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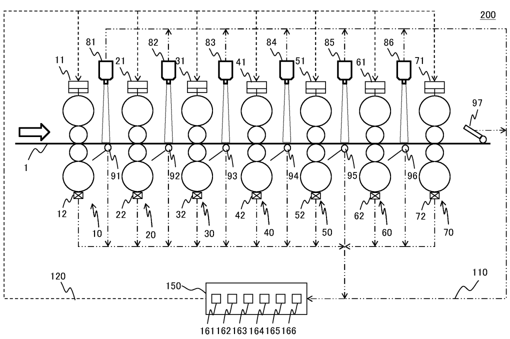
(54) LEVELING CONTROL DEVICE, ROLLING EQUIPMENT PROVIDED WITH SAME, AND LEVELING CONTROL METHOD

(57) A leveling control apparatus 150 includes a torque acquisition unit 161 that calculates, from torques measured by shapemeters 91, 92, 93, 94, 95, and 96 individually provided between a plurality of rolling stands, a torque distribution applied in a widthwise direction of a steel sheet 1 between each adjacent ones of the plurality of rolling stands, a primary component computing unit 162 that calculates a tension distribution in the widthwise direction from the calculated torque distribution and calculates a primary component in a case where a tension distribution of the steel strip 1 is represented by a polynomial from the tension distribution, a leveling correction amount computing unit 163 that calculates, on the basis of the calculated primary components, a leveling correction amount for a rolling stand immediately preceding on the rolling upstream side among the plurality of rolling stands, and a leveling amount changing unit 164 that changes, on the basis of the calculated leveling correction amounts, the leveling amounts in order toward the rolling upstream side from the (last - 1)th stand among the plurality of rolling stands.

Fig. 1



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Description

Technical Field

[0001] The present invention relates to a leveling control apparatus, a rolling facility including the leveling control apparatus, and a leveling control method.

Background Art

[0002] As an example of strip curvature control method in a tandem mill that can perform entirely reorganized and consolidated control on the tandem mill to thereby reliably prevent occurrence of curvature not only on the exit side of a last rolling mill stand but also throughout the entire tandem mill, Patent Document 1 describes a strip curvature control method in a tandem mill in which method a plurality of rolling mill stands perform rolling of a strip simultaneously by successively passing the strip through a plurality of rolling mill stands arranged in series, and left and right tension deviations of the strip between the rolling mill stands are removed by adjusting the left and right screw-down amounts of each of the rolling mill stands on the basis of the detected values of left and right tension deviations of the strip between the rolling mill stands, to thereby perform strip curvature control. Moreover, in the strip curvature control method, the adjustment of the screw-down amount at a rolling mill stand is performed in front of the position where the left and right tension deviation of the strip is detected, on the basis of the detected value of the left and right tension deviation of the strip that has exited from the rolling mill stand, and the adjusting operation is performed progressively toward a rolling mill stand on the entry side.

Prior Art Document

Patent Document

[0003] Patent Document 1: JP-S63-29605-A

Summary of the Invention

Problems to be Solved by the Invention

[0004] There has been well known in the art that rolling facilities that operate at high rolling speeds tend to cause the strip to curve largely due to the differences between left and right screw-down amounts at rolling mills or the differences between left and right thicknesses of the strip. Since the occurrence of such a strip curvature damages the quality of the product, there have been strong demands for the development of a control method for preventing a strip curvature from occurring.

[0005] Methods of preventing a strip curvature include the method disclosed in Patent Document 1, for example. According to Patent Document 1, screw-down control is performed at the rolling mill stand in front of the tension detecting position on the basis of the left and right tension deviations of the strip between the rolling mill stands, and the control is brought progressively toward the entry side.

[0006] However, since allowable tension deviations are different depending on the width of the strip and tension deviations contain measurement errors, the accuracy tends to be reduced if the measured tension deviations are used as they are for the screw-down control. It has thus become obvious that the method remains to be improved.

[0007] According to the present invention, there are provided a leveling control apparatus, a rolling facility including the leveling control apparatus, and a leveling control method that are capable of increasing, compared with the conventional art, the accuracy of screw-down control for each rolling mill stand of a hot rolling line that includes an array of rolling mill stands.

Means for Solving the Problems

[0008] The present invention includes a plurality of means for solving the above problems. According to an example of the invention, there is provided a leveling control apparatus for a hot rolling line that includes a plurality of arrayed rolling mill stands, including

a torque acquisition unit that calculates a torque distribution applied in a widthwise direction of a steel strip between each adjacent ones of the plurality of rolling mill stands from a torque measured by each of shapemeters disposed between the plurality of rolling mill stands, a primary component computing unit that calculates a tension distribution in the widthwise direction from the calculated torque distribution and that calculates a primary component in a case where a tension distribution of the steel strip is represented by a polynomial from the tension distribution, a leveling correction amount computing unit that calculates a leveling correction amount for a rolling mill stand immediately preceding on a rolling upstream side among the plurality of rolling mill stands, on the basis of the calculated primary component, and a leveling amount changing unit that changes a leveling amount in order toward the rolling upstream side from a (last - 1)th rolling mill stand among the plurality of rolling mill stands on the basis of the calculated leveling correction amount.

Advantages of the Invention

[0009] According to the present invention, the accuracy of screw-down control for each rolling mill stand of a hot rolling line that includes an array of rolling mill stands can be increased compared with the conventional art. Other problems, structures, and advantages than those described above will become apparent from the description of embodiments given below.

Brief Description of the Drawings

[0010]

FIG. 1 is a schematic view illustrating the configuration of a rolling facility incorporating a leveling control apparatus according to a first embodiment of the present invention.

FIG. 2 is a view illustrating an example of method of determining an allowable range for a primary component in the leveling control apparatus according to the first embodiment.

FIG. 3 is a flowchart illustrating an example of sequence of control for correcting a leveling amount in the leveling control apparatus according to the first embodiment.

FIG. 4 is a schematic view illustrating the configuration of a rolling facility incorporating a leveling control apparatus according to a second embodiment of the present invention.

FIG. 5 is a flowchart illustrating an example of sequence of control for correcting a leveling amount in the leveling control apparatus according to the second embodiment.

FIG. 6 is a schematic view illustrating the configuration of a rolling facility incorporating a leveling control apparatus according to a third embodiment of the present invention.

FIG. 7 is a flowchart illustrating an example of sequence of control for correcting a leveling amount in the leveling control apparatus according to the third embodiment.

Modes for Carrying Out the Invention

[0011] Leveling control apparatuses, rolling facilities including the leveling control apparatuses, and leveling control methods according to embodiments of the present invention will be described hereinbelow with reference to the drawings.

[0012] In the drawings accompanying the present description, those constituent elements which are identical or correspond to each other are denoted by identical or similar reference characters, and their repetitive explanation may be omitted from the description.

[0013] Furthermore, materials to be rolled according to the present invention are not limited to steel strips, but may be metal strips that can generally be rolled, and are not restricted to any particular types, but may be nonferrous materials such as aluminum and copper other than steel strips.

<First Embodiment>

[0014] A leveling control apparatus, a rolling facility including the leveling control apparatus, and a leveling control method according to a first embodiment of the present invention will be described below with reference to FIGS. 1 through 3.

[0015] First, the overall configuration of a rolling facility including the leveling control apparatus will be described below with reference to FIG. 1. FIG. 1 is a schematic view illustrating the configuration of the rolling facility incorporating the leveling control apparatus according to the first embodiment.

[0016] A rolling facility 200 in FIG. 1, is a finishing rolling facility for rolling a steel strip 1, and includes an F1 rolling mill stand 10, an F2 rolling mill stand 20, an F3 rolling mill stand 30, an F4 rolling mill stand 40, an F5 rolling mill stand 50, an F6 rolling mill stand 60, an F7 rolling mill stand 70, cameras 81, 82, 83, 84, 85, and 86, shapemeters 91, 92, 93, 94, 95, and 96, a leveling control apparatus 150, etc.

[0017] The rolling facility 200 is not limited to the configuration including the seven rolling mill stands as illustrated in FIG. 1, but may include a minimum of three rolling mill stands or more.

[0018] A rolling mill is provided with the F1 stand 10, the F2 stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70 each includes: a top work roll and a bottom work roll; a top backup roll and a bottom backup roll that support the top work roll and the bottom work roll, respectively, by contacting them; screw-down devices 11, 21, 31, 41, 51, 61, and 71 disposed above the respective top backup rolls; and load detectors 12, 22, 32, 42, 52, 62, 72. The information on rolling loads measured by the load detectors 12, 22, 32, 42, 52, 62, and 72 is transmitted via communication line 110 to the leveling control apparatus 150.

[0019] Each of the rolling mill stands may be configured as a six-high rolling mill including top and bottom intermediate rolls disposed between the top and bottom work rolls and the top and bottom backup rolls. The roll configuration of the rolling mill is not limited to the above configurations, but may include a minimum of top and bottom work rolls.

[0020] The shapemeters 91, 92, 93, 94, 95, and 96 are disposed between the F1 rolling mill stand 10, the F2 rolling mill stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70, respectively, and are measuring instruments for measuring torques on the steel strip 1. The shapemeters 91, 92, 93, 94, 95, and 96 are capable of detecting a tension distribution on the steel strip 1 along the widthwise direction thereof, and are also capable of detecting the position of the steel strip 1.

[0021] The information on a surface shape, measured by the shapemeter 91, of the steel strip 1 on the exit side of the F1 rolling mill stand 10 (the entry side of the F2 rolling mill stand 20) is transmitted via the communication line 110 to the leveling control apparatus 150. The information on a surface shape, measured by the shapemeter 92, of the steel strip 1 at the exit side of the F2 rolling ill stand 20 (the entry side of the F3 rolling mill stand 30) is transmitted via the communication line 110 to the leveling control apparatus 150. The information on a surface shape, measured by the shapemeter 93, of the steel strip 1 at the exit side of the F3 rolling mill stand 30 (the entry side of the F4 rolling mill stand 40) is transmitted via the communication line 110 to the leveling control apparatus 150. The information on a surface shape, measured by the shapemeter 94, of the steel strip 1 at the exit side of the F4 rolling mill stand 40 (the entry side of the F5 rolling mill stand 50) is transmitted via the communication line 110 to the leveling control apparatus 150. The information on a surface shape, measured by the shapemeter 95, of the steel strip 1 at the exit side of the F5 rolling mill stand 50 (the entry side of the F6 rolling mill stand 60) is transmitted via the communication line 110 to the leveling control apparatus 150. The information on a surface shape, measured by the shapemeter 96, of the steel strip 1 at the exit side of the F6 rolling mill stand 60 (the entry side of the F7 rolling mill stand 70) is transmitted via the communication line 110 to the leveling control apparatus 150.

[0022] A shapemeter 97 is also a measuring instrument for measuring a surface shape of the steel strip 1 as with the shapemeter 91, etc., and is disposed on the exit side of the F7 rolling mill stand 70. The information on a surface shape, measured by the shapemeter 97, of the steel strip 1 at the exit side of the F7 rolling mill stand 70 is transmitted via the communication line 110 to the leveling control apparatus 150.

[0023] The camera 81 is disposed in a position where it can photograph an image including the steel strip 1 on the exit side of the F1 rolling mill stand 10 and the entry side of the F2 rolling mill stand 20. The camera 82 is disposed in a position where it can photograph an image including the steel strip 1 on the exit side of the F2 rolling mill stand 20 and the entry side of the F3 rolling mill stand 30. The camera 83 is disposed in a position where it can photograph an image including the steel strip 1 on the exit side of the F3 rolling mill stand 30 and the entry side of the F4 rolling mill stand 40. The camera 84 is disposed in a position where it can photograph an image including the steel strip 1 on the exit side of the F4 rolling mill stand 40 and the entry side of the F5 rolling mill stand 50. The camera 85 is disposed in a position where it can photograph an image including the steel strip 1 on the exit side of the F5 rolling mill stand 50 and the entry side of the F6 rolling mill stand 60. The camera 86 is disposed in a position where it can photograph an image including the steel strip 1 on the exit side of the F6 rolling mill stand 60 and the entry side of the F7 rolling mill stand 70.

[0024] These cameras 81, 82, 83, 84, 85, and 86 photograph images including the steel strip 1 directly from above the steel strip 1 or obliquely from above the steel strip 1 at intervals shorter than 0.1 second, for example, preferably in a moving image format. The data on the photographed images are transmitted via the communication line 110 to the leveling control apparatus 150.

[0025] The leveling control apparatus 150 is an apparatus configured with a computer for controlling operation of the various devices in the rolling facility 200, and has a torque acquisition unit 161, a primary component computing unit 162, a leveling correction amount computing unit 163, a leveling amount changing unit 164, an off-center amount computing unit 165, and a storage unit 166.

[0026] The torque acquisition unit 161 calculates a toque distribution on the steel strip 1 along the widthwise direction thereof between the F1 rolling mill stand 10, the F2 rolling mill stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70 from the torques measured by the shapemeters 91, 92, 93, 94, 95, and 96 that are disposed respectively between the F1 rolling mill stand 10, the F2 rolling mill stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70. The torque acquisition unit 161 is preferably a main entity for carrying out a torque acquiring step.

[0027] The torque acquisition unit 161 also calculates a toque distribution along the widthwise direction of the steel strip 1 on the rolling downstream side of the F7 rolling mill stand 70, from the torque on the steel strip 1 acquired by the shapemeter 97 disposed on the rolling downstream side of the last F7 rolling mill stand 70.

[0028] The off-center amount computing unit 165 calculates deviations between the center of the steel strip 1 along the widthwise direction thereof and the rolling center between respective rolling mill stands of the F1 rolling mill stand 10, the F2 rolling mill stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70, from the results measured by strip position detectors disposed respectively between the F1 rolling mill stand 10, the F2 rolling mill stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70.

[0029] The strip position detectors whose measured results are acquired by the off-center amount computing unit 165 are represented by the cameras 81, 82, 83, 84, 85, and 86 or the shapemeters 91, 92, 93, 94, 95, 96, and 97.

[0030] The primary component computing unit 162 calculates a tension distribution on the steel strip 1 along the widthwise direction thereof from the torque distribution calculated by the torque acquisition unit 161. The primary component computing unit 162 also calculates a primary component of a polynomial that represents the tension distribution on the steel strip 1 from the calculated tension distribution. At this time, the primary component computing unit 162 can correct the torque distribution on the steel strip 1 along the widthwise direction thereof on the basis of the deviations (off-center amount ΔYc in FIG. 2) calculated by the off-center amount computing unit 165. The primary component computing unit 162 is preferably a main entity for carrying out a primary component computing step.

[0031] The leveling correction amount computing unit 163 calculates leveling correction amounts for the rolling mill stands 10, 20, 30, 40, 50, and 60 immediately preceding on the rolling upstream side, on the basis of the primary component calculated by the primary component computing unit 162. The leveling correction amount computing unit 163 should preferably calculate a leveling correction amount for the F7 rolling mill stand 70 on the basis of the primary component calculated by the primary component computing unit 162. The leveling correction amount computing unit 163 is preferably a main entity for carrying out a leveling correction amount computing step.

[0032] More specifically, the leveling correction amount computing unit 163 performs leveling correction on the F6 rolling mill stand 60 using the primary component of the tension distribution calculated from the torque on the steel strip 1 that has been measured by the shapemeter 96 disposed on the exit side of the F6 rolling mill stand 60. This processing is performed progressively toward the rolling upstream side.

[0033] When the leveling of each rolling mill stand is changed, both the primary components on the entry and exit sides of each rolling mill stand vary. Therefore, it is desirable to determine an amount of adjustment using the primary component on the exit side of the last F7 rolling mill stand 70. It is thus desirable to perform leveling correction on the F7 rolling mill stand 70 using the primary component of the tension distribution calculated from the torque on the steel strip 1 that has been measured by the shapemeter 97 disposed on the exit side of the F7 rolling mill stand 70.

[0034] When the leveling is corrected at an upstream rolling mill stand, its effect is propagated to downstream rolling mill stands. Consequently, it is desirable to perform feedback control on the leveling amount of each rolling mill stand such that the strip wedge ratio is constant, i.e., the primary component is zero.

[0035] When the trailing end (terminal strip end) of the steel strip 1 reaches the shapemeter 94 on the entry side of the F5 rolling mill stand 5, the shapemeter 96 of the F7 rolling mill stand 70 starts being lowered vertically downwardly (starts being spaced from the steel strip 1). From this timing, therefore, it is desirable to perform leveling correction on the F6 rolling mill stand 60 and the F7 rolling mill stand 70 using the off-center amounts of the steel strip 1 that have been input from the camera 85 on the entry side of the F6 rolling mill stand 60 and the camera 86 on the entry side of the F7 rolling mill stand 70. More specifically, it is desirable to correct the leveling of the F6 rolling mill stand 60 using the off-center amount between the F5 rolling mill stand 50 and the F6 rolling mill stand 60 and to correct the leveling of the F7 rolling mill stand 70 using the off-center amount between the F6 rolling mill stand 60 and the F7 rolling mill stand 70.

[0036] Moreover, when the trailing end of the steel strip 1 has passed through the position below the camera 86 on the entry side of the F7 rolling mill stand 70, no off-center amount can be measured. It is therefore desirable to switch to lock-on control on the differential load on the F7 rolling mill stand 70.

[0037] The leveling correction amount computing unit 163 can calculate leveling correction amounts such that the calculated primary component falls within an allowable range.

[0038] FIG. 2 is a view illustrating an example of method of determining an allowable range for a primary component.

[0039] FIG. 2 illustrates the timing when the trailing end of the steel strip 1 has left the F6 rolling mill stand 60. Inasmuch as the steel strip 1 has left the F6 rolling mill stand 60, only the F7 rolling mill stand 70 exerts lateral restraint forces on the steel strip 1, tending to allow the steel strip 1 to move off-center to a large extent.

[0040] It is assumed that the average thickness of the steel strip 1 on the entry side of the F7 rolling mill stand 70 is indicated by H, the difference between the thicknesses of both edges of the steel strip 1 on the entry side of the F7 rolling mill stand 70 is indicated by ΔH, the average thickness of the steel strip 1 on the exit side of the F7 rolling mill stand 70 is indicated by h, the difference between the thicknesses of both edges of the steel strip 1 on the exit side of the F7 rolling mill stand 70 is indicated by Δh, and the difference between the center of the F7 rolling mill stand 70 along the widthwise direction thereof and the center of the steel strip 1 along the widthwise direction thereof, i.e., the off-center amount of the steel strip 1, is indicated by ΔYc. The off-center amount ΔYc of the steel strip 1 is calculated using the angular velocity of rotation of the tail end of the steel strip 1 and the speed at which the steel strip 1 moves in the widthwise direction thereof. Further, the angular velocity of rotation of the tail end of the steel strip 1 and the speed at which the steel strip 1 moves in the widthwise direction thereof are calculated using a change in the strip wedge ratio ($\Delta h/h - \Delta H/H$). Furthermore, the primary component (elongation difference ratio) of the polynomial that represents the tension distribution on the steel strip 1 is correlated to the change in the strip wedge ratio ($\Delta h/h - \Delta H/H$), and the leveling amount (difference between screw-down ratios) is also correlated to ΔH and Δh, so that they can be calculated by way of calculation. By determining the allowable maximum value of the off-center amount ΔYc (for example, the off-center amount ΔYc at the F7 rolling mill stand 70 at the time where the tail end of the steel strip 1 contacts a side guide (omitted from illustration)), it can be calculated by way of calculation how much the primary component of the torque distribution on the steel strip 1 along the widthwise direction thereof on the exit side of the F7 rolling mill stand 70 at the allowable maximum value of the off-center amount ΔYc will be.

[0041] The leveling correction amount computing unit 163 can calculate, using a range of primary components of torque distributions capable of keeping the off-center amount ΔYc within an allowable range as an allowable range, a leveling correction amount such that the primary component calculated by the primary component computing unit 162 falls within the allowable range.

[0042] The leveling amount changing unit 164 changes the leveling amount progressively toward the rolling upstream side from a (last - 1)th rolling mill stand among the F1 stand 10, the F2 stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70, on the basis of the leveling correction amount calculated by the leveling correction amount computing unit 163. Moreover, it is desirable that the leveling amount changing unit 164 should change the leveling amount of the F7 rolling mill stand 70 before the leveling amount of the (last - 1)th rolling mill stand is changed. The leveling amount changing unit 164 is preferably a main entity for carrying out a leveling amount changing step.

[0043] The leveling amount changing unit 164 outputs control parameter information on the calculated leveling amount to the screw-down devices 11, 21, 31, 41, 51, 61, and 71 via communication line 120. The screw-down devices 11, 21, 31, 41, 51, 61, and 71 then operate to realize the leveling amount having been input.

[0044] The storage unit 166 is a storage device of the computer configuring the leveling control apparatus 150, and should preferably be an SSD or an HDD.

[0045] Control of operation of the devices by the leveling control apparatus 150 and control of operation of the torque acquisition unit 161, the primary component computing unit 162, the leveling correction amount computing unit 163, the leveling amount changing unit 164, the off-center amount computing unit 165, and the storage unit 166 are carried out in accordance with various programs recorded in the storage unit 166.

[0046] Control processing for controlling operation that is carried out by the leveling control apparatus 150 may be combined in one program or separated in a plurality of programs, or represented by a combination of those programs. The programs may be partly or wholly implemented by dedicated hardware or modularized.

[0047] Now, a leveling control method, preferably performed by the leveling control apparatus 150 according to the present embodiment, for a hot rolling line including the array of the F1 stand 10, the F2 stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70 will be described below with reference to FIG. 3. FIG. 3 is a flowchart illustrating an example of sequence of control for correcting a leveling amount in the leveling control apparatus according to the first embodiment.

[0048] As illustrated in FIG. 3, first, the shapemeter 97 measures the torque on the steel strip 1 on the exit side of the F7 rolling mill stand 70 (last rolling mill stand), and the torque acquisition unit 161 of the leveling control apparatus 150 calculates a torque distribution on the steel strip 1 along the widthwise direction thereof and the primary component computing unit 162 calculates a primary component along the widthwise direction of the steel strip 1 (step S101).

[0049] Then, the leveling correction amount computing unit 163 of the leveling control apparatus 150 computes a leveling correction amount for the F7 rolling mill stand 70 in view of the primary component calculated in step S101, and the leveling amount changing unit 164 changes the leveling amount (step S102).

[0050] Thereafter, the primary component computing unit 162 calculates a primary component of a tension distribution on the steel strip 1 between the F6 rolling mill stand 60 and the F7 rolling mill stand 70 in the same manner as on the exit side of the F7 rolling mill stand 70 (last rolling mill stand) (step S103).

[0051] Thereafter, the leveling correction amount computing unit 163 computes a leveling correction amount for the F6 rolling mill stand 60 in view of the primary component calculated in step S103, and the leveling amount changing unit 164 changes the leveling amount (step S104).

[0052] The same processing as with step S101 and step S102 or step S103 and step S104 is carried out with respect to the F5 rolling mill stand 50, the F4 rolling mill stand 40, the F3 rolling mill stand 30, the F2 rolling mill stand 20, and the F1 rolling mill stand 10 (corresponding respectively to steps S105, S106, S107, S108, S109, S110, S111, S112, S113, and S114 (a leveling correction amount for F1 is computed in view of the primary component, and the leveling is changed)).

[0053] When the leveling is corrected on an upstream rolling mill stand, its effect is propagated to downstream rolling mill stands. Consequently, it is desirable to compute a leveling correction amount for the F7 rolling mill stand 70 on the assumption that the leveling correction at the F6 rolling mill stand 60 represents a constant strip wedge ratio (step S121) and to reflect the computed leveling correction amount in the processing of step S102.

[0054] The processing of step S121 is the same as with the F5 rolling mill stand 50, etc. It is thus possible to compute leveling correction amounts respectively for the F1 rolling mill stand 10, the F2 stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, and the F6 rolling mill stand 60 on the assumption that the leveling corrections at these rolling mill stands represent a constant strip wedge ratio (corresponding respectively to steps S122, S123, S124, S125, and S126) and to reflect the computed leveling correction amounts in the processing of step S102, etc.

[0055] In order to avoid endless looping through step S121, etc., it is desirable to record the number of times that step S121 is performed, and, if step S121 has been performed a predetermined number of times, to stop performing steps S121, ···, S126, or to stop performing steps S121, ···, S126 after a predetermined time has passed after they had been performed for the first time, or to stop performing steps S121, ···, S126 in a case where the corrections in those steps are lower than a prescribed value.

[0056] Thereafter, it is determined whether the primary component of the tension distribution on the steel strip 1 at the exit side of each of all the rolling mill stands satisfies an allowable value or not (step S130). If it is determined that the primary component satisfies the allowable value, then the processing is completed (the control parameter information on the calculated leveling amount is output to the gear-down devices 11, 21, 31, 41, 51, 61, and 71). In contrast, if the primary component does not satisfy the allowable value with respect to even one of the rolling mill stands, then the processing goes back to step S101, and the processing is continued to calculate control parameters for the leveling amount until the primary component satisfies the allowable value at the exit sides of all the rolling mill stands.

[0057] While rolling the steel strip 1, it is desirable to perform the processing illustrated in FIG. 3 uninterruptedly. In other words, after the processing is completed, it is desirable to start the processing afresh from the outset.

[0058] Of the above steps, steps S101 and S103 correspond to the primary component computing step, and steps S102, S104, S114, and S126 correspond to the leveling correction amount computing step and the leveling amount changing step.

[0059] Advantages of the present embodiment will be described below.

[0060] The leveling control apparatus 150 of the rolling facility 200 according to the first embodiment of the present invention as described above includes: the torque acquisition unit 161 that calculates a toque distribution on the steel strip 1 along the widthwise direction thereof between the F1 rolling mill stand 10, the F2 rolling mill stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70 from the torques measured by the shapemeters 91, 92, 93, 94, 95, and 96 that are disposed between the F1 rolling mill stand 10, the F2 rolling mill stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70; the primary component computing unit 162 that calculates a tension distribution on the steel strip 1 along the widthwise direction thereof from the calculated torque distribution and that calculates a primary component of a polynomial that represents the tension distribution on the steel strip 1 from the tension distribution; the leveling correction amount computing unit 163 that calculates leveling correction amounts for the rolling mill stands 10, 20, 30, 40, 50, and 60 immediately preceding on the rolling upstream side, on the basis of the calculated primary component; and the leveling amount changing unit 164 that changes the leveling amount progressively toward the rolling upstream side from the F6 rolling mill stand 60, on the basis of the calculated leveling correction amounts.

[0061] It is thus possible to compute appropriate leveling amounts in view of the width of the steel strip 1 and measurement errors, and to increase the accuracy of screw-down control compared with the conventional art.

[0062] Furthermore, since the leveling correction amount computing unit 163 calculates leveling correction amounts so as to keep the calculated primary component within the allowable range, the primary component can be reduced and the strip wedge ratio becomes nearly constant. As the steel strip 1 can thus be rolled while holding its stripe wedge, the steel strip 1 can have its off-center movement reduced. Because of these advantages, the steel strip 1 can be rolled more stably.

[0063] Moreover, when the leveling of each rolling mill stand is changed, both the primary components on the entry and exit sides of each rolling mill stand vary. Therefore, the torque acquisition unit 161 calculates a toque distribution on the steel strip 1 along the widthwise direction thereof on the rolling downstream side of the F7 rolling mill stand 70 from the torque on the steel strip 1 that has been acquired by the shapemeter 97 disposed on the rolling downstream side of the F7 rolling mill stand 70, and the leveling amount changing unit 164 changes the leveling amount at the F7 rolling mill stand 70 prior to the (last - 1)th rolling mill stand, thereby making the accuracy of screw-down control higher.

[0064] The left and right tension deviations are difficult to be measured correctly in a case where the steel strip 1 is shifted from the rolling center. Therefore, the leveling control apparatus 150 further includes the off-center amount computing unit 165 that calculates deviations between the center of the steel strip 1 along the widthwise direction thereof and the rolling center between the F1 rolling mill stand 10, the F2 rolling mill stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70, from the results measured by the respective strip position detectors disposed between the F1 rolling mill stand 10, the F2 rolling mill stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70. The primary component computing unit 162 corrects the torque distribution on the steel strip 1 along the widthwise direction thereof on the basis of the deviations calculated by the off-center amount computing unit 165, thereby correcting the torque difference by the deviations, so that the primary component can be calculated with better accuracy. Consequently, the accuracy of screw-down control can further be increased.

<Second Embodiment>

[0065] A leveling control apparatus, a rolling facility including the leveling control apparatus, and a leveling control method according to a second embodiment of the present invention will be described below with reference to FIGS. 4 and 5. FIG. 4 is a schematic view illustrating the configuration of a rolling facility incorporating the leveling control apparatus according to the second embodiment of the present invention, and FIG. 5 is a flowchart illustrating an example of sequence of control for correcting a leveling amount.

[0066] A rolling facility 200A in FIG. 4 includes a strip wedge amount measuring instrument 98 for measuring a strip thickness distribution of the steel strip 1 along the widthwise direction thereof, in place of the shapemeter 97 disposed on the exit side of the F7 rolling mill stand 70 of the rolling facility 200 according to the first embodiment described above. The strip wedge amount measuring instrument 98 may be a strip thickness meter or a profile meter as long as it can measure data from which a strip wedge amount can be calculated.

[0067] A leveling control apparatus 150A further includes a strip wedge amount acquiring unit 167A in addition to the leveling control apparatus 150 according to the first embodiment.

[0068] The strip wedge amount acquiring unit 167A calculates a strip wedge amount of the steel strip 1 on the rolling downstream side of the F7 rolling mill stand 70, from the strip thickness distribution of the steel strip 1 along the widthwise direction thereof that has been measured by the strip wedge amount measuring instrument 98 disposed on the rolling downstream side of the F7 rolling mill stand 70.

[0069] A leveling correction amount computing unit 163A calculates a leveling correction amount for the F7 rolling mill stand 70 on the basis of the strip wedge amount calculated by the strip wedge amount acquiring unit 167A, and a leveling amount changing unit 164A also changes the leveling amount at the F7 rolling mill stand 70 prior to the (last - 1)th rolling mill stand.

[0070] When the steel strip 1 is rolled at the F7 rolling mill stand 70 of the rolling facility 200A, the transcription ratio of the strip wedge is considered to be essentially zero, and the strip wedge (strip wedge ratio) of the steel strip 1 before it is rolled is thought to be inherited as it is. A leveling correction amount for the F7 rolling mill stand 70 is computed from the measured value of the strip wedge after the steel strip 1 has been rolled, i.e., on the exit side of the F7 rolling mill stand 70, and the difference between oil columns of the screw-down device 71 on the drive side and the work side is adjusted.

[0071] Now, a leveling control method, preferably performed by the leveling control apparatus 150A according to the present embodiment, will be described below with reference to FIG. 5.

[0072] As illustrated in FIG. 5, first, the strip wedge amount measuring instrument 98 and the strip wedge amount acquiring unit 167A of the leveling control apparatus 150A measure the strip wedge of the steel strip 1 on the exit side of the F7 rolling mill stand 70 (step S201).

[0073] Then, the leveling correction amount computing unit 163A of the leveling control apparatus 150A computes a leveling correction amount for the F7 rolling mill stand 70 in view of the strip wedge calculated in step S101, and the leveling amount changing unit 164 changes the leveling amount (S202). The leveling correction amount computing unit 163A may compute a leveling correction amount from the calculated strip wedge according to a known method.

[0074] The subsequent processing of steps S203 through S230 is the same as the processing of steps S103 through S130 illustrated in FIG. 3 and will be omitted from detailed description.

[0075] The other structural and operational details are substantially the same as those of the leveling control apparatus, the rolling facility including the leveling control apparatus, and the leveling control method according to the first embodiment described above, and will be omitted from detailed description.

[0076] The leveling control apparatus, the rolling facility including the leveling control apparatus, and the leveling control method according to the second embodiment offer essentially the same advantages as those of the leveling control apparatus, the rolling facility including the leveling control apparatus, and the leveling control method according to the first embodiment described above.

[0077] The leveling control apparatus 150A further includes the strip wedge amount acquiring unit 167A that calculates a strip wedge amount of the steel strip 1 on the rolling downstream side of the F7 rolling mill stand 70 from the strip thickness distribution of the steel strip 1 along the widthwise direction thereof that has been measured by the strip wedge amount measuring instrument 98 disposed on the rolling downstream side of the F7 rolling mill stand 70. The leveling correction amount computing unit 163A calculates a leveling correction amount for the F7 rolling mill stand 70 on the basis of the strip wedge amount calculated by the strip wedge amount acquiring unit 167A, and the leveling amount changing unit 164A also changes the leveling amount at the F7 rolling mill stand 70 prior to the (last - 1)th rolling mill stand, thereby making the accuracy of screw-down control higher even in case shape data on the exit side of the F7 rolling mill stand 70 cannot be used.

<Third Embodiment>

[0078] A leveling control apparatus, a rolling facility including the leveling control apparatus, and a leveling control method according to a third embodiment of the present invention will be described below with reference to FIGS. 6 and 7. FIG. 6 is a schematic view illustrating the configuration of a rolling facility incorporating the leveling control apparatus according to the third embodiment, and FIG. 7 is a flowchart illustrating an example of sequence of control for correcting a leveling amount.

[0079] A rolling facility 200B in FIG. 6 is free of the shapemeter 97 in the rolling facility 200 according to the first embodiment and the strip wedge amount measuring instrument 98 in the rolling facility 200A according to the second embodiment, but is configured to provide calculated values representing a strip wedge amount of and a tension distribution on the steel strip 1 on the exit side of the last F7 rolling mill stand 70 if the data of such a strip wedge amount of and a tension distribution are not available. A leveling control apparatus 150B further includes a strip wedge amount computing unit 168B that calculates a strip wedge amount of the steel strip 1 on the rolling upstream side of the F7 rolling mill stand 70, on the basis of rolling loads and leveling amounts from an upstream rolling stand mill to the (last - 1)th rolling mill stand among the F1 stand 10, the F2 stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70.

[0080] A leveling correction amount computing unit 163B of the leveling control apparatus 150B calculates a leveling correction amount for the F7 rolling mill stand 70 on the basis of the strip wedge amount calculated by the strip wedge amount computing unit 168B, and a leveling amount changing unit 164B also changes the leveling amount at the F7 rolling mill stand 70 prior to the (last - 1)th rolling mill stand.

[0081] With a rolling facility including a plurality of rolling mill stands, at the F1 rolling mill stand and the F2 rolling mill stand as former stages, a strip wedge is formed substantially according to the leveling, i.e., transcription is dominant. In contrast, at rolling mill stands beginning with the F3 rolling mill stand 30 as later stages, a wedge (ratio) that enters a rolling mill stand also appears on the exist side, i.e., inheritance is dominant, in order to avoid deformations that are large in shape.

[0082] Based on these phenomena, consequently, a strip wedge on the exit side of each rolling mill stand can be predicted. Therefore, a strip wedge on the entry side of the F7 rolling mill stand 70 as the last stage can be calculated, and when the leveling at the F7 rolling mill stand 70 is changed on the basis of the calculated strip wedge amount on the exit side of the F6 rolling mill stand 60, its effect occurs at upstream rolling mill stands, changing tensions measured by the shapemeters 91, 92, 93, 94, 95, and 96. Subsequently, control for changing the leveling amount is performed progressively toward upstream as with the first and second embodiments.

[0083] However, since when the leveling is changed at an upstream rolling mill stand, it affects the calculated value of the strip wedge on the entry side of the F7 rolling mill stand 70, it is desirable to control the leveling mount and calculate a strip wedge independently of each other at each rolling mill stand. For example, the strip wedge is computed at all times in steps S301 through S306, whereas the leveling change processing in steps S307 through S330 is carried out between the start and the end.

[0084] Now, a leveling control method, preferably performed by the leveling control apparatus 150B according to the present embodiment, will be described below with reference to FIG. 7.

[0085] As illustrated in FIG. 7, first, the strip wedge amount computing unit 168B of the leveling control apparatus 150B computes a strip wedge on the exit side of the F1 rolling mill stand 10 using a measured rolling load P, a predicted roll profile value Cw, and a measured leveling amount ΔS at the F1 rolling mill stand 10 (step S301).

[0086] Then, the strip wedge amount computing unit 168B computes a strip wedge on the exit side of the F2 rolling mill stand 20 using the calculated strip wedge value on the exit side of the F1 rolling mill stand 10 that has been calculated in step S301, a measured rolling load P, a predicted roll profile value Cw, and a measured leveling amount ΔS at the F2 rolling mill stand 20 (step S302).

[0087] The same processing as with step S301 and step S302 is carried out with respect to the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, and the F6 rolling mill stand 60 (corresponding respectively to steps S303, S304, S305, and S306).

[0088] Thereafter, inasmuch as when the steel strip 1 is rolled at the F7 rolling mill stand 70, the transcription ratio of the strip wedge is considered to be essentially zero, the leveling correction amount computing unit 163B of the leveling control apparatus 150B computes a leveling correction amount for the F7 rolling mill stand 70 in view of the strip wedge (strip wedge ratio) on the exit side of the F6 rolling mill stand 60 that has been computed in a step corresponding to step S306 prior to the rolling, and the leveling amount changing unit 164B changes the leveling amount (step S307).

[0089] Step S308 and subsequent steps are basically the same as the processing of steps S103 through S130 illustrated in FIG. 3 and will be omitted from detailed description, the difference being that if the primary component does not satisfy the allowable value with respect to even one of the rolling mill stands in step S330, then the processing goes back to step S307, and the processing is continued to calculate control parameters for the leveling amount until the primary component satisfies the allowable value at all of the rolling mill stands.

[0090] The other structural and operational details are substantially the same as those of the leveling control apparatus, the rolling facility including the leveling control apparatus, and the leveling control method according to the first embodiment described above, and will be omitted from detailed description.

[0091] The leveling control apparatus, the rolling facility including the leveling control apparatus, and the leveling control method according to the third embodiment offer essentially the same advantages as those of the leveling control apparatus, the rolling facility including the leveling control apparatus, and the leveling control method according to the first embodiment described above.

[0092] The leveling control apparatus 150B further includes the strip wedge amount computing unit 168B that calculates a strip wedge amount of the steel strip 1 on the rolling upstream side of the F7 rolling mill stand 70, on the basis of rolling loads and leveling amounts from an upstream rolling stand mill to the (last - 1)th rolling mill stand among the F1 stand 10, the F2 stand 20, the F3 rolling mill stand 30, the F4 rolling mill stand 40, the F5 rolling mill stand 50, the F6 rolling mill stand 60, and the F7 rolling mill stand 70. The leveling correction amount computing unit 163B calculates a leveling correction amount for the F7 rolling mill stand 70 on the basis of the strip wedge amount calculated by the strip wedge amount computing unit 168B, and the leveling amount changing unit 164B also changes the leveling amount of the F7 rolling mill stand 70 prior to the (last - 1)th rolling mill stand, thereby making the accuracy of screw-down control higher even in a case where various data cannot be used on the exit side of the F7 rolling mill stand 70.

<Others>

[0093] The present invention is not limited to the embodiments described above, but covers various changes and modifications therein. The above embodiments have been described in detail for an easier understanding of the present invention, and the present invention should not be limited to any configurations including all the features described above.

[0094] Some of the configurations of one of the embodiments may be replaced with some of the configurations of the other embodiments, and some of the configurations of one of the embodiments may be added to some of the configurations of the other embodiments. Moreover, some of the configurations of each of the embodiments may be added to, or deleted, or replaced with some of the configurations of the other embodiments.

Description of Reference Characters

[0095]

1: Steel strip
10: F1 rolling mill stand
11, 21, 31, 41, 51, 61, 71: Screw-down device
12, 22, 32, 42, 52, 62, 72: Load detector
20: F2 rolling mill stand
30: F3 rolling mill stand
40: F4 rolling mill stand
50: F5 rolling mill stand
60: F6 rolling mill stand
70: F7 rolling mill stand
81, 82, 83, 84, 85, 86: Camera
91, 92, 93, 94, 95, 96, 97: Shapemeter
98: Strip wedge amount measuring instrument
110, 120: Communication line
150, 150A, 150B: Leveling control apparatus
161: Torque acquisition unit
162: Primary component computing unit
163, 163A, 163B: Leveling correction amount computing unit
164, 164A, 164B: Leveling amount changing unit
165: Off-center amount computing unit
166: Storage unit
167A: Strip wedge amount acquiring unit
168B: Strip wedge amount computing unit
200, 200A, 200B: Rolling facility

Claims

1. A leveling control apparatus for a hot rolling line that includes a plurality of arrayed rolling mill stands, the leveling control apparatus comprising:

   a torque acquisition unit that calculates a torque distribution applied in a widthwise direction of a steel strip between each adjacent ones of the plurality of rolling mill stands from a torque measured by each of shapemeters disposed between the plurality of rolling mill stands;
   a primary component computing unit that calculates a tension distribution in the widthwise direction from the calculated torque distribution and that calculates a primary component in a case where a tension distribution of the steel strip is represented by a polynomial from the tension distribution;
   a leveling correction amount computing unit that calculates a leveling correction amount for a rolling mill stand immediately preceding on a rolling upstream side among the plurality of rolling mill stands, on a basis of the calculated primary component; and
   a leveling amount changing unit that changes a leveling amount in order toward the rolling upstream side from a (last - 1)th rolling mill stand among the plurality of rolling mill stands on a basis of the calculated leveling correction amount.

2. The leveling control apparatus according to claim 1, wherein
   the leveling correction amount computing unit calculates the leveling correction amount such that the calculated primary component falls within an allowable range.

3. The leveling control apparatus according to claim 1 or 2, wherein

   the torque acquisition unit calculates a torque distribution on the steel strip along the widthwise direction thereof on a rolling downstream side of a last rolling mill stand among the plurality of rolling mill stands, from a torque on the steel strip that has been acquired by the shapemeter disposed on the rolling downstream side of the last rolling mill stand, and
   the leveling amount changing unit also changes a leveling amount of the last stand prior to the (last - 1)th rolling mill stand.

4. The leveling control apparatus according to claim 1 or 2, further comprising a strip wedge amount acquiring unit that calculates a strip wedge amount of the steel strip on a rolling downstream side of a last

rolling mill stand from a strip thickness distribution of the steel strip along the widthwise direction thereof, the strip thickness distribution having been measured by a strip wedge amount measuring instrument disposed on a rolling downstream side of the last rolling mill stand among the plurality of rolling mill stands, wherein

the leveling correction amount computing unit calculates a leveling correction amount for the last rolling mill stand on a basis of the strip wedge amount calculated by the strip wedge amount acquiring unit, and
the leveling amount changing unit also changes a leveling amount of the last stand prior to the (last - 1)th rolling mill stand.

5. The leveling control apparatus according to claim 1 or 2, further comprising a strip wedge amount computing unit that calculates a strip wedge amount of the steel strip on the rolling upstream side of a last rolling mill stand on a basis of rolling loads and leveling amounts from an upstream rolling stand mill to the (last - 1)th rolling mill stand among the plurality of rolling mill stands, wherein

the leveling correction amount computing unit calculates a leveling correction amount for the last rolling mill stand on a basis of the strip wedge amount calculated by the strip wedge amount computing unit, and
the leveling amount changing unit also changes a leveling amount of the last stand prior to the (last - 1)th rolling mill stand.

6. The leveling control apparatus according to any one of claims 1 through 5, further comprising:

an off-center amount computing unit that calculates deviations between a center of the steel strip along the widthwise direction thereof and a rolling center between the plurality of rolling mill stands from results measured by respective strip position detectors disposed between the plurality of rolling mill stands, wherein
the primary component computing unit corrects the torque distribution on the steel strip along the widthwise direction thereof on a basis of a deviation calculated by the off-center amount computing unit.

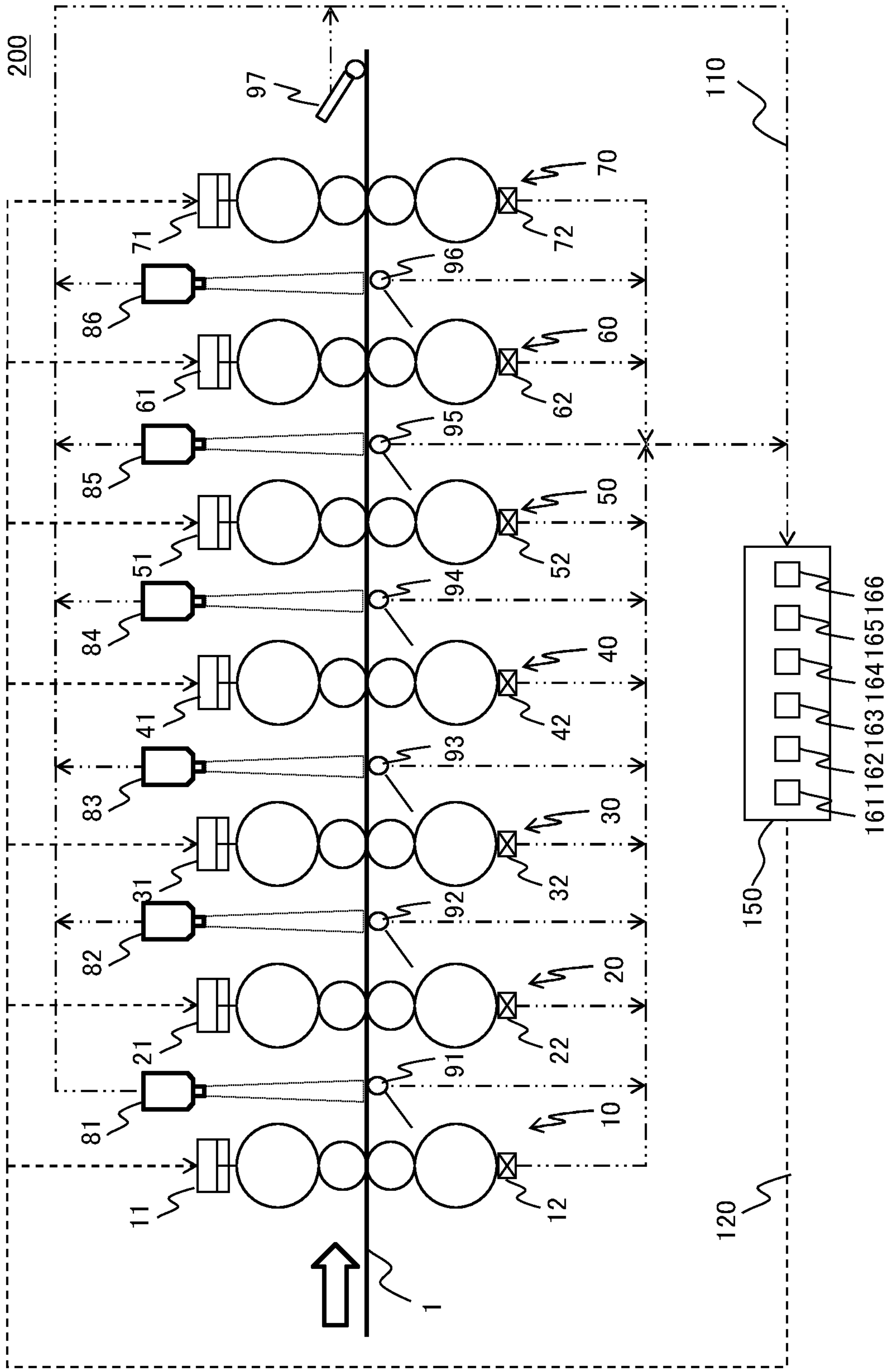
7. A rolling facility comprising:

a leveling control apparatus according to any one of claims 1 through 6;
a plurality of rolling mill stands for rolling a steel strip; and
shapemeters disposed between the plurality of rolling mill stands.

8. A leveling control method for a hot rolling line that includes a plurality of arrayed rolling mill stands, the leveling control method comprising:

a torque acquiring step that calculates a torque distribution applied in a widthwise direction of a steel strip between each adjacent ones of the plurality of rolling mill stands from a torque measured by each of shapemeters disposed between the plurality of rolling mill stands;
a primary component computing step that calculates a tension distribution in the widthwise direction from the calculated torque distribution and that calculates a primary component in a case where a tension distribution of the steel strip is represented by a polynomial from the tension distribution;
a leveling correction amount computing step that calculates a leveling correction amount for a rolling mill stand immediately preceding on a rolling upstream side among the plurality of rolling mill stands, on a basis of the calculated primary component; and
a leveling amount changing step that changes a leveling amount in order toward a rolling upstream side from a (last - 1)th rolling mill stand among the plurality of rolling mill stands on a basis of the calculated leveling correction amount.

Fig. 1


200
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166

Fig. 2

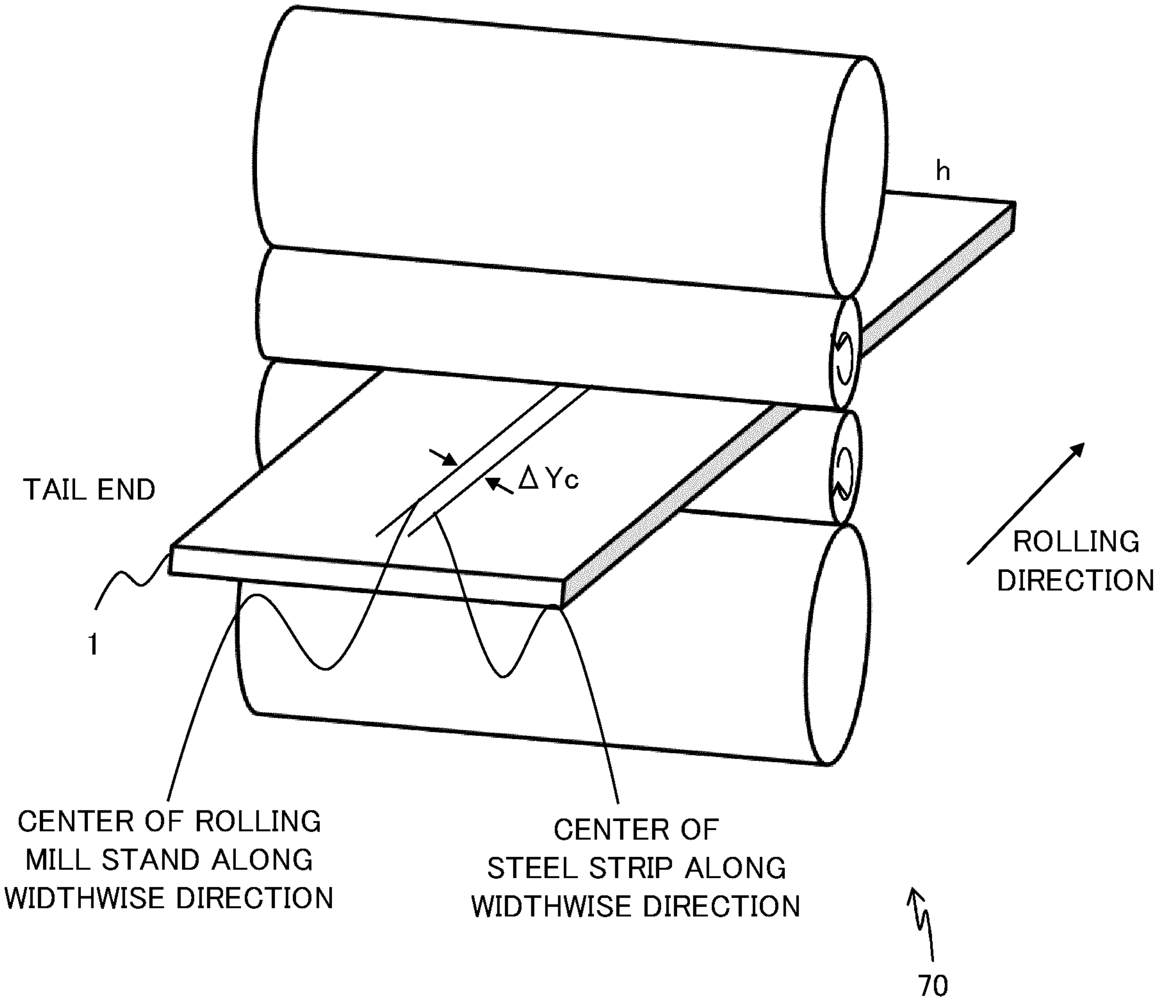

h
TAIL END
ΔYc
ROLLING
DIRECTION
1
CENTER OF ROLLING
MILL STAND ALONG
WIDTHWISE DIRECTION
CENTER OF
STEEL STRIP ALONG
WIDTHWISE DIRECTION
70

Fig. 3

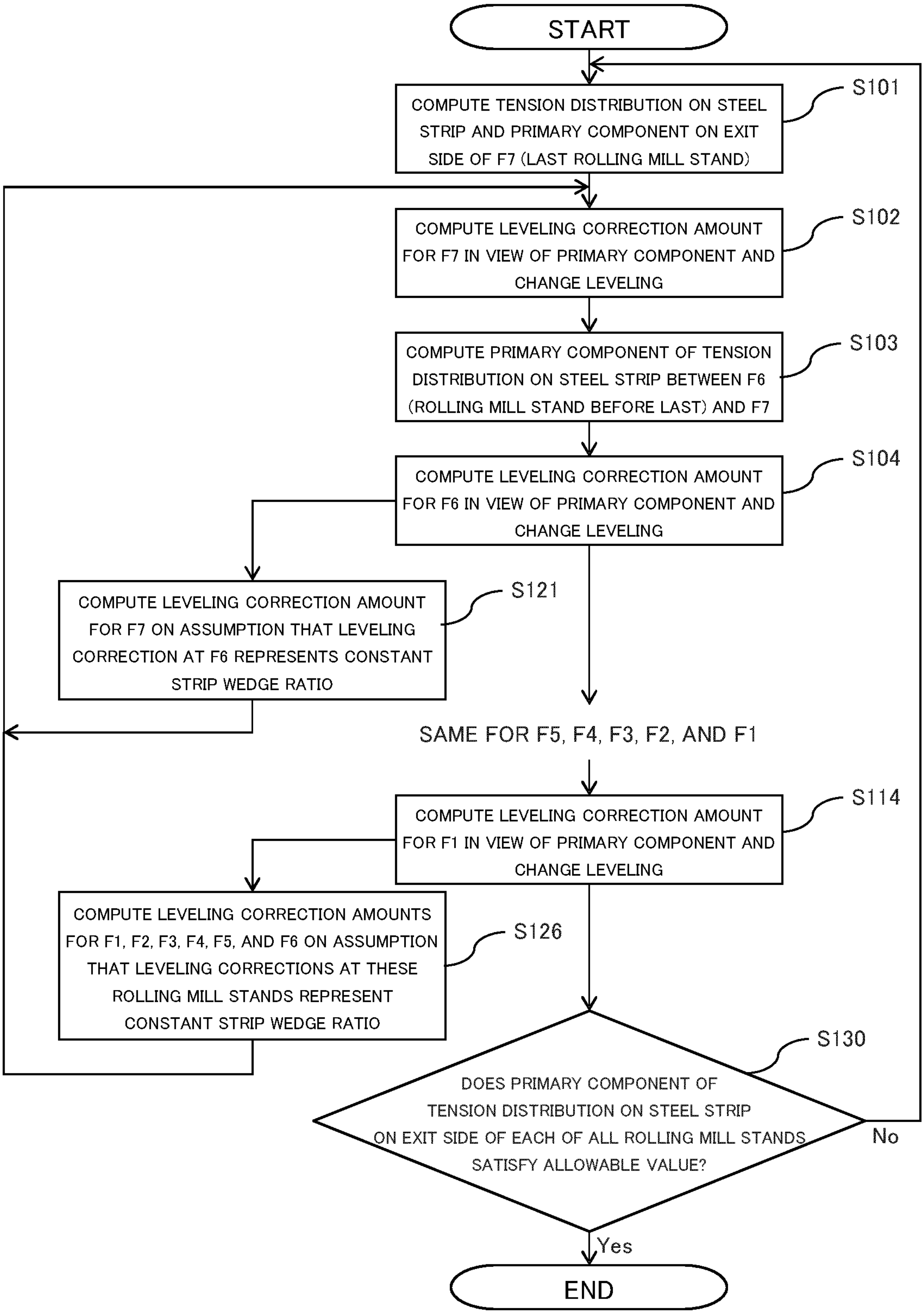
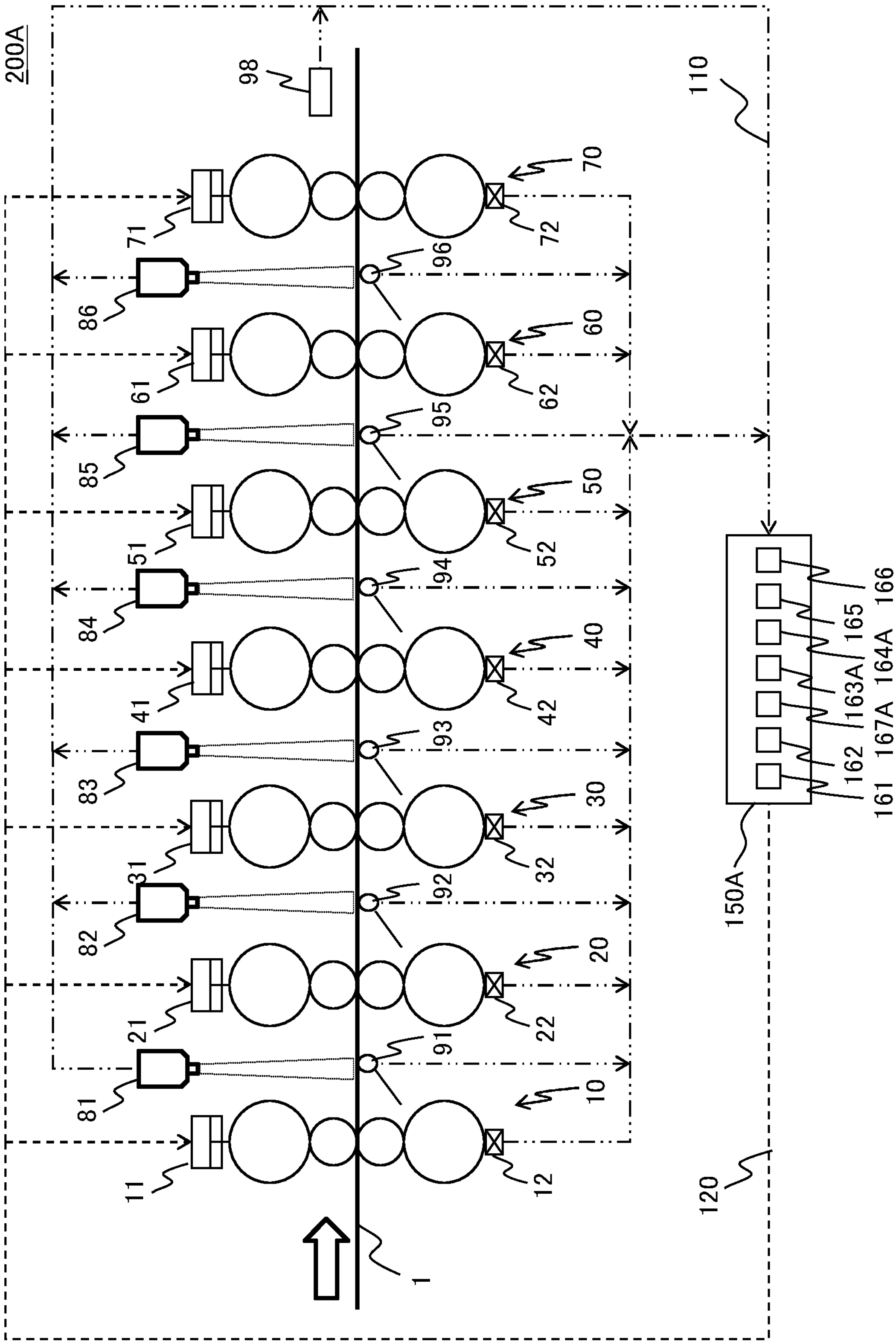

START
COMPUTE TENSION DISTRIBUTION ON STEEL STRIP AND PRIMARY COMPONENT ON EXIT SIDE OF F7 (LAST ROLLING MILL STAND)
S101
COMPUTE LEVELING CORRECTION AMOUNT FOR F7 IN VIEW OF PRIMARY COMPONENT AND CHANGE LEVELING
S102
COMPUTE PRIMARY COMPONENT OF TENSION DISTRIBUTION ON STEEL STRIP BETWEEN F6 (ROLLING MILL STAND BEFORE LAST) AND F7
S103
COMPUTE LEVELING CORRECTION AMOUNT FOR F6 IN VIEW OF PRIMARY COMPONENT AND CHANGE LEVELING
S104
COMPUTE LEVELING CORRECTION AMOUNT FOR F7 ON ASSUMPTION THAT LEVELING CORRECTION AT F6 REPRESENTS CONSTANT STRIP WEDGE RATIO
S121
SAME FOR F5, F4, F3, F2, AND F1
COMPUTE LEVELING CORRECTION AMOUNT FOR F1 IN VIEW OF PRIMARY COMPONENT AND CHANGE LEVELING
S114
COMPUTE LEVELING CORRECTION AMOUNTS FOR F1, F2, F3, F4, F5, AND F6 ON ASSUMPTION THAT LEVELING CORRECTIONS AT THESE ROLLING MILL STANDS REPRESENT CONSTANT STRIP WEDGE RATIO
S126
DOES PRIMARY COMPONENT OF TENSION DISTRIBUTION ON STEEL STRIP ON EXIT SIDE OF EACH OF ALL ROLLING MILL STANDS SATISFY ALLOWABLE VALUE?
S130
No
Yes
END

Fig. 4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150A
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167A
163A
164A
165
166

Fig. 5

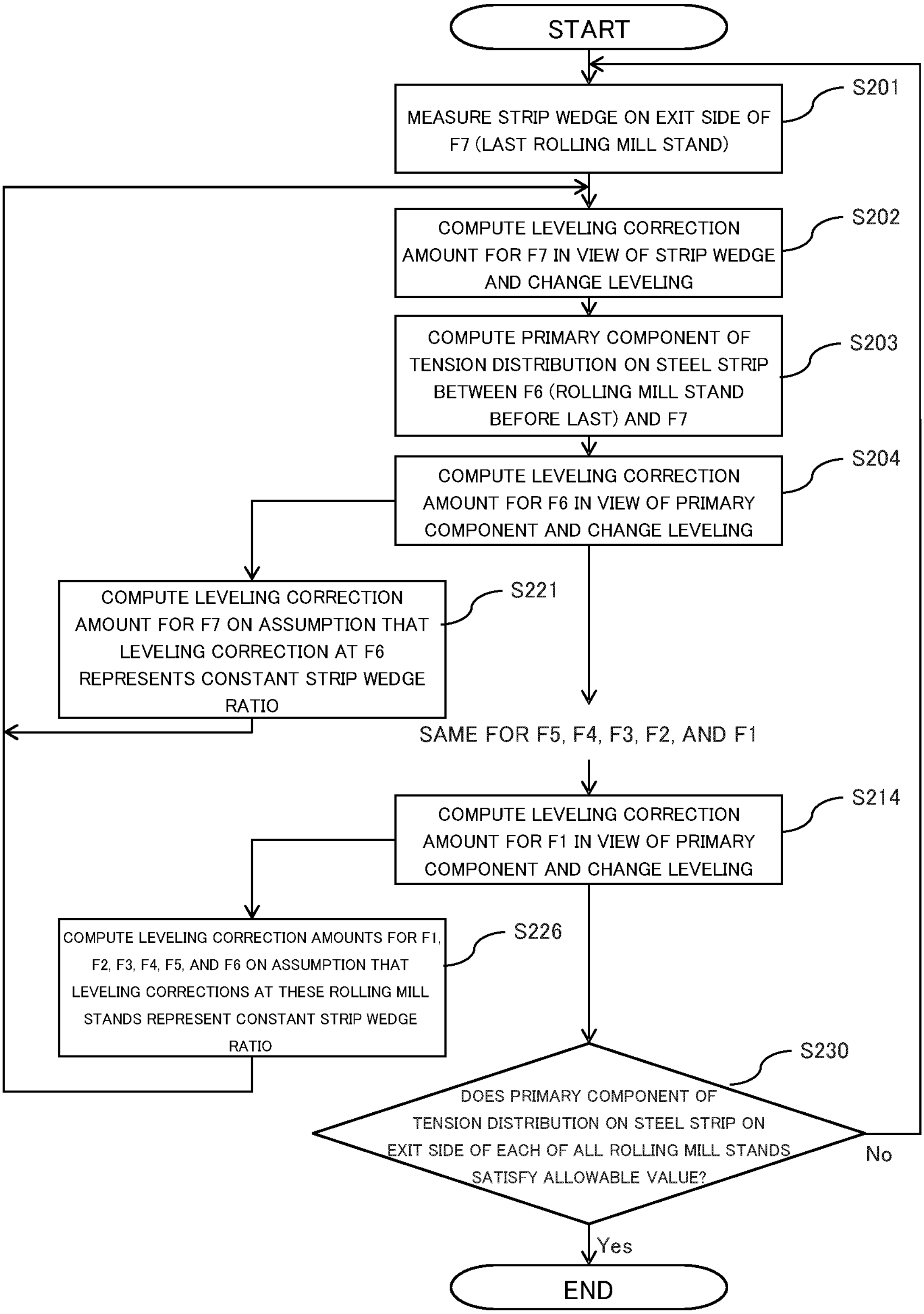
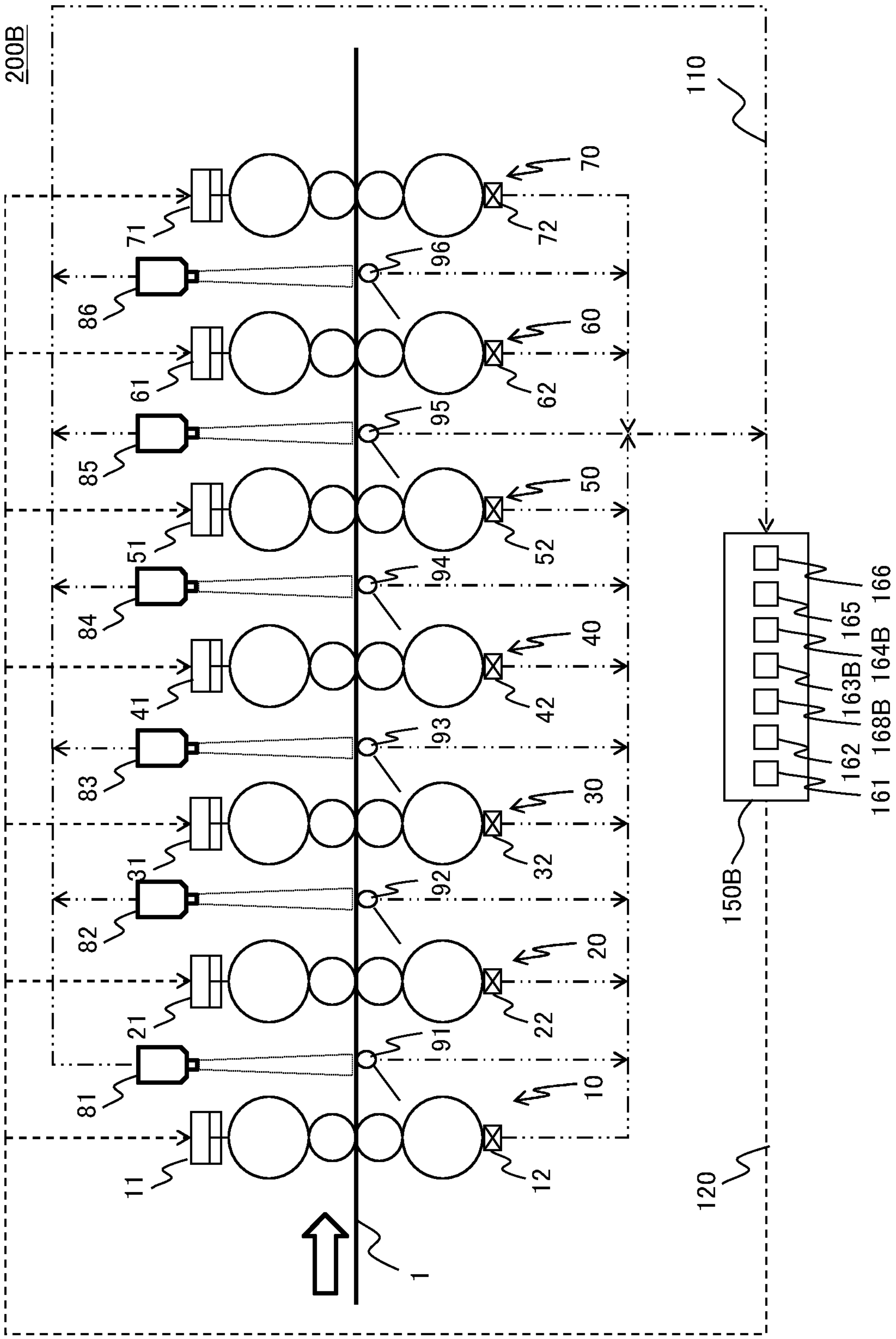

START
MEASURE STRIP WEDGE ON EXIT SIDE OF F7 (LAST ROLLING MILL STAND)
S201
COMPUTE LEVELING CORRECTION AMOUNT FOR F7 IN VIEW OF STRIP WEDGE AND CHANGE LEVELING
S202
COMPUTE PRIMARY COMPONENT OF TENSION DISTRIBUTION ON STEEL STRIP BETWEEN F6 (ROLLING MILL STAND BEFORE LAST) AND F7
S203
COMPUTE LEVELING CORRECTION AMOUNT FOR F6 IN VIEW OF PRIMARY COMPONENT AND CHANGE LEVELING
S204
COMPUTE LEVELING CORRECTION AMOUNT FOR F7 ON ASSUMPTION THAT LEVELING CORRECTION AT F6 REPRESENTS CONSTANT STRIP WEDGE RATIO
S221
SAME FOR F5, F4, F3, F2, AND F1
COMPUTE LEVELING CORRECTION AMOUNT FOR F1 IN VIEW OF PRIMARY COMPONENT AND CHANGE LEVELING
S214
COMPUTE LEVELING CORRECTION AMOUNTS FOR F1, F2, F3, F4, F5, AND F6 ON ASSUMPTION THAT LEVELING CORRECTIONS AT THESE ROLLING MILL STANDS REPRESENT CONSTANT STRIP WEDGE RATIO
S226
DOES PRIMARY COMPONENT OF TENSION DISTRIBUTION ON STEEL STRIP ON EXIT SIDE OF EACH OF ALL ROLLING MILL STANDS SATISFY ALLOWABLE VALUE?
S230
No
Yes
END

Fig. 6


200B
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72
81
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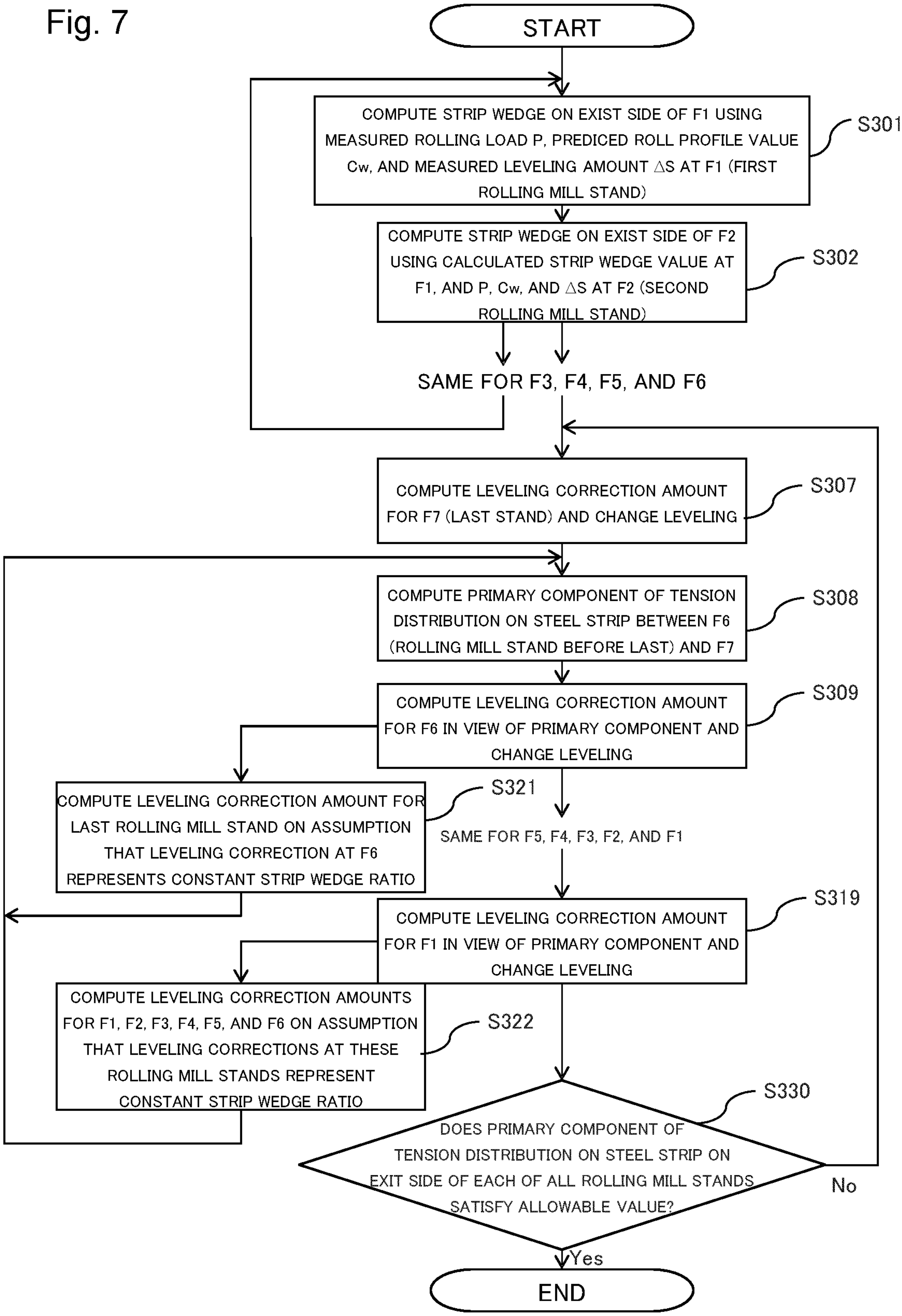
150B
161
162
168B
163B
164B
165
166

Fig. 7


START
COMPUTE STRIP WEDGE ON EXIST SIDE OF F1 USING MEASURED ROLLING LOAD P, PREDICED ROLL PROFILE VALUE Cw, AND MEASURED LEVELING AMOUNT ΔS AT F1 (FIRST ROLLING MILL STAND)
S301
COMPUTE STRIP WEDGE ON EXIST SIDE OF F2 USING CALCULATED STRIP WEDGE VALUE AT F1, AND P, Cw, AND ΔS AT F2 (SECOND ROLLING MILL STAND)
S302
SAME FOR F3, F4, F5, AND F6
COMPUTE LEVELING CORRECTION AMOUNT FOR F7 (LAST STAND) AND CHANGE LEVELING
S307
COMPUTE PRIMARY COMPONENT OF TENSION DISTRIBUTION ON STEEL STRIP BETWEEN F6 (ROLLING MILL STAND BEFORE LAST) AND F7
S308
COMPUTE LEVELING CORRECTION AMOUNT FOR F6 IN VIEW OF PRIMARY COMPONENT AND CHANGE LEVELING
S309
COMPUTE LEVELING CORRECTION AMOUNT FOR LAST ROLLING MILL STAND ON ASSUMPTION THAT LEVELING CORRECTION AT F6 REPRESENTS CONSTANT STRIP WEDGE RATIO
S321
SAME FOR F5, F4, F3, F2, AND F1
COMPUTE LEVELING CORRECTION AMOUNT FOR F1 IN VIEW OF PRIMARY COMPONENT AND CHANGE LEVELING
S319
COMPUTE LEVELING CORRECTION AMOUNTS FOR F1, F2, F3, F4, F5, AND F6 ON ASSUMPTION THAT LEVELING CORRECTIONS AT THESE ROLLING MILL STANDS REPRESENT CONSTANT STRIP WEDGE RATIO
S322
DOES PRIMARY COMPONENT OF TENSION DISTRIBUTION ON STEEL STRIP ON EXIT SIDE OF EACH OF ALL ROLLING MILL STANDS SATISFY ALLOWABLE VALUE?
S330
No
Yes
END

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/032839

A. CLASSIFICATION OF SUBJECT MATTER

B21B 37/58(2006.01)i
FI: B21B37/58 B

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B21B37/58

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 1971-2021
Registered utility model specifications of Japan 1996-2021
Published registered utility model applications of Japan 1994-2021

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2012/086043 A1 (MITSUBISHI-HITACHI METALS MACHINERY INC.) 28 June 2012 (2012-06-28) entire text, all drawings	1-8
A	JP 63-029605 B2 (HITACHI, LTD.) 14 June 1988 (1988-06-14) entire text, all drawings	1-8
A	JP 11-033615 A (NKK CORP.) 09 February 1999 (1999-02-09) entire text, all drawings	1-8

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
16 November 2021	**22 November 2021**

Name and mailing address of the ISA/JP	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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