interpreted as illustrative only and not intended to limit the scope of the present invention.

[0011] First, an overall configuration of a rolling mill facility including a rolling mill device according to some embodiments will be described.

[0012] FIGs. 1 and 2 are each a schematic configuration diagram of a rolling mill facility equipped with a control device according to an embodiment. As shown in FIGs. 1 and 2, the rolling mill facility 1 includes a rolling mill device 2 and a control device 100 for controlling the rolling mill device 2. In some embodiments, the rolling mill device 2 may include one rolling mill 10 as shown in FIG. 1 for example, or may include two rolling mills 10 (10A, 10B) as shown in FIG. 2 for example, or may include three or more rolling mills 10.

[0013] The rolling mill device 2 shown in FIG. 1 is a rolling mill device (reverse mill) that reciprocates and rolls a metal plate 90 passed between a pair of mill rolls 15, 16. The rolling mill device 2 shown in FIG. 1 includes a rolling mill 10 including a pair of mill rolls (work rolls) 15, 16 disposed on opposite sides of a metal plate 90, which is a rolled material, an unwinding device 4 disposed on the entry side of the mill rolls 15, 16 in the traveling direction of the metal plate 90, and a winding device 14 disposed on the exit side of the mill rolls 15, 16 in the traveling direction of the metal plate 90, and is configured to roll the metal plate 90 by the pair of mill rolls 15, 16.

[0014] The rolling mill device 2 shown in FIG. 2 is a rolling mill device (reverse mill) that reciprocates and rolls a metal plate 90 passed between a pair of first mill rolls 15A, 16A and a pair of second mill rolls 15B, 16B. The rolling mill device 2 shown in FIG. 2 includes a first rolling mill 10A including a pair of first mill rolls (work rolls) 15A, 16A disposed on opposite sides of a metal plate 90, which

is a rolled material, a second rolling mill 10B including a pair of second mill rolls (work rolls) 15B, 16B disposed on opposite sides of the metal plate 90, an unwinding device 4 disposed on the entry side of the first mill rolls 15A, 16A in the traveling direction of the metal plate 90, and a winding device 14 disposed on the exit side of the second mill rolls 15B, 16B in the traveling direction of the metal plate 90, and is configured to roll the metal plate 90 by the pair of first mill rolls 15A, 16A and the pair of second mill rolls 15B, 16B.

[0015] The illustrated rolling mills 10, 10A, and 10B have a similar configuration. Hereinafter, the configuration of the rolling mill 10 will be described, but the same description applies to the rolling mills 10A and 10B. In FIG. 2, components (mill rolls, etc.) of the rolling mills 10A and 10B are marked with "A" or "B" respectively, with the same sign for components of the rolling mill 10 shown in FIG. 1.

[0016] The rolling mill 10 includes, in addition to the pair of mill rolls (work rolls) 15, 16, a pair of intermediate rolls 17, 18 and a pair of backup rolls 19, 20 disposed on the opposite sides of the metal plate 90 to sandwich the pair of mill rolls 15, 16. The intermediate rolls 17, 18 and the backup rolls 19, 20 are configured to support the mill rolls 15, 16. Further, the rolling mill 10 includes a roll reduction device 22 for reducing the thickness of the metal plate 90 sandwiched between the pair of mill rolls 15, 16 by applying a load to the pair of mill rolls 15, 16. The roll reduction device 22 may include a hydraulic cylinder.

[0017] A motor (not shown) is connected to the mill rolls 15, 16 via, for example, a spindle (not shown), and the mill rolls 15, 16 are rotationally driven by the motor. During the rolling of the metal plate 90, the mill rolls 15, 16 are rotated by the motor while the metal plate 90 is pressed by the roll reduction device 22, which creates a frictional force between the mill rolls 15, 16 and the metal plate 90 and moves the metal plate 90 to the exit side of the mill rolls 15, 16 by this frictional force.

[0018] The unwinding device 4 is configured to unwind the metal plate 90 toward the rolling mill 10. The winding device 14 is configured to wind the metal plate 90 from the rolling mill 10. The unwinding device 4 and the winding device 14 are driven by respective motors (not shown).

[0019] The unwinding device 4 is configured to apply an entry-side tension to the metal plate 90 during the rolling of the metal plate 90. The winding device 14 is configured to apply an exit-side tension to the metal plate 90 during the rolling of the metal plate 90. In other words, the motors appropriately drive the unwinding device 4 and the winding device 14 to apply the entry-side tension and exit-side tension to the metal plate 90. By appropriately applying the entry-side tension and exit-side tension to the metal plate 90, it is possible to suppress meandering of the metal plate 90 during rolling.

[0020] The rolling is stopped just before the tail end of the metal plate 90 unwound from the unwinding device 4, and the odd-numbered rolling (e.g., first pass) is com-

pleted in a state where the metal plate 90 is pressed by the mill rolls 15, 16. The metal plate 90 is then rewound from the winding device 14 toward the rolling mill 10, and the metal plate 90 travels in a direction opposite to the previous traveling direction and is wound by the unwinding device 4 for the even-numbered rolling (e.g., second pass). In other words, the roles of the unwinding device 4 and the winding device 14 are interchangeable depending on the traveling direction of the metal plate 90.

[0021] The rolling mill device 2 shown in FIGs. 1 and 2 further includes an entry pinch roll 6 and a side guide 8 for guiding the metal plate 90 introduced from the unwinding device 4 to the rolling mill 10, and an exit pinch roll 12 for guiding the metal plate 90 fed from the rolling mill 10 to the winding device 14.

[0022] As shown in FIGs. 1 and 2, the control device 100 for controlling the rolling mill device 2 includes a first plate end detection part 32 and a second plate end detection part 34 for detecting plate end positions in the plate width direction of the metal plate 90, and a controller 40 configured to control the operation of the rolling mill device 2 on the basis of detection results of the first plate end detection part 32 and the second plate end detection part 34.

[0023] The first plate end detection part 32 is disposed on the entry side of the pair of mill rolls 15, 16 in the conveying direction of the metal plate 90, and is configured to detect a first plate end position x1, which is the plate end position in the plate width direction of the metal plate at a first position Y1 in the conveying direction. The second plate end detection part 34 is disposed on the exit side of the pair of mill rolls 15, 16 in the conveying direction, and is configured to detect a second plate end position x2, which is the plate end position in the plate width direction of the metal plate at a second position Y2 in the conveying direction.

[0024] The control device 100 shown in FIG. 2 is provided with first plate end detection parts 32A, 32B on the entry side in the conveying direction and second plate end detection parts 34A, 34B on the exit side in the conveying direction for each of the first mill rolls 15A, 16A and the second mill rolls 15B, 16B.

[0025] The controller 40 is configured to receive signals indicating measurement results from the first plate end detection part 32 and the second plate end detection part 34, and to control the operation of the motors for driving the roll reduction device 22 and the mill rolls 15, 16 based on these measurement results.

[0026] The controller 40 may include a CPU, a memory (RAM), an auxiliary memory, and an interface. The controller 40 is configured to receive signals from the first plate end detection part 32 and the second plate end detection part 34 via the interface. The CPU is configured to process the signals thus received. Further, the CPU is configured to process a program loaded into the memory.

[0027] The processing contents in the controller 40 may be implemented as a program executed by the CPU

and stored in the auxiliary memory. When the program is executed, the program is loaded into the memory. The CPU reads the program from the memory and executes instructions contained in the program.

[0028] FIG. 3 is a schematic configuration diagram of the controller 40 constituting the control device 100 according to an embodiment. As shown in FIG. 3, the controller 40 includes a determination part 42 and a rolling control part 44. The determination part 42 is configured to determine whether the rolling of the metal plate 90 by the pair of mill rolls 15, 16 in a state where the exit-side tension applied to the metal plate 90 is zero (tip end tension-free rolling) can be started, on the basis of the first plate end position x_1 of the metal plate 90 detected by the first plate end detection part 32 and the second plate end position x_2 of the metal plate 90 detected by the second plate end detection part 34. The rolling control part 44 is configured to control the operation of the pair of mill rolls 15, 16. More specifically, the rolling control part 44 is configured to control the motors for driving the roll reduction device 22 and the mill rolls 15, 16 in order to adjust the gap between the rolls and the rotation speed of the mill rolls 15, 16.

[0029] Parts other than the determination part 42 of the controller 40 will be described later.

[0030] The control device 100 may further have a display part (e.g., display; not shown) for displaying the determination result of the determination part 42.

[0031] The operation control of the rolling mill device 2 by the control device 100 will now be described. The rolling mill device 2 may be operated by manually performing some or all of the processing by the control device 100 described below.

[0032] FIGs. 4 and 16 are each a flowchart showing an example of the method for operating the rolling mill device 2 according to an embodiment. FIGs. 4 and 16 are flowcharts showing an example of the operating method up to the start of tip end tension-free rolling of the metal plate 90. The operating method after the start of tip end tension-free rolling of the metal plate 90 will be described later with reference to the flowcharts of FIGs. 11, 14 and 17.

[0033] FIGs. 5A to 5C are each a schematic diagram showing the state of the metal plate 90 and the mill rolls 15, 16 at the time of start of the tip end tension-free rolling of the metal plate 90. FIGs. 6 and 7 are each a diagram for describing determination by the determination part 42 whether the tip end tension-free rolling can be started.

[0034] In an embodiment, as shown in FIGs. 4 and 16, first, the controller 40 adjusts the positions of the pair of mill rolls 15, 16 so that the gap (roll-to-roll gap) between the pair of mill rolls 15, 16 is larger than the thickness of the metal plate 90 (step S102). At this time, the position of the pair of mill rolls 15, 16 may be adjusted by operating the roll reduction device 22 as needed. Then, while maintaining the gap between the rolls larger than the thickness of the plate, the tip end portion of the metal plate 90 including a tip end 91 (see FIG. 5A) is passed between the

pair of mill rolls 15, 16 (step S104).

[0035] FIG. 5A is a schematic diagram showing the state of the metal plate 90 and the mill rolls 15, 16 when step S104 is completed. As shown in FIG. 5A, at the completion of step S104, the tip end portion of the metal plate 90 including the tip end 91 has passed between the mill rolls 15, 16 while the gap d_0 between the pair of mill rolls 15, 16 is larger than the thickness H_0 of the metal plate 90 before rolling. The tip end portion of the metal plate 90 including the tip end 91 is located on the exit side of the mill rolls 15, 16 and has not reached the winding device 14. Therefore, the exit-side tension T_d acting on the metal plate 90 is zero. Further, at this point, the entry-side tension T_e is also zero because it is not acting on the metal plate 90.

[0036] After step S104, the tip end tension-free rolling of the metal plate 90 starts (step S112 in FIG. 4 or step S122 in FIG. 16).

[0037] In the embodiment according to the flowchart of FIG. 4, for example, as described below, it is determined whether the tip end tension-free rolling of the metal plate 90 can be started (steps S106 to S108), and if it is determined that the tip end tension-free rolling can be started, the tip end tension-free rolling of the metal plate 90 is started.

[0038] This determination will be described with reference to the flowchart of FIG. 4. First, the first plate end detection part 32 is used to detect the first plate end position x_1 at the first position Y_1 in the conveying direction, and the second plate end detection part 34 is used to detect the second plate end position x_2 at the second position Y_2 in the conveying direction (step S106).

[0039] Here, FIGs. 6 and 7 are each a schematic diagram of the mill rolls 15, 16 and the metal plate 90 in plan view before the rolling is started. As shown in FIGs. 6 and 7, the metal plate 90 has a plate width W , and has a first edge 92 and a second edge 93, which are opposite edges in the plate width direction. In some embodiments, the first plate end detection part 32 and the second plate end detection part 34 may be configured to detect the position of the first edge 92 at the first position Y_1 and the second position Y_2 as the first plate end position x_1 and the second plate end position x_2 , respectively (see FIGs. 6 and 7). Alternatively, in some embodiments, the first plate end detection part 32 and the second plate end detection part 34 may be configured to detect the position of the second edge 93 at the first position Y_1 and the second position Y_2 as the first plate end position x_1 and the second plate end position x_2 , respectively.

[0040] After step S106, the determination part 42 determines whether the tip end tension-free rolling of the metal plate 90 can be started, on the basis of the first plate end position x_1 and the second plate end position x_2 detected in step S106 (step S108).

[0041] In step S108, for example, if the longitudinal direction of the metal plate 90 is substantially parallel to the conveying direction of the metal plate 90 in the rolling mill device 2 (see FIG. 6), it is determined that the tip end

tension-free rolling of the metal plate 90 can be started, and if the inclination of the longitudinal direction of the metal plate 90 with respect to the conveying direction of the metal plate 90 is greater than a specified degree (see FIG. 7), it is determined that the tip end tension-free rolling of the metal plate 90 cannot be started.

[0042] More specifically, in an embodiment, in step S108, if the difference $|x_1 - x_2|$ between the first plate end position x_1 and the second plate end position x_2 is equal to or less than a threshold Δx_{th1} , it is determined that the tip end tension-free rolling of the metal plate 90 can be started, and if the difference $|x_1 - x_2|$ is greater than the threshold Δx_{th1} , it is determined that the tip end tension-free rolling of the metal plate 90 cannot be started.

[0043] Alternatively, in an embodiment, in step S108, if the difference $(x_1 - x_{ref})$ between the first plate end position x_1 and a reference position x_{ref} in the plate width direction of the metal plate 90 and the difference $(x_2 - x_{ref})$ between the second plate end position x_2 and the reference position x_{ref} are both equal to or less than a threshold x_{th2} , it is determined that the tip end tension-free rolling of the metal plate 90 can be started, and if at least one of the difference $(x_1 - x_{ref})$ or $(x_2 - x_{ref})$ is greater than the threshold x_{th2} , it is determined that the tip end tension-free rolling of the metal plate 90 cannot be started.

[0044] Here, the reference position x_{ref} is a predetermined position in the plate width direction (i.e., in the axial direction (direction of the center axis O) of the mill rolls 15, 16) when the longitudinal direction of the metal plate 90 coincides with the conveying direction by the mill rolls 15, 16 (rolling mill). The reference position x_{ref} may be, for example, the center position in the axial direction of the mill rolls 15, 16 (see FIGs. 6 and 7). In FIG. 6, the longitudinal direction of the metal plate 90 coincides with the conveying direction by the mill rolls, and at this time, the position of the center line Lc along the longitudinal direction of the metal plate 90 coincides with the reference position x_{ref} in the plate width direction (i.e., the axial direction of the mill rolls 15, 16).

[0045] If it is determined in the step S108 that the tip end tension-free rolling of the metal plate 90 cannot be started (No in step S108), the position of the metal plate 90 in the plate width direction is corrected (step S110), and the process returns to step S106 to detect the first plate end position x_1 and the second plate end position x_2 (step S106) and it is determined whether the tip end tension-free rolling of the metal plate 90 can be started based on the detection results in step S106 (step S108).

[0046] Conversely, if it is determined in the step S108 that the tip end tension-free rolling of the metal plate 90 can be started (Yes in step S108), the rolling control part 44 starts the tip end tension-free rolling of the metal plate 90.

[0047] In step S112, in a state where the exit-side tension T_d applied to the metal plate 90 is zero, the metal plate 90 is pressed by the pair of mill rolls 15, 16, and the rotation of the pair of mill rolls 15, 16 is started to start the tip end tension-free rolling of the metal plate 90 (see

FIG. 5B).

[0048] When the metal plate 90 is pressed by the pair of mill rolls 15, 16, as shown in FIG. 5B, the roll reduction device 22 is operated so that the gap between the rolls is set to a value d_1 corresponding to a target thickness. The gap d_1 between the rolls at this time is smaller than the thickness H_0 of the metal plate 90 before rolling. At the start of rotation and after the start of rotation of the mill rolls 15, 16, the rotation speed of the mill rolls 15, 16 is adjusted to an appropriate value by adjusting the current value of the motor used to drive the mill rolls 15, 16.

[0049] When the tip end tension rolling of the metal plate 90 is started, the metal plate 90 travels in the direction of the arrow shown in FIG. 5B. Then, as shown in FIG. 5C, after the start of rolling, the portion of the metal plate 90 that has been pressed by the mill rolls 15, 16 and has advanced to the exit side of the mill rolls 15, 16 has a thickness H_1 that is thinner than the thickness H_0 before rolling.

[0050] Thus, the tip end tension-free rolling of the metal plate 90 allows the rolling to start from a portion close to the tip end of the metal plate 90, compared to the case where the rolling is started in a state where the tip end of the metal plate is wound around the winding device and the exit-side tension is applied, so that the yield of the metal plate 90 can be improved.

[0051] Further, as described above, after it is determined in step S108 that the tip end tension-free rolling of the metal plate 90 can be started, the tip end tension-free rolling is started in step S112, so that the metal plate 90 rolled with no tension applied to the tip end can be appropriately wound by the winding device 14.

[0052] If a plate end position detection part is installed only at one position on the exit side of the mill roll 15, 16, the following problems may occur. Specifically, as shown in FIG. 7 for example, even if the longitudinal direction of the metal plate 90 is oblique to the conveying direction of the metal plate 90 by the mill rolls 15, 16 (rolling mill 10) before the start of rolling, it is unclear whether the longitudinal direction of the metal plate 90 is oblique to the conveying direction from the detection result of the plate end position at only one point in the conveying direction. When the tip end tension-free rolling is started in this case, the outgoing direction of the metal plate 90 from the mill rolls 15, 16 remains oblique to the conveying direction by the rolling mill 10. Accordingly, the plate end position (e.g., second plate end position x_2 in FIG. 7) detected by the plate end position detection part disposed on the exit side is almost fixed even after the rolling is started. Therefore, even if the control is based on the detected plate end position, the inclination of the metal plate 90 with respect to the conveying direction cannot be corrected, and if the rolling is continued in this state, the tip end of the metal plate 90 will be separated from the conveyance line of the rolling mill 10 in the plate width direction, and the rolled metal plate 90 may not be appropriately wound by the winding device 14.

[0053] In this regard, according to the above-described

embodiment, in step S106, the plate end positions (first plate end position x1 and second plate end position x2) in the plate width direction of the metal plate 90 are detected at the first position Y1 on the entry side and the second position Y2 on the exit side of the pair of mill rolls 15, 16. Accordingly, on the basis of these detection results, it is possible to ascertain the degree of inclination of the longitudinal direction of the metal plate 90 with respect to the conveying direction before the tip end tension-free rolling is started, that is, it is possible to ascertain the degree of inclination of the outgoing direction of the metal plate 90 with respect to the conveying direction at the start of tip end tension-free rolling. Then, in step S108, it is determined whether the tip end tension-free rolling can be started based on the detection results of the first plate end position x1 and the second plate end position x2. Thus, for example, when it is determined that the longitudinal direction of the metal plate 90 (i.e., the outgoing direction of the metal plate 90 at the start of rolling) is almost parallel to the conveying direction based on the detection results, it can be determined that the tip end tension-free rolling of the metal plate 90 can be started.

[0054] Therefore, according to the above-described embodiment, the tip end tension-free rolling can be started in a state where the outgoing direction of the metal plate 90 is almost parallel to the conveying direction, so that the tip end portion of the metal plate 90 can be prevented from deviating from the conveyance line by the rolling mill 10 in the plate width direction. Thus, it is easy to appropriately wind the rolled metal plate 90 by the winding device 14.

[0055] Further, according to the above-described embodiment, since the tip end tension-free rolling can be started in a state where the outgoing direction of the metal plate 90 is almost parallel to the conveying direction, by using the second plate end position x2 obtained at the start of tip end tension-free rolling as a reference, the roll tilting control of the rolling mill 10, such as meandering control of the metal plate 90, can be appropriately performed based on the second plate end position detected during the tip end tension-free rolling.

[0056] Thus, the metal plate 90 rolled with no tension applied to the tip end can be wound by the winding device 14 appropriately.

[0057] In the case of the rolling mill facility 1 including two rolling mills 10 (first rolling mill 10A and second rolling mill 10B) shown in FIG. 2, the control device 100 is configured to determine whether the first tip end tension-free rolling of the metal plate 90 by the pair of first mill rolls 15A, 16A (first rolling mill 10A) can be started, and if it is determined that the first tip end tension-free rolling can be started, after the tip end tension-free rolling is started by the pair of first mill rolls 15A, 16A, determine whether the second tip end tension-free rolling of the metal plate 90 by the pair of second mill rolls 15B, 16B can be started.

[0058] In other words, after the steps S102 to S112 are performed for the first rolling mill 10A and the tip end

tension-free rolling of the metal plate 90 is started, the S102 to S112 are performed for the second rolling mill 10B.

[0059] Thus, for each of the first mill rolls 15A, 16A (first rolling mill 10A) and the second mill rolls 15B, 16B (second rolling mill 10B) arranged in the conveying direction, it is determined whether the tip end tension-free rolling can be started in step S108, and on the basis of the determination result, the tip end tension-free rolling is started in step S112. This enables more efficient rolling using the pair of mill rolls 15A, 16A and the pair of mill rolls 15B, 16B, while enabling the winding device to appropriately wind the metal plate 90 rolled by the mill rolls 15, 16 with no tension applied to the tip end.

[0060] In contrast, in the embodiment according to the flowchart of FIG. 16, after the step S104, the rolling control part 44 starts the tip end tension-free rolling of the metal plate 90 (step S122, see FIGs. 5A to 5C). Here, in step 122, the rolling is performed at a rolling speed lower than a target rolling speed at least until the tip end 91 of the metal plate 90 reaches the second position Y2 on the exit side of the mill rolls 15, 16 (detection position by the second plate end detection part 34 disposed on the exit side of the pair of mill rolls 15, 16).

[0061] Thus, after the rolling of the metal plate 90 is started, the tip end tension-free rolling is performed at a speed lower than the target rolling speed in the tip end tension-free rolling, which makes it easier to maintain the longitudinal direction of the metal plate 90 parallel to the conveying direction, and thus prevents the tip end portion of the metal plate 90 from deviating from the conveyance line by the rolling mill 10 in the plate width direction. In this embodiment, compared to the embodiment according to the flowchart in FIG. 4, the metal plate 90 can be appropriately conveyed to the second plate end detection part 34 without detecting the second plate end position x2 on the exit side of the mill rolls 15, 16 and correcting the plate end position.

[0062] Further, since it is easier to maintain the longitudinal direction of the metal plate 90 parallel to the conveying direction, the roll tilting control of the rolling mill 10, such as meandering control of the metal plate 90, can be appropriately performed based on the position (e.g., second plate end position) of the metal plate 90 detected during the tip end tension-free rolling.

[0063] Thus, the metal plate 90 rolled with no tension applied to the tip end can be wound by the winding device 14 appropriately.

[0064] The first plate end detection part 32 and the second plate end detection part 34 are preferably disposed as close as possible to the mill rolls 15, 16 in the conveying direction of the metal plate 90 by the mill rolls 15, 16. With this configuration, the first plate end position x1 and the second plate end position x2 can be detected by the first plate end detection part 32 and the second plate end detection part 34 in a state where the tip end portion of the metal plate 90 is placed close to the mill rolls 15, 16, and on the basis of the detection results, the

rolling can be started in a state where the tip end 91 of the metal plate 90 is placed close to the mill rolls 15, 16, so that the yield of the metal plate 90 can be improved.

[0065] In some embodiments, when a distance between the pair of mill rolls 15, 16 and the winding device 14 in the conveying direction is defined as L_2 (see FIGs. 1 and 2), a distance L_b (see FIGs. 1 and 2) between the pair of mill rolls 15, 16 and the second plate end detection part 34 in the conveying direction is $0.1 \times L_2$ or less.

[0066] The distance in the conveying direction between the pair of mill rolls 15, 16 and the winding device 14 is the distance in the conveying direction between the center axis O of the pair of mill rolls 15, 16 and the center axis of the winding device 14. The distance in the conveying direction between the pair of mill rolls 15, 16 and the second plate end detection part 34 is the distance in the conveying direction between the center axis of the pair of mill rolls 15, 16 and the center position of the second plate end detection part 34 or the plate end detection position (second position Y2) by the second plate end detection part 34. The direction of the center axis O of the mill rolls 15, 16, the direction of the center axis of the unwinding device 4, and the direction of the center axis of the winding device 14 are substantially parallel to each other.

[0067] Thus, since the distance L_b between the second plate end detection part 34 and the mill rolls 15, 16 in the conveying direction is relatively short, the second plate end position x2 can be detected at the start of tension-free rolling and during tension-free rolling while keeping the tip end 91 of the metal plate 90 relatively close to the mill rolls at the start of tension-free rolling. Therefore, the tip end tension-free rolling can be appropriately performed while reducing the length of the tip end portion of the metal plate 90 not to be rolled, so that the yield of the metal plate 90 can be effectively improved.

[0068] In some embodiments, when a distance between the pair of mill rolls 15, 16 and the unwinding device 4 in the conveying direction is defined as L_1 (see FIGs. 1 and 2), a distance L_a (see FIGs. 1 and 2) between the pair of mill rolls 15, 16 and the first plate end detection part 32 in the conveying direction is $0.1 \times L_1$ or less.

[0069] The distance in the conveying direction between the pair of mill rolls 15, 16 and the unwinding device 4 is the distance in the conveying direction between the center axis O of the pair of mill rolls 15, 16 and the center axis of the unwinding device 4. The distance in the conveying direction between the pair of mill rolls 15, 16 and the first plate end detection part 32 is the distance in the conveying direction between the center axis of the pair of mill rolls 15, 16 and the center position of the first plate end detection part 32 or the plate end detection position (first position Y1) by the first plate end detection part 32.

[0070] In the case of the rolling mill device (reverse mill) that reciprocates and rolls the metal plate 90 passed between the pair of mill rolls 15, 16, in the second pass after the first pass, the conveying direction of the metal plate 90 is reversed, and the rolling with the mill rolls 15,

16 starts from the rear end side of the metal plate 90. In this regard, according to the above-described embodiment, since the distance between the first plate end detection part 32 and the mill rolls 15, 16 in the conveying direction in the second pass (opposite to the conveying direction in the first pass) is relatively short, the first plate end position x1 can be detected at the start of tension-free rolling and during tension-free rolling while keeping the rear end of the metal plate 90 relatively close to the mill rolls at the start of tension-free rolling in the second pass. Therefore, the tip end tension-free rolling can be appropriately performed while reducing the length of the rear end portion of the metal plate 90 not to be rolled, so that the yield of the metal plate 90 can be effectively improved.

[0071] In some embodiments, the rolling mill facility 1 is equipped with a plate thickness gauge disposed on at least one of the entry side or exit side of the pair of mill rolls 15, 16 in the conveying direction and configured to measure the thickness of the metal plate 90. The first plate end detection part 32 or the second plate end detection part 34 is disposed between the pair of mill rolls 15, 16 and the plate thickness gauge in the conveying direction.

[0072] In the embodiment shown in FIGs. 1 and 2, a plate thickness gauge 36 is disposed on the entry side of the pair of mill rolls 15, 16 in the conveying direction, and the first plate end detection part 32 is disposed between the pair of mill rolls 15, 16 and the plate thickness gauge 36 in the conveying direction. Further, in the embodiment shown in FIGs. 1 and 2, a plate thickness gauge 38 is disposed on the exit side of the pair of mill rolls 15, 16 in the conveying direction, and the second plate end detection part 34 is disposed between the pair of mill rolls 15, 16 and the plate thickness gauge 38 in the conveying direction.

[0073] The plate thickness gauges 36, 38 used to control the thickness of the metal plate 90 are preferably disposed near the mill rolls 15, 16 in the conveying direction to ensure good control response. In this regard, according to the above-described embodiment, since the first plate end detection part 32 or the second plate end detection part 34 is disposed closer to the mill rolls 15, 16 in the conveying direction than the plate thickness gauges 36, 38 for measuring the thickness of the metal plate 90, the first plate end position x1 or the second plate end position x2 can be detected at the start of tension-free rolling and during tension-free rolling while keeping the tip end of the metal plate 90 relatively close to the mill rolls 15, 16 at the start of tension-free rolling. Therefore, the tip end tension-free rolling can be appropriately performed while reducing the length of the tip end portion of the metal plate not to be rolled, so that the yield of the metal plate can be effectively improved.

[0074] In some embodiments, the first plate end detection part 32 or the second plate end detection part 34 is configured to detect the first plate end position x1 or the second plate end position x2 using radiation (e.g., X-

rays or gamma rays).

[0075] The vicinity of the mill rolls 15, 16 is often a harsh environment, such as a large amount of rolling oil and fumes, vibration of the mill rolls 15 and 16, and darkness. In this regard, according to the above-described embodiment, since the first plate end detection part 32 or the second plate end detection part 34 is configured to detect the plate end position using radiation, it is possible to detect the plate end position appropriately even if they are disposed in the vicinity of the mill rolls 15, 16 in a harsh environment.

[0076] FIG. 8 is a schematic partial cross-sectional view of the metal plate 90 rolled by the rolling mill facility 1 according to an embodiment, in a cross-section including the plate width direction and the longitudinal direction of the metal plate 90. As shown in FIG. 8, the metal plate 90 has a first surface 94 located adjacent to the mill roll 15 in the thickness direction, and a second surface 95 located adjacent to the mill roll 16 in the thickness direction.

[0077] FIGs. 9 and 10 are each a graph showing an example of a graph representing a relationship between time and gap (roll-to-roll gap) between the pair of mill rolls 15, 16 in a period including the start of rolling of the metal plate 90.

[0078] In some embodiments, when the determination part 42 determines that the tip end tension-free rolling of the metal plate 90 can be started in the step S108, the rolling control part 44 of the controller 40 brings the pair of mill rolls 15, 16 into contact with the metal plate 90 in the step S120 (time t_0 in FIG. 9). At this point, the metal plate 90 is not yet pressed, and the contact position between the mill rolls 15, 16 and the metal plate 90 (the position of the center axis O of the mill rolls 15, 16 in the conveying direction) is at positions 94a, 95a (see FIG. 8) downstream of the tip end 91, and the thickness of the plate at the positions 94a, 95a is H_0 (initial value). Then, while rotating the pair of mill rolls 15, 16, the rolling reduction and the rotation speed of the pair of mill rolls 15, 16 are adjusted so that the gap between the pair of mill rolls 15, 16 gradually decreases to a control value d_c corresponding to the target thickness H_c of the metal plate 90 as the metal plate 90 is conveyed until the positions 94b, 95b (see FIG. 8) downstream of the positions 94a, 95a are reached (from time t_1 to t_2 in FIG. 9). After time t_2 , the gap between the rolls is maintained at the control value d_c corresponding to the target thickness H_c so that the thickness of the metal plate 90 passed between the mill rolls 15, 16 becomes the target thickness H_c .

[0079] As a result, the portion including the tip end 91 of the metal plate 90 has a shape shown by the solid line in FIG. 8. Specifically, the metal plate 90 includes a tip end portion 90a including the tip end 91 and having the thickness H_0 , a following portion 90c kept at the target thickness H_c , and a transition portion 90b disposed between the tip end portion 90a and the following portion 90c in the longitudinal direction of the metal plate. In the

transition portion 90b, the plate thickness gradually decreases from H_0 to H_c from the positions 94a, 95a to the positions 94b, 95b.

[0080] When the roll reduction and tip end tension-free rolling of the metal plate 90 by the mill rolls 15, 16 are started in a state where the tip end portion (the portion indicated by the sign 90a in FIG. 8) of the metal plate 90 is passed between the pair of mill rolls 15, 16, the thickness difference between the tip end portion 90a, which is not rolled by the mill rolls 15, 16, and the following portion 90c, which is rolled, of the metal plate 90 may become large. For example, as shown in FIG. 10, if the gap between the pair of mill rolls 15, 16 is narrowed to the control value d_c corresponding to the target thickness H_c (time t_1 in FIG. 10), and the rotation of the mill rolls 15, 16 is started in this state (time t_1 in FIG. 10), as shown by the long dashed double-dotted line in FIG. 8, the shape of the metal plate 90 changes abruptly in thickness between the tip end portion 90a (thickness is H_0), which is in front of the positions 94a, 95a where rolling starts, and the following portion 90c (thickness is H_t), which is behind the positions 94a, 95a.

[0081] In this case, when the metal plate 90 is wound by the winding device 14, stress may concentrate at the boundary between the tip end portion 90a and the following portion 90c, and the metal plate 90 may be broken at this boundary.

[0082] In this regard, in the above-described embodiment, at the start of tip end tension-free rolling of the metal plate 90, the pair of mill rolls 15, 16 are brought into contact with the metal plate 90, and then while rotating the pair of mill rolls 15, 16, the rolling reduction and the rotation speed of the pair of mill rolls 15, 16 are adjusted so that the gap between the mill rolls 15, 16 gradually decreases to the control value d_c corresponding to the target thickness H_c of the metal plate 90 as the metal plate 90 is conveyed. As a result, the transition portion 90b (see FIG. 8) where the thickness gradually decreases is formed between the tip end portion 90a, which has the same thickness H_0 as before rolling, and the following portion 90c, which is rolled to the target thickness H_c . Thereby, it is possible to alleviate stress concentration that may occur at the boundary between the tip end portion 90a and the following portion 90c when the metal plate is wound by the winding device 14, for example. Consequently, the rolled metal plate 90 can be wound by the winding device 14 more appropriately.

[0083] In some embodiments, as described above, when the gap between the pair of mill rolls 15, 16 is gradually reduced to the control value d_c corresponding to the target thickness H_c of the metal plate 90 as the metal plate 90 is conveyed, the rolling reduction and the rotation speed of the pair of mill rolls 15, 16 are adjusted so that the inclination angle α_1 of the first surface 94 at the transition portion 90b with respect to the longitudinal direction of the metal plate 90 or the inclination angle α_2 of the second surface 95 at the transition portion 90b with respect to the longitudinal direction of the metal plate 90 is

20 degrees or less.

[0084] This prevents abrupt thickness change at the transition portion 90b (see FIG. 8), so that it is possible to effectively alleviate stress concentration that may occur at the boundary between the tip end portion 90a and the following portion 90c when the metal plate is wound by the winding device 14, for example. Consequently, the rolled metal plate 90 can be wound by the winding device 14 more appropriately.

[0085] Next, the method for operating the rolling mill device 2 after the tip end tension-free rolling of the metal plate 90 is started (the part following the flowchart of FIG. 4 or FIG 16) and the control device of the control device 100 of the rolling mill facility 1 for executing this operating method will be described.

[0086] In some embodiments, the control device 100 includes a detection part configured to detect a plate end position x_B in the plate width direction of the metal plate 90 at a position on the exit side of the pair of mill rolls 15, 16 while rolling the metal plate 90 by the pair of mill rolls 15, 16 in a state where the exit-side tension applied to the metal plate 90 is zero (i.e., while performing the tip end tension-free rolling of the metal plate 90). In the embodiment shown in FIGs. 1 and 2, the second plate end detection part 34 disposed on the exit side of the pair of mill rolls 15, 16 functions as this detection part.

[0087] Further, in some embodiments, the controller 40 (see FIG. 3) of the control device 100 includes a first tilting part 46 and a second tilting part 48.

[0088] The first tilting part 46 is configured to perform, when the detection result of the plate end position by the second plate end detection part 34 as the detection part (hereinafter, also simply referred to as "plate end detection part 34") is deviated from a reference position to one side (one of the first edge 92 side or the second edge 93 side; see FIG. 12A, etc.) in the plate width direction, a roll tilting control of the pair of mill rolls 15, 16 so that the outgoing direction of the metal plate 90 from the mill rolls 15, 16 is along the conveying direction of the metal plate 90 in the rolling mill device 2.

[0089] The second tilting part 48 is configured to perform a roll tilting control of the pair of mill rolls 15, 16 after the roll tilting control by the first tilting part 46 so that the outgoing direction of the metal plate 90 from the mill rolls 15, 16 is displaced to the other side (the other of the first edge 92 side or the second edge 93 side; see FIG. 12A, etc.) in the plate width direction with respect to the conveying direction, and then the outgoing direction of the metal plate 90 returns to the conveying direction.

[0090] In the control device 100, while rolling the metal plate 90 with no tension applied to the tip end, the second plate end detection part 34 (detection part) detects the plate end position x_B in the plate width direction of the metal plate 90 at the position on the exit side of the mill rolls 15, 16. This allows to detect the displacement of the outgoing direction of the metal plate 90 to one side in the plate width direction (tip end bending of the metal plate 90) based on the fact that the detected plate end position

x_B has deviated from the reference position to one side in the plate width direction. Further, when the tip end bending of the metal plate 90 is detected, the first tilting part 46 performs the roll tilting control to make the outgoing direction of the metal plate 90 parallel to the conveying direction of the metal plate 90 in the rolling mill device 2, and then the second tilting part 48 performs the roll tilting control to displace the outgoing direction of the metal plate 90 to the other side in the plate width direction with respect to the conveying direction and then make the outgoing direction of the metal plate 90 parallel to the conveying direction. This allows to correct the tip end bending of the metal plate 90, and the tip end tension-free rolling to continue with the front edge (tip end 91) of the metal plate 90 close to parallel to the axial direction of the winding device 14. Therefore, with the above configuration, the metal plate 90 rolled with no tension applied to the tip end can be wound by the winding device 14 appropriately.

[0091] Further, in some embodiments, the controller 40 may include at least one of an elongation difference calculation part 50, a displacement angle calculation part 52, or a remaining time calculation part 54.

[0092] The elongation difference calculation part 50 is configured to calculate a relative first elongation difference $d1$ on the other side relative to the one side of the metal plate 90 from the time the plate end position x_B detected by the second plate end detection part 34 moves away from the reference position to the one side until the plate end position x_B returns to the reference position by the roll tilting control by the first tilting part 46.

[0093] The displacement angle calculation part 52 is configured to acquire a first displacement angle $\theta1$ of the outgoing direction of the metal plate 90 to the one side with respect to the conveying direction at the time of start of the roll tilting control by the first tilting part 46, and determine a second displacement angle $\theta2$ of the outgoing direction of the metal plate 90 to the other side with respect to the conveying direction during execution of the roll tilting control by the second tilting part.

[0094] The remaining time calculation part 54 is configured to calculate a remaining time Tc until the tip end 91 of the metal plate 90 reaches the winding device 14 disposed downstream of the pair of mill rolls 15, 16.

[0095] The method for operating the rolling mill device 2 by the control device 100 according to some embodiments will now be described with reference to FIGs. 1 to 3, 11 to 15, and 17. The rolling mill device 2 may be operated by manually performing some or all of the processing by the control device 100 described below.

[0096] FIGs. 11, 14 and 17 are each a flowchart showing an example of the method for operating the rolling mill device 2 according to an embodiment. FIG. 12A to 12D are each a diagram showing a state transition of the metal plate 90 when the rolling mill device 2 is operated according to the flowchart shown in FIG. 11. FIG. 13 is a graph for describing an example of a method of calculating a first elongation difference and a second elonga-

tion difference of the metal plate 90. In this graph, the horizontal axis represents time, and the vertical axis represents displacement amount Δe described later. FIGs. 15A to 15D are a diagram showing a state transition of the metal plate 90 when the rolling mill device 2 is operated according to the flowchart shown in FIG. 14.

[0097] In the embodiments according to the flowcharts shown in FIGs. 11 and 17, first, the plate end position x_B in the plate width direction of the metal plate 90 at the position ("plate end detection position on exit side" shown in FIGs. 12A to 12D) on the exit side of the pair of mill rolls 15, 16 is detected using the second plate end detection part 34 while rolling the metal plate 90 by the pair of mill rolls 15, 16 in a state where the exit-side tension applied to the metal plate 90 is zero (i.e., while performing the tip end tension-free rolling of the metal plate 90) (step S202; detection step). Further, in the embodiment according to the flowchart shown in FIG. 17, the plate end position x_A in the plate width direction of the metal plate 90 at the position ("plate end detection position on entry side" shown in FIGs. 12A to 12D) on the entry side of the pair of mill rolls 15, 16 is detected using the first plate end detection part 32 while performing the tip end tension-free rolling of the metal plate 90 (step S203). In the graph of FIG. 13, the time t_{20} is the point when the tip end tension-free rolling of the metal plate 90 is started.

[0098] Then, the displacement amount Δe of the plate end position x_B detected in step S202 from the reference position in the plate width direction to one side in the plate width direction (one of the first edge 92 side or the second edge 93 side) is calculated (step S204), and the calculated displacement amount Δe is compared with a threshold Δe_{th} (step S206).

[0099] Here, the reference position is a specific position in the plate width direction when the longitudinal direction of the metal plate 90 is parallel to the conveying direction by the rolling mill device 2 (the direction perpendicular to the center axis of the mill rolls 15, 16). In some embodiments, the reference position may be the position of the first edge 92 of the metal plate 90 when the longitudinal direction of the metal plate 90 is parallel to the conveying direction by the rolling mill device 2 (see FIGs. 12A to 12D). Alternatively, for example, as shown in the flowchart of FIG. 17, in an embodiment that includes a step of detecting the plate end position at a position on the entry side of the pair of mill rolls 15, 16 (step S203 in FIG. 17), this plate end position (e.g., the plate end position x_A detected by the first plate end detection part 32) may be used as the reference position. The "reference position" may be the center position of the metal plate 90 in the plate width direction (the position of the center line L_c) when the longitudinal direction of the metal plate 90 is parallel to the conveying direction by the rolling mill device 2.

[0100] At the stage shown in FIG. 12A, the reference position coincides with the plate end position x_B in the plate width direction, and the displacement amount Δe calculated in step S204 is zero. Therefore, in step S206,

it is determined that the displacement amount Δe is smaller than the threshold (NO in step S206), and the process returns to step S202 to detect the plate end position x_B by the second plate end detection part 34 again.

[0101] FIG. 12B shows the stage where the tip end bending of the metal plate 90 occurs due to some disturbance (e.g., non-uniformity of the thickness of the metal plate 90 in the plate width direction) from the state shown in FIG. 12A. In the example shown in FIG. 12B, the plate end position x_B detected in step S202 is deviated from the reference position to the first edge 92 side (one side) in the plate width direction. In other words, the outgoing direction of the metal plate 90 from the mill rolls 15, 16 is displaced to the first edge 92 side (one side) in the plate width direction with respect to the conveying direction by the mill rolls 15, 16. At this time, the displacement amount Δe calculated in step S204 is greater than zero. In the graph shown in FIG. 13, the displacement amount Δe starts to increase from zero at time t_{21} , and the displacement amount Δe reaches the maximum at time t_{23} (the state shown in FIG. 12B).

[0102] If the displacement amount Δe calculated in step S204 is not greater than the threshold Δe_{th} (NO in step S206), the process returns to step S202 to detect the plate end position x_B by the second plate end detection part 34 again (S222 and S224 in the flowchart of FIG. 17 will be described later). Conversely, if the displacement amount Δe calculated in step S204 is greater than the threshold Δe_{th} (YES in step S206, time t_{23} in the graph of FIG. 13), a tilting control of the mill rolls 15, 16 by the roll reduction device 22 is performed in step S208 so that the displacement amount Δe is zero (step S208). In other words, in step S208, the roll tilting control of the pair of mill rolls 15, 16 is performed so that the outgoing direction of the metal plate 90 from the mill rolls 15, 16 is along the conveying direction of the metal plate 90 in the rolling mill device 2 (first tilting step). FIG. 12C shows the stage at the completion of step S208 (when the displacement amount Δe is zero; time t_{24} in the graph of FIG. 13).

[0103] Then, a relative first elongation difference $E1$ on the other side (in this case, the second edge 93 side) relative to the one side (the first edge 92 side) of the metal plate 90 from the time the plate end position x_B detected by the second plate end detection part 34 moves away from the reference position to the one side (the first edge 92 side) (the state shown in FIG. 12B) until the plate end position x_B detected by the second plate end detection part 34 returns to the reference position (the state shown in FIG. 12C) in the first tilting step (step S208) is calculated (step S210; elongation difference calculation step). In the example shown in FIGs. 12B and 12C, the elongation of the metal plate 90 on the second edge 93 side is $E1$, while the elongation of the metal plate 90 on the first edge 92 side is zero. That is, the first elongation difference is $E1$.

[0104] In the elongation difference calculation step (step S210), the first elongation difference $E1$ is calcu-

lated based on a time integral (area S_{1B}' shown in the graph of FIG. 13) of the displacement amount Δe of the plate end position x_B with respect to the reference position from the time the plate end position x_B moves away from the reference position to the one side (the first edge 92 side) (time t_{21} in the graph of FIG. 13) until the plate end position x_B returns to the reference position (time t_{24} in the graph of FIG. 13) in the first tilting step. The reason why the first elongation difference $E1$ can be calculated based on the area S_{1B}' shown in the graph of FIG. 13 is that the triangle shown by the sign S_{1A} in FIG. 12B is similar to the triangle shown by the sign S_{1B} , and there is a specific correlation between the triangle shown by the sign S_{1B} in FIG. 12B and the area S_{1B}' in the graph of FIG. 13.

[0105] Then, a remaining time T_c until the tip end 91 of the metal plate 90 reaches the winding device 14 disposed downstream of the pair of mill rolls 15, 16 is calculated (step S212; remaining time calculation step). The starting point of the remaining time T_c may be, for example, the point when the displacement amount Δe becomes zero in the first tilting step (at the completion of step S208; time t_{24} in the graph of FIG. 13), or the start of the second tilting step (at the start of steps S214 to S218 described below; time t_{25} in the graph of FIG. 13). In the graph of FIG. 13, the time from the start of the second tilting step (time t_{25}) to time t_{27} is the remaining time T_c . The remaining time T_c can be calculated based on the distance between the tip end 91 of the metal plate 90 and the winding device 14, and the conveyance speed of the metal plate 90.

[0106] Then, a roll tilting control of the pair of mill rolls 15, 16 is performed so that the outgoing direction of the metal plate 90 from the mill rolls 15, 16 is displaced to the other side (the second edge 93 side) in the plate width direction with respect to the conveying direction, and then the outgoing direction of the metal plate 90 returns to the conveying direction (steps S214 to S218; second tilting step). Here, FIG. 12D shows the state at the completion of the second tilting step (i.e., the state at the completion of step S218).

[0107] In step S214, the control command values for the driving motors of the roll reduction device 22 and the mill rolls 15, 16 are calculated so that a second elongation difference $E2$ (see FIG. 12D) equal to the first elongation difference $E1$ is applied to the metal plate 90 within the remaining time T_c . The second elongation difference $E2$ is a relative second elongation difference on the one side (first edge 92 side) of the metal plate 90 relative to the other side (second edge 93 side).

[0108] That is, by performing the second tilting step, the plate end position x_B is displaced to the second edge 93 side by the displacement amount Δe , as shown in FIGs. 12D and 13. Further, by performing tilting control of the mill rolls 15, 16 so that the time integrated value of Δe (area S_{2B}' in the graph of FIG. 13) on the second edge 93 side is equal to the area S_{2A}' in the graph of FIG. 13, the second elongation difference $E2$ (see FIG. 12D)

can be given to the metal plate 90 to form the triangle shown by the sign S_{2B} in FIG. 12D. This is because there is a specific correlation between the triangle indicated by the sign S_{2B} in FIG. 12D and the area S_{2B}' in the graph of FIG. 13, and the triangle indicated by the sign S_{2A} in FIG. 12D is similar to the triangle indicated by the sign S_{2B} .

[0109] In step S216, tilting control of the mill rolls 15, 16 is performed based on the control command values calculated in step S214. While the difference $|E1-E2|$ between the first elongation difference $E1$ and the second elongation difference $E2$ is not within a predetermined range, the control of step S216 is repeated (NO in step S218). If the difference $|E1-E2|$ is within the predetermined range (YES in step S218), the tip end bending of the metal plate 90 detected in steps S202 to S206 has been corrected, and the process returns to step S202 to detect the next possible tip end bending of the metal plate 90.

[0110] The first elongation difference $E1$ caused by the tip end bending of the metal plate 90 indicates the magnitude of the displacement of the outgoing direction of the metal plate 90 to one side in the plate width direction. In this regard, according to the above-described embodiment, the first elongation difference $E1$ caused by the tip end bending of the metal plate 90 is calculated, and the roll tilting control of the mill rolls 15, 16 is performed so that the second elongation difference $E2$ is equal to the first elongation difference $E1$. In other words, since the roll tilting control is performed so that an elongation (corresponding to the second elongation difference $E2$) equal to the elongation (corresponding to the first elongation difference $E1$) caused on one side (the first edge 92 side) of the metal plate 90 due to the tip end bending of the metal plate 90 is applied to the other side (the second edge 93 side) of the metal plate 90, the tip end bending of the metal plate 90 can be appropriately corrected, and the front edge (tip end 91) of the metal plate 90 can be brought closer to parallel to the axial direction of the winding device 14. Thus, the metal plate rolled with no tension applied to the tip end can be wound by the winding device appropriately.

[0111] The first elongation difference $E1$ caused in the metal plate 90 due to the tip end bending of the metal plate 90 has a correlation with the time integral of the displacement amount Δe of the plate end position x_B with respect to the reference position, and typically, the first elongation difference $E1$ and the time integral of the displacement amount Δe have a proportional relationship. In this regard, according to the above-described embodiment, the first elongation difference $E1$ can be appropriately calculated based on the time integral of the displacement amount Δe . Therefore, by performing the roll tilting control in the second tilting step to apply the second elongation difference $E2$ equal to the first elongation difference $E1$ thus calculated to the metal plate 90, the tip end bending of the metal plate 90 can be appropriately corrected.

[0112] Further, in the above-described embodiment, after the tip end bending of the metal plate 90 occurs, the remaining time T_c until the tip end 91 of the metal plate 90 reaches the winding device 14 is calculated, and the second elongation difference E_2 is applied to the metal plate 90 within the calculated remaining time T_c , so that the tip end bending of the metal plate 90 can be appropriately corrected before the metal plate 90 starts to be wound.

[0113] In an embodiment, when the tip end tension-free rolling is performed, the rolling speed may be adjusted as described below. The rolling speed may be adjusted by the rolling control part 44.

[0114] For example, in the flowchart shown in FIG. 17, as a result of comparing the displacement amount Δe of the plate end position x_B in the plate width direction from the reference position to one side of the plate width direction with the threshold Δe_{th} in step S206, if the displacement amount Δe is less than the threshold Δe_{th} (NO in step S206; i.e., if the longitudinal direction of the metal plate 90 is substantially parallel to the conveying direction), the rolling speed of the metal plate 90 is compared with a preset target rolling speed in the tip end tension-free rolling (step S222). The rolling speed of the metal plate 90 may be the conveyance speed of the metal plate 90 in the conveying direction. Alternatively, the rolling speed may be the rotation speed of the mill rolls 15, 16.

[0115] If the rolling speed is higher than the target rolling speed (NO in step S222), the process returns to step S202 without changing the rolling speed. Conversely, if the rolling speed is lower than the target rolling speed (YES in step S222), the rolling speed is increased (S224) so that the rolling speed approaches the target rolling speed, and then the process returns to step S202.

[0116] Such adjustment of the rolling speed during the tip end tension-free rolling may be applied, for example, to the case described with reference to FIG. 16, i.e., when the rolling is performed at a lower rolling speed than the target rolling speed after the start of tip end tension-free rolling of the metal plate 90.

[0117] Thus, by appropriately increasing the rolling speed during the tip end tension-free rolling, the productivity with the rolling mill device 2 can be improved.

[0118] In the embodiment according to the flowcharts shown in FIGs. 11 and 12, the first elongation difference E_1 is calculated based on the time integral of the displacement amount Δe of the detected plate end position x_B from the reference position, and the roll tilting control of the mill rolls 15, 16 is performed based on this first elongation difference E_1 . In contrast, in the embodiment according to the flowchart in FIG. 14, the roll tilting control of the mill rolls 15, 16 is performed based on the displacement angle of the outgoing direction of the metal plate 90 with respect to the conveying direction when the tip end bending of the metal plate 90 occurs. More specifically, in the embodiment according to the flowchart of FIG. 14, on the basis of a displacement angle θ_1 (see

FIG. 15B) of the outgoing direction of the metal plate 90 to one side (first edge 92 side) with respect to the conveying direction at the time of start of the first tilting step, a second displacement angle θ_2 (see FIG. 15C) of the outgoing direction to the other side (second edge 93 side) with respect to the conveying direction during execution of the second tilting step is determined.

[0119] In the flowchart of FIG. 14, the contents of steps S302, S304, S306, S312, S316, and S318 are the same as in steps S202, S204, S206, S212, S216, and S218 shown in FIG. 11, so detailed explanations will be omitted.

[0120] In the embodiment according to the flowchart shown in FIG. 14, if the displacement amount Δe calculated in step S304 based on the plate end position x_B detected in step S302 (detection step) is greater than a threshold (YES in step S306), the first displacement angle θ_1 of the outgoing direction of the metal plate 90 to one side (the first edge 92 side) with respect to the conveying direction at this point (the start point of the first tilting step; stage shown in FIG. 15B) is acquired (step S308). The first displacement angle θ_1 may be acquired based on the displacement amount Δe and the distance m between the center axis O of the mill rolls 15, 16 in the conveying direction and the plate end detection position by the second plate end detection part 34 ($\tan\theta_1 = \Delta e/m$). Alternatively, the first displacement angle θ_1 may be acquired based on an image captured by an imaging device.

[0121] Next, on the basis of the first displacement angle θ_1 acquired in step S308, a second displacement angle θ_2 to be given to the metal plate 90 in the second tilting step, i.e., the second displacement angle θ_2 of the outgoing direction of the metal plate 90 to the other side (the second edge 93 side) with respect to the conveying direction is determined (step S310; see FIG. 15C).

[0122] Then, the control command values for the driving motors of the roll reduction device 22 and the mill rolls 15, 16 are calculated so that the displacement angle to the other side (the second edge 93 side) of the metal plate 90 reaches the second displacement angle θ_2 within the remaining time T_c calculated in step S312 (step S314). Then, on the basis of the control command values thus calculated, the tilting control (first tilting step and second tilting step) of the mill rolls 15, 16 is performed (step S316). If the displacement angle to the other side (the second edge 93 side) of the metal plate 90 reaches the second displacement angle θ_2 (YES in step S318), the tip end bending of the metal plate 90 detected in steps S302 to S306 has been corrected, and the process returns to step S302 to detect the next possible tip end bending of the metal plate 90.

[0123] The first displacement angle θ_1 of the outgoing direction of the metal plate 90 to one side (first edge 92 side) with respect to the conveying direction caused by the tip end bending of the metal plate 90 indicates the magnitude of the displacement of the outgoing direction of the metal plate 90 to one side (first edge 92 side) in the plate width direction as well as the first elongation

difference E1 described above. In this regard, in the above-described embodiment, the second displacement angle $\theta 2$ of the outgoing direction to the other side with respect to the conveying direction during execution of the second tilting step can be appropriately determined based on the first displacement angle $\theta 1$. Therefore, by performing the roll tilting control to apply the second displacement angle $\theta 2$ thus determined to the metal plate 90, the tip end bending of the metal plate 90 can be appropriately corrected, and the front edge of the metal plate 90 can be brought close to parallel to the axial direction of the winding device 14. Thus, the metal plate 90 rolled with no tension applied to the tip end can be wound by the winding device 14 appropriately.

[0124] The second displacement angle $\theta 2$ determined in step S310 may be given to the metal plate 90 at once in the second tilting step of step S316 (see FIG. 15C), or may be divided and given to the metal plate 90 at separate times (see FIG. 15D). In FIG. 15D, angle $\theta 2a$ is given for the first time, angle $\theta 2b$ for the second time, and angle $\theta 2c$ for the third time as the displacement angle to the other side (second edge 93 side) of the metal plate 90. The sum of $\theta 2a$, $\theta 2b$ and $\theta 2c$ is $\theta 2$ ($\theta 2a + \theta 2b + \theta 2c = \theta 2$).

[0125] In this case, since small second displacement angles $\theta 2a$, $\theta 2b$ and $\theta 2c$ are given to the metal plate 90 at separate times, the tip end bending of the metal plate 90 can be corrected more stably, compared to the case where a large second displacement angle $\theta 2$ is given to the other side (second edge 93 side) of the metal plate 90 at once (see FIG. 15C).

[0126] In some embodiments, after the completion of the first tilting step, the second tilting step is started within a time equal to or less than the time required for the first tilting step.

[0127] For example, in the embodiment described in FIGs. 11 to 12D, the time required for the first tilting step (from the YES determination in step S206 of FIG. 11 to the end of step S208) is from time $t22$ to time $t24$ in the graph of FIG. 13. The time from the end of the first tilting step to the start of the second tilting step is from time $t24$ to $t25$ in the graph of FIG. 13, which is shorter than the time required for the first tilting step.

[0128] Further, in the embodiment described with reference to FIGs. 14 to 15D, the first tilting step and the second tilting step are performed without distinction (continuously) in step S316, and the time from the end of the first tilting step to the start of the second tilting step is substantially zero, which is smaller than the time required for the first tilting step (from the time when the outgoing direction of the metal plate 90 is displaced to one side (the first edge 92 side) until it returns to the same direction as the conveying direction).

[0129] In this case, after the outgoing direction of the metal plate 90 is made parallel to the conveying direction in the first tilting step, the second tilting step is started within a time equal to or less than the time required for the first tilting step to displace the outgoing direction of the metal plate 90 to the other side (second edge 93

side). That is, by displacing the outgoing direction of the metal plate 90 to the other side (the second edge 93 side) without much time after the completion of the first tilting step, it is possible to reduce the displacement amount (Δd shown in FIG. 12D) in the plate width direction between the center position of the metal plate 30 at the tip end bend portion in the plate width direction and the center position of the metal plate 90 at the mill rolls 15, 16 in the plate width direction at the completion of the second tilting step (In other words, the area of the rectangle portion A1 shown in FIGs. 12C and 12D can be made as small as possible.). For example, as shown in FIG. 15C, when the first tilting step and the second tilting step are continuously performed, the displacement amount Δd is almost zero. Thus, the metal plate 90 rolled with no tension applied to the tip end can be wound by the winding device 14 more appropriately.

[0130] Hereinafter, overviews of the method for operating a rolling mill device, the control device of the rolling mill device, and the rolling mill facility according to some embodiments will be described.

(1) A method for operating a rolling mill device according to at least one embodiment of the present invention is a method for operating a rolling mill device including a pair of mill rolls disposed on opposite sides of a metal plate, comprising: a detection step of detecting a plate end position in a plate width direction of the metal plate at a position on an exit side of the pair of mill rolls while rolling the metal plate by the pair of mill rolls in a state where an exit-side tension applied to the metal plate is zero; a first tilting step of performing, when a detection result of the plate end position in the detection step is deviated from a reference position to one side in the plate width direction, a roll tilting control of the pair of mill rolls so that an outgoing direction of the metal plate from the mill rolls is along a conveying direction of the metal plate in the rolling mill device; and a second tilting step of performing a roll tilting control of the pair of mill rolls after the first tilting step so that the outgoing direction of the metal plate from the mill rolls is displaced to the other side in the plate width direction with respect to the conveying direction, and then the outgoing direction of the metal plate returns to the conveying direction.

[0131] According to the above method (1), while rolling the metal plate with no tension applied to the tip end, the plate end position in the plate width direction of the metal plate is detected at the position on the exit side of the mill rolls. This allows to detect the displacement of the outgoing direction of the metal plate to one side in the plate width direction (tip end bending of the metal plate) based on the fact that the detected plate end position has deviated from the reference position to one side in the plate width direction. Further, when the tip end bending of the metal plate is detected, the roll tilting control is

performed to make the outgoing direction of the metal plate parallel to the conveying direction of the metal plate in the rolling mill device, and then the roll tilting control is performed to displace the outgoing direction of the metal plate to the other side in the plate width direction with respect to the conveying direction and then make the outgoing direction parallel to the conveying direction. This allows to correct the tip end bending of the metal plate, and the tip end tension-free rolling to continue with the front edge of the metal plate close to parallel to the axial direction of the winding device. Therefore, with the above method (1), the metal plate rolled with no tension applied to the tip end can be wound by the winding device appropriately.

[0132] (2) In some embodiments, in the above method (1), the method comprises an elongation difference calculation step of calculating a relative first elongation difference on the other side relative to the one side of the metal plate from a time the plate end position moves away from the reference position to the one side until the plate end position returns to the reference position in the first tilting step. The second tilting step includes performing the roll tilting control of the pair of mill rolls so that a relative second elongation difference on the one side relative to the other side of the metal plate is equal to the first elongation difference.

[0133] The first elongation difference caused by the tip end bending of the metal plate indicates the magnitude of the displacement of the outgoing direction of the metal plate to one side in the plate width direction. In this regard, according to the above method (2), the first elongation difference caused by the tip end bending of the metal plate is calculated, and the roll tilting control of the mill rolls is performed so that the second elongation difference is equal to the first elongation difference. In other words, since the roll tilting control is performed so that an elongation (corresponding to the second elongation difference) equal to the elongation (corresponding to the first elongation difference) caused on one side of the metal plate due to the tip end bending of the metal plate is applied to the other side of the metal plate, the tip end bending of the metal plate can be appropriately corrected, and the front edge of the metal plate can be brought closer to parallel to the axial direction of the winding device. Thus, the metal plate rolled with no tension applied to the tip end can be wound by the winding device appropriately.

[0134] (3) In some embodiments, in the above method (2), the elongation difference calculation step includes calculating the first elongation difference, on the basis of a time integral of displacement amount of the plate end position with respect to the reference position from the time the plate end position moves away from the reference position to the one side until the plate end position returns to the reference position in the first tilting step.

[0135] The first elongation difference caused in the metal plate due to the tip end bending of the metal plate has a correlation with the time integral of the displacement

amount of the plate end position with respect to the reference position, and typically, the first elongation difference and the time integral of the displacement amount have a proportional relationship. In this regard, according to the above method (3), the first elongation difference can be appropriately calculated based on the time integral of the displacement amount. Therefore, by performing the roll tilting control in the second tilting step to apply the second elongation difference equal to the first elongation difference thus calculated to the metal plate, the tip end bending of the metal plate can be appropriately corrected, and the front edge of the metal plate can be brought close to parallel to the axial direction of the winding device. Thus, the metal plate rolled with no tension applied to the tip end can be wound by the winding device appropriately.

[0136] (4) In some embodiments, in the above method (2) or (3), the method comprises a remaining time calculation step of calculating a remaining time until a tip end of the metal plate reaches a winding device disposed downstream of the pair of mill rolls. The second tilting step includes performing the roll tilting control of the pair of mill rolls so that the second elongation difference equal to the first elongation difference is applied to the metal plate within the remaining time.

[0137] According to the above method (4), after the tip end bending of the metal plate occurs, the remaining time until the tip end of the metal plate reaches the winding device is calculated, and the second elongation difference is applied to the metal plate within the calculated remaining time, so that the tip end bending of the metal plate can be appropriately corrected before the metal plate starts to be wound, and the front edge of the metal plate can be brought close to parallel to the axial direction of the winding device. Thus, the metal plate rolled with no tension applied to the tip end can be wound by the winding device appropriately.

[0138] (5) In some embodiments, in any one of the above methods (1) to (4), on the basis of a first displacement angle θ_1 of the outgoing direction of the metal plate to the one side with respect to the conveying direction at the time of start of the first tilting step, a second displacement angle θ_2 of the outgoing direction to the other side with respect to the conveying direction during execution of the second tilting step is determined.

[0139] The first displacement angle θ_1 of the outgoing direction of the metal plate to the one side with respect to the conveying direction caused by the tip end bending of the metal plate indicates the magnitude of the displacement of the outgoing direction of the metal plate to the one side in the plate width direction as well as the first elongation difference described above. In this regard, according to the above method (5), the second displacement angle θ_2 of the outgoing direction to the other side with respect to the conveying direction during execution of the second tilting step can be appropriately determined based on the first displacement angle θ_1 . Therefore, by performing the roll tilting control to apply the second displacement

placement angle θ_2 thus determined to the metal plate, the tip end bending of the metal plate can be appropriately corrected, and the front edge of the metal plate can be brought close to parallel to the axial direction of the winding device. Thus, the metal plate rolled with no tension applied to the tip end can be wound by the winding device appropriately.

[0140] (6) In some embodiments, in any one of the above configurations (1) to (5), after the first tilting step is completed, the second tilting step is started within a time equal to or less than a time required for the first tilting step.

[0141] According to the above configuration (6), after the outgoing direction of the metal plate is made parallel to the conveying direction in the first tilting step, the second tilting step is started within a time equal to or less than the time required for the first tilting step to displace the outgoing direction of the metal plate to the other side. That is, by displacing the outgoing direction of the metal plate to the other side without much time after the completion of the first tilting step, it is possible to reduce the displacement amount in the plate width direction between the center position of the metal plate at the tip end bend portion in the plate width direction and the center position of the metal plate at the mill rolls in the plate width direction at the completion of the second tilting step. Thus, the metal plate rolled with no tension applied to the tip end can be wound by the winding device more appropriately.

[0142] (7) In some embodiments, in any one of the above methods (1) to (6), the method comprises a rolling start step of, before the detection step, detecting the plate end position at two different positions in the conveying direction, and if a difference between detection results of the plate end position at the two positions is within a predetermined range, starting rolling of the metal plate by the pair of mill rolls.

[0143] If the tip end tension-free rolling is started in a state where the longitudinal direction of the metal plate is oblique to the conveying direction of the rolling mill device, it may not be possible to appropriately detect the occurrence of displacement of the outgoing direction of the metal plate to one side in the plate width direction (tip end bending of the metal plate) based on the plate end position detected on the exit side of the mill rolls. In this regard, according to the above method (7), the plate end position is detected at two different positions in the conveying direction, and if the difference between the detection results is within a predetermined range, the tip end tension-free rolling of the metal plate is started. In other words, the tip end tension-free rolling is started after it is confirmed that the difference between the plate end positions detected at two positions is small and the longitudinal direction of the metal plate is close to parallel to the conveying direction. Thus, it is possible to appropriately detect the occurrence of displacement of the outgoing direction of the metal plate to one side in the plate width direction (tip end bending of the metal plate) based

on the plate end positions detected on the exit side of the mill rolls after the rolling is started.

[0144] (8) In some embodiments, in any one of the above methods (1) to (7), the method comprises a rolling start step of, before the detection step, detecting the plate end position in the plate width direction of the metal plate at a position on an exit side of the pair of mill rolls, and if a difference between the plate end position and a reference position in the plate width direction of the metal plate is within a predetermined range, starting rolling of the metal plate by the pair of mill rolls.

[0145] According to the above configuration (8), since the difference between the plate end position and the reference position of the metal plate in the plate width direction is set within a predetermined range before the start of tip end tension-free rolling, the metal plate can be placed in an appropriate position in the plate width direction before starting the tip end tension-free rolling. For example, the tip end tension-free rolling can be started in a state where the center position of the mill rolls coincides with the center position of the metal plate in the plate width direction. Therefore, with the above method (8), the metal plate rolled with no tension applied to the tip end can be wound by the winding device more appropriately.

[0146] (9) In some embodiments, in any one of the above methods (1) to (6), the method comprises a step of, before the detection step, starting rolling of the metal plate by the pair of mill rolls in a state where the exit-side tension is zero, and performing the rolling at a rolling speed lower than a target rolling speed when the exit-side tension is zero, at least until a tip end of the metal plate reaches the position on the exit side of the pair of mill rolls.

[0147] According to the above method (9), since the tip end tension-free rolling is performed at a speed lower than the target rolling speed in the tip end tension-free rolling at least until the tip end of the metal plate reaches the plate end detection position on the exit side of the mill rolls, it is easier to maintain the longitudinal direction of the metal plate parallel to the conveying direction. Thus, it is possible to appropriately detect the occurrence of displacement of the outgoing direction of the metal plate to one side in the plate width direction (tip end bending of the metal plate) based on the plate end position detected on the exit side of the mill rolls after the tip end of the metal plate reaches the plate end detection position on the exit side of the mill rolls.

[0148] (10) In some embodiments, in any one of the above methods (1) to (9), the method comprises a step of, after the detection step is started, increasing a rolling speed of the metal plate to approach a target rolling speed when the exit-side tension is zero.

[0149] With the above configuration (10), by appropriately increasing the rolling speed during the tip end tension-free rolling, the productivity with the rolling mill device can be improved.

[0150] (11) A control device for a rolling mill device

according to at least one embodiment of the present invention is a control device for controlling a rolling mill device including a pair of mill rolls disposed on opposite sides of a metal plate, comprising: a detection part configured to detect a plate end position in a plate width direction of the metal plate at a position on an exit side of the pair of mill rolls while rolling the metal plate by the pair of mill rolls in a state where an exit-side tension applied to the metal plate is zero; a first tilting part configured to perform, when a detection result of the plate end position by the detection part is deviated from a reference position to one side in the plate width direction, a roll tilting control of the pair of mill rolls so that an outgoing direction of the metal plate from the mill rolls is along a conveying direction of the metal plate in the rolling mill device; and a second tilting part configured to perform a roll tilting control of the pair of mill rolls after the roll tilting control by the first tilting part so that the outgoing direction of the metal plate from the mill rolls is displaced to the other side in the plate width direction with respect to the conveying direction, and then the outgoing direction of the metal plate returns to the conveying direction.

[0151] According to the above configuration (11), while rolling the metal plate with no tension applied to the tip end, the plate end position in the plate width direction of the metal plate is detected at the position on the exit side of the mill rolls. This allows to detect the displacement of the outgoing direction of the metal plate to one side in the plate width direction (tip end bending of the metal plate) based on the fact that the detected plate end position has deviated from the reference position to one side in the plate width direction. Further, when the tip end bending of the metal plate is detected, the roll tilting control is performed to make the outgoing direction of the metal plate parallel to the conveying direction of the metal plate in the rolling mill device, and then the roll tilting control is performed to displace the outgoing direction of the metal plate to the other side in the plate width direction with respect to the conveying direction and then make the outgoing direction parallel to the conveying direction. This allows to correct the tip end bending of the metal plate, and the tip end tension-free rolling to continue with the front edge of the metal plate close to parallel to the axial direction of the winding device. Therefore, with the above configuration (11), the metal plate rolled with no tension applied to the tip end can be wound by the winding device appropriately.

[0152] (12) A rolling mill facility according to at least one embodiment of the present invention comprises: a rolling mill device including a pair of mill rolls disposed on opposite sides of a metal plate; and the control device described in the above (11).

[0153] According to the above configuration (12), while rolling the metal plate with no tension applied to the tip end, the plate end position in the plate width direction of the metal plate is detected at the position on the exit side of the mill rolls. This allows to detect the displacement of the outgoing direction of the metal plate to one side in

the plate width direction (tip end bending of the metal plate) based on the fact that the detected plate end position has deviated from the reference position to one side in the plate width direction. Further, when the tip end bending of the metal plate is detected, the roll tilting control is performed to make the outgoing direction of the metal plate parallel to the conveying direction of the metal plate in the rolling mill device, and then the roll tilting control is performed to displace the outgoing direction of the metal plate to the other side in the plate width direction with respect to the conveying direction and then make the outgoing direction parallel to the conveying direction. This allows to correct the tip end bending of the metal plate, and the tip end tension-free rolling to continue with the front edge of the metal plate close to parallel to the axial direction of the winding device. Therefore, with the above configuration (12), the metal plate rolled with no tension applied to the tip end can be wound by the winding device appropriately.

[0154] Embodiments of the present invention were described in detail above, but the present invention is not limited thereto, and various amendments and modifications may be implemented.

[0155] Further, in the present specification, an expression of relative or absolute arrangement such as "in a direction", "along a direction", "parallel", "orthogonal", "centered", "concentric" and "coaxial" shall not be construed as indicating only the arrangement in a strict literal sense, but also includes a state where the arrangement is relatively displaced by a tolerance, or by an angle or a distance whereby it is possible to achieve the same function.

[0156] For instance, an expression of an equal state such as "same" "equal" and "uniform" shall not be construed as indicating only the state in which the feature is strictly equal, but also includes a state in which there is a tolerance or a difference that can still achieve the same function.

[0157] Further, for instance, an expression of a shape such as a rectangular shape or a cylindrical shape shall not be construed as only the geometrically strict shape, but also includes a shape with unevenness or chamfered corners within the range in which the same effect can be achieved.

[0158] On the other hand, an expression such as "comprise", "include", "have", "contain" and "constitute" are not intended to be exclusive of other components.

Reference Signs List

[0159]

1	Rolling mill facility
2	Rolling mill device
4	Unwinding device
5	Mill roll
6	Entry pinch roll
8	Side guide

10	Rolling mill
10A	First rolling mill
10B	Second rolling mill
12	Exit pinch roll
14	Winding device
15	Mill roll
15A	First mill roll
15B	Second mill roll
16	Mill roll
16A	First mill roll
16B	Second mill roll
17	Intermediate roll
18	Intermediate roll
19	Backup roll
20	Backup roll
22	Roll reduction device
30	Metal plate
32	First plate end detection part
32A	First plate end detection part
32B	First plate end detection part
34	Second plate end detection part
34A	Second plate end detection part
34B	Second plate end detection part
36	Plate thickness gauge
38	Plate thickness gauge
40	Controller
42	Determination part
44	Rolling control part
46	First tilting part
48	Second tilting part
50	Difference calculation part
52	Displacement angle calculation part
54	Time calculation part
90	Metal plate
90a	Tip end portion
90b	Transition portion
90c	Following portion
91	Tip end
92	First edge
93	Second edge
94	First surface
95	Second surface
100	Control device
A1	Rectangle portion
Lc	Center line
O	Center axis
S2A'	Area
S2B'	Area
Y1	First position
Y2	Second position
m	Distance
x1	First plate end position
x2	Second plate end position
x _B	Plate end position
x _{ref}	Reference position
Δe	Displacement amount
θ1	First displacement angle
θ2	Second displacement angle

Claims

1. A method for operating a rolling mill device including a pair of mill rolls disposed on opposite sides of a metal plate, the method comprising:
 - 5 a detection step of detecting a plate end position in a plate width direction of the metal plate at a position on an exit side of the pair of mill rolls while rolling the metal plate by the pair of mill rolls in a state where an exit-side tension applied to the metal plate is zero;
 - 10 a first tilting step of performing, when a detection result of the plate end position in the detection step is deviated from a reference position to one side in the plate width direction, a roll tilting control of the pair of mill rolls so that an outgoing direction of the metal plate from the mill rolls is along a conveying direction of the metal plate in the rolling mill device; and
 - 15 a second tilting step of performing a roll tilting control of the pair of mill rolls after the first tilting step so that the outgoing direction of the metal plate from the mill rolls is displaced to the other side in the plate width direction with respect to the conveying direction, and then the outgoing direction of the metal plate returns to the conveying direction.
2. The method for operating the rolling mill device according to claim 1, comprising an elongation difference calculation step of calculating a relative first elongation difference on the other side relative to the one side of the metal plate from a time the plate end position moves away from the reference position to the one side until the plate end position returns to the reference position in the first tilting step, wherein the second tilting step includes performing the roll tilting control of the pair of mill rolls so that a relative second elongation difference on the one side relative to the other side of the metal plate is equal to the first elongation difference.
3. The method for operating the rolling mill device according to claim 2, wherein the elongation difference calculation step includes calculating the first elongation difference, on the basis of a time integral of displacement amount of the plate end position with respect to the reference position from the time the plate end position moves away from the reference position to the one side until the plate end position returns to the reference position in the first tilting step.
4. The method for operating the rolling mill device according to claim 2 or 3, comprising a remaining time calculation step of calculating a remaining time until a tip end of the metal plate reaches a winding device

disposed downstream of the pair of mill rolls, wherein the second tilting step includes performing the roll tilting control of the pair of mill rolls so that the second elongation difference equal to the first elongation difference is applied to the metal plate within the remaining time.

5. The method for operating the rolling mill device according to any one of claims 1 to 4, wherein, on the basis of a first displacement angle θ_1 of the outgoing direction of the metal plate to the one side with respect to the conveying direction at the time of start of the first tilting step, a second displacement angle θ_2 of the outgoing direction to the other side with respect to the conveying direction during execution of the second tilting step is determined. 10
6. The method for operating the rolling mill device according to any one of claims 1 to 5, wherein, after the first tilting step is completed, the second tilting step is started within a time equal to or less than a time required for the first tilting step. 15
7. The method for operating the rolling mill device according to any one of claims 1 to 6, comprising a rolling start step of, before the detection step, detecting the plate end position at two different positions in the conveying direction, and if a difference between detection results of the plate end position at the two positions is within a predetermined range, starting rolling of the metal plate by the pair of mill rolls. 20
8. The method for operating the rolling mill device according to any one of claims 1 to 7, comprising a rolling start step of, before the detection step, detecting the plate end position in the plate width direction of the metal plate at a position on an exit side of the pair of mill rolls, and if a difference between the plate end position and a reference position in the plate width direction of the metal plate is within a predetermined range, starting rolling of the metal plate by the pair of mill rolls. 25
9. The method for operating the rolling mill device according to any one of claims 1 to 6, comprising a step of, before the detection step, starting rolling of the metal plate by the pair of mill rolls in a state where the exit-side tension is zero, and performing the rolling at a rolling speed lower than a target rolling speed when the exit-side tension is zero, at least until a tip end of the metal plate reaches the position on the exit side of the pair of mill rolls. 30
10. The method for operating the rolling mill device according to any one of claims 1 to 9, comprising a step of, after the detection step is started, increasing a 35

rolling speed of the metal plate to approach a target rolling speed when the exit-side tension is zero.

11. A control device for controlling a rolling mill device including a pair of mill rolls disposed on opposite sides of a metal plate, the control device comprising: 40

a detection part configured to detect a plate end position in a plate width direction of the metal plate at a position on an exit side of the pair of mill rolls while rolling the metal plate by the pair of mill rolls in a state where an exit-side tension applied to the metal plate is zero; a first tilting part configured to perform, when a detection result of the plate end position by the detection part is deviated from a reference position to one side in the plate width direction, a roll tilting control of the pair of mill rolls so that an outgoing direction of the metal plate from the mill rolls is along a conveying direction of the metal plate in the rolling mill device; and a second tilting part configured to perform a roll tilting control of the pair of mill rolls after the roll tilting control by the first tilting part so that the outgoing direction of the metal plate from the mill rolls is displaced to the other side in the plate width direction with respect to the conveying direction, and then the outgoing direction of the metal plate returns to the conveying direction. 45

12. A rolling mill facility, comprising: 50

a rolling mill device including a pair of mill rolls disposed on opposite sides of a metal plate; and the control device according to claim 11. 55

FIG. 1

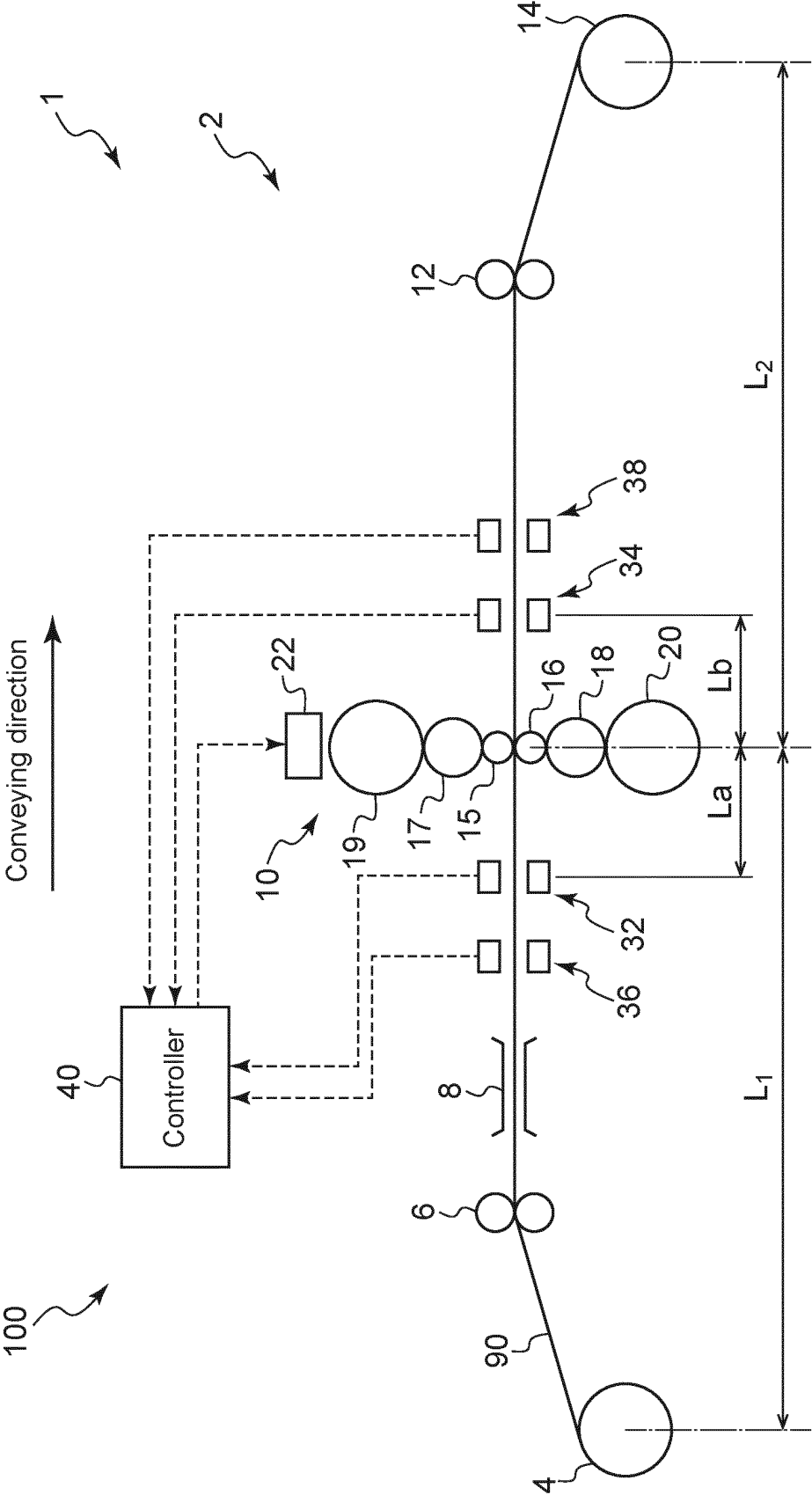


FIG. 2

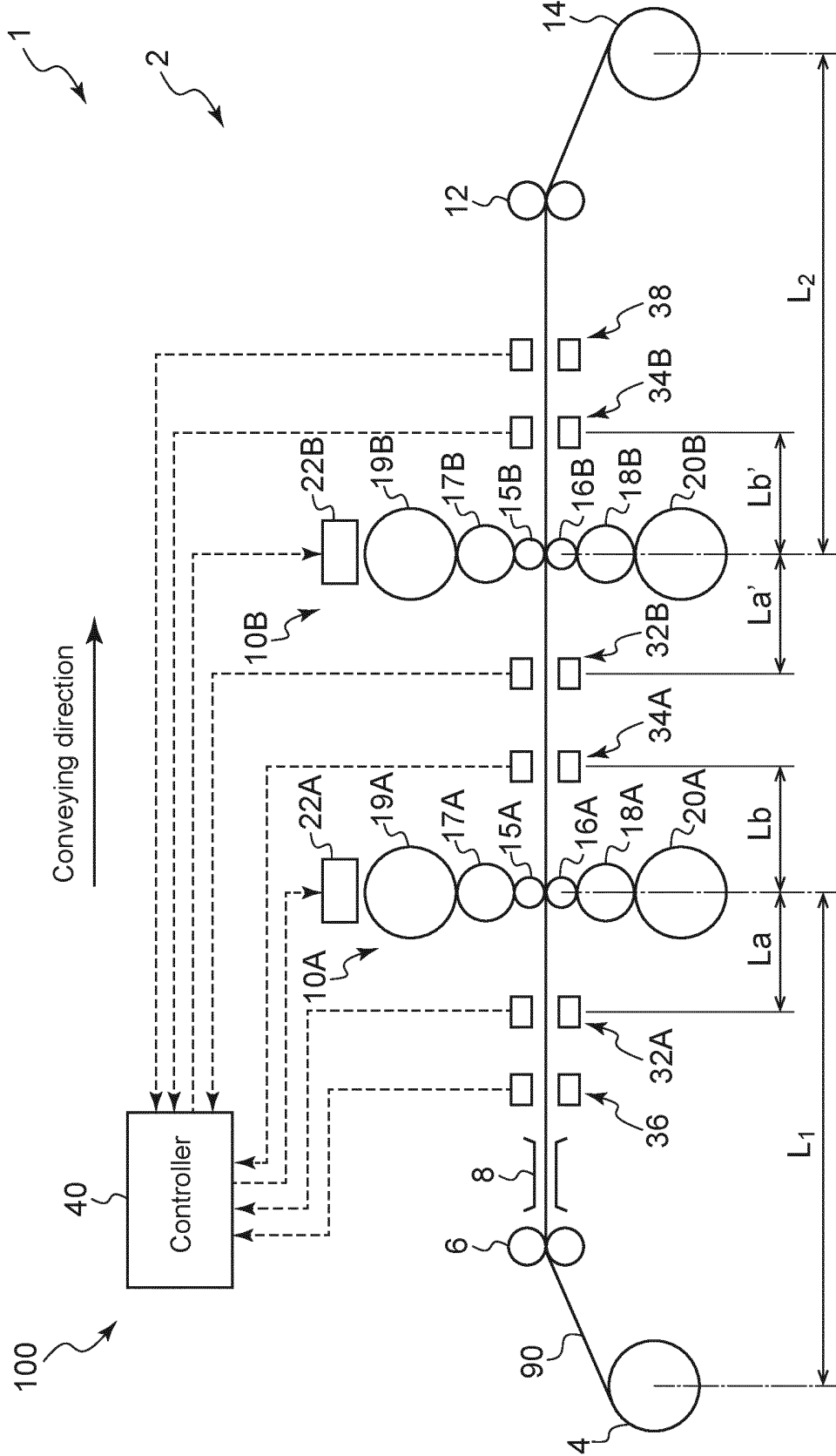


FIG. 3

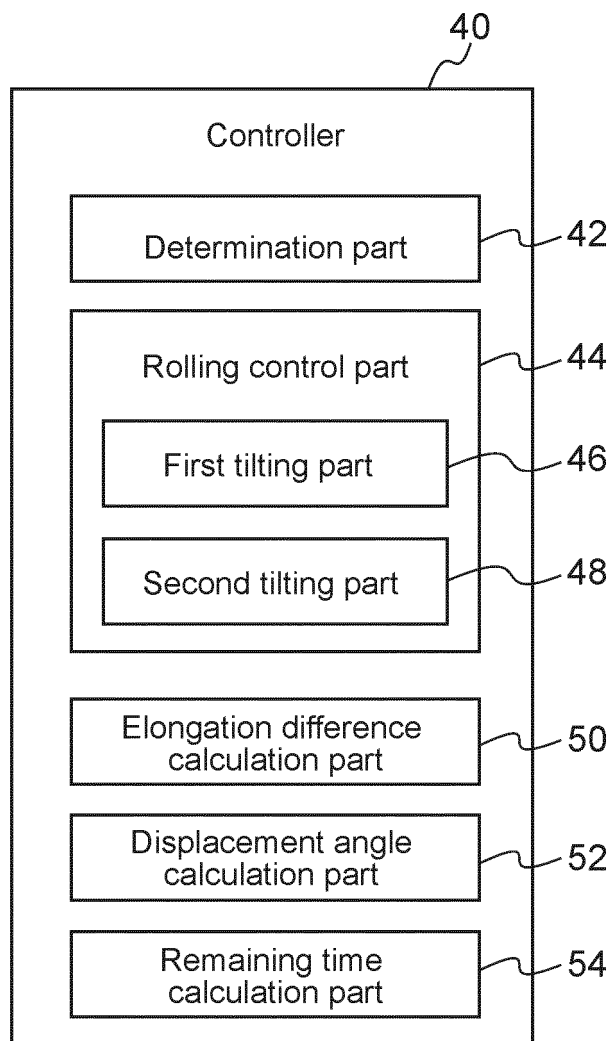


FIG. 4

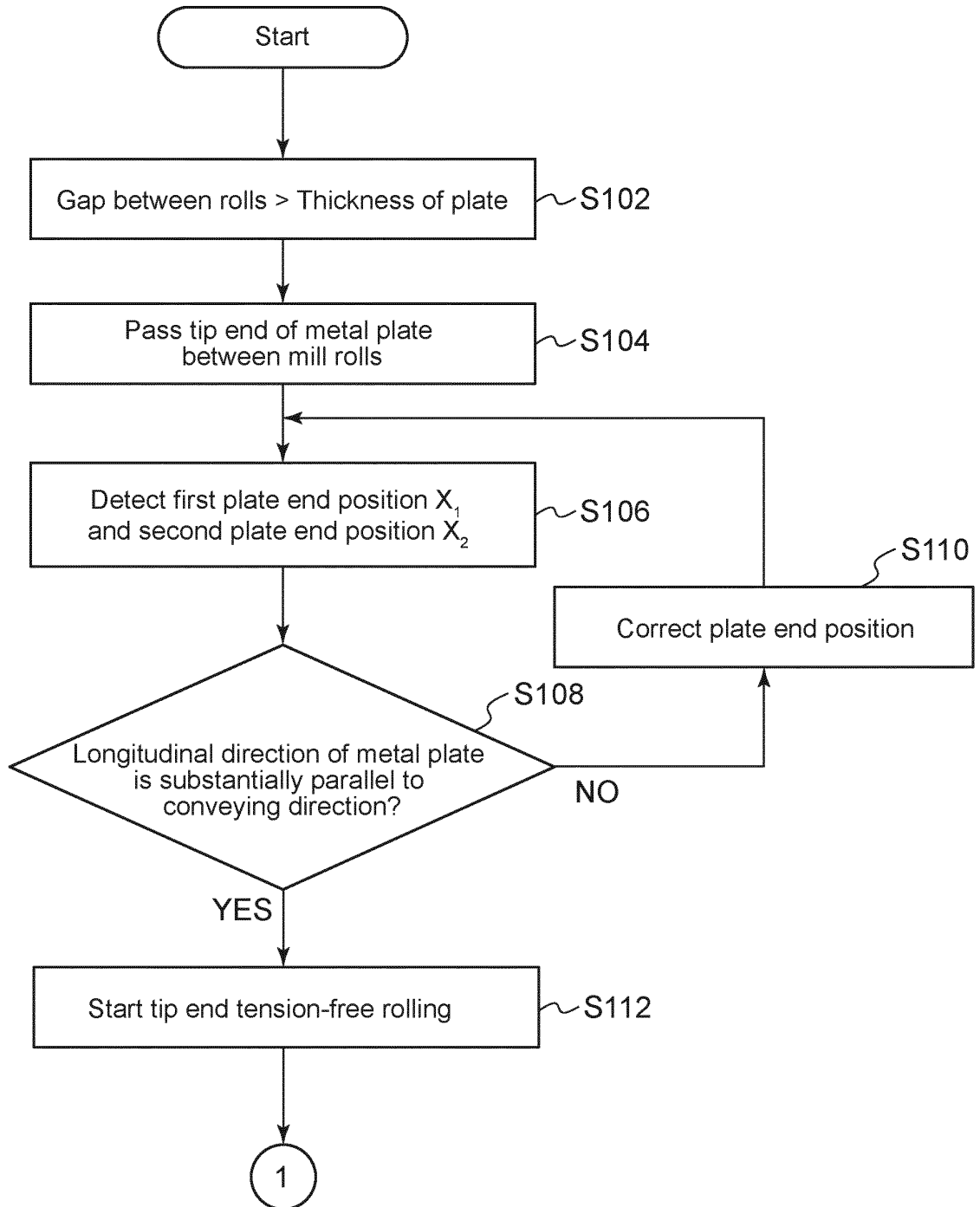


FIG. 5A

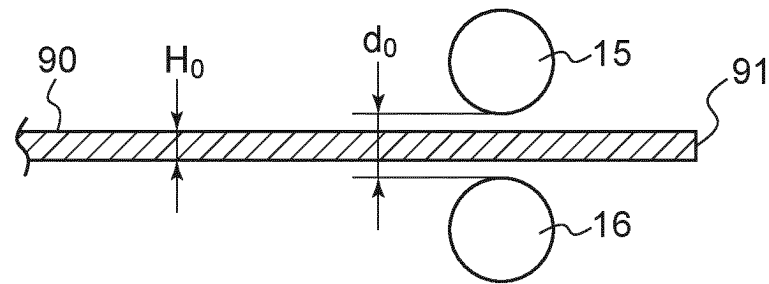


FIG. 5B

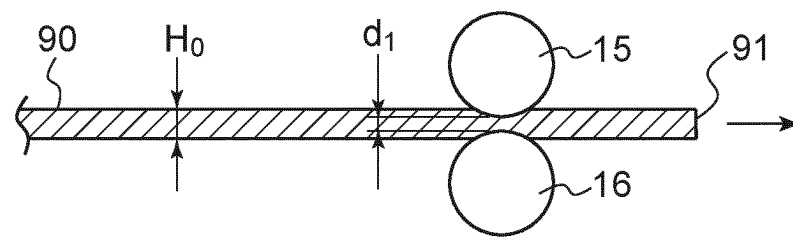


FIG. 5C

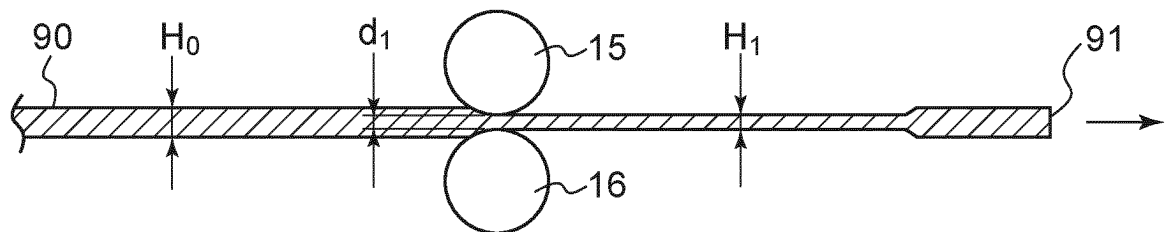


FIG. 6

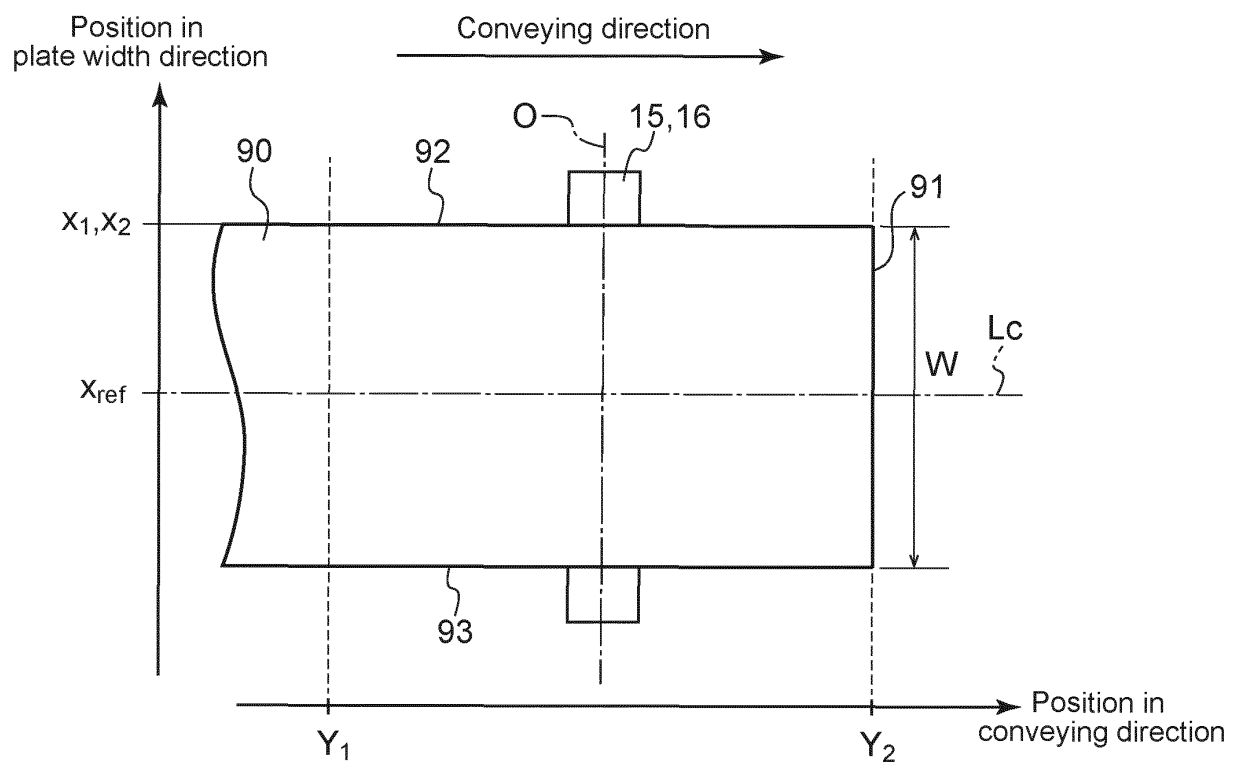


FIG. 7

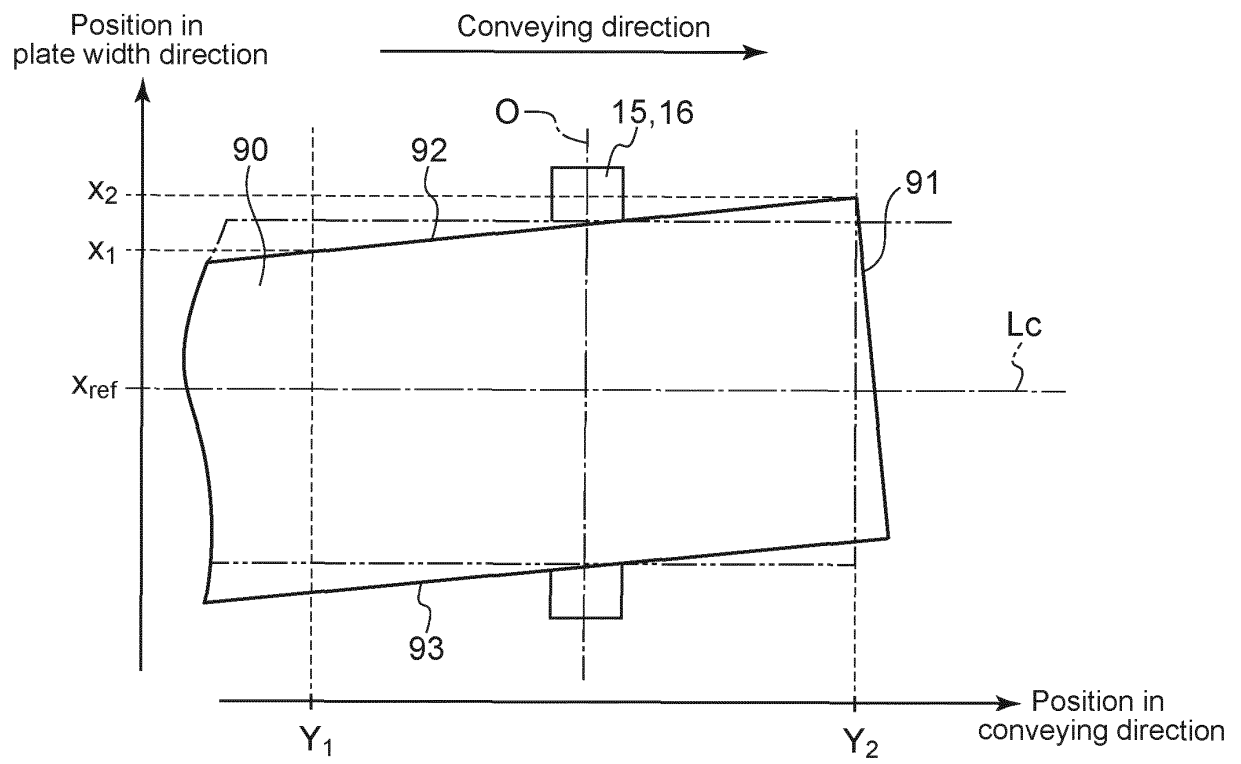


FIG. 8

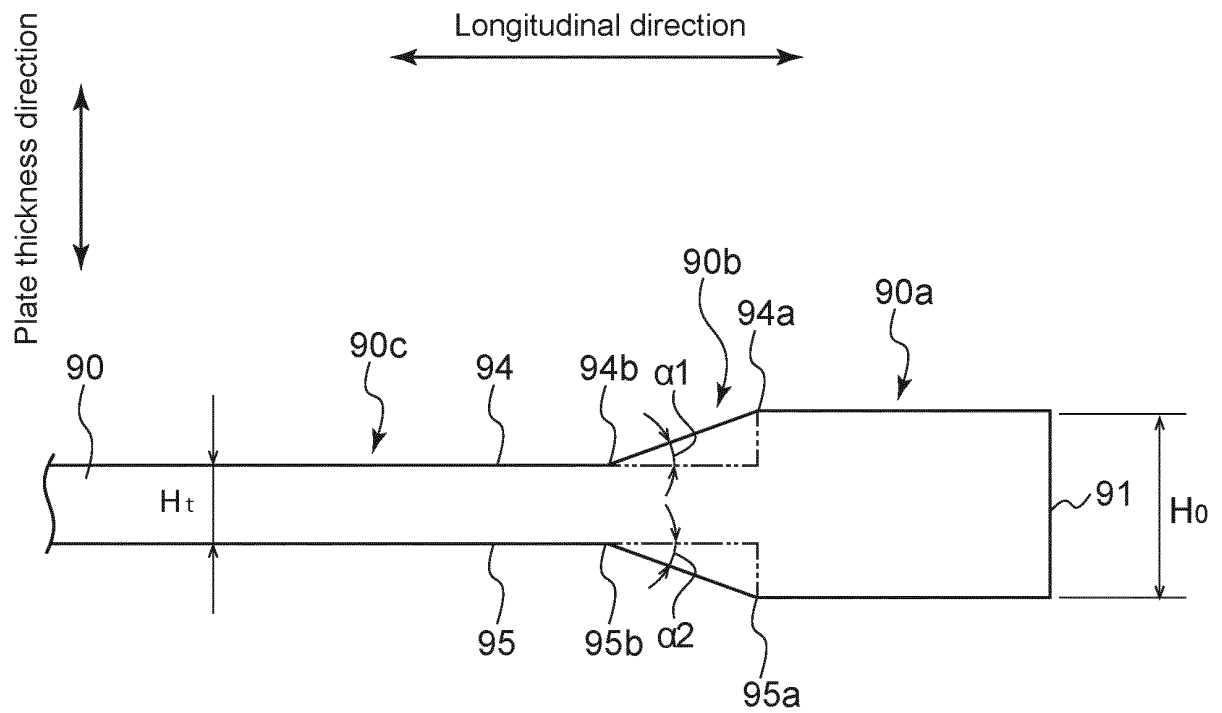


FIG. 9

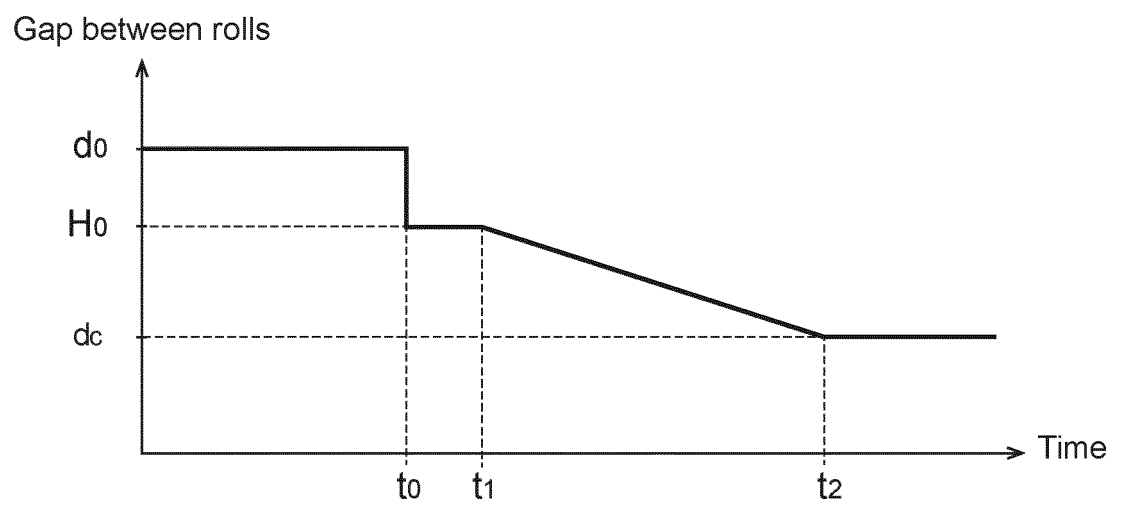


FIG. 10

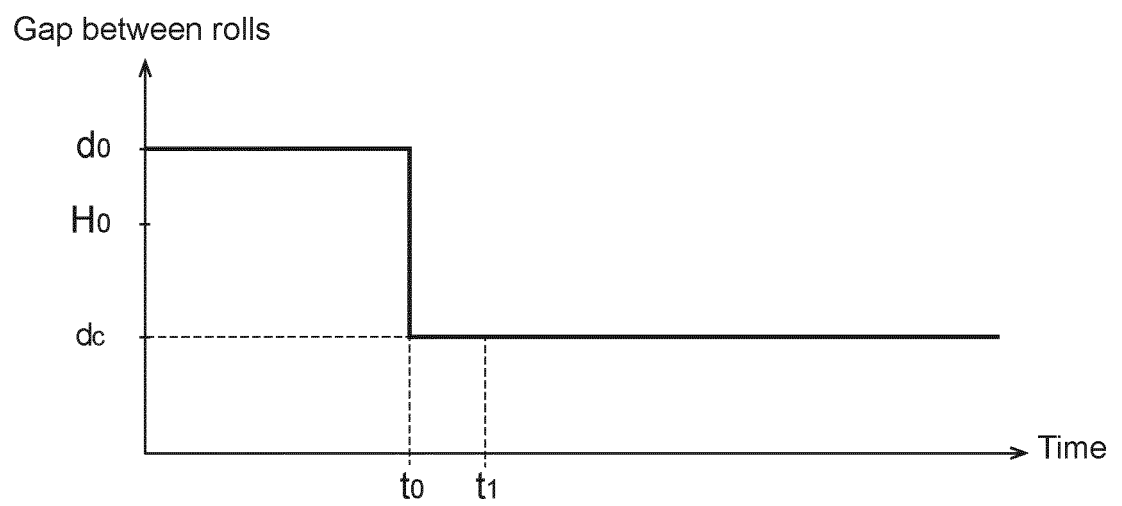


FIG. 11

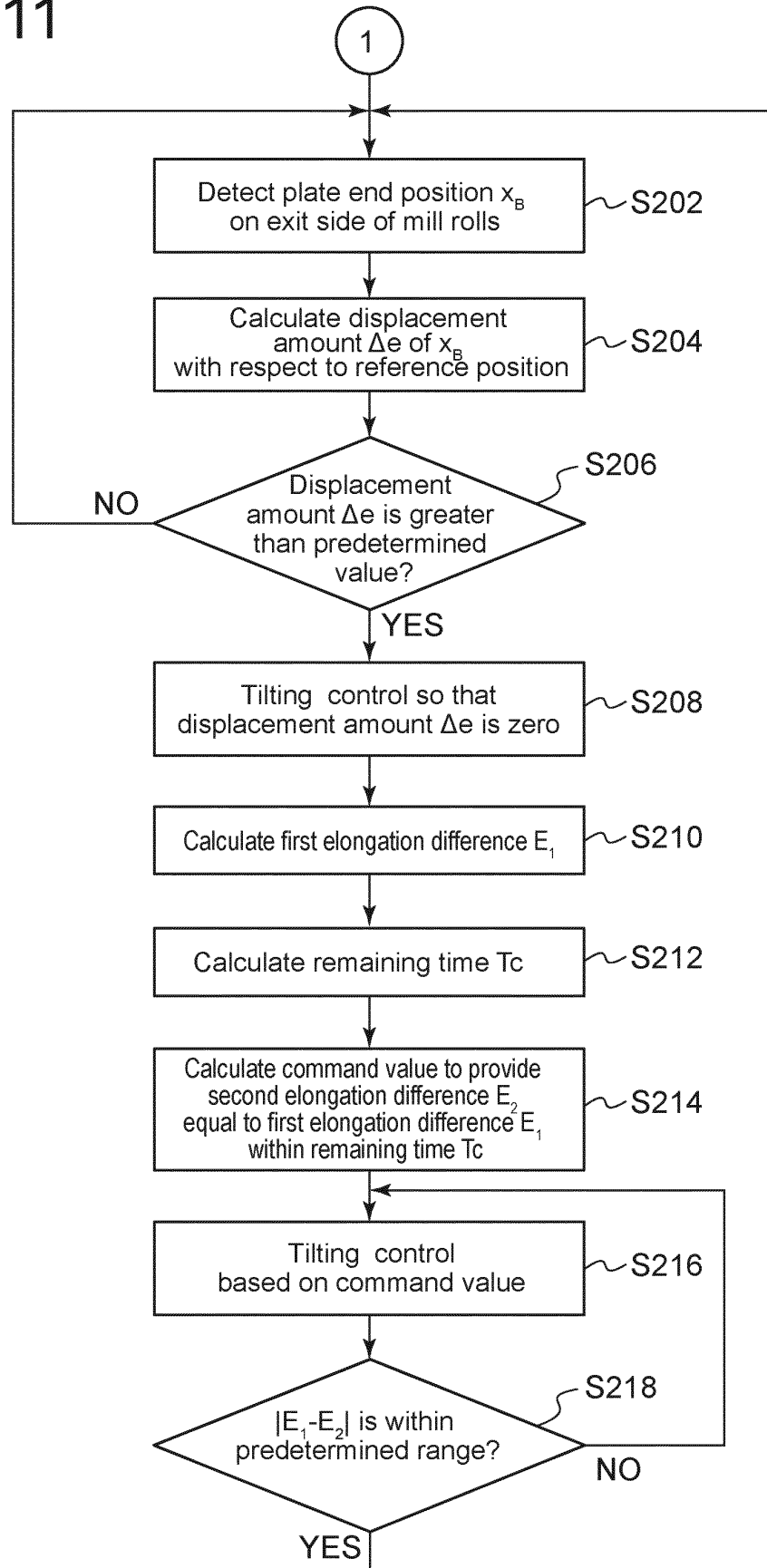


FIG. 12A

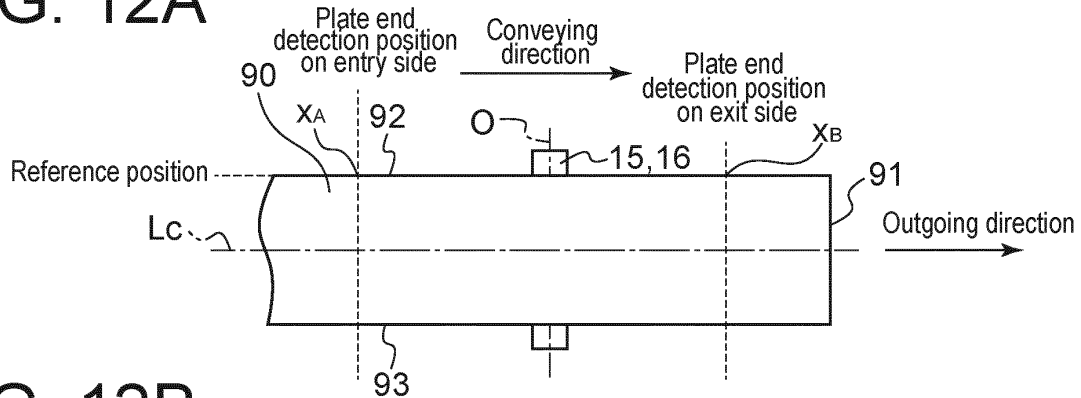


FIG. 12B

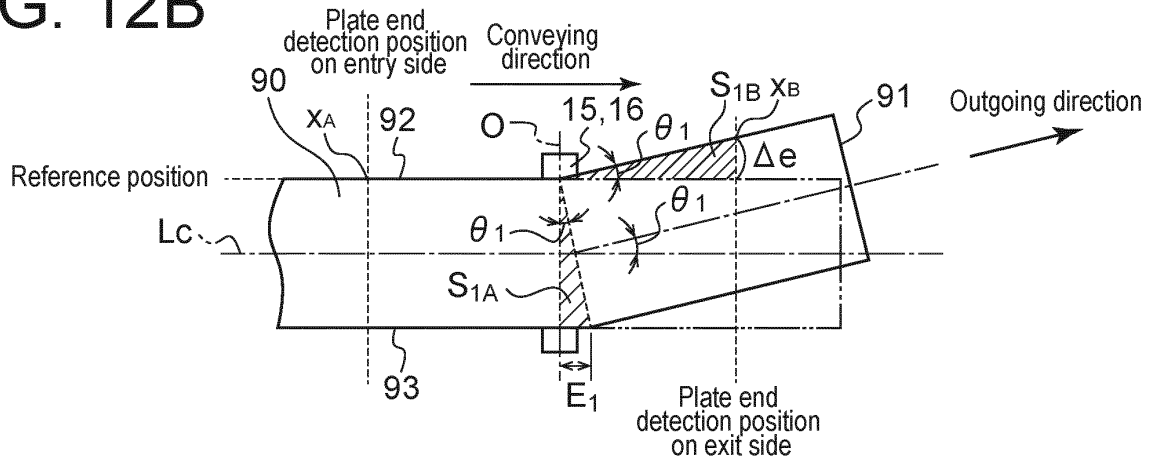


FIG. 12C

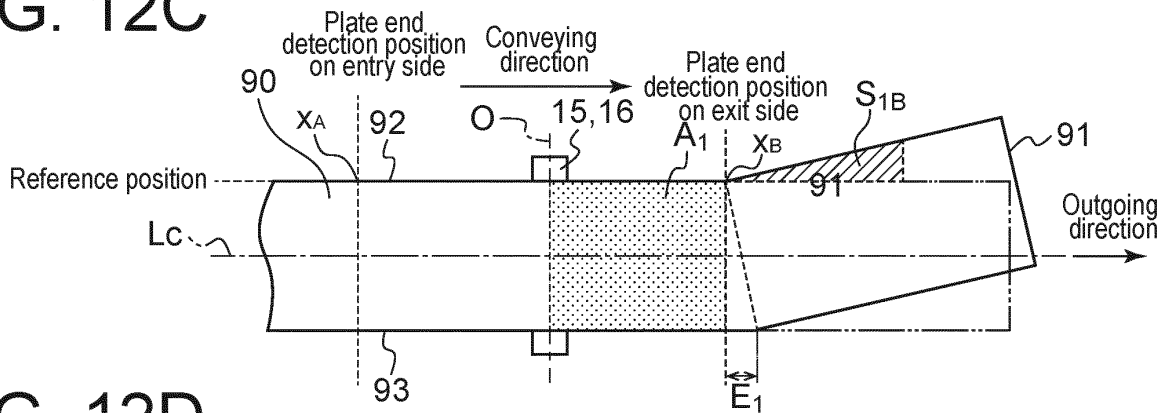


FIG. 12D

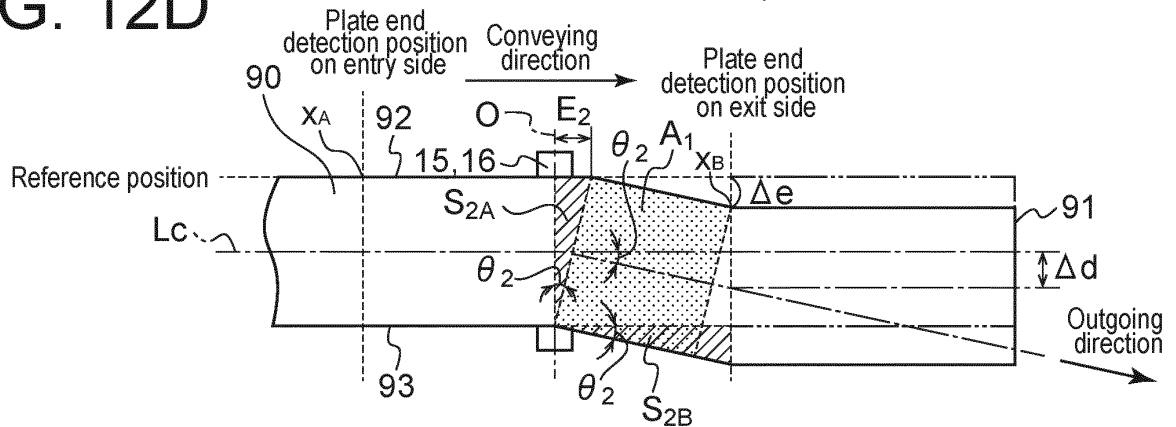


FIG. 13

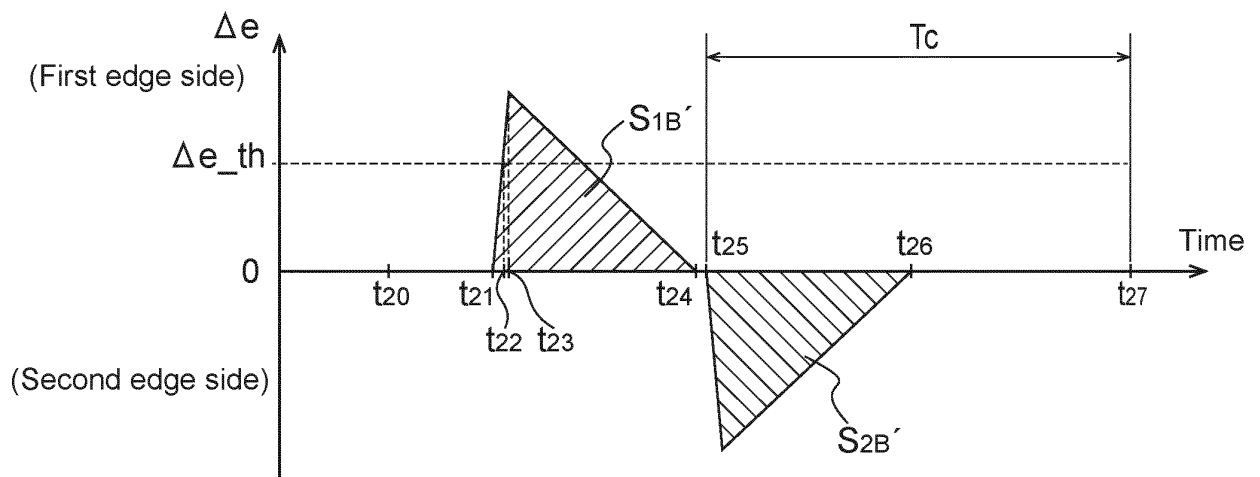


FIG. 14

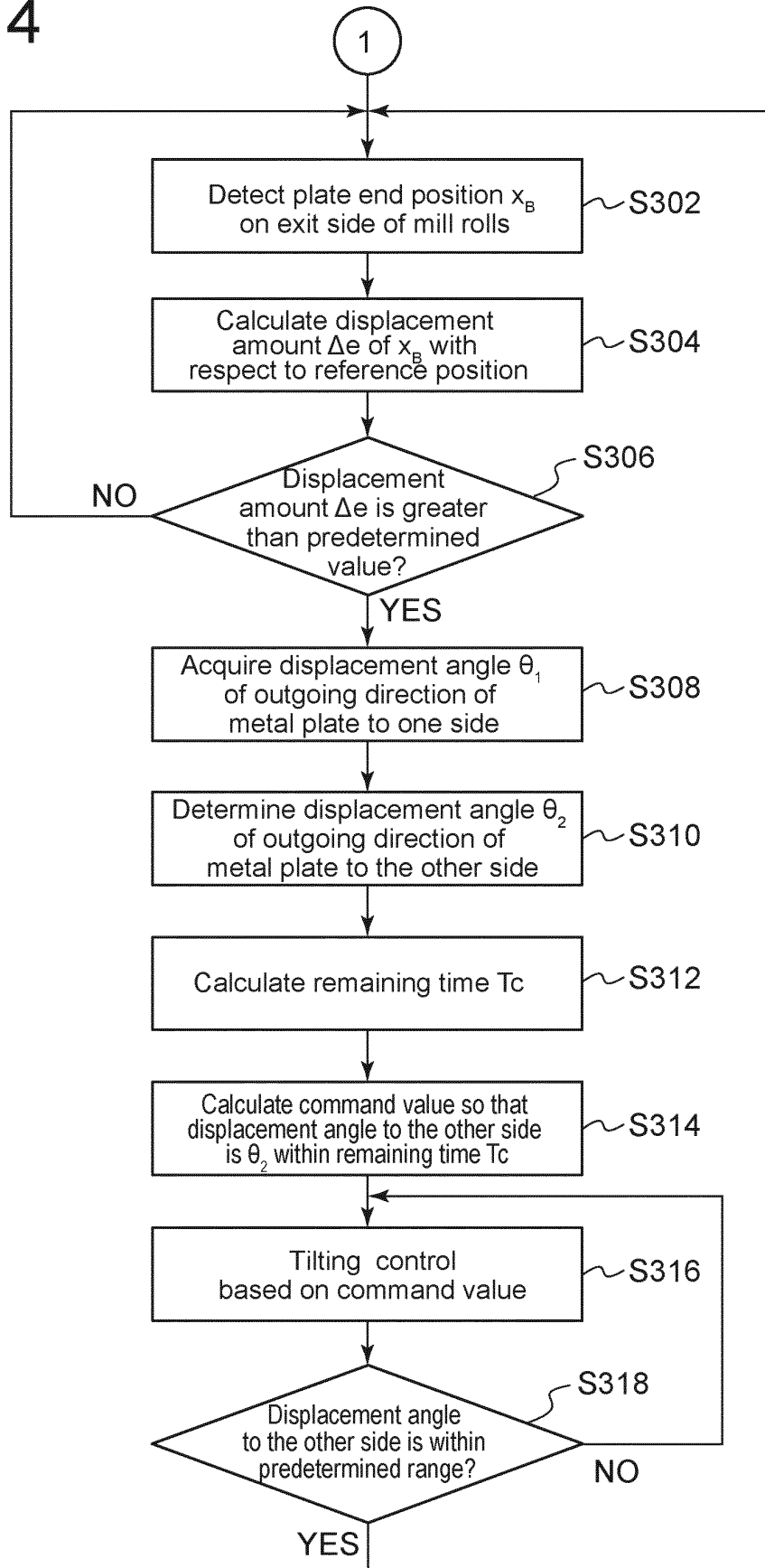


FIG. 15A

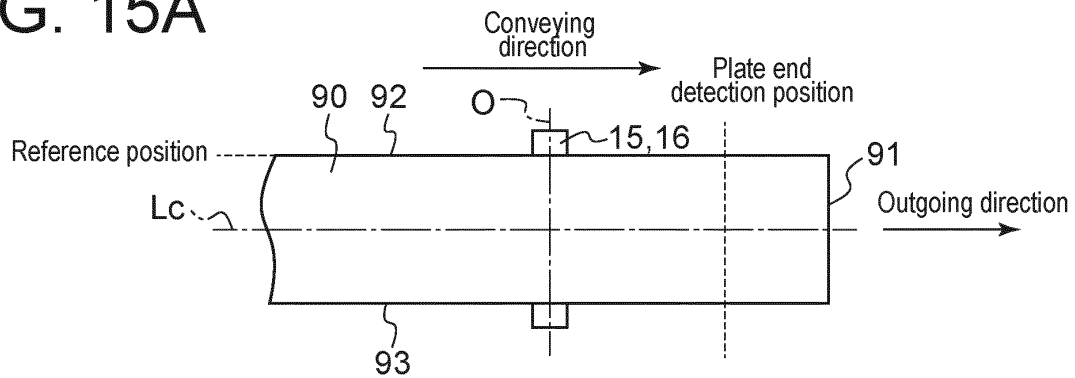


FIG. 15B

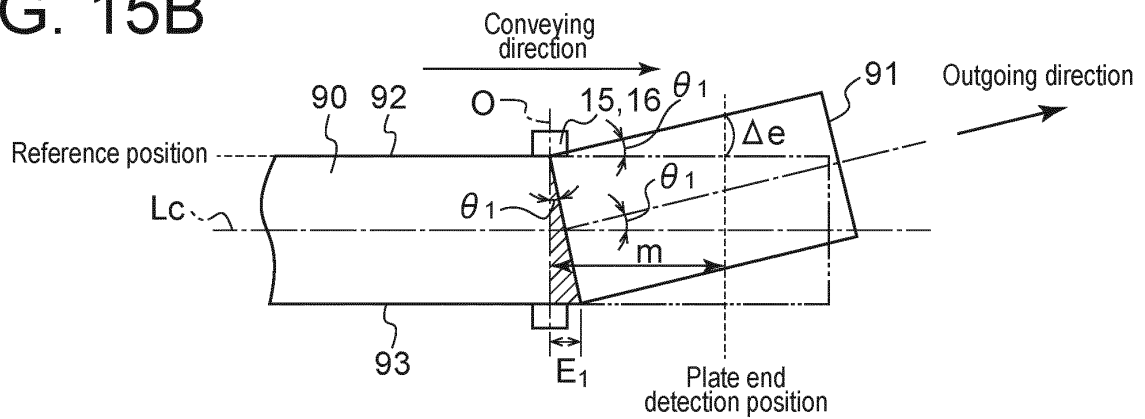


FIG. 15C

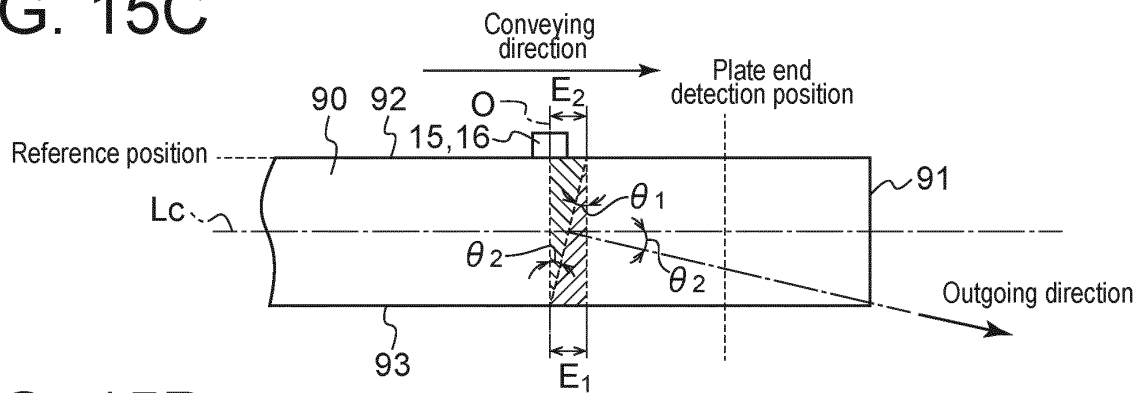


FIG. 15D

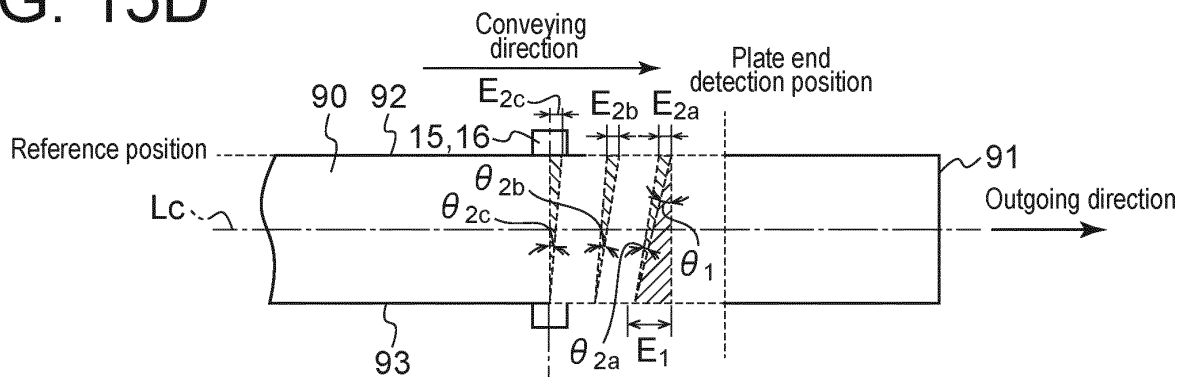


FIG. 16

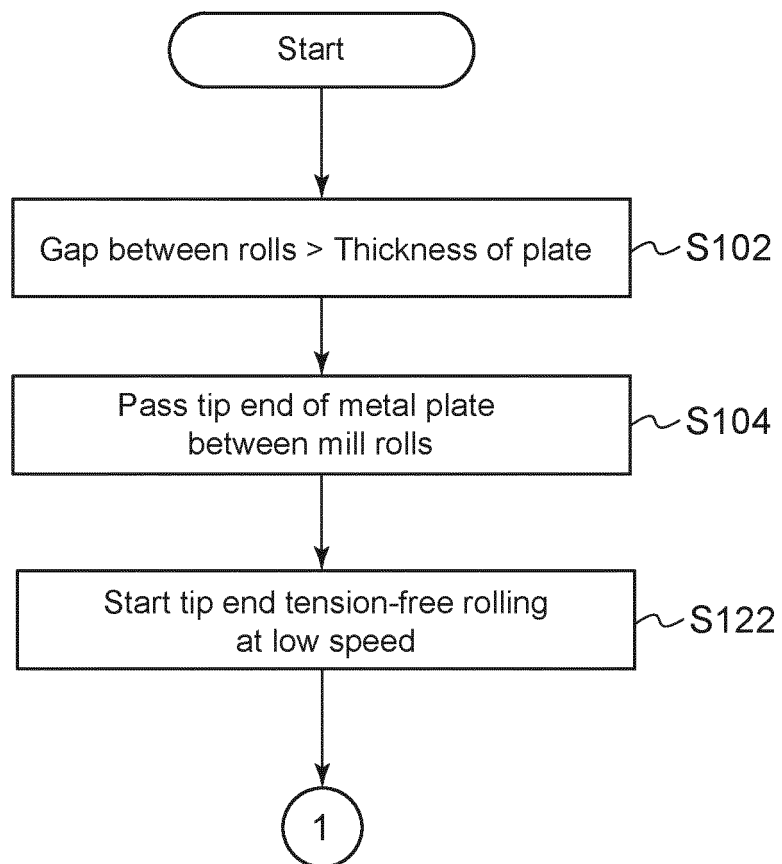
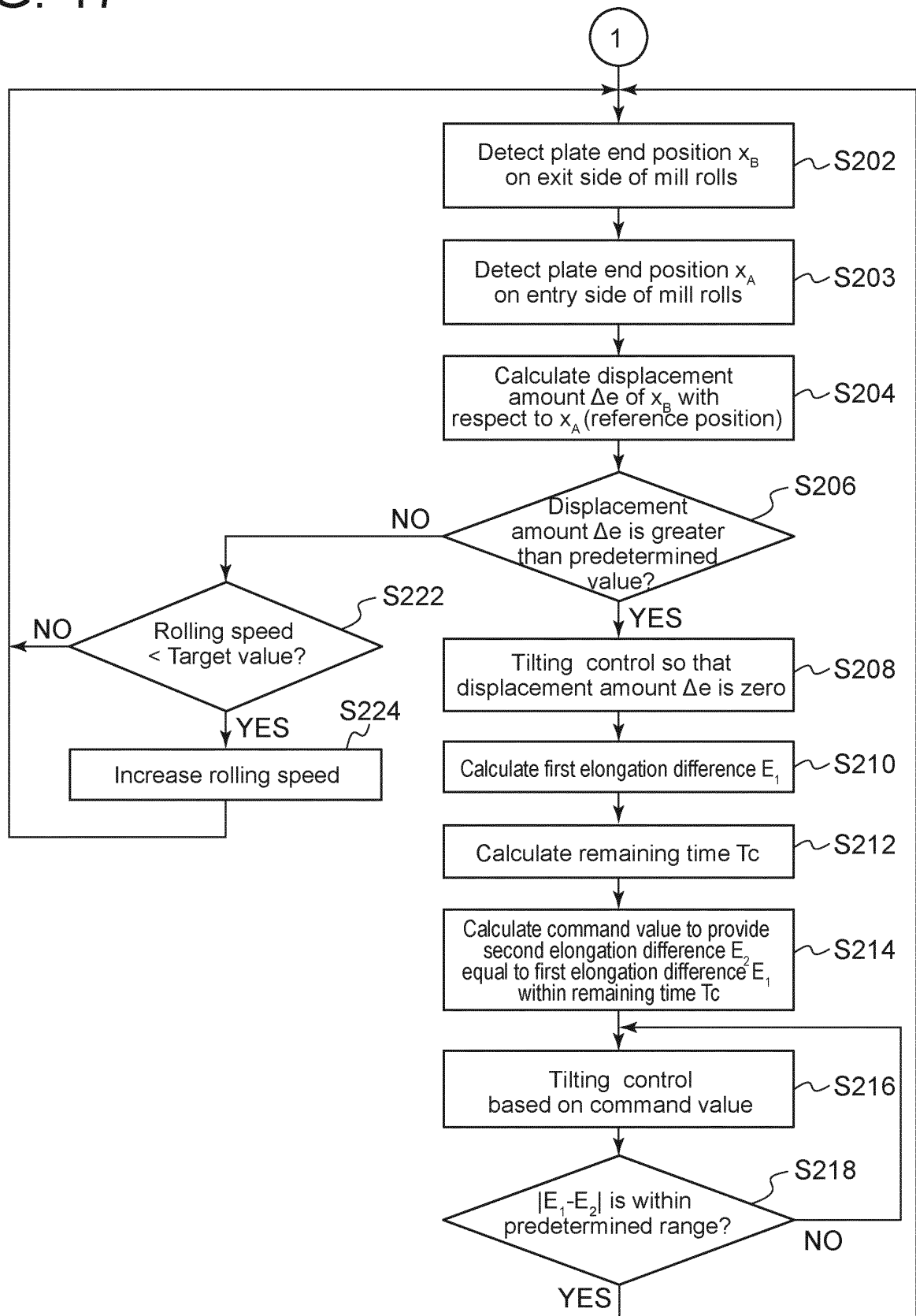


FIG. 17



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/004004

10

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. B21B39/14 (2006.01) i, B21B39/16 (2006.01) i, B21B39/18 (2006.01) i,
B21B37/28 (2006.01) i, B21B37/58 (2006.01) i
FI: B21B37/28Z, B21B37/58A, B21B39/14D, B21B39/14J, B21B39/16, B21B39/18
According to International Patent Classification (IPC) or to both national classification and IPC

15

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. B21B39/00-39/34, B21B37/00-37/78, B21B41/00-41/04

20

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 1971-2020

Registered utility model specifications of Japan 1996-2020

Published registered utility model applications of Japan 1994-2020

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

25

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 45-8780 B1 (HITACHI, LTD.) 30.03.1970 (1970-03-30), entire text, all drawings	1-12
A	JP 49-96955 A (NIPPON STEEL CORPORATION) 13.09.1974 (1974-09-13), entire text, all drawings	1-12
A	JP 2-20608 A (SUMITOMO METAL INDUSTRIES, LTD.) 24.01.1990 (1990-01-24), entire text, all drawings	1-12
A	JP 2014-117743 A (JFE STEEL CORPORATION) 30.06.2014 (2014-06-30), entire text, all drawings	1-12
A	JP 2018-158365 A (JFE STEEL CORPORATION) 11.10.2018 (2018-10-11), entire text, all drawings	1-12
A	JP 7-132310 A (MITSUBISHI HEAVY INDUSTRIES, LTD.) 23.05.1995 (1995-05-23), entire text, all drawings	1-12

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

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"P" document published prior to the international filing date but later than the priority date claimed

"I" 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

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"&" document member of the same patent family

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Date of the actual completion of the international search
31.03.2020Date of mailing of the international search report
14.04.2020

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Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2020/004004

10

JP 45-8780 B1 30.03.1970 (Family: none)

JP 49-96955 A 13.09.1974 (Family: none)

JP 2-20608 A 24.01.1990 (Family: none)

JP 2014-117743 A 30.06.2014 (Family: none)

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JP 2018-158365 A 11.10.2018 (Family: none)

JP 7-132310 A 23.05.1995 (Family: none)

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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 H11179414 A [0004]