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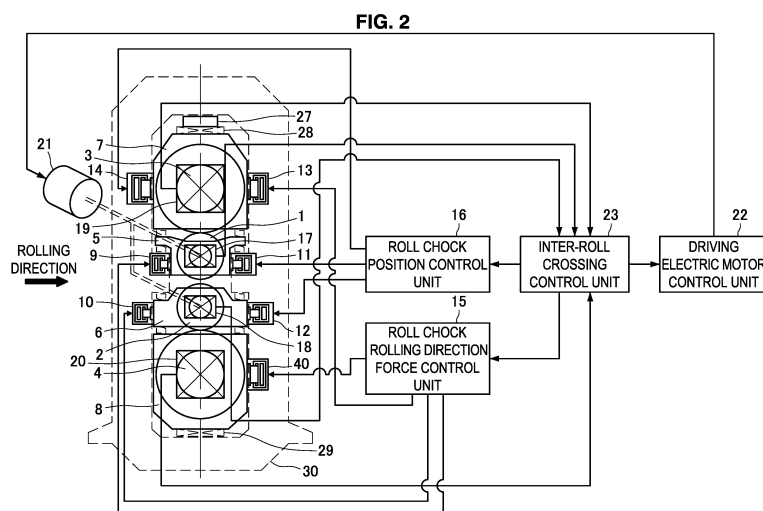
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(54) **ROLLING MILL AND METHOD FOR SETTING ROLLING MILL**

(57) A method for setting a rolling mill is provided, in which the rolling mill is a rolling mill of four-high or more that includes a plurality of rolls including at least a pair of work rolls and a pair of backup rolls that support the work rolls, wherein, before zero point of reduction position adjustment or before starting rolling, any one roll among respective rolls arranged in a vertical direction is taken as a reference roll, the method comprising: a thrust counterforce measurement step of measuring thrust

counterforces in the axial direction of rolls which act on at least the rolls other than the backup rolls; and a roll chock position adjustment step of fixing a rolling direction position of a roll chock of the reference roll as a reference position, and moving roll chocks of the rolls other than the reference roll in a rolling direction of a workpiece to adjust positions of the roll chocks so that the thrust counterforces measured fall within an allowable range.



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a rolling mill that rolls a workpiece, and a method for setting the rolling mill.

BACKGROUND ART

10 **[0002]** An example of a phenomenon that causes troubles of threading in a hot rolling process is zigzagging (lateral traveling) of a steel plate. One of causes of a steel plate zigzagging is a thrust force generated at an inter-roll minute cross (also referred to as roll skew) of a rolling mill, but a thrust force is difficult to measure directly. Hence, it conventionally has been proposed that zigzagging of a steel plate could be controlled on the basis of measuring a thrust counterforce detected as a counterforce of the sum of thrust forces generated between rolls or measuring the roll skew angle that causes a thrust force to be generated.

15 **[0003]** For example, Patent Document 1 discloses a flat rolling method that measures a thrust counterforce force in an axial direction of rolls and a load in a vertical direction, obtains either one or both of a zero point of reduction position and deformation characteristics of a rolling mill, and sets a reduction position in rolling execution to control rolling. In addition, Patent Document 2 discloses a zigzagging control method that calculates a thrust force generated on a roll on the basis of an inter-roll minute cross angle (skew angle) measured using a distance sensor provided inside a rolling mill, calculates a differential load component due to zigzagging from a load measurement value in the vertical direction on the basis of the thrust force, and controls reduction leveling.

20 **[0004]** In addition, Patent Document 3 discloses a cross-point correcting device which corrects a deviation in a point (cross point) at which the central axes of upper and lower rolls cross in the horizontal direction in a pair cross rolling mill. The apparatus includes an actuator that absorbs play that arises between a crosshead and roll chocks, and a detector that detects roll chock positions, and corrects a deviation in the cross point based on the roll chock positions.

25 **[0005]** Further, Patent Document 4 discloses a rolling mill control method that, in detecting a load difference between the driving side and the operator side, and independently operating reduction positions on the driving side and the operator side on the basis of the detected load difference to control zigzagging of a rolled material, estimates a differential load due to thrust during rolling, thereby separating a differential load during rolling into that caused by zigzagging of the rolled material and that caused by thrust, and operates reduction positions on the driving side and the operator side on the basis of these separated differential loads.

LIST OF PRIOR ART DOCUMENTS

35 PATENT DOCUMENT

[0006]

Patent Document 1: JP3499107B

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Patent Document 2: JP2014-4599A

Patent Document 3: JP8-294713A

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Patent Document 4: JP4962334B

SUMMARY OF INVENTION

TECHNICAL PROBLEM

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[0007] However, according to the technique disclosed in Patent Document 1, it is necessary to measure the thrust counterforce of rolls other than a backup roll both at a time of zero point of reduction position adjustment and during rolling. However, in the case of measuring thrust counterforce during rolling, changes in the rolling conditions such as the rolling load may in some cases cause changes in characteristics such as the working point of the thrust counterforce, and asymmetric deformation that accompanies the thrust force cannot be correctly identified. Therefore, there is the possibility that reduction leveling control cannot be accurately performed.

55 **[0008]** Further, according to the technique disclosed in Patent Document 2, a roll skew angle is determined based on a distance in the horizontal direction of a roll measured by a distance sensor such as a vortex sensor. However, because

a roll vibrates in the horizontal direction depending on the degree of machining precision such as the eccentricity or cylindricity of a roll body length portion, and chock positions in the horizontal direction fluctuate due to impact at the time of biting at the start of rolling and the like, it is difficult to accurately measure the horizontal displacement of a roll, which may be a cause of a thrust force. Furthermore, the coefficient of friction of a roll changes from one minute to the next because the degree of roughness of a roll changes with time as the number of rolled workpieces increases. Therefore, calculation of a thrust force without identification of the coefficient of friction cannot be performed accurately based on only a roll skew angle measurement.

[0009] In addition, according to the technique disclosed in Patent Document 3, an inter-roll cross angle arises due to relative crossing between rolls, and since there is also looseness in roll bearings and the like, even if position control of each roll chock position is individually performed in the rolling direction, deviations in the relative positional relation between the rolls themselves are not eliminated. Consequently, thrust forces generated due to inter-roll cross angles cannot be eliminated.

[0010] Further, according to the technique disclosed in Patent Document 4, prior to rolling, a bending force is imparted in a state in which upper and lower rolls do not contact each other while the rolls are driven, and a differential load to be caused by thrust is estimated based on a thrust factor or a skew amount determined based on a load difference between the drive side and the work side that arises at such time. According to Patent Document 4, the thrust factor or the skew amount is identified based on only measurement values of one of the upper and lower rolls that is rotating. Therefore, in a case where there is a deviation in a zero point at a load detection apparatus or in a case where the influence of frictional resistance between the housing and roll chocks differs between left and right, there is a possibility that a left-right asymmetry error may arise between a measurement value on the drive side and a measurement value on the work side. In particular, in a case where the load level is small, such as in the case of a bending force load, the error in question can become a critical error with respect to identification of a thrust factor or a skew amount. Further, according to the technique of Patent Document 4, a thrust factor or a skew amount cannot be identified unless a coefficient of friction between rolls is applied.

[0011] In addition, according to Patent Document 4, it is assumed that a thrust counterforce of a backup roll acts at the center position of the roll axis, and a change in the position of the working point of the thrust counterforce is not taken into consideration. Usually, because the chocks of a backup roll are supported by a pressing-down device or the like, the position of the working point of a thrust counterforce is not always located at the center of the roll axis. Consequently, an error occurs in an inter-roll thrust force that is determined based on a load difference between a vertical roll load on the drive side and a vertical roll load on the work side, and an error also occurs in a thrust factor or a skew amount that is calculated based on the inter-roll thrust force.

[0012] An objective of the present invention, which has been made in view of the problems described above, is to provide a novel and improved rolling mill that is capable of reducing thrust forces generated between rolls and suppressing the occurrence of zigzagging and camber of a workpiece, as well as a method for setting a rolling mill.

SOLUTION TO PROBLEM

[0013] To solve the problems described above, according to one aspect of the present invention there is provided a method for setting a rolling mill, the rolling mill being a rolling mill of four-high or more that includes a plurality of rolls including at least a pair of work rolls and a pair of backup rolls which support the work rolls, wherein, before zero point of reduction position adjustment or before starting rolling, any one roll among respective rolls arranged in a vertical direction is taken as a reference roll, the method including: a thrust counterforce measurement step of measuring thrust counterforces in an axial direction of rolls which act on at least the rolls other than the backup rolls; and a roll chock position adjustment step of fixing a rolling direction position of a roll chock of the reference roll as a reference position, and moving roll chocks of the rolls other than the reference roll in a rolling direction of a workpiece to adjust positions of the roll chocks so that the thrust counterforces measured fall within an allowable range.

[0014] In this case, a roll located at a lowermost part or an uppermost part in the vertical direction among the plurality of rolls may be taken as the reference roll.

[0015] In the roll chock position adjustment step, operations may be performed so that the work rolls are set in a kiss roll state, and in order from a roll on an opposite side to the reference roll, the roll chocks of the roll that is a position adjustment object are moved in the rolling direction of the workpiece to adjust the position of the roll chocks so that a thrust counterforce generated between the rolls that are adjacent falls within an allowable range, and at such time, the roll chocks of the rolls for which the position of the roll chocks is already adjusted are controlled simultaneously and in a same direction while maintaining a relative position with respect to the roll chocks of the roll that is the position adjustment object.

[0016] Further, in the roll chock position adjustment step, operations may be performed so that the work rolls are set in a kiss roll state, and in order from the reference roll side, the roll chocks of the roll that is a position adjustment object are moved in the rolling direction of the workpiece to adjust the position of the roll chocks so that a thrust counterforce

generated between the rolls that are adjacent falls within an allowable range, and at such time, the roll chocks of the rolls for which the position of the roll chocks is not adjusted are controlled simultaneously and in a same direction while maintaining a relative position with respect to the roll chocks of the roll that is the position adjustment object.

[0017] Further, in a four-high rolling mill, a configuration may be adopted so that, when a plurality of rolls provided on an upper side in the vertical direction with respect to the workpiece are taken as an upper roll assembly and a plurality of rolls provided on a lower side in the vertical direction with respect to the workpiece are taken as a lower roll assembly, in the roll chock position adjustment step, the followings are performed: a first adjustment in which a roll gap between the work rolls is placed in an open state, and with respect to each of the upper roll assembly and the lower roll assembly, positions of the roll chocks of the work roll and the roll chocks of the backup roll are adjusted, and after the first adjustment ends, a second adjustment in which the work rolls are set in a kiss roll state, and either one of the upper roll assembly and the lower roll assembly is taken as a reference roll assembly, and positions of the roll chocks of each roll of the other roll assembly are adjusted by controlling the roll chocks simultaneously and in a same direction while maintaining relative positions of the roll chocks; and in the first adjustment, with respect to each of the upper roll assembly and the lower roll assembly, in a state in which a bending force is applied by a bending apparatus to the roll chocks of the work rolls, the roll chocks of the work roll on the reference roll side and either one of the roll chocks of the work roll and the roll chocks of the backup roll of a roll assembly on an opposite side to the reference roll are moved in a rolling direction of the workpiece to adjust positions of the roll chocks so that the thrust counterforce measured falls within an allowable range.

[0018] Alternatively, the rolling mill may be a six-stage rolling mill that includes an intermediate roll between the work rolls and the backup rolls, respectively, a configuration may be adopted so that, when a plurality of rolls provided on an upper side in the vertical direction with respect to the workpiece are taken as an upper roll assembly and a plurality of rolls provided on a lower side in the vertical direction with respect to the workpiece are taken as a lower roll assembly, in the roll chock position adjustment step, the followings are performed: a first adjustment in which a roll gap between the work rolls is placed in an open state, and with respect to each of the upper roll assembly and the lower roll assembly, positions of the roll chocks of the intermediate roll and the roll chocks of the backup roll are adjusted; after the first adjustment ends, a second adjustment in which the roll gap between the work rolls is maintained in an open state, and with respect to each of the upper roll assembly and the lower roll assembly, positions of the roll chocks of the intermediate roll and the roll chocks of the work roll are adjusted; and after the second adjustment ends, a third adjustment in which the work rolls are set in a kiss roll state, either one of the upper roll assembly and the lower roll assembly is taken as a reference roll assembly, and positions of the roll chocks of each roll of the other roll assembly are adjusted by controlling the roll chocks simultaneously and in a same direction while maintaining relative positions of the roll chocks; wherein: the first adjustment and the second adjustment are performed in a state in which a bending force is applied by a bending apparatus to the roll chocks of the intermediate rolls and the roll chocks of the work rolls; in the first adjustment, with respect to each of the upper roll assembly and the lower roll assembly, the roll chocks of the intermediate roll on the reference roll side and either one of the roll chocks of the intermediate roll and the roll chocks of the backup roll of a roll assembly on an opposite side to the reference roll are moved in the rolling direction of the workpiece to adjust positions of the roll chocks so that the thrust counterforce measured falls within an allowable range; and in the second adjustment, with respect to each of the upper roll assembly and the lower roll assembly, the roll chocks of the work roll on the reference roll side and either one of the roll chocks of the intermediate roll and the roll chocks of the work roll of the roll assembly on the opposite side to the reference roll are moved in the rolling direction of the workpiece to adjust positions of the roll chocks so that the thrust counterforce measured falls within an allowable range, and in a case of moving the roll chocks of the intermediate roll of the roll assembly on the opposite side to the reference roll, the roll chocks of the intermediate roll and the roll chocks of the backup roll that is adjacent to the intermediate roll are controlled simultaneously and in a same direction while maintaining relative positions between the roll chocks of the intermediate roll and the roll chocks of the backup roll.

[0019] Further, to solve the problem described above, according to a different aspect of the present invention there is provided a rolling mill of four-high or more that includes a plurality of rolls including at least a pair of work rolls and a pair of backup rolls which support the work rolls, the rolling mill comprising: with any one roll among respective rolls arranged in a vertical direction being taken as a reference roll, a measurement apparatus that measures at least thrust counterforces in an axial direction of rolls that act on each of the rolls other than the backup roll; a pressing apparatus provided on either one of an entrance side and an exit side in the rolling direction with respect to at least roll chocks of the rolls other than the reference roll, the pressing apparatus pressing a workpiece in the rolling direction; a driving apparatus provided so as to face the pressing apparatus in the rolling direction with respect to at least roll chocks of the rolls other than the reference roll, the driving apparatus moving a workpiece in the rolling direction; and a position control unit that fixes a rolling direction position of a roll chock of the reference roll as a reference position, and drives the driving apparatus to control positions in the rolling direction of the roll chocks of the rolls other than the reference roll so that thrust counterforces at each of the rolls become values that are within an allowable range.

[0020] In this case, a roll located at a lowermost part or an uppermost part in the vertical direction among the plurality

of rolls may be taken as the reference roll.

[0021] Further, the rolling mill may include a bending apparatus that imparts a bending force to the rolls; and the position control unit may place a roll gap between the roll that is taken as a position adjustment object and the roll that is other than a position adjustment object in an open state, and impart a bending force by means of the bending apparatus to the roll chocks of the roll that is the position adjustment object.

[0022] The driving apparatus may be a hydraulic cylinder that includes a roll chock position detection apparatus.

ADVANTAGEOUS EFFECTS OF INVENTION

[0023] As described above, according to the present invention it is possible to reduce thrust forces generated between rolls, and suppress the occurrence of zigzagging and camber of a workpiece.

BRIEF DESCRIPTION OF DRAWINGS

[0024]

[Figure 1] Figure 1 is a multiple view drawing including a schematic side view and a schematic front view of a rolling mill for describing a thrust force and a thrust counterforce which are generated between rolls of a rolling mill during rolling.

[Figure 2] Figure 2 is an explanatory drawing illustrating the configuration of a rolling mill according to a first embodiment of the present invention, and an apparatus for controlling the rolling mill.

[Figure 3A] Figure 3A is a flowchart describing a method for setting a rolling mill according to the first embodiment, which illustrates an example of a case of performing position adjustment from a roll on an opposite side to a reference roll.

[Figure 3B] Figure 3B is a flowchart describing the method for setting a rolling mill according to the first embodiment, which illustrates an example of a case of performing position adjustment from a roll on an opposite side to a reference roll.

[Figure 4] Figure 4 is an explanatory drawing showing procedures for roll position adjustment in the method for setting a rolling mill illustrated in Figure 3A and Figure 3B.

[Figure 5A] Figure 5A is a flowchart describing the method for setting a rolling mill according to the first embodiment, which illustrates an example of a case of performing position adjustment from a roll on a reference roll side.

[Figure 5B] Figure 5B is a flowchart describing the method for setting a rolling mill according to the first embodiment, which illustrates an example of a case of performing position adjustment from a roll on a reference roll side.

[Figure 6] Figure 6 is an explanatory drawing showing procedures for roll position adjustment in the method for setting a rolling mill illustrated in Figure 5A and Figure 5B.

[Figure 7] Figure 7 is an explanatory drawing illustrating the configuration of a rolling mill according to a second embodiment of the present invention, and an apparatus for controlling the rolling mill.

[Figure 8A] Figure 8A is a flowchart describing the method for setting a rolling mill according to the second embodiment.

[Figure 8B] Figure 8B is a flowchart describing the method for setting a rolling mill according to the second embodiment.

[Figure 9] Figure 9 is an explanatory drawing showing procedures for roll position adjustment in the method for setting a rolling mill illustrated in Figure 8A and Figure 8B.

[Figure 10] Figure 10 is an explanatory drawing illustrating the arrangement of work rolls and backup rolls of a rolling mill in which a roll gap is in an open state.

[Figure 11] Figure 11 is an explanatory drawing showing the definition of an inter-roll cross angle.

[Figure 12] Figure 12 is a graph showing a relation between a backup roll cross angle and a backup roll thrust counterforce, a work roll thrust counterforce and a differential load of a vertical roll load, in a state in which a roll gap is open.

[Figure 13] Figure 13 is an explanatory drawing illustrating the arrangement of work rolls and backup rolls of a rolling mill set in a kiss roll state, that shows a state without pair cross.

[Figure 14] Figure 14 is a graph showing a relation between a backup roll cross angle and a backup roll thrust counterforce and work roll thrust counterforce in the kiss roll state illustrated in Figure 13.

[Figure 15] Figure 15 is an explanatory drawing illustrating the arrangement of work rolls and backup rolls of a rolling mill set in a kiss roll state, that shows a state with pair cross.

[Figure 16] Figure 16 is a graph illustrating a relation between a pair cross angle between a work roll and a backup roll, and a backup roll thrust counterforce and work roll thrust counterforce in the kiss roll state illustrated in Figure 15.

[Figure 17] Figure 17 is an explanatory drawing illustrating an example of applying a servo-motor with a rotation

angle detection function instead of a hydraulic cylinder equipped with a roll chock position detection apparatus.

[Figure 18] Figure 18 is an explanatory drawing illustrating procedures for roll position adjustment in a case where the method for setting a rolling mill illustrated in Figure 4 is applied to a six-high rolling mill.

[Figure 19] Figure 19 is an explanatory drawing illustrating procedures for roll position adjustment in a case where the method for setting a rolling mill illustrated in Figure 6 is applied to a six-high rolling mill.

[Figure 20] Figure 20 is an explanatory drawing illustrating procedures for roll position adjustment in a case where the method for setting a rolling mill illustrated in Figure 9 is applied to a six-high rolling mill.

[Figure 21] Figure 21 is a block diagram illustrating one example of the hardware configuration of an information processing apparatus that functions as an apparatus for controlling the rolling mills of each embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0025] Hereunder, preferred embodiments of the present invention are described in detail while referring to the accompanying drawings. Note that, in the present specification and the accompanying drawings, constituent elements having substantially the same functional configuration are denoted by the same reference characters and a redundant description thereof is omitted.

<1. Objective>

[0026] An objective of the rolling mill as well as a method for setting the rolling mill according to the embodiments of the present invention is to eliminate thrust forces generated between rolls, and stably produce products without zigzagging and camber or with extremely little zigzagging and camber. In Figure 1, a schematic side view and a schematic front view of a rolling mill are illustrated for describing a thrust force and a thrust counterforce which are generated between rolls of a rolling mill during rolling of a workpiece S. Hereunder, as illustrated in Figure 1, the work side in the axial direction of rolls is represented by "WS", and the drive side is represented by "DS".

[0027] The rolling mill illustrated in Figure 1 has a pair of work rolls consisting of an upper work roll 1 and a lower work roll 2, and a pair of backup rolls consisting of an upper backup roll 3 that supports the upper work roll 1 in the vertical direction (Z direction) and a lower backup roll 4 that supports the lower work roll 2 in the vertical direction. The plate thickness of the workpiece S is made a predetermined thickness by passing the workpiece S between the work rolls to perform rolling of the workpiece S.

[0028] In the rolling mill, upper load detection apparatuses 28a, 28b which detect a vertical roll load relating to an upper roll assembly that includes the upper work roll 1 and the upper backup roll 3 which are arranged on the top surface side of the workpiece S, and lower load detection apparatuses 29a, 29b which detect a vertical roll load relating to a lower roll assembly that includes the lower work roll 2 and the lower backup roll 4 which are arranged on the undersurface side of the workpiece S are provided in the vertical direction (Z direction). The upper load detection apparatus 28a and the lower load detection apparatus 29a detect a vertical roll load on the work side, and the upper load detection apparatus 28b and the lower load detection apparatus 29b detect a vertical roll load on the drive side. Note that the term "roll assembly" as used in the terms upper roll assembly and lower roll assembly means a roll group that includes a plurality of rolls.

[0029] The upper work roll 1, the lower work roll 2, the upper backup roll 3 and the lower backup roll 4 are arranged in a manner in which the barrel length directions of the respective roll are parallel, so as to be orthogonal with the conveyance direction of the workpiece S. However, if a roll rotates slightly about an axis (Z-axis) that is parallel with the vertical direction and a deviation arises between the barrel length directions of the upper work roll 1 and the upper backup roll 3, or a deviation arises between the barrel length directions of the lower work roll 2 and the lower backup roll 4, a thrust force that acts in the barrel length direction of the rolls arises between the work roll and the backup roll. An inter-roll thrust force gives an extra moment to the rolls and is a factor that causes the rolling to enter an unstable state due to asymmetric roll deformation, and for example gives rise to zigzagging or camber.

[0030] The inter-roll thrust force is generated as a result of a deviation arising between the axial direction of rolls of a work roll and a backup roll, and an inter-roll cross angle arising. For example, let us assume that an inter-roll cross angle arises between the lower work roll 2 and the lower backup roll 4. At such time, a thrust force is generated between the lower work roll 2 and the lower backup roll 4. Thrust forces of slight amounts arise between the workpiece S and the lower work roll, and a thrust counterforce acts on lower work roll chocks 6 as a reaction force that is the resultant force of the thrust forces. As a result, a moment occurs at the lower backup roll 4, and the load distribution among the rolls changes to balance with the moment, and thus an asymmetric roll deformation occurs. Zigzagging or camber or the like is caused by the asymmetric roll deformation, and the rolling becomes unstable.

[0031] As described above, an objective of the present invention is, during rolling of a workpiece by a rolling mill, to adjust the roll chock positions of each roll so that inter-roll thrust forces generated between rolls are eliminated, and

thereby stably produce products without zigzagging and camber or with extremely little zigzagging and camber.

<2. First Embodiment>

[0032] The configuration of a rolling mill according to a first embodiment of the present invention and an apparatus for controlling the rolling mill, as well as a method for setting a rolling mill will be described based on Figure 2 to Figure 6. In the method for setting a rolling mill according to the first embodiment, before zero point of reduction position adjustment or before the start of rolling, adjustment is performed so that an inter-roll cross angle between a roll that is to serve as a reference and other rolls is zero, and rolling in which thrust forces do not arise is realized.

[2-1. Configuration of rolling mill]

[0033] First, the rolling mill according to the present embodiment and an apparatus for controlling the rolling mill will be described based on Figure 2. Figure 2 is an explanatory drawing illustrating the configuration of the rolling mill according to the present embodiment and an apparatus for controlling the rolling mill. Note that, it is assumed that the rolling mill illustrated in Figure 2 is shown in a state as seen from the work side in the axial direction of rolls. Further, in Figure 2, a configuration in a case when a lower backup roll is taken as the reference roll is illustrated. Note that, the reference roll is preferably a roll in which the area of contact between the chocks and the housing is large, and which is located at the lowermost part or the uppermost part at which the position is stable.

[0034] The rolling mill illustrated in Figure 2 is a four-high rolling mill having a pair of work rolls 1, 2 and a pair of backup rolls 3, 4 that support the pair of work rolls 1, 2. The upper work roll 1 is supported by an upper work roll chock 5, and the lower work roll 2 is supported by a lower work roll chock 6. Note that the upper work roll chock 5 and the lower work roll chock 6 are similarly provided on the side facing away from the viewer (drive side) in Figure 2, and support the upper work roll 1 and the lower work roll 2, respectively. The upper work roll 1 and the lower work roll 2 are rotationally driven by a driving electric motor 21. Further, the upper backup roll 3 is supported by an upper backup roll chock 7, and the lower backup roll 4 is supported by a lower backup roll chock 8. The upper backup roll chock 7 and the lower backup roll chock 8 are also similarly provided on the side facing away from the viewer (drive side) in Figure 2, and support the upper backup roll 3 and the lower backup roll 4, respectively. The upper work roll chocks 5, the lower work roll chocks 6, the upper backup roll chocks 7 and the lower backup roll chocks 8 are retained by a housing 30.

[0035] The upper work roll chocks 5 are provided with an upper-work-roll-chock pressing apparatus 9 which is provided on the rolling-direction entrance side and which presses the upper work roll chocks 5 in the rolling direction, and a driving apparatus with upper work roll chock position detection function 11 which is provided on the rolling-direction exit side and which detects the position in the rolling direction and drives the upper work roll chocks 5 in the rolling direction. Further, an upper work roll thrust counterforce measurement apparatus 17 which measures a thrust counterforce that is applied to the upper work roll 1 is provided in the upper work roll 1.

[0036] Similarly, the lower work roll chocks 6 are provided with a lower-work-roll-chock pressing apparatus 10 which is provided on the rolling-direction entrance side and which presses the lower work roll chock 6 in the rolling direction, and a driving apparatus with lower work roll chock position detection function 12 which is provided on the rolling-direction exit side and which detects the position in the rolling direction and drives the lower work roll chocks 6 in the rolling direction. Further, a lower work roll thrust counterforce measurement apparatus 18 which measures a thrust counterforce that is applied to the lower work roll 2 is provided in the lower work roll 2.

[0037] For example, a hydraulic cylinder is used as the driving apparatus with upper work roll chock position detection function 11, the driving apparatus with lower work roll chock position detection function 12, a drive mechanism of the upper-work-roll-chock pressing apparatus 9 and a drive mechanism of the lower-work-roll-chock pressing apparatus 10. Note that although the driving apparatus with upper work roll chock position detection function 11, the driving apparatus with lower work roll chock position detection function 12, and the upper and lower work-roll-chock pressing apparatuses 9 and 10 are shown only on the work side in Figure 2, these apparatuses are also similarly provided on the side facing away from the viewer (drive side).

[0038] The upper backup roll chocks 7 are provided with an upper-backup-roll-chock pressing apparatus 13 which is provided on the rolling-direction exit side and which presses the upper backup roll chock 7 in the rolling direction, and a driving apparatus with upper backup roll chock position detection function 14 which is provided on the rolling-direction entrance side and which detects the position in the rolling direction and drives the upper backup roll chock 7 in the rolling direction. For example, a hydraulic cylinder is used as the driving apparatus with upper backup roll chock position detection function 14, and the drive mechanism of the upper-backup-roll-chock pressing apparatus 13. Further, an upper backup roll thrust counterforce measurement apparatus 19 which measures a thrust counterforce that is applied to the upper backup roll 3 is provided in the upper backup roll 3. Note that although the driving apparatus with upper backup roll chock position detection function 14 and the upper-backup-roll-chock pressing apparatus 13 are shown only on the work side in Figure 2, these apparatuses are also similarly provided on the side facing away from the viewer (drive side).

[0039] On the other hand, with respect to the lower backup roll chocks 8, since the lower backup roll 4 is taken as the reference roll in the present embodiment, the lower backup roll chocks 8 serve as reference roll chocks. Accordingly, since the lower backup roll chocks 8 are not driven to perform position adjustment, the lower backup roll chocks 8 do not necessarily need to have a driving apparatus and a position detecting apparatus as in the case of the upper backup roll chocks 7. However, as illustrated in Figure 2, for example, a lower-backup-roll-chock pressing apparatus 40 or the like may be provided on the entrance side or the exit side in the rolling direction. By this means, looseness of the lower backup roll chocks 8 can be suppressed so that the positions of the reference roll chocks that are taken as the reference for position adjustment do not change. Further, a lower backup roll thrust counterforce measurement apparatus 20 which measures a thrust counterforce that is applied to the lower backup roll 4 is provided in the lower backup roll 4. Note that although the lower-backup-roll-chock pressing apparatus 40 is shown only on the work side in Figure 2, this apparatus is also similarly provided on the side facing away from the viewer (drive side).

[0040] As apparatuses for controlling the rolling mill, for example, as illustrated in Figure 2, the configuration includes a roll chock rolling direction force control unit 15, a roll chock position control unit 16, a driving electric motor control unit 22 and an inter-roll crossing control unit 23.

[0041] The roll chock rolling direction force control unit 15 controls a pressing force in the rolling direction of the upper-work-roll-chock pressing apparatus 9, the lower-work-roll-chock pressing apparatus 10, the upper-backup-roll-chock pressing apparatus 13 and the lower-backup-roll-chock pressing apparatus 40. Based on a control instruction of the inter-roll crossing control unit 23 that is described later, the roll chock rolling direction force control unit 15 drives the upper-work-roll-chock pressing apparatus 9, the lower-work-roll-chock pressing apparatus 10 and the upper-backup-roll-chock pressing apparatus 13 that are control objects with respect to chock positions. By driving these roll chock pressing apparatuses to apply a predetermined pressing force to each roll chock, a state is entered in which it is possible to control the chock positions.

[0042] The roll chock position control unit 16 performs drive control of the driving apparatus with upper work roll chock position detection function 11, the driving apparatus with lower work roll chock position detection function 12 and the driving apparatus with upper backup roll chock position detection function 14. Based on a control instruction of the inter-roll crossing control unit 23, the roll chock position control unit 16 drives the driving apparatus with upper work roll chock position detection function 11, the driving apparatus with lower work roll chock position detection function 12 and the driving apparatus with upper backup roll chock position detection function 14 so that thrust counterforces between rolls fall within a predetermined range. The driving apparatuses with position detection functions 11, 12 and 14 are disposed on both the work side and the drive side. By controlling the driving apparatuses with position detection functions 11, 12 and 14 so that the positions in the rolling direction on the work side and the drive side of the upper work roll chocks 5, the lower work roll chocks 6 and the upper backup roll chocks 7 change by the same amount and in opposite directions between the work side and the drive side, only an inter-roll cross angle can be changed, without changing the average rolling direction position of the work side and the drive side.

[0043] The driving electric motor control unit 22 controls the driving electric motor 21 that rotationally drives the upper work roll 1 and the lower work roll 2. The driving electric motor control unit 22 according to the present embodiment controls driving of the upper work roll 1 or the lower work roll 2 based on an instruction from the inter-roll crossing control unit 23.

[0044] The inter-roll crossing control unit 23 controls the position of each of the upper work roll 1, the lower work roll 2, the upper backup roll 3 and the lower backup roll 4 constituting the rolling mill, so that an inter-roll cross angle is zero. Based on thrust counterforces measured by the upper work roll thrust counterforce measurement apparatus 17, the lower work roll thrust counterforce measurement apparatus 18, the upper backup roll thrust counterforce measurement apparatus 19 and the lower backup roll thrust counterforce measurement apparatus 20, the inter-roll crossing control unit 23 issues control instructions to the roll chock rolling direction force control unit 15, the roll chock position control unit 16 and the driving electric motor control unit 22 so that the thrust counterforces are not more than an allowable range. By this means, it is attempted to eliminate crossing that has occurred between rolls. Note that the details of the method for setting the rolling mill are described later.

[0045] Although an example has been described above in which, with respect to the work roll chocks 5, 6, the driving apparatuses with position detection function 11, 12 are arranged on the exit side and the pressing apparatuses 9, 10 are arranged on the entrance side of the rolling mill, and with respect to the backup roll chocks 7, the driving apparatuses with position detection function 14 are arranged on the entrance side and the pressing apparatus 13 is arranged on the exit side of the rolling mill, the present invention is not limited to this example. For example, the arrangement of these apparatuses with respect to the entrance side and the exit side of the rolling mill may be the reverse of the arrangement in the above example, or the pressing apparatuses 9, 10, 13 and the driving apparatuses with position detection functions 11, 12 and 14 may be installed on the same side with respect to the work rolls 1, 2 and the backup rolls 3, 4.

[0046] In addition, with regard to the driving apparatuses with position detection functions 11, 12 and 14, although an example has been described in which these apparatuses are provided on both the work side and the drive side and the respective apparatuses are subjected to position control, the present invention is not limited to this example. These

apparatuses may be provided on only one side among the work side and the drive side, or a configuration may be adopted so that only the apparatuses provided one side are actuated. In this case, it is possible to control an inter-roll cross angle by performing position control by taking the opposite side to the side on which the apparatuses are provided or to the side on which the apparatuses are actuated as the support point of rotation, and it is needless to say that the same effect of reducing inter-roll crossing is obtained.

[0047] Further, although an example has been described above in which all of the rolls are provided with a roll thrust counterforce measurement apparatus, the present invention is not limited to this example. For example, even in a case where only the upper work roll thrust counterforce measurement apparatus 17 and the lower work roll thrust counterforce measurement apparatus 18 are provided with a roll thrust counterforce measurement apparatus, or a case where the upper and lower work roll thrust counterforce measurement apparatuses 17 and 18 and also the upper backup roll thrust counterforce measurement apparatus 19 or the lower backup roll thrust counterforce measurement apparatus 20 are provided with a roll thrust counterforce measurement apparatus, it is possible to execute the method for setting a rolling mill, described later, in a similar manner. The procedures for executing the method in such a case are described later.

[0048] Furthermore, although an example has been described above in which all of the rolls except the reference roll are provided with a driving apparatus with a position detection function, the present invention is not limited to this example. For example, all of the rolls may be provided with a driving apparatus with a position detection function, and the reference roll may be changed according to the situation. In this case, the method for setting a rolling mill that is described later may be executed based on the changed reference roll.

[2-2. Method for setting rolling mill]

[0049] According to the method for setting a rolling mill of the present embodiment, before zero point of reduction position adjustment or before the start of rolling, any one roll among the respective rolls that are arranged in the vertical direction is taken as a reference roll, and firstly at least a thrust counterforce in the axial direction of rolls that acts on a roll other than a backup roll is measured. Further, the rolling direction position of the roll chocks of the reference roll is fixed as a reference position, and the roll chocks of the rolls other than the reference roll are moved in the rolling direction of the workpiece to adjust the positions of the roll chocks so that the measured thrust counterforce falls within an allowable range. By adjusting the positions of the roll chocks in this manner, inter-roll cross angles are eliminated so that inter-roll thrust forces are not generated. Hereunder, the method for setting a rolling mill according to the present embodiment is described specifically.

[0050] Note that, the method for setting a rolling mill according to the present embodiment is a method that adjusts the relative positions of rolls by adjusting the positions of roll chocks so that inter-roll cross angles occurring between rolls that are built into a rolling mill become zero so that inter-roll thrust forces are not generated when the rolling mill is operated. This setting of the rolling mill is executed, for example, prior to zero adjustment of reduction positions at a time of roll replacement. Thus, the method for setting a rolling mill according to the present embodiment is different from a method that controls a rolling mill in order to suppress zigzagging or camber by taking into consideration inter-roll thrust forces which are generated when a rolling mill is operating.

(1) Case of adjusting roll positions from roll on opposite side to reference roll (example of measuring thrust counterforces of all rolls)

[0051] First, the method for setting a rolling mill according to the present embodiment will be described based on Figure 3A to Figure 4. Figure 3A and Figure 3B are flowcharts that describe the method for setting a rolling mill according to the present embodiment, which illustrate an example of a case where roll positions are adjusted from a roll on the opposite side to the reference roll. Figure 4 is an explanatory drawing illustrating procedures for performing roll position adjustment in the method for setting a rolling mill according to the present embodiment. Note that, in Figure 4, a description of the distribution of a load that acts between rolls is omitted, and only a case in which, with respect to a thrust force and a thrust counterforce, only an inter-roll thrust force that is the target appears as a measurement value of the thrust counterforce.

[0052] Although in the present example the lower backup roll 4 is described as the reference roll, in some cases the upper backup roll 3 is the reference roll. Note that, it suffices to set any one roll constituting the rolling mill as the reference roll, and it is preferable to adopt a roll that is at the uppermost part or the lowermost part in the vertical direction as the reference roll. For example, in a case where the upper backup roll 3 is taken as the reference roll, by similar procedures as described hereunder, it suffices to perform position adjustments of rolls in order from the roll assembly on the opposite side to the reference roll in a manner such that, first, position adjustment is performed between the roll (lower backup roll 4) that is furthest from the reference roll (upper backup roll 3) and the roll (lower work roll 2) that is second furthest from the reference roll, followed by position adjustment between the aforementioned two rolls and the roll (upper work roll 1) that is third furthest from the reference roll, and finally position adjustment between the aforementioned three rolls

and the reference roll.

(Initial setting: S100a)

[0053] When starting rolling, first, as shown in Figure 3A, the inter-roll crossing control unit 23 causes a pressing-down device 27 to adjust roll positions in the vertical direction so that the upper work roll 1 and the lower work roll 2 enter a predetermined kiss roll state (S100a). The pressing-down device 27 applies a predetermined load to the rolls based on the instruction to thereby place the work rolls 1, 2 in a kiss roll state.

[0054] Next, position adjustment of the respective rolls is performed in a stepwise manner. At such time, the rolling direction position of the roll chocks of the reference roll is fixed as a reference position, and adjustment of the positions in the rolling direction of the roll chocks of the rolls other than the reference roll is performed by moving the roll chocks, to thereby adjust the relative positions of the rolls.

(First adjustment: S102a to S106a)

[0055] In the first adjustment, as illustrated in Figure 4, adjustment is performed so that an upper backup roll thrust counterforce acting on the upper backup roll 3 that is in the roll assembly on the opposite side to the lower backup roll 4 that is the reference roll becomes zero. Therefore, first, the inter-roll crossing control unit 23 drives the driving electric motor 21 by means of the driving electric motor control unit 22 to cause the respective rolls to rotate. Next, a thrust counterforce that acts on the upper backup roll 3 is measured by the upper backup roll thrust counterforce measurement apparatus 19 (S102a). The thrust counterforce acting on the upper backup roll 3 which was measured by the upper backup roll thrust counterforce measurement apparatus 19 is output to the inter-roll crossing control unit 23.

[0056] Next, the inter-roll crossing control unit 23 controls the position of the upper backup roll chocks 7 so that the measured thrust counterforce acting on the upper backup roll 3 falls within an allowable range (S104a). The upper and lower limit values with respect to the value of the thrust counterforce within an allowable range may be determined after performing roll deformation analysis under kiss roll conditions, and converting an asymmetric deformation amount into a reduction leveling amount. For example, it suffices to calculate upper and lower limit values within an allowable range of an inter-roll cross angle based on an existing rolling model in which a limit value of camber that is required for a product or a limit value of camber at which tail crash occurs is taken as a reference. Further, in a case where the number of thrust counterforce measurement apparatuses is small, and a thrust force other than a thrust force between rolls that are the objects of measurement is included in the measurement value for the thrust counterforce, the allowable range may be determined based on values at which the relevant thrust counterforce is maximum or minimum based on relative changes between the roll chock positions or inter-roll cross angle and the thrust counterforce.

[0057] The inter-roll crossing control unit 23 instructs the roll chock rolling direction force control unit 15 and the roll chock position control unit 16 so as to adjust the position of the upper backup roll chocks 7. While detecting the position of the upper backup roll chocks 7 by means of the roll chock position control unit 16, the roll chock rolling direction force control unit 15 adjusts the position of the upper backup roll chocks 7 until the thrust counterforce acting on the upper backup roll 3 falls within the allowable range (S106a).

[0058] Subsequently, in step S106a, when it is determined that the thrust counterforce acting on the upper backup roll 3 is within the allowable range, position adjustment of the upper backup roll chocks 7 ends. By performing the first adjustment, the inter-roll cross angle between the upper backup roll 3 and the upper work roll 1 is adjusted to within an allowable range.

(Second adjustment: S108a to S112a)

[0059] Next, in the second adjustment, as illustrated in Figure 4, the rolling mill is adjusted so that an upper work roll thrust counterforce that acts on the upper work roll 1 that is in the roll assembly on the opposite side to the lower backup roll 4 that is the reference roll becomes zero. In a state in which the respective rolls are being rotated by the driving electric motor 21, the inter-roll crossing control unit 23 measures a thrust counterforce that acts on the upper work roll 1 by means of the upper work roll thrust counterforce measurement apparatus 17 (S108a). The thrust counterforce acting on the upper work roll 1 that is measured by the upper work roll thrust counterforce measurement apparatus 17 is output to the inter-roll crossing control unit 23.

[0060] Next, the inter-roll crossing control unit 23 controls the position of the upper work roll chocks 5 so that the measured thrust counterforce acting on the upper work roll 1 falls within an allowable range (S110a). The inter-roll crossing control unit 23 instructs the roll chock rolling direction force control unit 15 and the roll chock position control unit 16 so as to adjust the position of the upper work roll chocks 5. While detecting the position of the upper work roll chocks 5 by means of the roll chock position control unit 16, the roll chock rolling direction force control unit 15 adjusts the position of the upper work roll chocks 5 until the thrust counterforce acting on the upper work roll 1 falls within the

allowable range (S112a). At this time, the position of the upper backup roll chocks 7 is controlled so that the upper backup roll 3 for which inter-roll crossing with respect to the upper work roll 1 was already adjusted also moves simultaneously with and in the same direction as the upper work roll 1 while maintaining the relative positions between the roll chocks with respect to the upper work roll 1. By this means, adjustment of inter-roll crossing between the upper backup roll 3, the upper work roll 1 and the lower work roll 2 can be performed.

[0061] Subsequently, in step S112a, when it is determined that the thrust counterforce acting on the upper work roll 1 is within the allowable range, position adjustment of the upper work roll chocks 5 ends. By performing the second adjustment, the positions of the respective rolls are adjusted by adjusting the positions of the roll chocks so that an inter-roll cross angle between the upper backup roll 3, the upper work roll 1 and the lower work roll 2 falls within an allowable range.

(Third adjustment: S114a to S120a)

[0062] Next, in the third adjustment, as illustrated in Figure 3B and Figure 4, the positions of the respective rolls are adjusted by adjusting the positions of the roll chocks so that a thrust counterforce that acts on the lower work roll 2 or the lower backup roll 4 that are in the roll assembly on the same side as the lower backup roll 4 that is the reference roll becomes zero. Because inter-roll crossing of the roll assembly that is upward from the lower work roll 2 has already been adjusted, inter-roll crossing exists only between the lower work roll 2 and the lower backup roll 4, and a thrust counterforce is generated due to such inter-roll crossing. At such time, thrust counterforces of the same magnitude with different signs are generated between the lower work roll 2 and the lower backup roll 4. Therefore, inter-roll crossing can be made zero by adjusting the roll chock positions so that either of the thrust counterforces is made zero.

[0063] The lower work roll thrust counterforce measurement apparatus 18 measures the thrust counterforce acting on the lower work roll 2, in a state in which each roll is being rotated by the driving electric motor 21. Alternatively, the thrust counterforce acting on the lower backup roll 4 is measured by the lower backup roll thrust counterforce measurement apparatus 20 (S114a). The thrust counterforce acting on the lower work roll 2 which was measured by the lower work roll thrust counterforce measurement apparatus 18, or the thrust counterforce acting on the lower backup roll 4 which was measured by the lower backup roll thrust counterforce measurement apparatus 20 is output to the inter-roll crossing control unit 23.

[0064] Next, the inter-roll crossing control unit 23 controls the position of the lower work roll chocks 6 so that the measured thrust counterforce falls within an allowable range (S116a). The inter-roll crossing control unit 23 instructs the roll chock rolling direction force control unit 15 and the roll chock position control unit 16 so as to adjust the position of the lower work roll chocks 6. While detecting the position of the lower work roll chocks 6 by means of the roll chock position control unit 16, the roll chock rolling direction force control unit 15 adjusts the position of the lower work roll chocks 6 until the thrust counterforce measured in step S114a falls within the allowable range (S118a). At this time, the positions of the upper work roll chocks 5 and the upper backup roll chocks 7 are controlled so that the upper work roll 1 and the upper backup roll 3 for which inter-roll crossing with respect to the lower work roll 2 was already adjusted also move simultaneously with and in the same direction as the lower work roll 2 while maintaining the relative positions between the roll chocks. By this means, adjustment of inter-roll crossing between the upper backup roll 3, the upper work roll 1, the lower work roll 2 and the lower backup roll 4 can be performed.

[0065] Next, in step S118a, when it is determined that the thrust counterforce acting on the lower work roll 2 is within the allowable range, position adjustment of the lower work roll chocks 6 ends. By means of the third adjustment, roll chock positions are adjusted so that inter-roll cross angles between the upper backup roll 3, the upper work roll 1, the lower work roll 2 and the lower backup roll 4 fall within an allowable range. When the inter-roll cross angles between all the rolls of the rolling mill have been made to fall within an allowable range in this manner, the inter-roll crossing control unit 23 causes the pressing-down device 27 to adjust the roll gap between the upper work roll 1 and the lower work roll 2 so that the roll gap becomes a predetermined size (S120a). Thereafter, rolling of a workpiece by the rolling mill is started.

(2) Case of adjusting roll positions from roll on reference roll side (example of measuring thrust counterforce of roll other than backup roll on opposite side to reference roll)

[0066] Next, as another example of the method for setting a rolling mill according to the present embodiment, a case of measuring a thrust counterforce of a roll other than a backup roll on the opposite side to the reference roll will be described based on Figure 5A to Figure 6. Figure 5A and Figure 5B are flowcharts that describe the method for setting a rolling mill according to the present embodiment, which illustrate an example of a case where roll positions are adjusted from a roll on the reference roll side. Figure 6 is an explanatory drawing illustrating procedures for performing roll position adjustment in the method for setting a rolling mill according to the present embodiment. Note that, in Figure 6, a description of the distribution of a load that acts between rolls is omitted, and only a case in which, with respect to a thrust force and a thrust counterforce, only an inter-roll thrust force that is the target appears as a measurement value of the thrust

counterforce.

[0067] Although in the present example also the lower backup roll 4 is described as the reference roll, in some cases the upper backup roll 3 is the reference roll. Note that, it suffices to set any one roll constituting the rolling mill as the reference roll, and it is preferable to adopt a roll that is at the uppermost part or the lowermost part in the vertical direction as the reference roll. In this case also, it suffices to perform position adjustment of the respective rolls by similar procedures as described hereunder.

(Initial setting: S100b)

[0068] When starting rolling, first, as shown in Figure 5A, the inter-roll crossing control unit 23 causes the pressing-down device 27 to adjust roll positions in the vertical direction so that the upper work roll 1 and the lower work roll 2 enter a predetermined kiss roll state (S100b). The pressing-down device 27 applies a predetermined load to the rolls based on the instruction to thereby place the work rolls 1, 2 in a kiss roll state.

[0069] Next, position adjustment of the respective rolls is performed in a stepwise manner. At such time, the rolling direction position of the roll chocks of the reference roll is fixed as a reference position, and adjustment of the positions in the rolling direction of the roll chocks of the rolls other than the reference roll is performed by moving the roll chocks, to thereby adjust the relative positions of the rolls.

(First adjustment: S102b to S106b)

[0070] In the first adjustment, as illustrated in Figure 6, adjustment is performed so that a lower backup roll thrust counterforce acting on the lower backup roll that is the reference roll becomes zero. Therefore, first, the inter-roll crossing control unit 23 drives the driving electric motor 21 by means of the driving electric motor control unit 22 to cause the respective rolls to rotate. Next, a thrust counterforce that acts on the lower backup roll 4 is measured by the lower backup roll thrust counterforce measurement apparatus 20 (S102b). The thrust counterforce acting on the lower backup roll 4 which was measured by the lower backup roll thrust counterforce measurement apparatus 20 is output to the inter-roll crossing control unit 23.

[0071] Next, the inter-roll crossing control unit 23 controls the position of the lower work roll chocks 6 so that the measured thrust counterforce acting on the lower backup roll 4 falls within an allowable range (S104b). The inter-roll crossing control unit 23 instructs the roll chock rolling direction force control unit 15 and the roll chock position control unit 16 so as to adjust the position of the lower work roll chocks 6. While detecting the position of the lower work roll chocks 6 by means of the roll chock position control unit 16, the roll chock rolling direction force control unit 15 adjusts the position of the lower work roll chocks 6 until the thrust counterforce acting on the lower backup roll 4 falls within the allowable range (S106b). At this time, the positions of the upper work roll chocks 5 and the upper backup roll chocks 7 are controlled so that the upper work roll 1 and the upper backup roll 3 also move simultaneously with and in the same direction as the lower work roll 2 while maintaining the relative positions between the roll chocks. By this means, adjustment of inter-roll crossing between the lower work roll 2 and the lower backup roll 4 can be performed while the state of inter-roll crossing between the upper backup roll 3 and the upper work roll 1 and the lower work roll 2 is maintained.

[0072] Subsequently, in step S106b, when it is determined that the thrust counterforce acting on the lower backup roll 4 is within the allowable range, position adjustment of the lower work roll chocks 6 ends. By performing the first adjustment, the inter-roll cross angle between the lower backup roll 4 and the lower work roll 2 is adjusted to within an allowable range.

(Second adjustment: S108b to S112b)

[0073] Next, in the second adjustment, as illustrated in Figure 6, the rolling mill is adjusted so that a lower work roll thrust counterforce that acts on the lower work roll 2 that is in the roll assembly on the side of the lower backup roll 4 that is the reference roll becomes zero. In a state in which the respective rolls are being rotated by the driving electric motor 21, the inter-roll crossing control unit 23 measures a thrust counterforce that acts on the lower work roll 2 by means of the lower work roll thrust counterforce measurement apparatus 18 (S108b). The thrust counterforce acting on the lower work roll 2 measured by the lower work roll thrust counterforce measurement apparatus 18 is output to the inter-roll crossing control unit 23.

[0074] Next, the inter-roll crossing control unit 23 controls the position of the upper work roll chocks 5 so that the measured thrust counterforce acting on the lower work roll 2 falls within an allowable range (S110b). The inter-roll crossing control unit 23 instructs the roll chock rolling direction force control unit 15 and the roll chock position control unit 16 so as to adjust the position of the upper work roll chocks 5. While detecting the position of the upper work roll chocks 5 by means of the roll chock position control unit 16, the roll chock rolling direction force control unit 15 adjusts the position of the upper work roll chocks 5 until the thrust counterforce acting on the upper work roll 1 falls within the allowable range (S112b). At this time, the position of the upper backup roll chocks 7 is controlled so that the upper

backup roll 3 also moves simultaneously with and in the same direction as the upper work roll 1 while maintaining the relative positions between the roll chocks. By this means, adjustment of inter-roll crossing between the upper work roll 1 and the lower work roll 2 and the lower backup roll 4 can be performed while maintaining the state of inter-roll crossing between the upper backup roll 3 and the upper work roll 1.

[0075] Subsequently, in step S112b, when it is determined that the thrust counterforce acting on the upper work roll 1 is within the allowable range, position adjustment of the upper work roll chocks 5 ends. By means of the second adjustment, the positions of the respective rolls are adjusted by adjusting the positions of the roll chocks so that an inter-roll cross angle between the upper work roll 1, the lower work roll 2 and the lower backup roll 4 falls within an allowable range.

(Third adjustment: S114b to S120b)

[0076] Next, in the third adjustment, as illustrated in Figure 5B and Figure 6, the positions of the respective rolls are adjusted by adjusting the positions of the roll chocks so that a thrust counterforce that acts on the upper work roll 1 that is in the roll assembly on the opposite side to the lower backup roll 4 that is the reference roll becomes zero. The upper work roll thrust counterforce measurement apparatus 17 measures the thrust counterforce acting on the upper work roll 1, in a state in which each roll is being rotated by the driving electric motor 21 (S114b). The thrust counterforce acting on the upper work roll 1 which was measured by the upper work roll thrust counterforce measurement apparatus 17 is output to the inter-roll crossing control unit 23.

[0077] Next, the inter-roll crossing control unit 23 controls the position of the upper backup roll chocks 7 so that the measured thrust counterforce falls within an allowable range (S116b). The inter-roll crossing control unit 23 instructs the roll chock rolling direction force control unit 15 and the roll chock position control unit 16 so as to adjust the position of the upper backup roll chocks 7. While detecting the position of the upper backup roll chocks 7 by means of the roll chock position control unit 16, the roll chock rolling direction force control unit 15 adjusts the position of the upper backup roll chocks 7 until the thrust counterforce measured in step S114b falls within the allowable range (S118b). By this means, adjustment of inter-roll crossing between the upper backup roll 3, the upper work roll 1, the lower work roll 2 and the lower backup roll 4 can be performed.

[0078] Subsequently, in step S118b, when it is determined that the thrust counterforce acting on the upper work roll 1 is within the allowable range, position adjustment of the upper backup roll chocks 7 ends. By means of the third adjustment, roll chock positions are adjusted so that inter-roll cross angles between the upper backup roll 3, the upper work roll 1, the lower work roll 2 and the lower backup roll 4 fall within an allowable range. When the inter-roll cross angles between all the rolls of the rolling mill have been made to fall within an allowable range in this manner, the inter-roll crossing control unit 23 causes the pressing-down device 27 to adjust the roll gap between the upper work roll 1 and the lower work roll 2 so that the roll gap becomes a predetermined size (S120b). Thereafter, rolling of a workpiece by the rolling mill is started.

[0079] A rolling apparatus and a method for setting a rolling mill according to the first embodiment of the present invention have been described above. Note that, although in the configuration described above a measurement apparatus for measuring a thrust counterforce is provided for rolls other than the backup roll on the opposite side to the reference roll, needless to say that the present invention can be similarly applied in a case where a measurement apparatus for measuring a thrust counterforce is provided for all of the rolls. Further, in a case where a thrust counterforce measurement apparatus is only provided for the work rolls also, it suffices to perform adjustment of inter-roll crossing in an exploratory manner based on values at which relative changes in a thrust counterforce with respect to the position of the roll chock position control unit becomes a maximum or a minimum.

<3. Second Embodiment>

[0080] Next, a rolling mill according to a second embodiment of the present invention, the configuration of an apparatus for controlling the rolling mill, and a method for setting a rolling mill will be described based on Figure 7 to Figure 9. In the method for setting a rolling mill according to the second embodiment, first, with respect to an upper roll assembly that is composed of the upper work roll 1 and the upper backup roll 3, and a lower roll assembly that is composed of the lower work roll 2 and the lower backup roll 4, operations are performed to make thrust counterforces between the upper work roll 1 and the upper backup roll 3 and between the lower work roll 2 and the lower backup roll 4 zero, respectively. Thereafter, the upper work roll 1 and the lower work roll 2 are set in a kiss roll state, and operations are performed to make a thrust counterforce between the upper work roll 1 and the lower work roll 2 zero. By this means, adjustment is performed to make the inter-roll cross angles for all the rolls constituting the rolling mill zero, and rolling in which a thrust force does not arise is realized.

[3-1. Configuration of rolling mill]

[0081] First, based on Figure 7, the rolling mill according to the present embodiment and an apparatus for controlling the rolling mill will be described. Figure 7 is an explanatory drawing illustrating the configuration of the rolling mill according to the present embodiment, and the configuration of an apparatus for controlling the rolling mill. The rolling mill illustrated in Figure 7 is shown in a state as seen from the work side in the axial direction of rolls, and in Figure 7 a configuration in a case where the lower backup roll is taken as the reference roll is illustrated.

[0082] The rolling mill according to the present embodiment illustrated in Figure 7 is a four-high rolling mill having a pair of work rolls 1, 2 and a pair of backup rolls 3, 4 which support the pair of work rolls 1, 2. The configuration of the rolling mill according to the present embodiment differs from the configuration of the rolling mill of the first embodiment illustrated in Figure 2 in that the upper backup roll thrust counterforce measurement apparatus 19 and the lower backup roll thrust counterforce measurement apparatus 20 are not provided in the rolling mill of the present embodiment, and that the rolling mill of the present embodiment includes increase bending apparatuses 24a, 24b, 25a, 25b and an increase bending control unit 26 that controls the increase bending apparatuses 24a, 24b, 25a, 25b. The remaining configuration is the same as the configuration of the rolling mill of the first embodiment illustrated in Figure 2, and therefore a description thereof is omitted in the present embodiment.

[0083] The rolling mill according to the present embodiment includes an entrance-side upper increase bending apparatus 24a and an exit-side upper increase bending apparatus 24b on a project block between the upper work roll chocks 5 and the housing 30. Further, the rolling mill includes an entrance-side lower increase bending apparatus 25a and an exit-side lower increase bending apparatus 25b on a project block between the lower work roll chocks 6 and the housing 30. The entrance-side upper increase bending apparatus 24a, the exit-side upper increase bending apparatus 24b, the entrance-side lower increase bending apparatus 25a and the exit-side lower increase bending apparatus 25b are also similarly provided on the side facing away from the viewer (drive side) in Figure 7. Each increase bending apparatus imparts an increase bending force for applying a load to the upper work roll 1 and the upper backup roll 3, and the lower work roll 2 and the lower backup roll 4.

[0084] The increase bending control unit 26 is an apparatus that controls the entrance-side upper increase bending apparatus 24a, the exit-side upper increase bending apparatus 24b, the entrance-side lower increase bending apparatus 25a and the exit-side lower increase bending apparatus 25b. The increase bending control unit 26 according to the present embodiment controls the increase bending apparatuses so as to impart an increase bending force to the work roll chocks, based on an instruction from the inter-roll crossing control unit 23. Note that, even in a case other than a case of performing adjustment of inter-roll crossing according to the present embodiment, for example, when performing crown control or shape control of a workpiece, the increase bending control unit 26 may perform control of the increase bending apparatuses.

[3-2. Method for setting rolling mill]

[0085] Next, the method for setting a rolling mill according to the present embodiment will be described based on Figure 8A to Figure 9. Figure 8A and Figure 8B are flowcharts illustrating the method for setting a rolling mill according to the present embodiment. Figure 9 is an explanatory drawing showing procedures for roll position adjustment in the method for setting a rolling mill illustrated in Figure 8A and Figure 8B. Note that, in Figure 9, a description of the distribution of a load that acts between rolls is omitted, and only a case in which, with respect to a thrust force and a thrust counterforce, only an inter-roll thrust force that is the target appears as a measurement value of the thrust counterforce.

[0086] In the method for setting a rolling mill according to the present embodiment, first, a roll gap between the upper work roll 1 and the lower work roll 2 is made an open state. Then, with respect to the upper roll assembly and the lower roll assembly, operations are performed independently and respectively to adjust the positions of the work roll chocks that have an increase bending apparatus so that a thrust counterforce between the work roll and the backup roll becomes zero, and an inter-roll cross angle between these is made to fall within an allowable range. Next, the upper work roll 1 and the lower work roll 2 are set in a kiss roll state. Thereafter, the positions of the roll chocks of either one of the roll assemblies are adjusted so that the thrust counterforce between the upper work roll 1 and the lower work roll 2 becomes zero. Thus, the inter-roll cross angle between the upper roll assembly and the lower roll assembly falls within an allowable range. As a result, the inter-roll cross angles of all the rolls constituting the rolling mill fall within an allowable range. Thus, in the present embodiment also, the rolling direction position of the roll chocks of the reference roll is fixed as a reference position, and the positions in the rolling direction of roll chocks of rolls other than the reference roll are moved to thereby adjust the positions of the roll chocks. These operations are described in detail hereunder.

(Adjustment of inter-roll crossing of each roll assembly (first adjustment): S200 to S208)

[0087] First, as illustrated in Figure 8A, the inter-roll crossing control unit 23 causes the pressing-down device 27 to

adjust the roll positions in the vertical direction so that the roll gap between the upper work roll 1 and the lower work roll 2 becomes an open state having a predetermined gap (S200). Based on the relevant instruction, the pressing-down device 27 places the increase bending forces in a balanced state, and places the roll gap between the work rolls 1, 2 in an open state. Note that, as used herein, the term "balanced state" refers to a state in which a bending force of a degree that lifts up the self-weight of the work roll and roll chocks or the like is applied, and means that a load acting between the work roll and the backup roll is approximately zero.

[0088] Further, the inter-roll crossing control unit 23 instructs the increase bending control unit 26 so as to apply a predetermined increase bending force from the balanced state to the work roll chocks 5, 6 by means of the increase bending apparatuses 24a, 24b, 25a, 25b (S202). The increase bending control unit 26 controls the respective increase bending apparatuses 24a, 24b, 25a, 25b based on the instruction, to thereby apply a predetermined increase bending force to the work roll chocks 5, 6. By this means, the roll gap between the work rolls is placed in an open state. Note that, either step among the step S200 and step S202 may be executed first.

[0089] Next, the inter-roll crossing control unit 23 drives the driving electric motor 21 by means of the driving electric motor control unit 22 to cause the respective rolls to rotate (S204). The thrust counterforces acting on the upper and lower work rolls are measured by the thrust counterforce measurement apparatuses 17, 18 of the work rolls, and the measured values are output to the inter-roll crossing control unit 23. The inter-roll crossing control unit 23 then controls the positions of the roll chocks of the rolls that have a bending apparatus, that is, the work roll chocks 5, 6, so that the thrust counterforces acting on the upper and lower work rolls become values that are within an allowable range (first adjustment illustrated on the upper side in Figure 9; S206). While the roll chock rolling direction force control unit 15 imparts a predetermined pressing force in the rolling direction, and the positions of the work roll chocks 5, 6 are being detected by the roll chock position control unit 16, the positions of the work roll chocks 5, 6 are adjusted until the thrust counterforces acting on the work rolls fall within an allowable range (S208).

[0090] Note that, although a case has been described above in which, with respect to the upper roll assembly, as illustrated on the upper side in Figure 9, the upper work roll chocks 5 are subjected to position control, position control of the upper backup roll chocks 7 may be performed. That is, as illustrated in the center in Figure 9, the first adjustment may be performed by performing position control of the backup roll of the roll assembly on the opposite side to the reference roll, that is, position control of the upper backup roll chocks 7 so that a thrust counterforce that acts on the upper work roll of the upper roll assembly becomes a value that is within an allowable range.

[0091] Subsequently, in step S208, with respect to the upper roll assembly and the lower roll assembly, when it is determined that thrust counterforces acting on the work rolls or backup rolls are within an allowable range, position adjustment of the work roll chocks 5, 6 ends. By means of the first adjustment performed in this manner, inter-roll crossing between the upper backup roll 3 and the upper work roll 1, and an inter-roll cross angle between the lower backup roll 4 and the lower work roll 2 are each adjusted to within an allowable range. Note that, although an example has been described here in which adjustment of inter-roll crossing for the upper roll assembly and the lower roll assembly are executed concurrently, the present invention is not limited to this example, and operations may be performed in a manner such that the inter-roll crossing of one of the roll assemblies is adjusted first, and thereafter inter-roll crossing of the other roll assembly is adjusted. Further, at the stage at which the processing up to step S208 has ended, driving of the driving electric motor 21 may be temporarily stopped, or the operations may proceed to the next step while maintaining the state in which rotation of the rolls is continuing.

(Adjustment of inter-roll crossing of upper roll assembly and lower roll assembly (second adjustment): S210 to S218)

[0092] In each of the upper roll assembly and the lower roll assembly, when inter-roll crossing between the work roll and the backup roll has been adjusted, next, as a second adjustment, the inter-roll crossing control unit 23 adjusts inter-roll crossing between the upper roll assembly and the lower roll assembly, as illustrated on the lower side in Figure 9. First, the inter-roll crossing control unit 23 causes the pressing-down device 27 to adjust roll positions in the vertical direction so that the upper work roll 1 and the lower work roll 2 enter a predetermined kiss roll state (S210). The pressing-down device 27 applies a predetermined load to the rolls based on the instruction to thereby cause the work rolls 1, 2 to come in contact and enter a kiss roll state.

[0093] Next, as illustrated in Figure 8B, the inter-roll crossing control unit 23 causes the driving electric motor 21 to drive by means of the driving electric motor control unit 22 to cause each roll to rotate. Next, thrust counterforces acting on the upper work roll 1 and the lower work roll 2 are measured by the upper work roll thrust counterforce measurement apparatus 17 and the lower work roll thrust counterforce measurement apparatus 18 (S212). The values of the thrust counterforces acting on the upper work roll 1 and the lower work roll 2 that were measured by the upper work roll thrust counterforce measurement apparatus 17 and the lower work roll thrust counterforce measurement apparatus 18 are output to the inter-roll crossing control unit 23.

[0094] Next, the inter-roll crossing control unit 23 controls the positions of the work roll chocks and the backup roll chocks of the upper roll assembly or the lower roll assembly simultaneously and in the same direction while maintaining

the relative position between the roll chocks, so that thrust counterforces acting on the upper work roll 1 and the lower work roll 2 become a value within an allowable range (S214). For example, when it is assumed that the lower roll assembly is taken as a reference roll assembly, the positions of the upper work roll chocks 5 and the upper backup roll chocks 7 of the upper roll assembly are controlled so that an inter-roll cross angle with respect to the lower roll assembly falls within an allowable range.

[0095] The inter-roll crossing control unit 23 instructs the roll chock rolling direction force control unit 15 and the roll chock position control unit 16 so as to adjust the positions of the work roll chocks and the backup roll chocks on the opposite side to the reference roll assembly. While detecting the positions of the work roll chocks and the backup roll chocks by means of the roll chock position control unit 16, the roll chock rolling direction force control unit 15 adjusts the positions of the work roll chocks and the backup roll chocks until thrust counterforces acting on the upper work roll 1 and the lower work roll 2 fall within the allowable range (S216). At this time, inter-roll crossing of the upper roll assembly and inter-roll crossing of the lower roll assembly have already been adjusted. Therefore, position control of not only the work roll chocks but also the backup roll chocks is performed so that the backup rolls move simultaneously with and in the same direction as the work rolls while maintaining the relative positions between the roll chocks.

[0096] Subsequently, in step S216, when it is determined that the thrust counterforces acting on the upper work roll 1 and the lower work roll 2 have entered the allowable range, the roll chock positions are adjusted so that an inter-roll cross angle between the upper backup roll 3, the upper work roll 1, the lower work roll 2 and the lower backup roll 4 falls within an allowable range. When the inter-roll cross angle with respect to all of the rolls of the rolling mill falls within an allowable range in this manner, the inter-roll crossing control unit 23 causes the pressing-down device 27 to perform adjustment so that the roll gap between the upper work roll 1 and the lower work roll 2 becomes a predetermined size (S218). Thereafter, rolling of a workpiece by the rolling mill is started.

[0097] A rolling apparatus and a method for setting a rolling mill according to the second embodiment of the present invention have been described above. Note that, although an example in which only the upper and lower work rolls are provided with a roll thrust counterforce measurement apparatus is described above, the present invention is not limited to this example. For example, in a case where, in addition to providing upper and lower work roll thrust counterforce apparatuses, a backup roll thrust counterforce measurement apparatus is provided in the upper or lower backup roll or in both of the upper and lower backup rolls, it need scarcely be said that control can be similarly performed.

<4. Relation between inter-roll cross angle and various values>

[0098] In the methods for setting a rolling mill according to the first and second embodiments that are described above, position control of roll chocks is performed so that a thrust counterforce generated between rolls becomes zero or becomes a value that is within an allowable range in order to eliminate inter-roll crossing. This is based on the finding that the correlation described hereunder exists between a thrust counterforce and an inter-roll cross angle. Hereunder, the relation between an inter-roll cross angle and various values will be described based on Figure 10 to Figure 16.

[4-1. Relation when roll gap is in open state]

[0099] First, based on Figure 10 to Figure 12, the relation between inter-roll crossing and various values in a case where the roll gap between the work rolls is in an open state will be described. Figure 10 is an explanatory drawing illustrating the arrangement of the work rolls 1, 2 and the backup rolls 3, 4 of a rolling mill in which the roll gap is in an open state. Figure 11 is an explanatory drawing showing the definition of an inter-roll cross angle. Figure 12 is a multiple view drawing showing graphs that illustrate a relation between a backup roll cross angle and upper and lower backup roll thrust counterforces and between a backup roll cross angle and upper and lower work roll thrust counterforces when a roll gap is in an open state, which are relations obtained as the results of an experiment performed using a small size rolling mill with a work roll diameter of 80 mm. Note that, in Figure 12, values are shown that were obtained by measuring upper and lower backup roll thrust counterforces and upper and lower work roll thrust counterforces in both a case where a backup roll cross angle was set in an increasing direction and a case where a backup roll cross angle was set in a decreasing direction, respectively, and averaging the measurement value for the increasing direction and the measurement value for the decreasing direction.

[0100] In the experiment, first, as illustrated in Figure 10, the roll gap between the upper work roll 1 and the lower work roll 2 was placed in an open state, and a state was formed in which an increase bending force was applied by an increase bending apparatus to the work roll chocks. Then, changes in the backup roll thrust counterforce, the work roll thrust counterforce and the differential load of the vertical roll load when the cross angles of the upper backup roll 3 and the lower backup roll 4 were changed, respectively, were investigated. As illustrated in Figure 11, with respect to the cross angle of a backup roll, a direction in which the work side of a roll axis A_{roll} extending in the axial direction of rolls extends from the width direction (X-direction) toward the exit side is represented as positive. Further, as the increase bending force, 0.5 tonf was applied per roll chock.

[0101] As a result it was found that, as illustrated in Figure 12, there is a relation such that, as the cross angle between the upper backup roll 3 and the lower backup roll 4 gradually increases from a negative angle to an angle of zero to a positive angle, the value for the backup roll thrust counterforce similarly increases with the cross angle, while the value for the work roll thrust counterforce gradually decreases. With respect to each of the backup roll thrust counterforce and the work roll thrust counterforce also, it was ascertained that the values of these forces also become zero when the cross angle between the backup rolls is zero.

[0102] Therefore, it can be said that, in a state in which the roll gap is in an open state and an increase bending force is applied, it is possible to ascertain the influence of thrust forces attributable to an inter-roll cross angle between a backup roll and a work roll of each roll assembly based on the value of either a backup roll thrust counterforce or a work roll thrust counterforce. Further, it can be said that it is possible to reduce an inter-roll thrust force by controlling the positions of roll chocks so that these values become zero.

[4-2. Relation in kiss roll state (without pair cross)]

[0103] Next, based on Figure 13 and Figure 14, the relation between inter-roll crossing and various values in a case where the work rolls are in a kiss roll state will be described. Figure 13 is an explanatory drawing illustrating the arrangement of the work rolls 1, 2 and the backup rolls 3, 4 of the rolling mill that has been set in a kiss roll state. Figure 14 is a multiple view drawing showing graphs that illustrate a relation between a backup roll cross angle and upper and lower backup roll thrust counterforces and between a backup roll cross angle and upper and lower work roll thrust counterforces in a kiss roll state. Note that, in Figure 14, values are shown that were obtained by measuring upper and lower backup roll thrust counterforces and upper and lower work roll thrust counterforces in both a case where a backup roll cross angle was set in an increasing direction and a case where a backup roll cross angle was set in a decreasing direction, respectively, and averaging the measurement value for the increasing direction and the measurement value for the decreasing direction.

[0104] In this case, as illustrated in Figure 13, changes in the backup roll thrust counterforce and the work roll thrust counterforce when the upper work roll 1 and the lower work roll 2 were set in a kiss roll state and the cross angles of the upper backup roll 3 and the lower backup roll 4 were changed, respectively, were investigated. At such time, a kiss roll load was made 1.0 tonf.

[0105] As a result it was found that, as illustrated in Figure 14, there is a relation such that, as the cross angle between the upper backup roll 3 and the lower backup roll 4 gradually increases from a negative angle to an angle of zero to a positive angle, the value for the backup roll thrust counterforce similarly increases with the cross angle, while the value for the work roll thrust counterforce gradually decreases. With respect to each of the backup roll thrust counterforce and the work roll thrust counterforce also, it was ascertained that the values of these forces also become zero when the cross angle between the backup rolls is zero.

[0106] Therefore, it can be said that, in a tightened state in the kiss roll state, it is possible to ascertain the influence of thrust forces attributable to an inter-roll cross angle between a backup roll and a work roll of each roll assembly based on the value of either a backup roll thrust counterforce or a work roll thrust counterforce. Further, it can be said that it is possible to reduce an inter-roll thrust force by controlling the positions of roll chocks so that these values become zero.

[4-3. Relation in kiss roll state (with pair cross)]

[0107] Next, based on Figure 15 and Figure 16, the relation between inter-roll crossing and various values in a case where the work rolls are in a kiss roll state will be described. Figure 15 is an explanatory drawing illustrating the arrangement of the work rolls 1, 2 and the backup rolls 3, 4 of the rolling mill that has been set in a kiss roll state. Figure 16 is a multiple view drawing showing graphs that illustrate a relation between a pair cross angle between a work roll and a backup roll and upper and lower backup roll thrust counterforces, and between a pair cross angle between a work roll and a backup roll and upper and lower work roll thrust counterforces in a kiss roll state. Note that, in Figure 16, values are shown that were obtained by measuring upper and lower backup roll thrust counterforces and upper and lower work roll thrust counterforces in both a case where a pair cross angle was set in an increasing direction and a case where a pair cross angle was set in a decreasing direction, respectively, and averaging the measurement value for the increasing direction and the measurement value for the decreasing direction.

[0108] In this case, as illustrated in Figure 15, changes in the work roll thrust counterforce and the backup roll thrust counterforce when the upper work roll 1 and the lower work roll 2 were set in a kiss roll state and pair cross angles between the work rolls and backup rolls were changed, respectively, were investigated. At such time, a kiss roll load was made 6.0 tonf.

[0109] As a result it was found that, as illustrated on the lower side in Figure 16, with respect to the work roll thrust counterforces, as the pair cross angle gradually increases from a negative angle to an angle of zero to a positive angle, the work roll thrust counterforces change in correspondence with the changes in the pair cross angle, and when the pair

cross angle is zero, these measurement values also become zero. By this means, in a state in which a kiss roll load is applied, it is possible to detect the influence of a thrust force attributable to crossing between upper and lower work rolls based on the work roll thrust counterforces. Further, it was ascertained that there is a possibility that inter-roll thrust forces between upper and lower work rolls can be reduced by controlling roll chock positions in a manner that takes

work rolls and backup rolls on the top and bottom, respectively, as a single body so that these values become zero.
[0110] Note that, with respect to the backup roll thrust counterforces, as illustrated on the upper side in Figure 16, the values do not change in correspondence with the cross angle. It is surmised that the reason is that because the load at the time of tightening in the kiss roll state was large, the sliding resistance in the axial direction of the roll at a portion supporting this reaction force in the backup roll chocks became large and it was difficult for the thrust force to be transmitted to the load cell. However, as shown in Figure 14, if the kiss roll load is around 1.0 tonf, the influence of an inter-roll thrust force acting between a work roll and a backup roll can be adequately measured as a thrust counterforce that acts on the backup roll.

[Example 1]

[0111] A comparison between a conventional method and the method of the present invention was conducted with respect to fifth to seventh stands of a hot finish rolling mill having the configuration illustrated in Figure 2, in relation to reduction leveling setting that takes into consideration the influence of inter-roll thrust forces generated by inter-roll crossing.

[0112] First, in the conventional method, without using the functions of the inter-roll crossing control unit of the present invention, replacement of housing liners and chock liners was periodically performed, and equipment management was conducted so that inter-roll crossing would not occur. As a result, in a period immediately before replacement of the housing liner, when a thin and wide material having an exit side plate thickness of 1.2 mm and a width of 1200 mm was rolled, zigzagging of 100 mm or more occurred at the sixth stand, and tail crash occurred as a result.

[0113] On the other hand, in the method of the present invention, using the functions of the inter-roll crossing control unit according to the first embodiment that is described above, in a kiss roll tightened state, a thrust counterforce of each roll was measured, and in accordance with the processing flow illustrated in Figure 3A and Figure 3B, the roll chock positions of the respective rolls were controlled so that the thrust counterforce prior to zero point of reduction position adjustment fell within an allowable range that was set in advance. As a result, in a period immediately before replacement of the housing liner also, even in a case where when a thin and wide material having an exit side plate thickness of 1.2 mm and a width of 1200 mm with respect to which tail crash occurred in the conventional method was rolled, the occurrence of zigzagging stayed at 10 mm or less, and the workpiece could be passed through the rolling line without causing tail crash to occur in the workpiece.

[0114] As described above, according to the method of the present invention, thrust counterforces of each roll are measured before zero point of reduction position adjustment or before the start of rolling, and the roll chock positions of the respective rolls are controlled based on a reference roll so that the thrust counterforces enter an allowable range based on appropriate logic. By this means, inter-roll crossing is itself eliminated, and left-right asymmetric deformation of a workpiece that occurs due to thrust forces caused by inter-roll crossing can be eliminated. Therefore, according to the method of the present invention, a metal plate material can be stably produced without zigzagging and camber or with extremely little zigzagging and camber.

[Example 2]

[0115] Next, comparison between a conventional method and the method of the present invention was conducted with respect to a hot rolled thick-gauge plate rolling mill having the configuration illustrated in Figure 7, in relation to reduction leveling setting that takes into consideration the influence of thrust forces generated by inter-roll crossing.

[0116] First, in the conventional method, without using the functions of the inter-roll crossing control unit of the present invention, replacement of housing liners and chock liners was periodically performed, and equipment management was conducted so that inter-roll crossing would not occur.

[0117] On the other hand, in the method of the present invention, using the functions of the inter-roll crossing control unit according to the second embodiment that is described above, adjustment of the positions of roll chocks was performed in accordance with the processing flow illustrated in Figure 8A and Figure 8B before performing zero point of reduction position adjustment. That is, in a state in which the roll gap is placed in an open state and an increase bending force is applied, thrust counterforces acting on the upper and lower work rolls were measured and the positions of the upper and lower work roll chocks were controlled. Next, the upper and lower work rolls were set in a kiss roll state, thrust counterforces acting on the upper and lower work rolls were measured, and the positions of the roll chocks of the upper and lower work rolls and the backup rolls were controlled so that the thrust counterforces in question entered an allowable range that was set in advance.

[0118] Table 1 shows actual measurement values for the occurrence of camber with regard to a representative number of rolled workpieces, with respect to the present invention and the conventional method. Among the actual measurement values for camber per 1 m of a front end position of the workpieces, when the value for immediately before backup roll replacement and immediately before housing liner replacement are seen, it is found that in the case of the present invention the value is kept to a relatively small value of 0.11 mm/m. In contrast, in the case of the conventional method, in a period immediately before backup roll replacement and immediately before housing liner replacement, the actual measurement value for camber is large in comparison to the case of the present invention.

[Table 1]

[0119]

Table 1

	Actual Measurement Values for Camber per 1 m at Front End Portion (mm/m)		
	Immediately After Backup Roll Replacement	Immediately Before Backup Roll Replacement	Immediately Before Backup Roll Replacement and Immediately Before Housing Liner Replacement
Present Invention	0.09	0.11	0.10
Conventional Method	0.21	0.57	0.85

[0120] As described above, according to the method of the present invention, thrust counterforces of work rolls are measured before zero point of reduction position adjustment or before the start of rolling, and the chock positions of the respective rolls are controlled based on a reference roll so that the thrust counterforces enter an allowable range based on appropriate logic. By this means, inter-roll crossing is itself eliminated, and left-right asymmetric deformation of a workpiece that occurs due to thrust forces caused by inter-roll crossing can be eliminated. Therefore, according to the method of the present invention, a metal plate material can be stably produced without zigzagging and camber or with extremely little zigzagging and camber.

[0121] Whilst preferred embodiments of the present invention have been described in detail above with reference to the accompanying drawings, the present invention is not limited to the above examples. It is clear that a person having common knowledge in the field of the art to which the present invention pertains will be able to contrive various examples of changes and modifications within the category of the technical idea described in the appended claims, and it should be understood that they also naturally belong to the technical scope of the present invention.

<5. Modifications>

[0122] Although, for example, in the above embodiments a driving apparatus with a roll chock position detection function that detects the position in the rolling direction of work roll chocks is used, for example, as illustrated in Figure 2, the present invention is not limited to this example. For example, even when using a servo-motor with a rotation angle detection function instead of a roll chock position detection apparatus, positions in the rolling direction of work roll chocks can be measured. That is, as shown in the example of the upper work roll 1 and the upper work roll chocks 5 illustrated in Figure 17, a servo-motor with a rotation angle detection function 34 may be provided so as to face the driving apparatus with upper work roll chock position detection function 11 in the rolling direction of the upper work roll chocks 5.

[0123] Further, whilst a four-high rolling mill having a pair of work rolls and a pair of backup rolls has been described in the above embodiments, the present invention is also applicable to a rolling mill having more rolls than a four-high rolling mill. In such a case also, it suffices to set any one roll constituting the rolling mill as the reference roll. For example, in the case of a six-high rolling mill, any roll among the work rolls, intermediate rolls and backup roll can be set as the reference roll. At such time, similarly to the case of a four-high rolling mill, it is preferable that among the respective rolls arranged in the vertical direction, a roll located at the lowermost part or the uppermost part is taken as the reference roll.

[0124] For example, as illustrated in Figure 18, in a six-high rolling mill, intermediate rolls 41, 42 are provided between the work roll 1 and the backup roll 3, and the work roll 2 and the backup roll 4, respectively. The upper intermediate roll 41 is supported by an upper intermediate roll chock 43a on the work side and an upper intermediate roll chock 43b on the drive side (the upper intermediate roll chocks 43a, 43b are also referred to together as "upper intermediate roll chocks 43"). The lower intermediate roll 42 is supported by a lower intermediate roll chock 44a on the work side and a lower

intermediate roll chocks 44b on the drive side (the lower intermediate roll chocks 44a, 44b are also referred to together as "lower intermediate roll chocks 44").

[0125] In the upper work roll 1, the upper work roll thrust counterforce measurement apparatus 17 that measures thrust counterforces applied to the upper work roll 1 is provided, and in the lower work roll 2 the lower work roll thrust counterforce measurement apparatus 18 that measures thrust counterforces applied to the lower work roll 2 is provided. Similarly, in the upper backup roll 3, the upper backup roll thrust counterforce measurement apparatus 19 that measures thrust counterforces applied to the upper backup roll 3 is provided, and in the lower backup roll 4 the lower backup roll thrust counterforce measurement apparatus 20 that measures thrust counterforces applied to the lower backup roll 4 is provided. Further, in the upper intermediate roll 41, an upper intermediate roll thrust counterforce measurement apparatus 45 that measures thrust counterforces applied to the upper intermediate roll 41 is provided, and in the lower intermediate roll 42 a lower intermediate roll thrust counterforce measurement apparatus 46 that measures thrust counterforces applied to the lower intermediate roll 42 is provided.

[0126] For example, when performing adjustment of an inter-roll cross angle in a kiss roll state, as illustrated in Figure 18, similarly to the case of the four-high rolling mill illustrated in Figure 4, it suffices to perform adjustment of the roll chock positions in sequence from the roll chocks of the backup roll on the opposite side to the reference roll so that a thrust counterforce arising at the adjacent roll falls within an allowable range.

[0127] That is, when performing adjustment of the six-high rolling mill illustrated in Figure 18, the adjustment is performed in sequence as follows: a first adjustment is performed that performs a roll chock adjustment between the upper backup roll chocks 7 of the upper backup roll 3 and the upper intermediate roll chocks 43 of the upper intermediate roll 41; a second adjustment is performed that performs a roll chock adjustment between the upper intermediate roll chocks 43 of the upper intermediate roll 41 and the upper work roll chocks 5 of the upper work roll 1; a third adjustment is performed that performs a roll chock adjustment between the upper work roll chocks 5 of the upper work roll 1 and the lower work roll chocks 6 of the lower work roll 2; a fourth adjustment is performed that performs a roll chock adjustment between the lower work roll chocks 6 of the lower work roll 2 and the lower intermediate roll chocks 44 of the lower intermediate roll 42; and a fifth adjustment is performed that performs a roll chock adjustment between the lower intermediate roll chocks 44 of the lower intermediate roll 42 and the lower backup roll chocks 8 of the lower backup roll 4. At this time, in the second adjustment to fifth adjustment, the roll chocks that were already adjusted prior thereto are controlled simultaneously with and in the same direction as the roll chocks that are being adjusted, while maintaining the relative positions with respect to the roll chocks that are being adjusted.

[0128] Alternatively, when performing adjustment of an inter-roll cross angle in the kiss roll state, for example, as illustrated in Figure 19, similarly to the case of the four-high rolling mill illustrated in Figure 6, adjustment of roll chock positions may be performed in sequence from the roll chocks of the intermediate roll on the reference roll side in a manner so that a thrust counterforce generated at the adjacent roll falls within an allowable range. Note that, in the six-high rolling mill illustrated in Figure 19, a roll thrust counterforce measurement apparatus is not provided in the backup roll (that is, the upper backup roll 3) on the opposite side from the reference roll. Similarly to Figure 18, the upper work roll thrust counterforce measurement apparatus 17, the lower work roll thrust counterforce measurement apparatus 18, the lower backup roll thrust counterforce measurement apparatus 20, the upper intermediate roll thrust counterforce measurement apparatus 45, and the lower intermediate roll thrust counterforce measurement apparatus 46 are provided in the upper work roll 1, the lower work roll 2, the lower backup roll 4, the upper intermediate roll 41 and the lower intermediate roll 42, respectively.

[0129] When performing adjustment of the six-high rolling mill illustrated in Figure 19, the adjustment is performed in sequence as follows: a first adjustment is performed that performs a roll chock adjustment between the lower backup roll chocks 8 of the lower backup roll 4 that is the reference roll and the lower intermediate roll chocks 44 of the lower intermediate roll 42; a second adjustment is performed that performs a roll chock adjustment between the lower intermediate roll chocks 44 of the lower intermediate roll 42 and the lower work roll chocks 6 of the lower work roll 2; a third adjustment is performed that performs a roll chock adjustment between the lower work roll chocks 6 of the lower work roll 2 and the upper work roll chocks 5 of the upper work roll 1; a fourth adjustment is performed that performs a roll chock adjustment between the upper work roll chocks 5 of the upper work roll 1 and the upper intermediate roll chocks 43 of the upper intermediate roll 41; and a fifth adjustment is performed that performs a roll chock adjustment between the upper intermediate roll chocks 43 of the upper intermediate roll 41 and the upper backup roll chocks 7 of the upper backup roll 3. At this time, in the first adjustment to fourth adjustment, non-adjusted roll chocks are controlled simultaneously with and in the same direction as the roll chocks that are being adjusted, while maintaining the relative positions with respect to the roll chocks that are being adjusted.

[0130] Further, when performing adjustment of an inter-roll cross angle when the roll gap is in an open state, as illustrated in Figure 20 for example, similarly to the case of the four-high rolling mill illustrated in Figure 9, it suffices to place the upper work roll and the lower work roll in an open state and perform adjustment of the roll chocks of the upper roll assembly and the lower roll assembly, respectively, and thereafter place the upper work roll and the lower work roll in a kiss roll state and perform adjustment between the roll chocks of the upper roll assembly and the roll chocks of the

lower roll assembly. Note that, in the six-high rolling mill illustrated in Figure 20, a roll thrust counterforce measurement apparatus is not provided in the upper backup roll 3 and the lower backup roll 4, and similarly to Figure 18, the upper work roll thrust counterforce measurement apparatus 17, the lower work roll thrust counterforce measurement apparatus 18, the upper intermediate roll thrust counterforce measurement apparatus 45, and the lower intermediate roll thrust counterforce measurement apparatus 46 are provided in the upper work roll 1, the lower work roll 2, the upper intermediate roll 41 and the lower intermediate roll 42, respectively.

[0131] For example, when performing adjustment of the six-high rolling mill illustrated in Figure 20, first, the roll gap between the work rolls 1, 2 is placed in an open state, and for the upper roll assembly and the lower roll assembly, respectively, a first adjustment is performed to adjust the positions between the roll chocks 43, 44 of the intermediate rolls 41, 42 and the roll chocks 7, 8 of the backup rolls 3, 4. Subsequently, after finishing the first adjustment, the roll gap between the work rolls 1, 2 is maintained in an open state, and for the upper roll assembly and the lower roll assembly, respectively, a second adjustment is performed to adjust the positions between the roll chocks 43, 44 of the intermediate rolls 41, 42 and the roll chocks 5, 6 of the work rolls 1, 2. After finishing the second adjustment, the work rolls 1, 2 are set in a kiss roll state, and either one of the upper roll assembly and the lower roll assembly is taken as the reference roll assembly. In the example in Figure 20, the lower roll assembly is taken as the reference roll assembly. Next, the roll chock positions of the reference roll assembly are fixed as reference positions, and a third adjustment is performed in which the positions of the roll chocks are adjusted between the upper roll assembly and the lower roll assembly by controlling the roll chocks 5, 43, 7 of the respective rolls 1, 41, 3 of the upper roll assembly simultaneously and in the same direction while maintaining the relative positions between the roll chocks 5, 43, 7.

[0132] Note that, in the first adjustment, bending apparatuses of the intermediate rolls 41, 42 are used to apply loads between the intermediate rolls 41, 42 and the backup rolls 3, 4, and the bending apparatuses of the work rolls 1, 2 are set at zero or in a balanced state. Further, in the second adjustment, bending apparatuses of the work rolls 1, 2 are used to apply loads between the work rolls 1, 2 and the intermediate rolls 41, 42, and the bending apparatuses of the intermediate rolls 41, 42 are set at zero or in a balanced state. Note that, in a case where the intermediate rolls 41, 42 have a decrease bending apparatus, the decrease bending apparatuses may be case to act in a direction (minus direction) such that the respective loads between the intermediate rolls 41, 42 and the backup rolls 3, 4 are decreased.

[0133] Thus, the present invention is also applicable to a six-high rolling mill, and not just a four-high rolling mill. Furthermore, the present invention is similarly applicable to rolling mills other than a four-high rolling mill and a six-high rolling mill, and for example the present invention can also be applied to an eight-high rolling mill or a five-high rolling mill.

<6. Example of hardware configuration>

[0134] An example of the hardware configuration of an apparatus for controlling the rolling mills according to the respective embodiments of the present invention that are described above will now be described in detail based on Figure 21. Figure 21 is a block diagram illustrating an example of the hardware configuration of an information processing apparatus 100 that functions as an apparatus for controlling the rolling mills according to the respective embodiments of the present invention.

[0135] The information processing apparatus 100 includes a CPU 901, a ROM 903 and a RAM 905 as main components. The information processing apparatus 100 also includes a bus 907, an input device 909, an output device 911, a storage device 913, a drive 915, a connection port 917 and a communication device 919.

[0136] The CPU 901 functions as an arithmetic processing unit and a control unit, and controls all or some of the operations inside the information processing apparatus 100 in accordance with various programs recorded on the ROM 903, the RAM 905, the storage device 913 or the removable recording medium 921. The ROM 903 stores programs or computation parameters or the like that the CPU 901 uses. The RAM 905 performs primary storage of programs that the CPU 901 uses as well as parameters that change as appropriate during execution of a program. These components are connected to each other by the bus 907 that is constituted by an internal bus such as a CPU bus.

[0137] The bus 907 is connected to an external bus such as a PCI (Peripheral Component Interconnect/Interface) bus through a bridge.

[0138] The input device 909 is a device for inputting information, and has operation means that allows a user to operate the information processing apparatus 100. The input device 909 has an input control circuit that generates an input signal based on information that is inputted by the user using the operation means, and outputs the input signal to the CPU 901. By operating the input device 909, a user can input various kinds of data into the rolling mill and issue instructions for performing processing operations. The input device 909 has, for example, a mouse, a keyboard, a touch panel, buttons, switches and a lever as input means. The input device 909 may be, for example, a remote control that utilizes infrared rays or other electric waves, and may be an external connection device 923 such as a PDA (Personal Digital Assistant) that can operate the information processing apparatus 100.

[0139] The output device 911 is a device that is capable of information to the user visually or auditorily. The output device 911 is, for example, a display device such as a CRT display device, a liquid crystal display device, a plasma

display device, an EL display device or a lamp, or a sound output device such as a speaker and a headphone, or is a printer device. The output device 911 outputs, for example, results acquired by various kinds of processing executed by the information processing apparatus 100. Specifically, the output device 911 can display results acquired by various kinds of processing executed by the information processing apparatus 100, as text or images. Alternatively, the output device 911 can convert an audio signal including sound data and acoustic data into an analog signal and output the analog signal.

[0140] The storage device 913 is a device for data storage constituted as an example of a storage unit of the information processing apparatus 100. The storage device 913 is, for example, a magnetic storage unit device such as an HDD (Hard Disk Drive), a semiconductor storage device, an optical storage device, or a magneto-optical storage device. The storage device 913 stores programs that are executed by the CPU 901 and various kinds of data, as well as various kinds of data acquired from outside.

[0141] The drive 915 is a reader/writer for use as a recording medium, and is built into the information processing apparatus 100 or is attached to the information processing apparatus 100 from outside. The drive 915 reads out information recorded on the removable recording medium 921 such as an inserted magnetic disk, optical disk, magneto-optical disk or semiconductor memory, and outputs the information to the RAM 905. The drive 915 can also write information onto the removable recording medium 921 that is inserted. The removable recording medium 921 is, for example, a CD medium, a DVD medium, or a Blu-ray (registered trademark) medium. The removable recording medium 921 may also be a CompactFlash (CF) (registered trademark), a flash memory or an SD memory card (Secure Digital memory card) or the like. The removable recording medium 921 may also be, for example, an IC card (Integrated Circuit card) or an electronic device in which a non-contact IC chip is mounted.

[0142] The connection port 917 is a port for directly connecting a device to the information processing apparatus 100. The connection port 917 is, for example, a USB (Universal Serial Bus) port, an IEEE1394 port, an SCSI (Small Computer System Interface) port, or an RS-232C port. By connecting the external connection device 923 to the connection port 917, the information processing apparatus 100 can directly acquire various kinds of data from the external connection device 923, and provide various kinds of data to the external connection device 923.

[0143] The communication device 919 is a communication interface constituted by a communication device or the like for connecting to a communication network 925. The communication device 919 is, for example, a wired or wireless LAN (Local Area Network), Bluetooth (registered trademark), or a communication card for a WUSB (Wireless USB). Further, the communication device 919 may be a router for optical communication, a router for ADSL (Asymmetric Digital Subscriber Line), or a modem for various kinds of communication. The communication device 919 can, for example, transmit and receive signals and the like according to a predetermined protocol such as TCP/IP to and from the Internet or other communication devices. Further, the communication network 925 that is connected to by the communication device 919 is a network that is connected to by wire or wirelessly, and may be, for example, the Internet, a LAN, infrared-ray communication, radio wave communication, or satellite communication.

[0144] An example of the hardware configuration of the information processing apparatus 100 that can realize functions of an apparatus for controlling the rolling mill according to each embodiment of the present invention has been described above. Each of the constituent elements described above may be constituted by using general-purpose members, or may be constituted by hardware that is specialized for the function of the respective constituent elements. Therefore, the configuration can be appropriately changed in accordance with the technical level when implementing the present embodiment.

REFERENCE SIGNS LIST

[0145]

- 1 Upper work roll
- 2 Lower work roll
- 3 Upper backup roll
- 4 Lower backup roll
- 5a Upper work roll chock (work side)
- 5b Upper work roll chock (drive side)
- 6a Lower work roll chock (work side)
- 6b Lower work roll chock (drive side)
- 7a Upper backup roll chock (work side)
- 7b Upper backup roll chock (drive side)
- 8a Lower backup roll chock (work side)
- 8b Lower backup roll chock (drive side)
- 9 Upper-work-roll-chock pressing apparatus

- 10 Lower-work-roll-chock pressing apparatus
- 11 Driving apparatus with upper work roll chock position detection function
- 12 Driving apparatus with lower work roll chock position detection function
- 13 Upper-backup-roll-chock pressing apparatus
- 5 14 Driving apparatus with upper backup roll chock position detection function
- 15 Roll chock rolling direction force control unit
- 16 Roll chock position control unit
- 17 Upper work roll thrust counterforce measurement apparatus
- 18 Lower work roll thrust counterforce measurement apparatus
- 10 19 Upper backup roll thrust counterforce measurement apparatus
- 20 Lower backup roll thrust counterforce measurement apparatus
- 21 Driving electric motor
- 22 Driving electric motor control unit
- 23 Inter-roll crossing control unit
- 15 24a Entrance-side upper increase bending apparatus
- 24b Exit-side upper increase bending apparatus
- 25a Entrance-side lower increase bending apparatus
- 25b Exit-side lower increase bending apparatus
- 26 Increase bending control unit
- 20 27 Pressing-down device
- 28a Upper load measurement apparatus (work side)
- 28b Upper load measurement apparatus (drive side)
- 29a Lower load measurement apparatus (work side)
- 29b Lower load measurement apparatus (drive side)
- 25 30 Housing
- 32 Upper-side differential load computation portion [subtractor]
- 33 Lower-side differential load computation portion [subtractor]
- 34 Servo-motor with a rotation angle detection function
- 40 Lower-backup-roll-chock pressing apparatus
- 30 41 Upper intermediate roll
- 42 Lower intermediate roll
- 43 Upper intermediate roll chocks
- 43a Upper intermediate roll chock (work side)
- 43b Upper intermediate roll chock (drive side)
- 35 44 Lower intermediate roll chocks
- 44a Lower intermediate roll chock (work side)
- 44b Lower intermediate roll chock (drive side)
- 45 Upper intermediate roll thrust counterforce measurement apparatus
- 46 Lower intermediate roll thrust counterforce measurement apparatus
- 40

Claims

1. A method for setting a rolling mill,
 45 the rolling mill being a rolling mill of four-high or more that includes a plurality of rolls including at least a pair of work rolls and a pair of backup rolls which support the work rolls,
 wherein, before zero point of reduction position adjustment or before starting rolling, any one roll among respective rolls arranged in a vertical direction is taken as a reference roll,
 the method comprising:
 50
 - a thrust counterforce measurement step of measuring thrust counterforces in an axial direction of rolls which act on at least the rolls other than the backup rolls; and
 - a roll chock position adjustment step of fixing a rolling direction position of a roll chock of the reference roll as a reference position, and moving roll chocks of the rolls other than the reference roll in a rolling direction of a
 55 workpiece to adjust positions of the roll chocks so that the thrust counterforces measured fall within an allowable range.
2. The method for setting a rolling mill according to claim 1, wherein a roll located at a lowermost part or an uppermost

part in the vertical direction among the plurality of rolls is taken as the reference roll.

3. The method for setting a rolling mill according to claim 2, wherein:

5 in the roll chock position adjustment step, the work rolls are set in a kiss roll state, and in order from a roll on an opposite side to the reference roll, the roll chocks of the roll that is a position adjustment object are moved in the rolling direction of the workpiece to adjust the position of the roll chocks so that a thrust counterforce generated between the rolls that are adjacent falls within an allowable range, and
10 at such time, the roll chocks of the rolls for which the position of the roll chocks is already adjusted are controlled simultaneously and in a same direction while maintaining a relative position with respect to the roll chocks of the roll that is the position adjustment object.

4. The method for setting a rolling mill according to claim 2, wherein:

15 in the roll chock position adjustment step, the work rolls are set in a kiss roll state, and in order from the reference roll side, the roll chocks of the roll that is a position adjustment object are moved in the rolling direction of the workpiece to adjust the position of the roll chocks so that a thrust counterforce generated between the rolls that are adjacent falls within an allowable range, and
20 at such time, the roll chocks of the rolls for which the position of the roll chocks is not adjusted are controlled simultaneously and in a same direction while maintaining a relative position with respect to the roll chocks of the roll that is the position adjustment object.

5. The method for setting a rolling mill according to claim 2, wherein:

25 in the rolling mill that is a four-high rolling mill, a plurality of rolls provided on an upper side in the vertical direction with respect to the workpiece are taken as an upper roll assembly, and a plurality of rolls provided on a lower side in the vertical direction with respect to the workpiece are taken as a lower roll assembly;
in the roll chock position adjustment step, the followings are performed:

30 a first adjustment in which a roll gap between the work rolls is placed in an open state, and with respect to each of the upper roll assembly and the lower roll assembly, positions of the roll chocks of the work roll and the roll chocks of the backup roll are adjusted, and
after the first adjustment ends, a second adjustment in which the work rolls are set in a kiss roll state, and either one of the upper roll assembly and the lower roll assembly is taken as a reference roll assembly, and
35 positions of the roll chocks of each roll of the other roll assembly are adjusted by controlling the roll chocks simultaneously and in a same direction while maintaining relative positions of the roll chocks; and

in the first adjustment, with respect to each of the upper roll assembly and the lower roll assembly, in a state in which a bending force is applied by a bending apparatus to the roll chocks of the work rolls, the roll chocks of
40 the work roll on the reference roll side and either one of the roll chocks of the work roll and the roll chocks of the backup roll of a roll assembly on an opposite side to the reference roll are moved in a rolling direction of the workpiece to adjust positions of the roll chocks so that the thrust counterforce measured falls within an allowable range.

45 **6.** The method for setting a rolling mill according to claim 2, the rolling mill being the rolling mill that is six-high and comprises intermediate rolls between the work rolls and the backup rolls, respectively, wherein:

50 a plurality of rolls provided on an upper side in the vertical direction with respect to the workpiece are taken as an upper roll assembly, and a plurality of rolls provided on a lower side in the vertical direction with respect to the workpiece are taken as a lower roll assembly;
in the roll chock position adjustment step, the followings are performed:

55 a first adjustment in which a roll gap between the work rolls is placed in an open state, and with respect to each of the upper roll assembly and the lower roll assembly, positions of the roll chocks of the intermediate roll and the roll chocks of the backup roll are adjusted,
after the first adjustment ends, a second adjustment in which the roll gap between the work rolls is maintained in an open state, and with respect to each of the upper roll assembly and the lower roll assembly, positions

of the roll chocks of the intermediate roll and the roll chocks of the work roll are adjusted, and after the second adjustment ends, a third adjustment in which the work rolls are set in a kiss roll state, either one of the upper roll assembly and the lower roll assembly is taken as a reference roll assembly, and positions of the roll chocks of each roll of the other roll assembly are adjusted by controlling the roll chocks simultaneously and in a same direction while maintaining relative positions of the roll chocks;

the first adjustment and the second adjustment are performed in a state in which a bending force is applied by a bending apparatus to the roll chocks of the intermediate rolls and the roll chocks of the work rolls; in the first adjustment, with respect to each of the upper roll assembly and the lower roll assembly, the roll chocks of the intermediate roll on the reference roll side and either one of the roll chocks of the intermediate roll and the roll chocks of the backup roll of a roll assembly on an opposite side to the reference roll are moved in the rolling direction of the workpiece to adjust positions of the roll chocks so that the thrust counterforce measured falls within an allowable range; and in the second adjustment, with respect to each of the upper roll assembly and the lower roll assembly:

the roll chocks of the work roll on the reference roll side and either one of the roll chocks of the intermediate roll and the roll chocks of the work roll of the roll assembly on the opposite side to the reference roll are moved in the rolling direction of the workpiece to adjust positions of the roll chocks so that the thrust counterforce measured falls within an allowable range, and

in a case of moving the roll chocks of the intermediate roll of the roll assembly on the opposite side to the reference roll, the roll chocks of the intermediate roll and the roll chocks of the backup roll that is adjacent to the intermediate roll are controlled simultaneously and in a same direction while maintaining relative positions between the roll chocks of the intermediate roll and the roll chocks of the backup roll.

7. A rolling mill of four-high or more that includes a plurality of rolls including at least a pair of work rolls and a pair of backup rolls which support the work rolls, the rolling mill comprising:

with any one roll among respective rolls arranged in a vertical direction being taken as a reference roll, a measurement apparatus that measures at least thrust counterforces in an axial direction of rolls that act on each of the rolls other than the backup roll;

a pressing apparatus provided on either one of an entrance side and an exit side in the rolling direction with respect to at least roll chocks of the rolls other than the reference roll, the pressing apparatus pressing a workpiece in the rolling direction;

a driving apparatus provided so as to face the pressing apparatus in the rolling direction with respect to at least roll chocks of the rolls other than the reference roll, the driving apparatus moving a workpiece in the rolling direction; and

a position control unit that fixes a rolling direction position of a roll chock of the reference roll as a reference position, and drives the driving apparatus to control positions in the rolling direction of the roll chocks of the rolls other than the reference roll so that thrust counterforces at each of the rolls become values that are within an allowable range.

8. The rolling mill according to claim 7, wherein a roll located at a lowermost part or an uppermost part in the vertical direction among the plurality of rolls is taken as the reference roll.

9. The rolling mill according to claim 7 or 8, comprising:

a bending apparatus that imparts a bending force to the rolls; wherein the position control unit places a roll gap between the roll that is taken as a position adjustment object and the roll that is other than a position adjustment object in an open state, and imparts a bending force by means of the bending apparatus to the roll chocks of the roll that is the position adjustment object.

10. The rolling mill according to any one of claims 7 to 9, wherein the driving apparatus is a hydraulic cylinder comprising a roll chock position detection apparatus.

FIG. 1

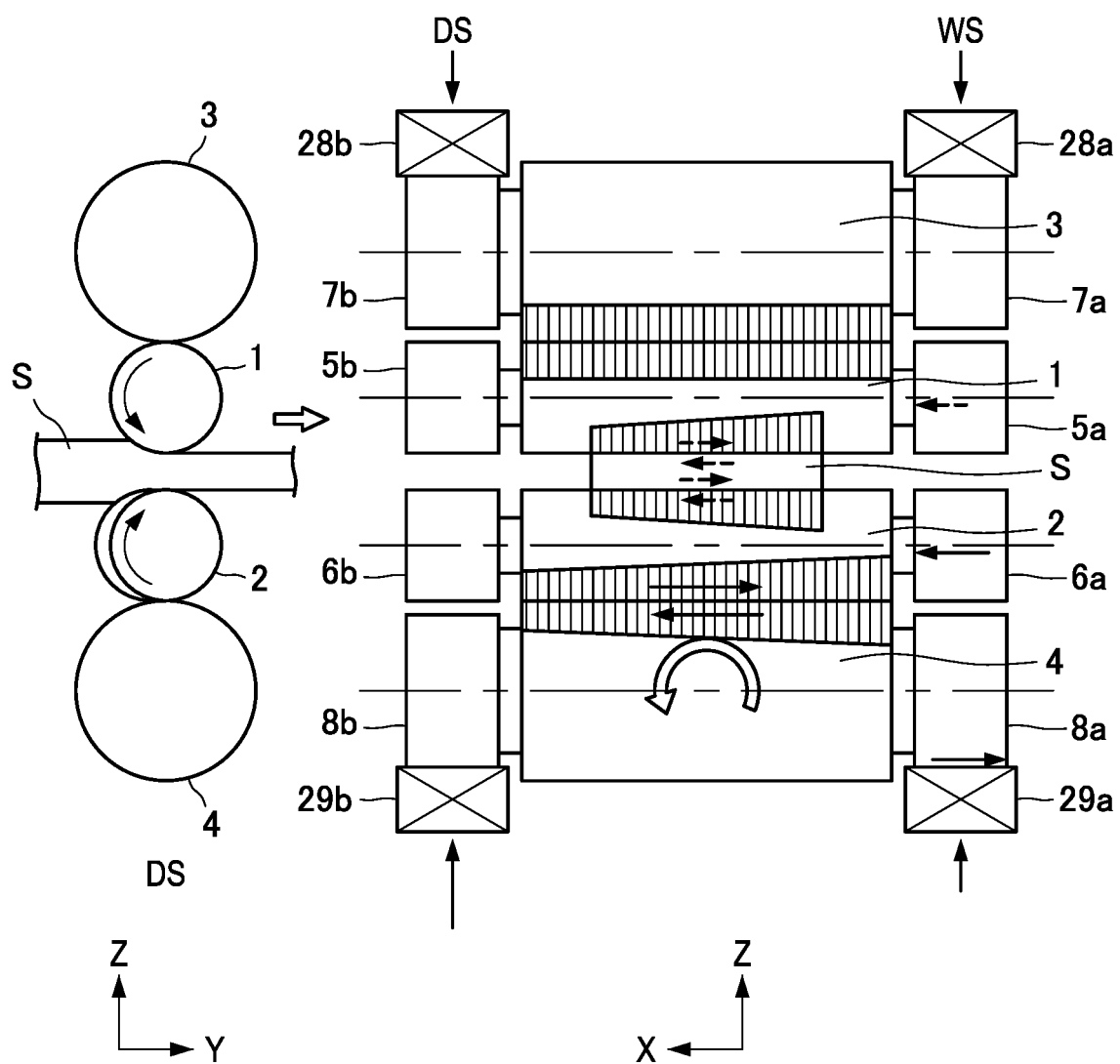


FIG. 2

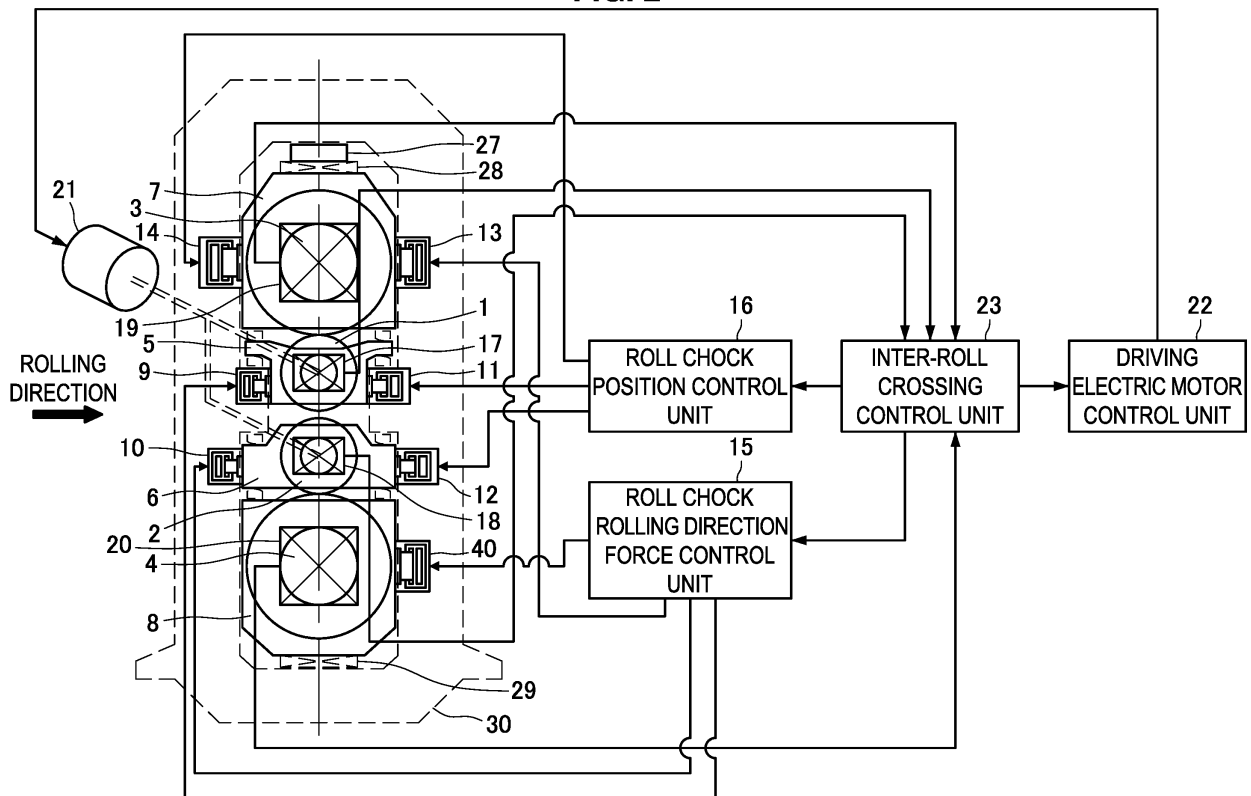


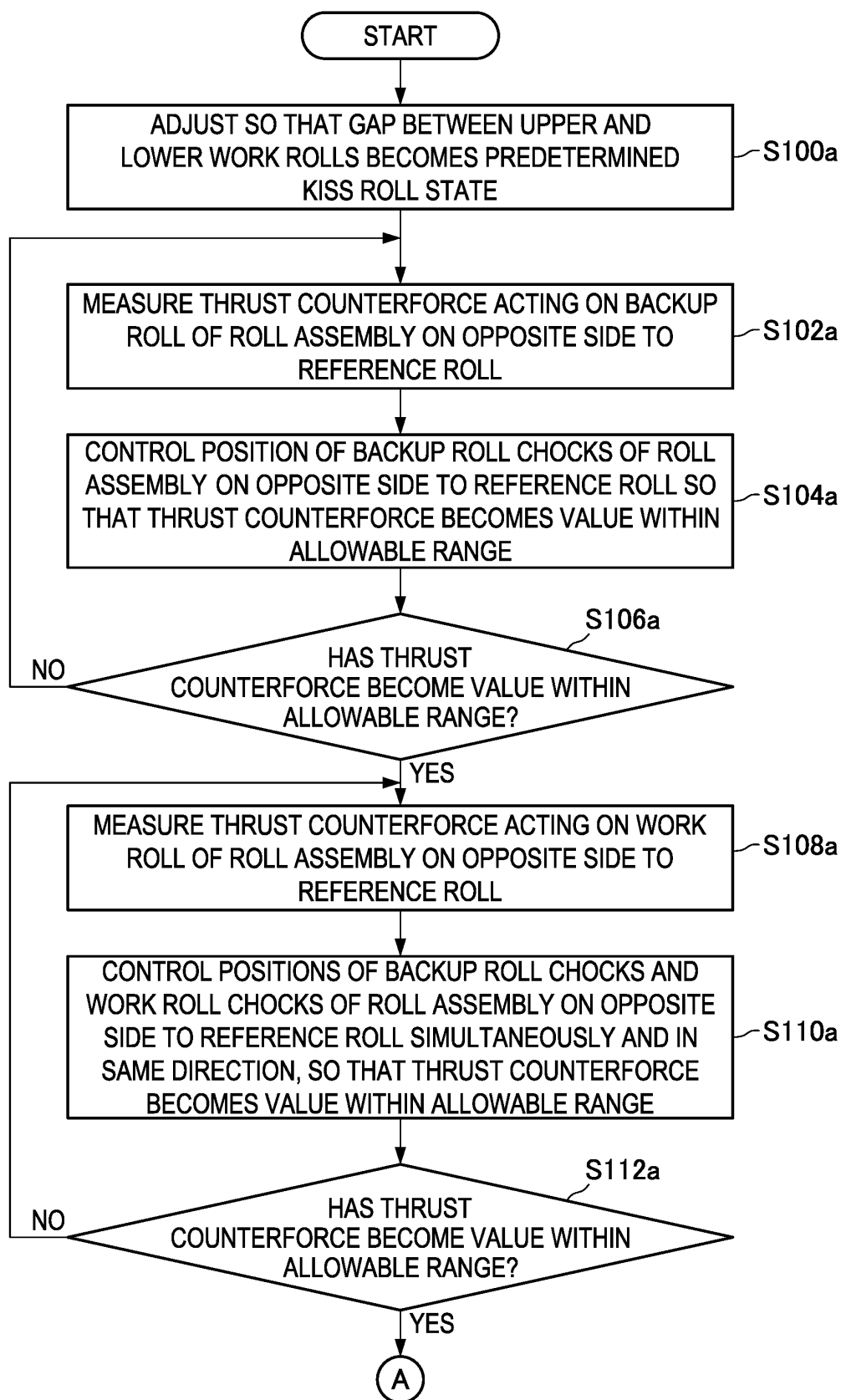
FIG. 3A

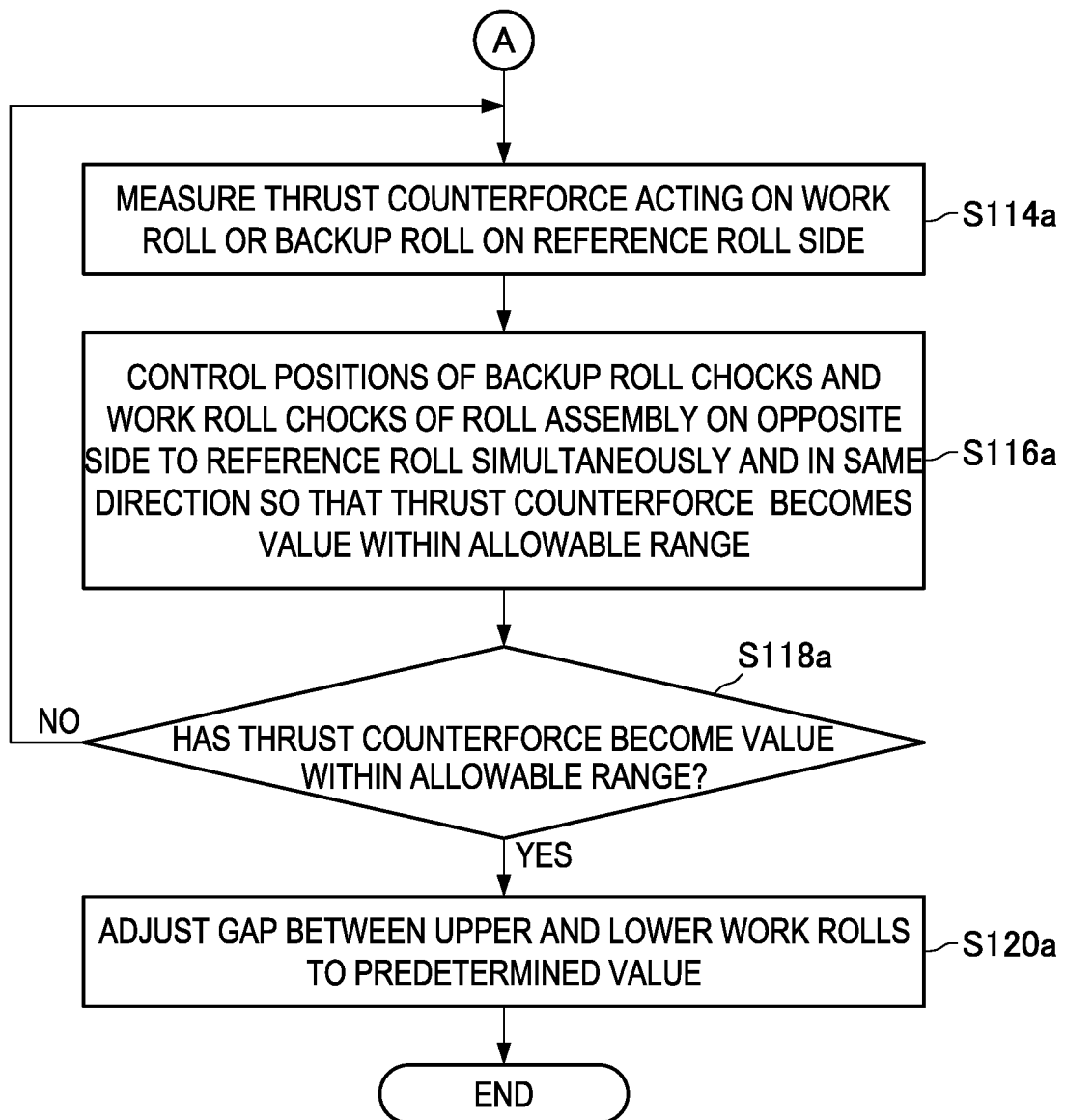
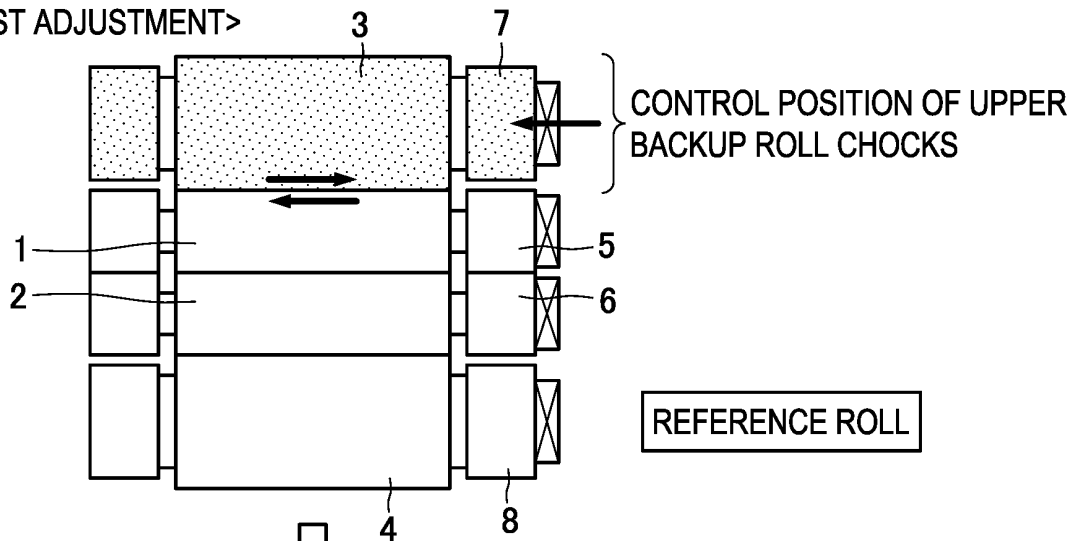
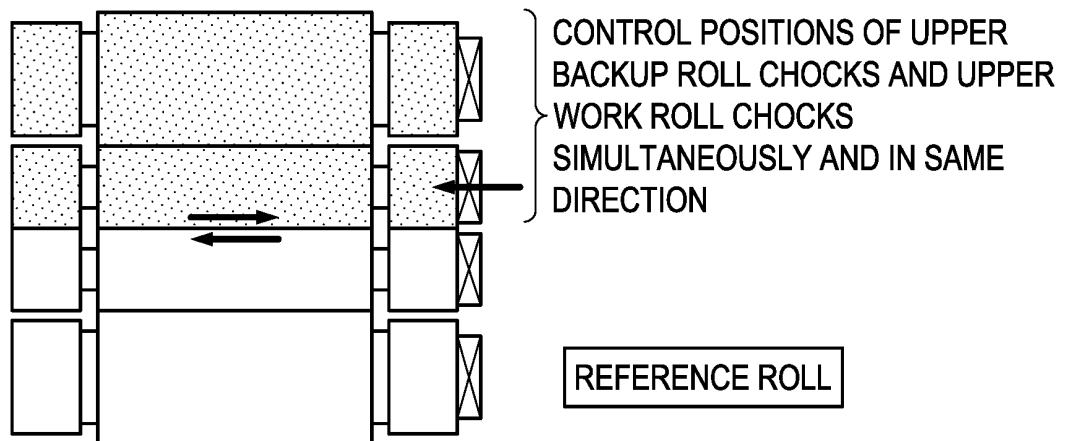
FIG. 3B

FIG. 4

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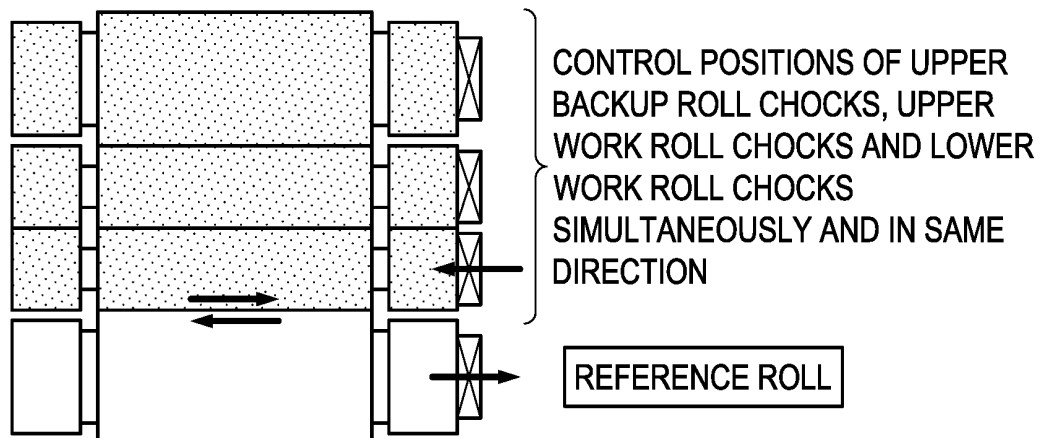


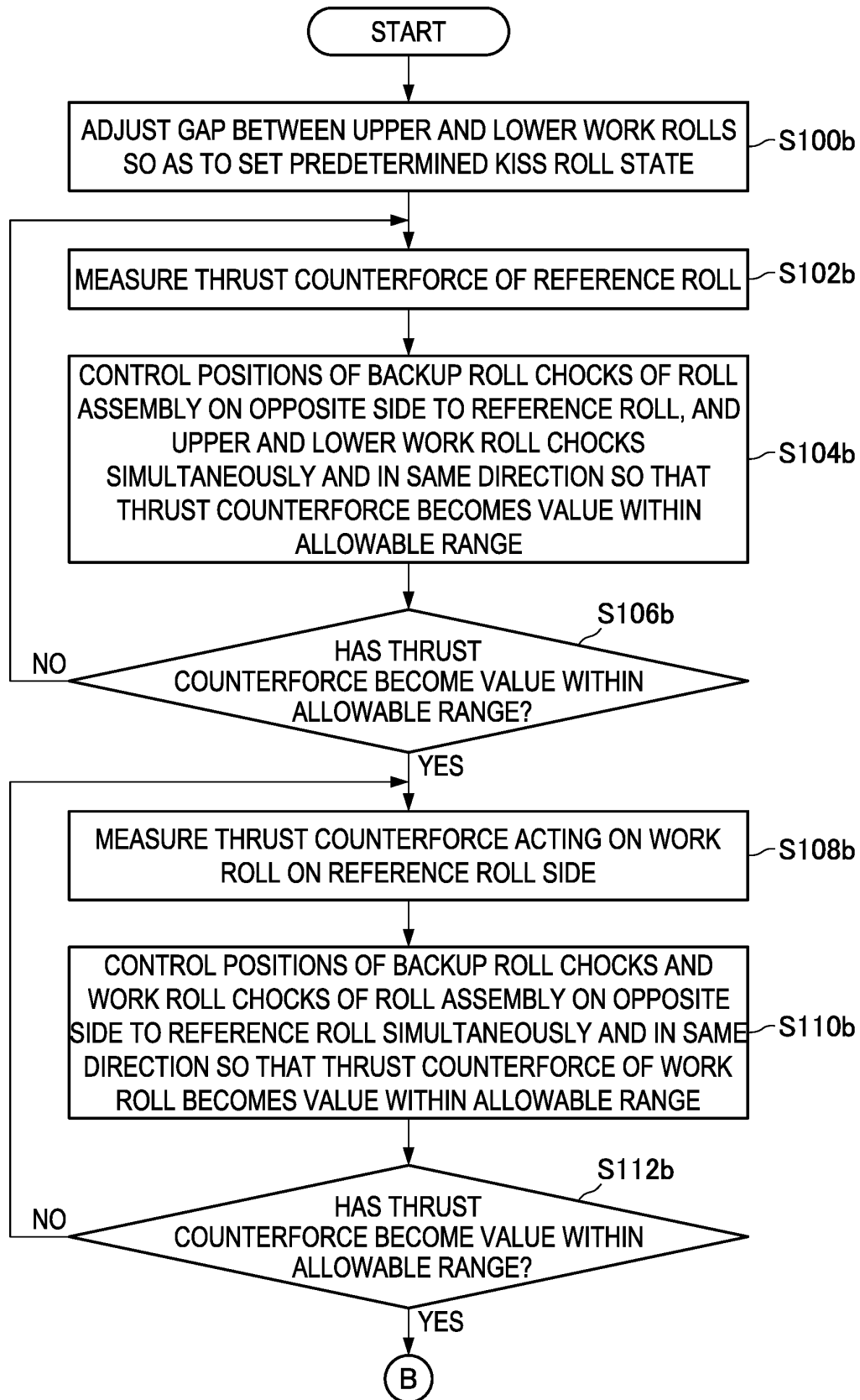
FIG. 5A

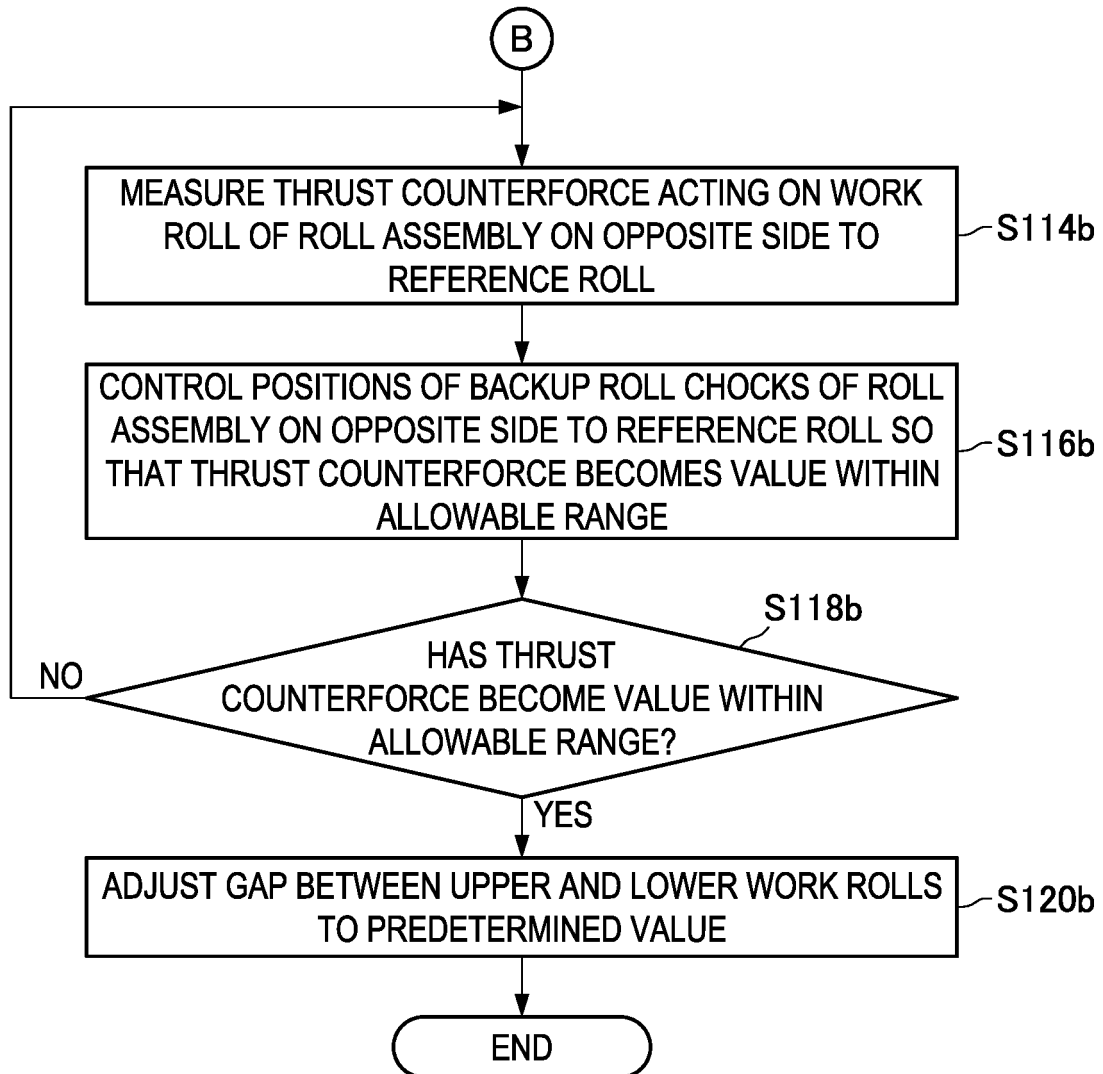
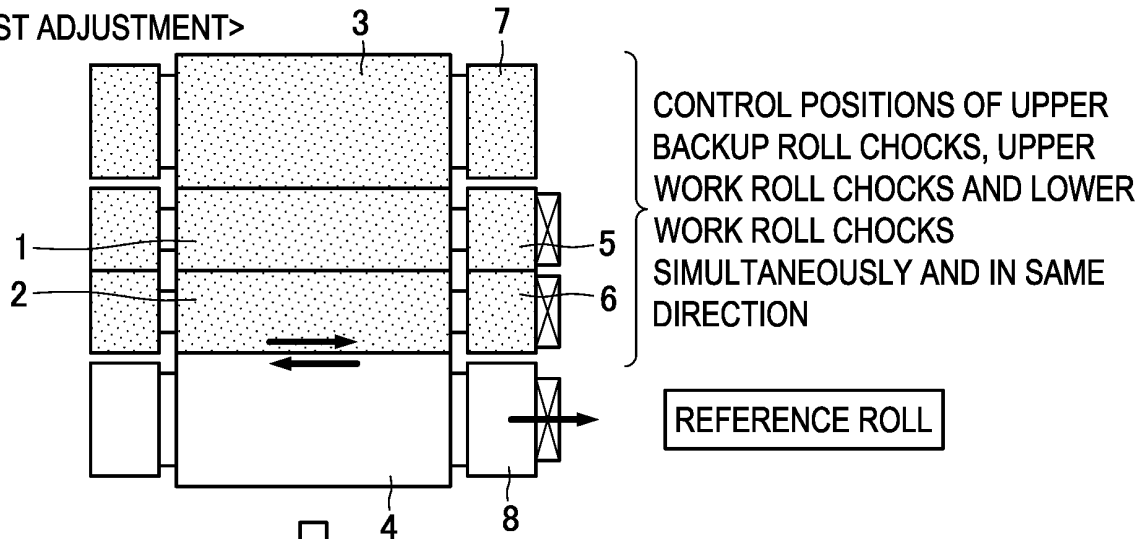
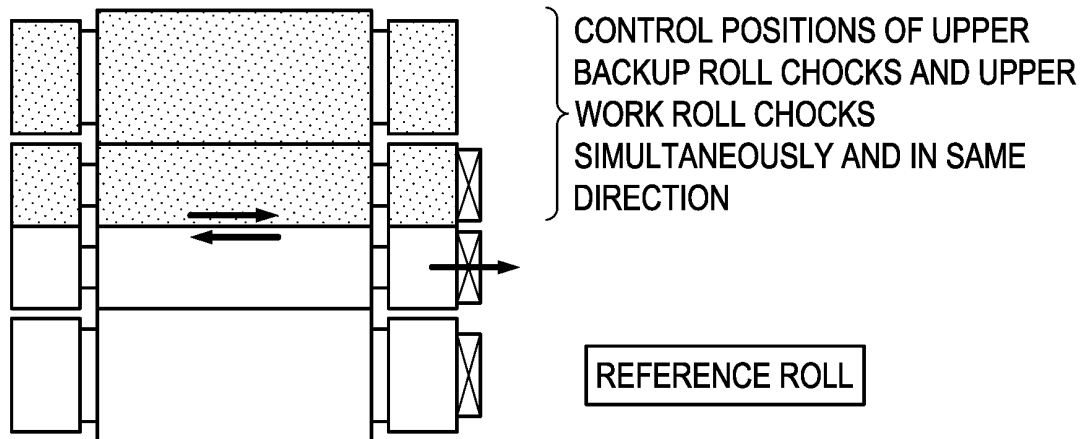
FIG. 5B

FIG. 6

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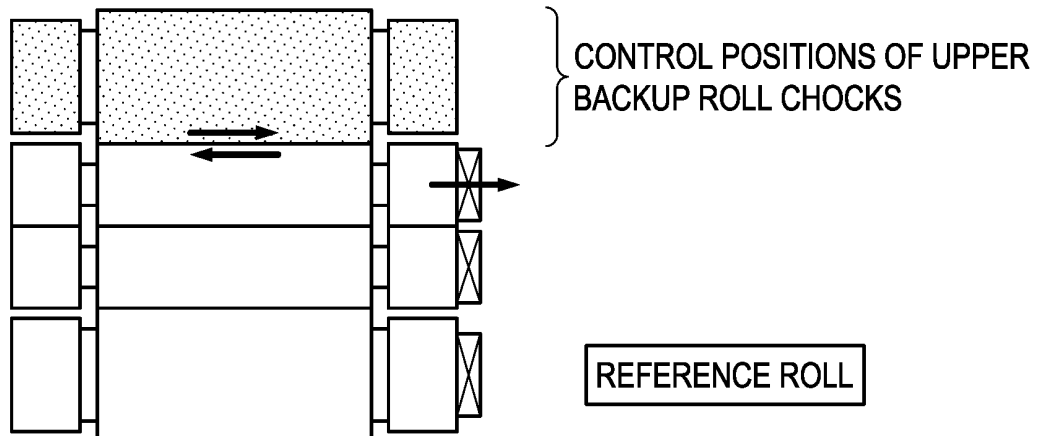


FIG. 7

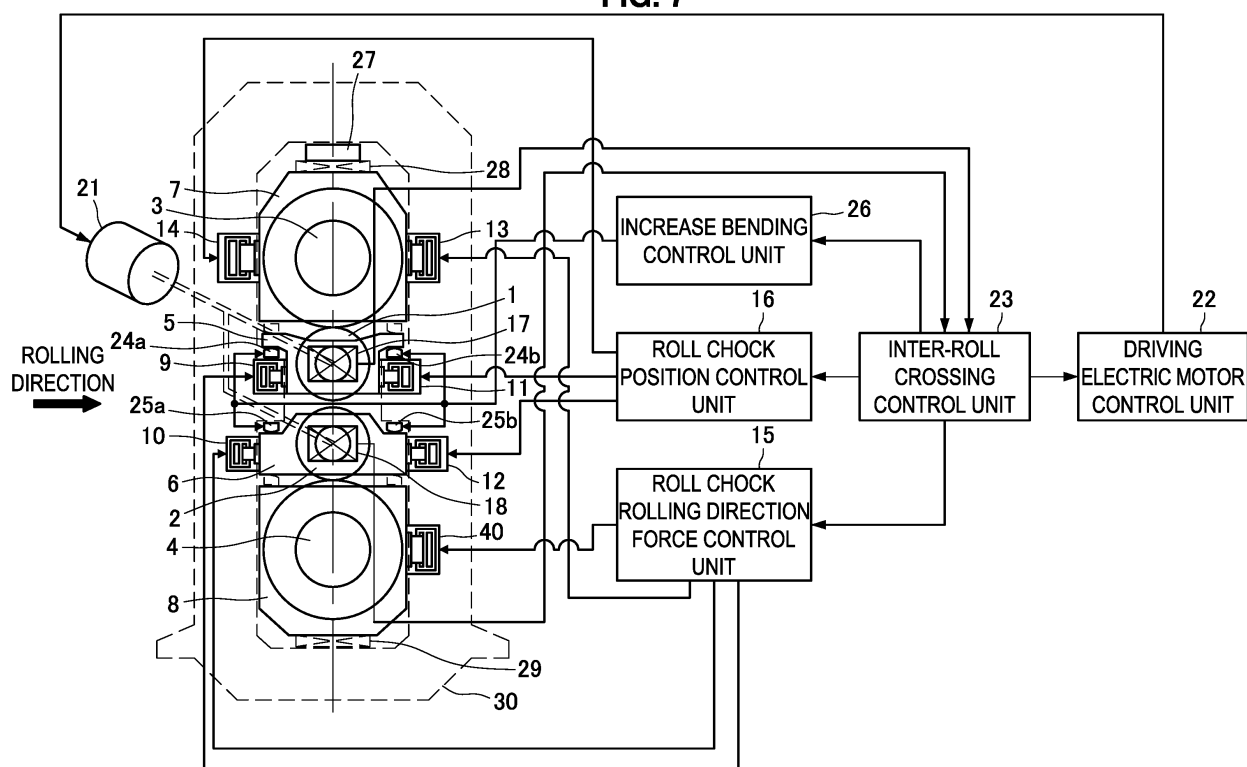


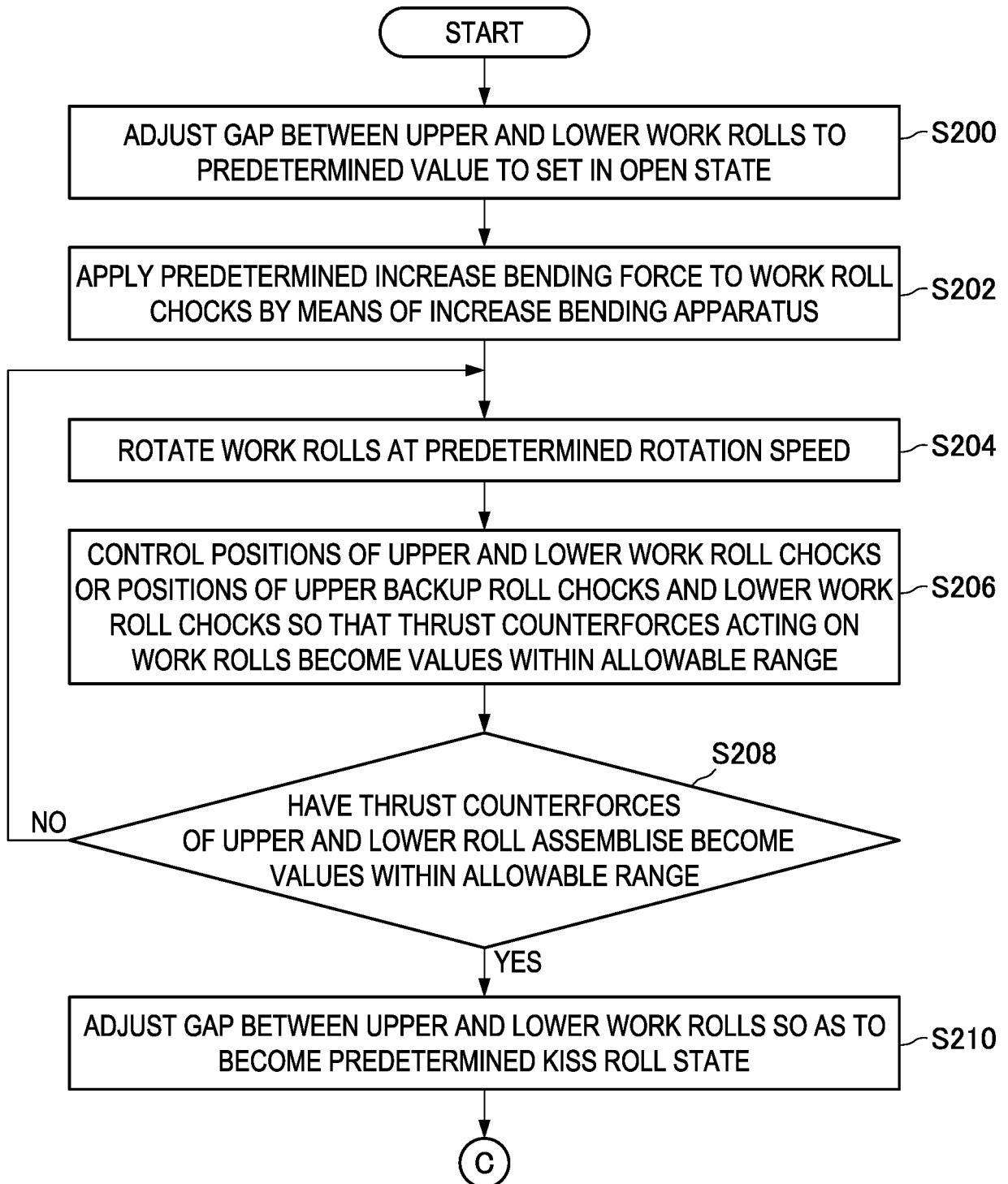
FIG. 8A

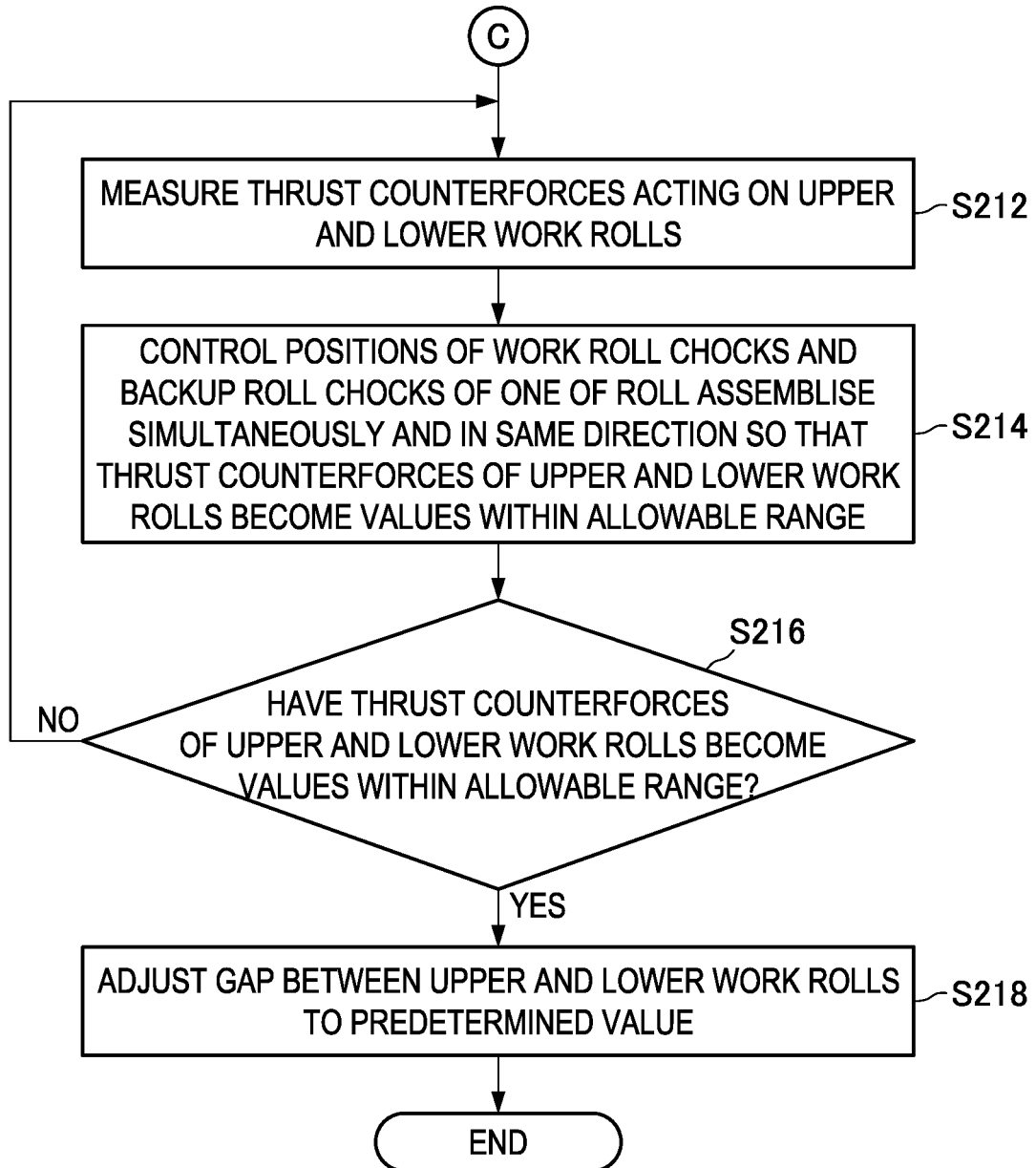
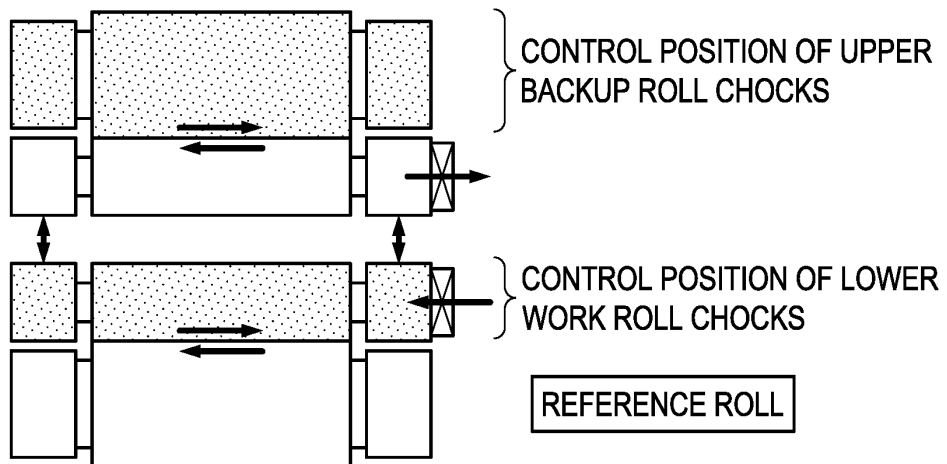
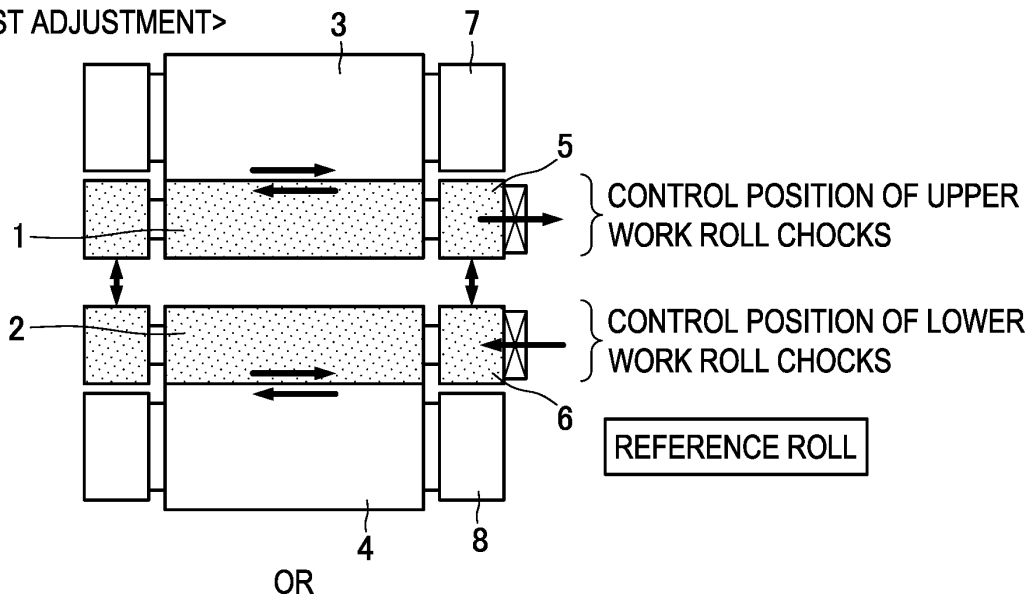
FIG. 8B

FIG. 9

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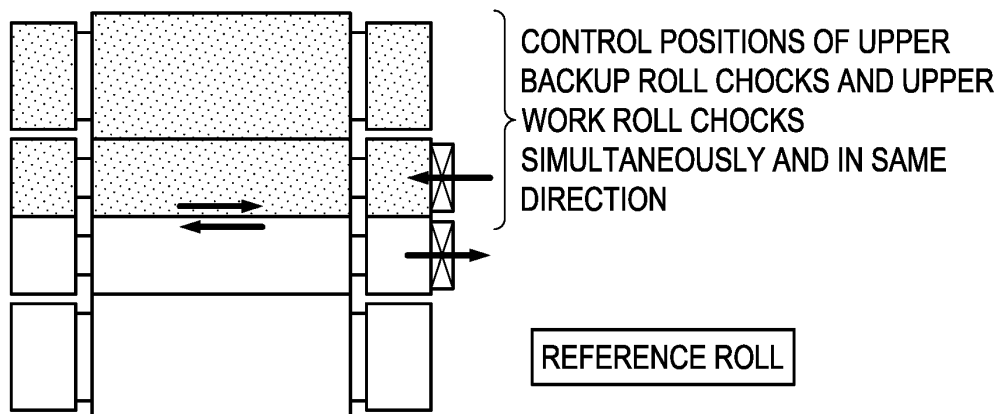


FIG. 10

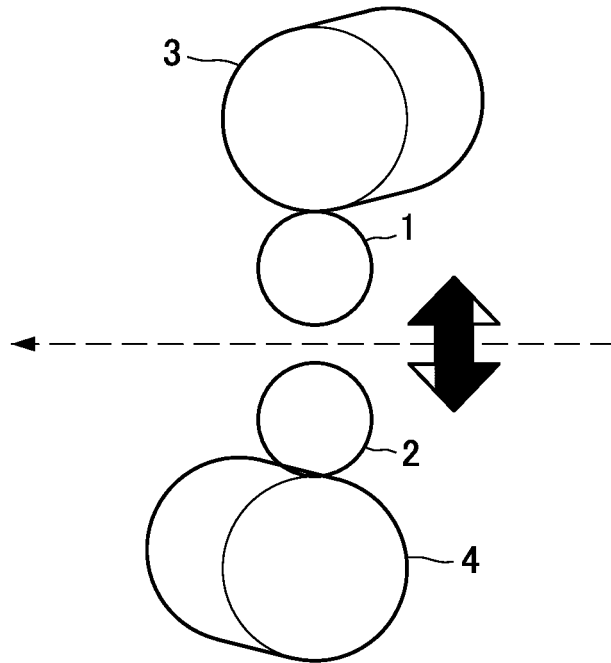


FIG. 11

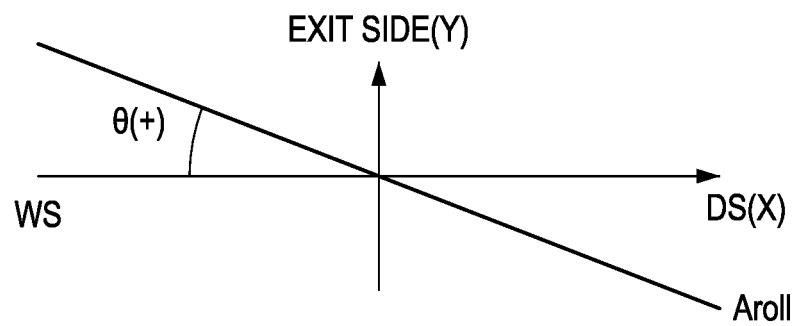
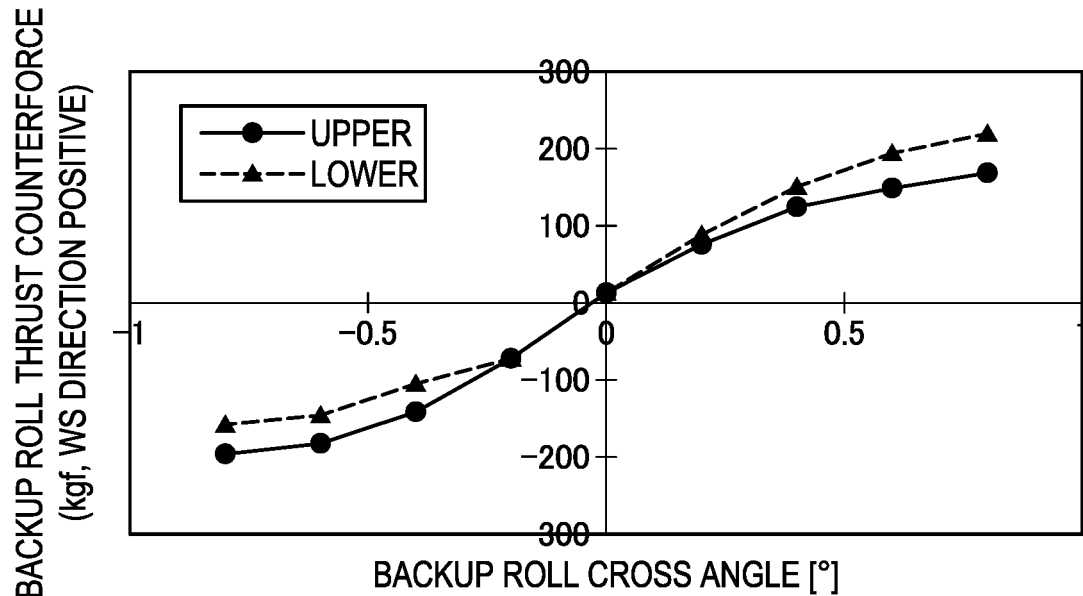
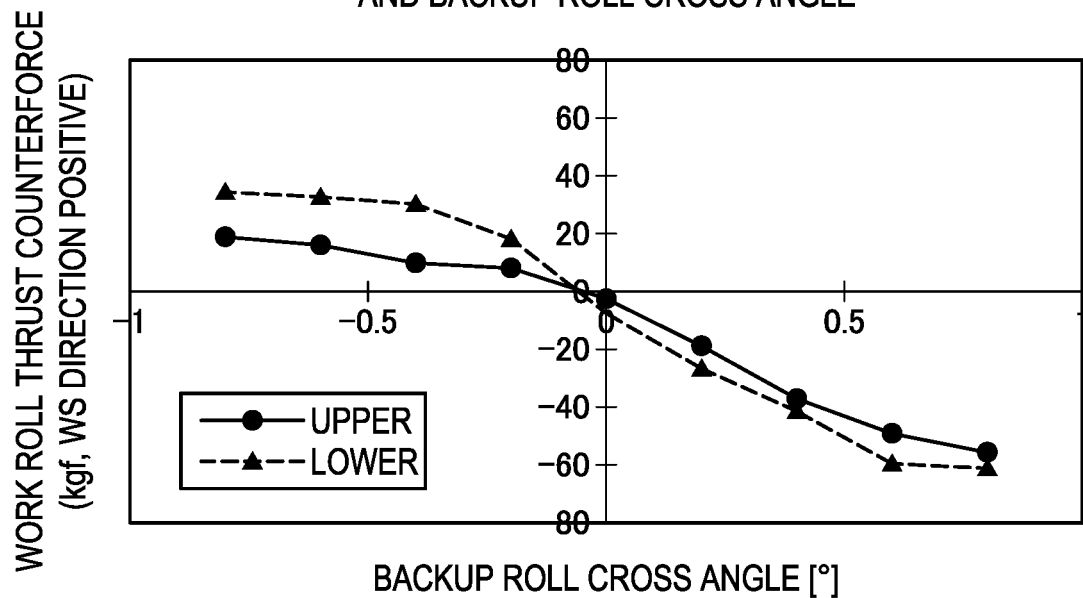


FIG. 12



a. RELATION BETWEEN BACKUP ROLL THRUST COUNTERFORCE AND BACKUP ROLL CROSS ANGLE



b. RELATION BETWEEN WORK ROLL THRUST COUNTERFORCE AND BACKUP ROLL CROSS ANGLE

FIG. 13

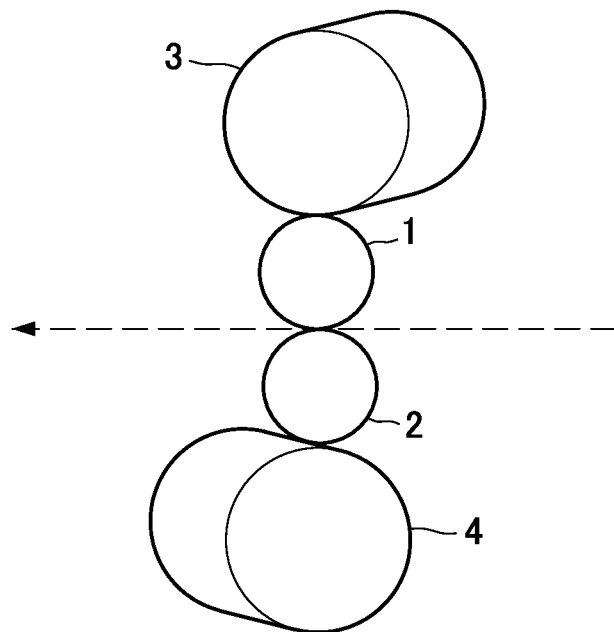


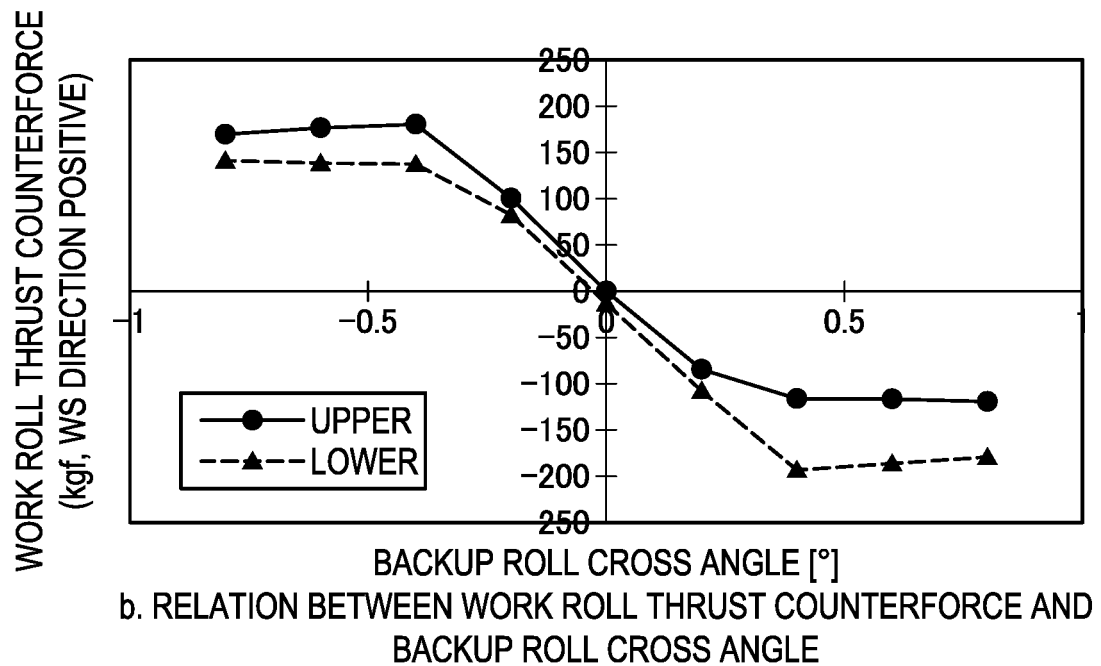
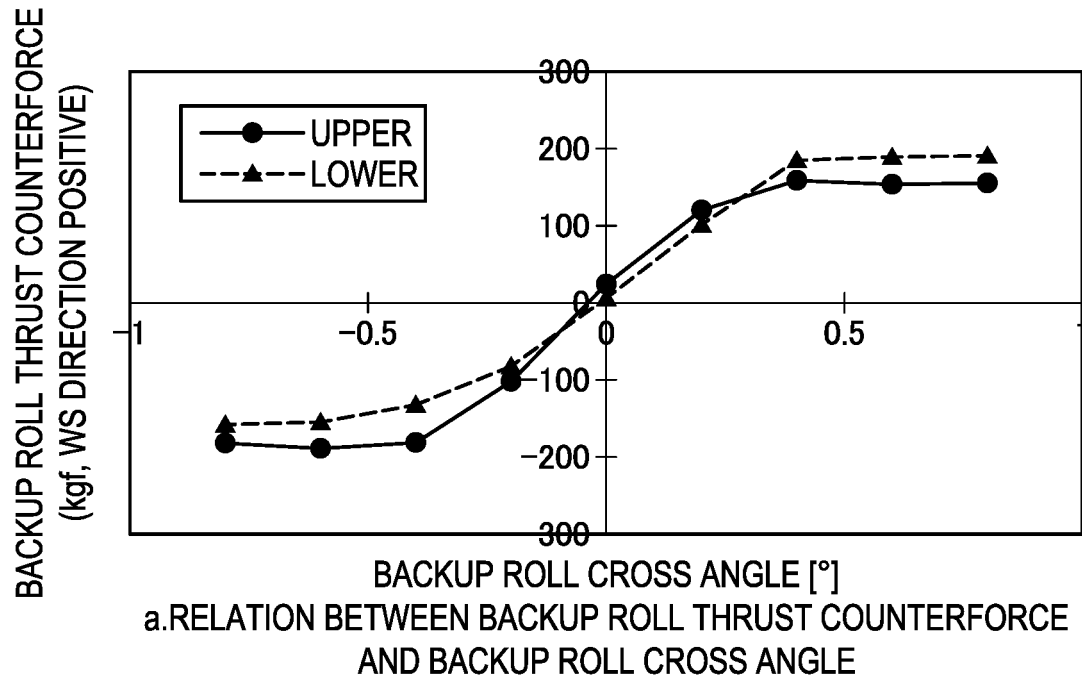
FIG. 14

FIG. 15

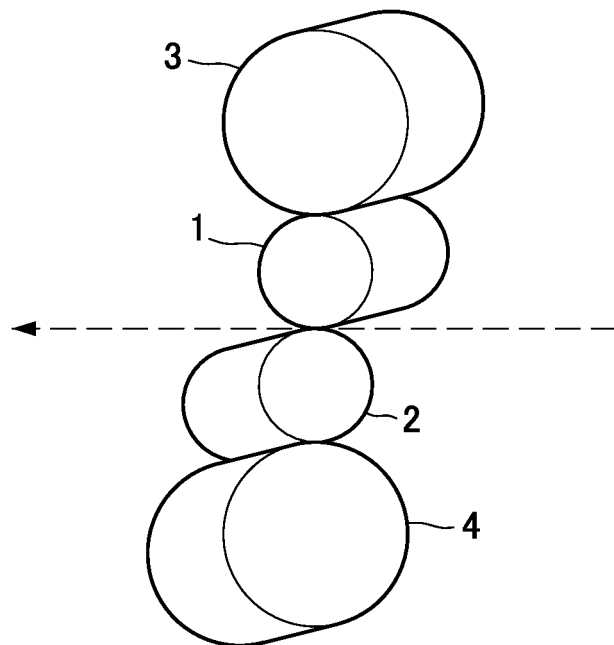
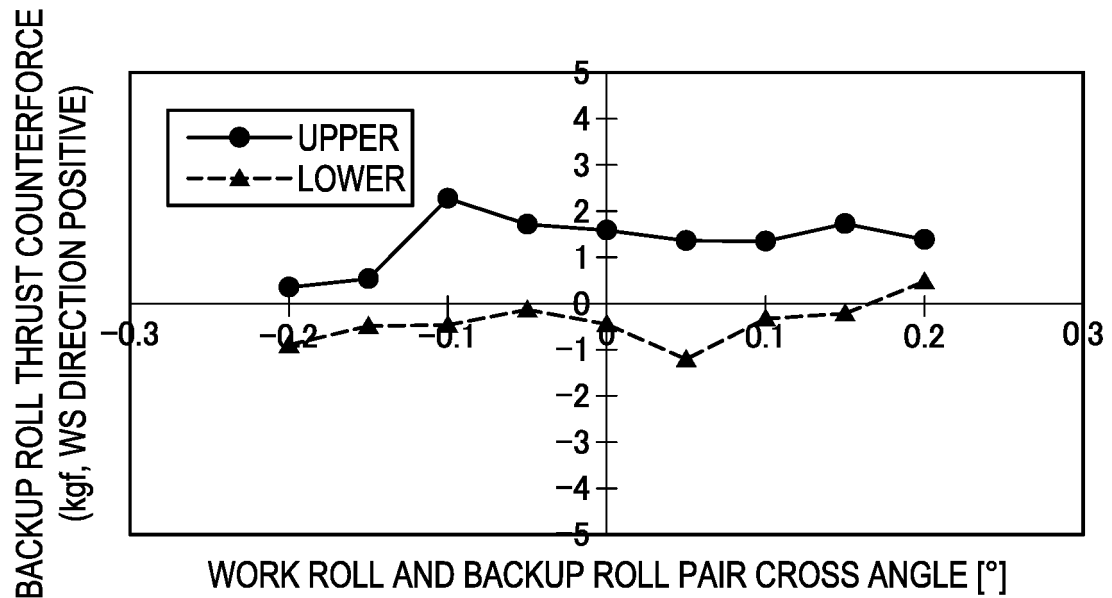
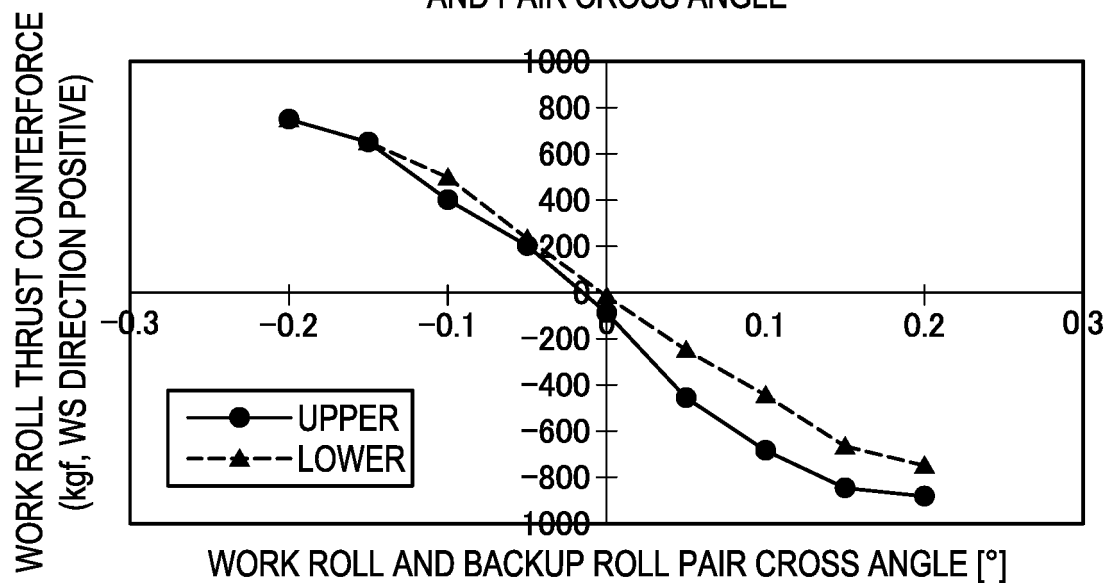


FIG. 16

a. RELATION BETWEEN BACKUP ROLL THRUST COUNTERFORCE
AND PAIR CROSS ANGLE



b. RELATION BETWEEN WORK ROLL THRUST COUNTERFORCE
AND PAIR CROSS ANGLE

FIG. 17

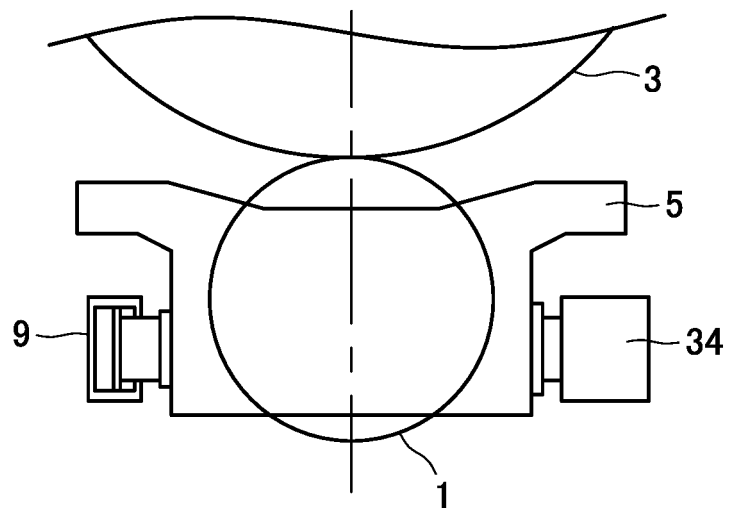
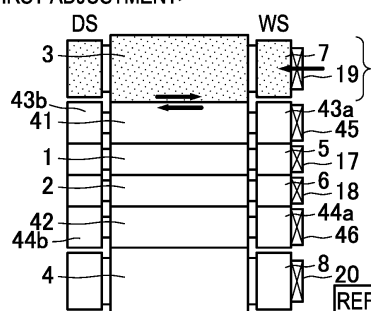
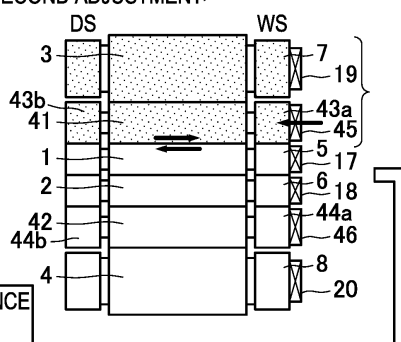


FIG. 18

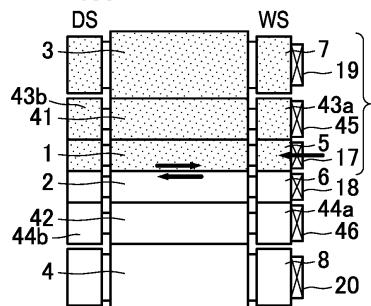
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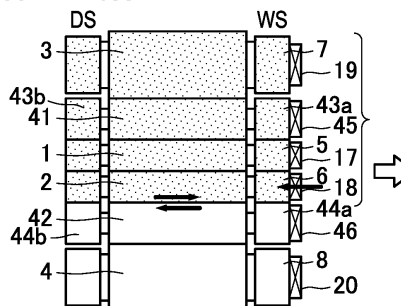
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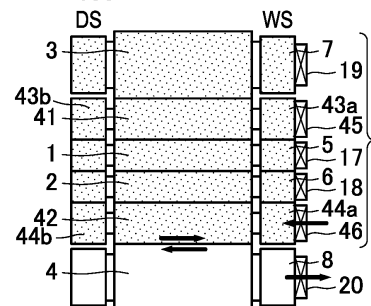
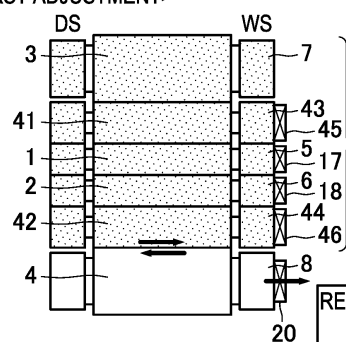
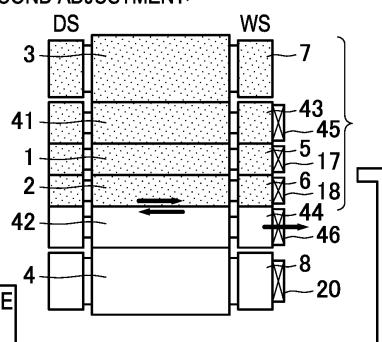


FIG. 19

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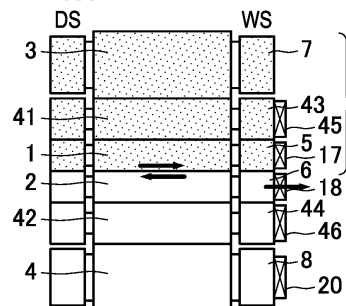


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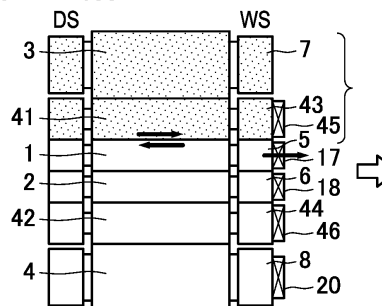


REFERENCE
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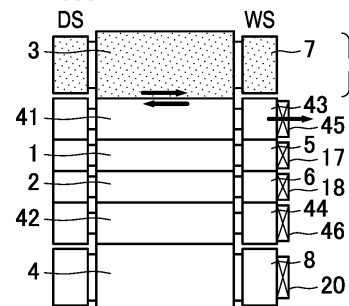
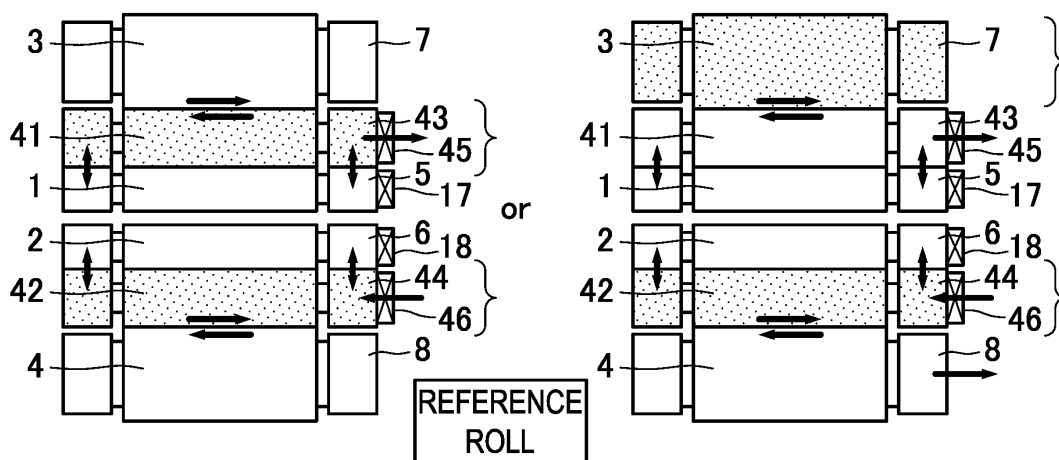
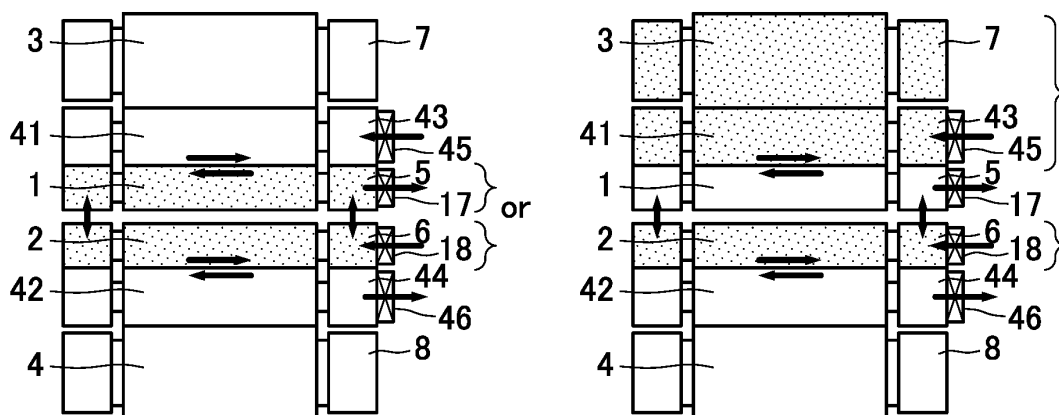


FIG. 20

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<THIRD ADJUSTMENT>

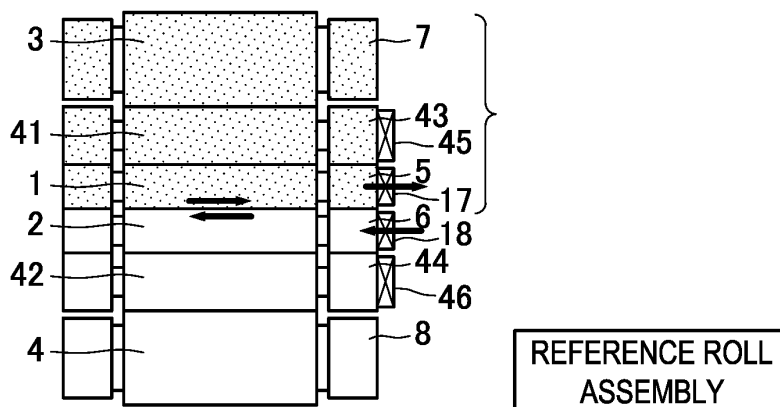
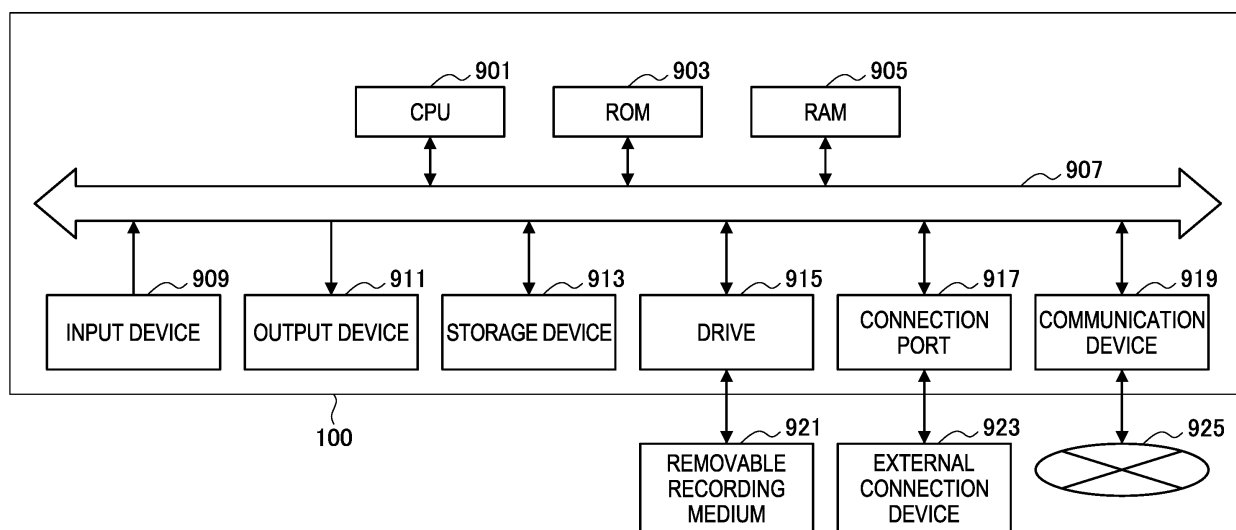


FIG. 21



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/031307

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. B21B31/16(2006.01)i, B21B13/14(2006.01)i, B21B37/00(2006.01)i,
B21B37/58(2006.01)i, B21B37/68(2006.01)i

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)

Int.Cl. B21B31/16, B21B13/14, B21B37/00, B21B37/58, B21B37/68

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 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 10-263656 A (NIPPON STEEL CORP.) 06 October 1998, claims, paragraphs [0017], [0021], [0042]-[0049], fig. 1-2 (Family: none)	1-2, 7-10 3-6
Y A	JP 3701981 B2 (NIPPON STEEL CORP.) 05 October 2005, claims 4, 6, page 8, lines 3-9, page 24, lines 22-24, fig. 3-4 & US 2002/0053230 A1, claims 4, 6, paragraphs [0016], [0196], fig. 3-4 & WO 1999/043452 A1	1-2, 7-10 3-6



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
16 October 2018 (16.10.2018)

Date of mailing of the international search report
30 October 2018 (30.10.2018)

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

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/031307

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
<u>Y</u> <u>A</u>	WO 2011/129453 A1 (NIPPON STEEL & SUMITOMO METAL CORPORATION) 20 October 2011, paragraphs [0006], [0020]-[0025], [0052]-[0054], fig. 1-3, 7 & US 2013/0000371 A1, paragraphs [0006], [0030]-[0046], [0080]-[0082], fig. 1-3, 7 & KR 10-2012-0027550 A & CN 102548678 A	1-2, 7-10 <u>3-6</u>
<u>Y</u> <u>A</u>	JP 4962334 B2 (JFE STEEL CORPORATION) 27 June 2012, claims, paragraphs [0052]-[0058] (Family: none)	9-10 <u>1-8</u>
<u>A</u>	JP 2013-52396 A (JFE STEEL CORPORATION) 21 March 2013, entire text, fig. 1-7 (Family: none)	<u>1-10</u>

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 3499107 B [0006]
- JP 2014004599 A [0006]
- JP 8294713 A [0006]
- JP 4962334 B [0006]