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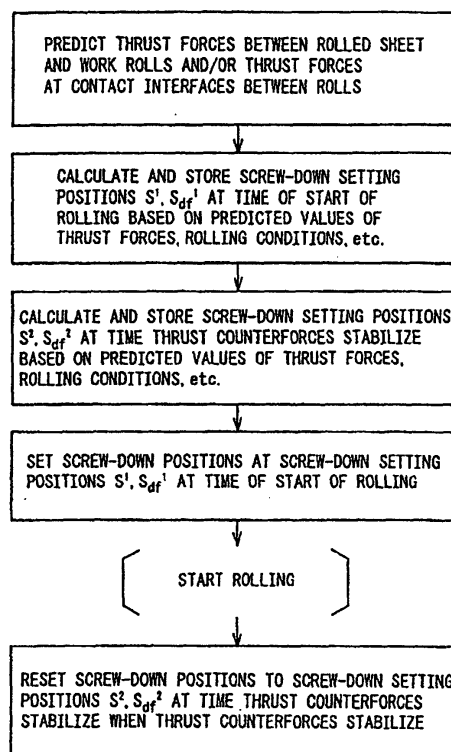
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(54) **DEPRESSING POSITION SETTING METHOD FOR ROLLING PLATE**

(57) A method of setting a screw-down position comprising accurately considering the change in the mill stretch after threading of the leading end of a rolled sheet and the change in plate thickness and thickness wedge due to the same based on the predicted values of the thrust forces arising at the rolls during the flat rolling and reflecting the same to the screw-down setting positions so as to improve the dimensional accuracy of the product and eliminate passage trouble due to snake, camber, etc. is provided. The thrust forces between the rolled sheet and work rolls arising during rolling are predicted before the start of rolling and the screw-down positions at the two points of the time when the rolling starts and the time when the thrust counterforces arising at the support points of the thrust forces stabilize are set individually based on the predicted value of the thrust forces. At the time of executing rolling, the screw-down position is set to the screw-down position before the start of rolling or at the time when the rolling starts, the stability of the thrust counterforces is monitored after the start of rolling, and the screw-down position is reset to the screw-down position at the time the thrust counterforces stabilize at the time when it is judged that the thrust counterforces stabilize.

Fig.1



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a method of setting the screw-down position for suppressing a change in plate thickness and change in thickness wedge of the leading end of a rolled material and improving the dimensional accuracy and rollability of a rolled material.

BACKGROUND ART

10 **[0002]** Normally, there are significant gaps between the roll chocks and housing posts in a flat rolling stand, so in the case of a for example four-high rolling stand, fine skews between a contacting work rolls and backup rolls (fine skews between work roll axes and backup roll axes projected on a horizontal plane) occur and forces in the roll axis directions, that is, thrust forces, occur between rolls. Further, like in a so-called roll cross rolling stand when rolling while deliberately giving skew angles between top and bottom work rolls, thrust forces are also generated between 15 the rolled sheet and the (top and bottom) work rolls. When thrust forces are generated in this way, excess moments act on the rolls and the widthwise distribution of the contact pressure between the rolls and the difference in rolling loads at the work side and drive side of the rolling stand (hereinafter called the "left" and "right") (hereinafter called "rolling load difference") changes. Due to the change in deformation, the so-called mill stretch, of the rolling stand, a change occurs in the plate thickness and/or the thickness wedge (left/right thickness difference) after rolling and becomes a cause of not only defects in dimensional accuracy, but also passage trouble arising due to the occurrence of snake and camber. The methods of adjustment of the screw-down positions considering these thrust forces may be roughly divided into the method of adjusting the screw-down positions in accordance with the estimated values (and changes in the same) of thrust forces estimated based on detected values of thrust counterforces arising at the mechanisms supporting the thrust forces, for example, the keeper plates of the work roll chocks, or detected values of the 25 rolling load etc. obtained from other counterforce detecting means (hereinafter called "screw-down position control technology considering the thrust forces which are measured") and the method of setting the screw-down positions in advance based on the thrust forces predicted before the start of rolling (hereinafter called "screw-down position setting technology considering the thrust forces which are predicted").

30 **[0003]** As prior art classified as screw-down position control technology considering the thrust forces which are measured (hereinafter called the "measured thrust forces"), there is the method of setting thrust counterforce detectors at the support mechanisms of the axial displacement of the work rolls and adjusting the screw-down positions in accordance with the detected values from the detectors and the detected values of the left/right rolling loads during rolling as disclosed in Japanese Unexamined Patent Publication (Kokai) No. 59-144511 or the method of estimating the thrust forces between the work rolls and rolled sheet based on the detected values of the rolling loads at four locations, that is, the top, bottom, left, and right, of the housing during rolling and adjusting the screw-down positions in accordance with the estimated values of the thrust forces as disclosed in Japanese Unexamined Patent Publication (Kokai) No. 35 58-218302. Further, as prior art classified as screw-down position setting technology considering the thrust forces which are predicted (hereinafter referred to as the "predicted thrust forces"), there is the method of predicting the thrust forces occurring during the next rolling pass based on the rolling results of the previous pass and setting the screw-down positions considering the same as disclosed for example in Japanese Unexamined Patent Publication (Kokai) No. 6-154832.

40 **[0004]** Among the above prior art, in screw-down position control technology considering the measured thrust forces using various detected values (and their changes) during rolling, a margin of time (so-called "control cycle") is required for detection → processing (calculation of amounts of correction of screw-down positions) → correction of screw-down positions. For example, it is inherently impossible to deal with changes occurring in the extremely short time during which the leading end of a rolled sheet passes through the later stands of a hot finishing rolling mill and the range of application is limited. Further, in general, when the leading end of a rolled sheet is threaded in the rolling stand, remarkable fluctuation occurs in the rolling loads due to the impact force etc. and external disturbances unable to be 50 ignored enter the detected values, so it is extremely difficult to suppress and control changes in the plate thickness and thickness wedge of the leading end of the rolled sheet and the occurrence of snake and camber during passage due to the same.

55 **[0005]** On the other hand, in screw-down position setting technology for setting the screw-down positions considering the predicted thrust forces before the start of rolling, the above difficulties do not inherently occur, but in the prior art disclosed in the above-mentioned Japanese Unexamined Patent Publication (Kokai) No. 6-154832, even if thrust forces of the same values as the predicted values actually occur, it is not possible to deal with changes in the plate thickness and thickness wedge of the leading end of the rolled sheet occurring due to the later explained reasons and a practically sufficient effect cannot be obtained.

[0006] The present invention has as its object to solve the various problems seen in the prior art explained above and provide a method of setting screw-down positions accurately considering changes in mill stretch after threading of the leading end of a rolled sheet due to the thrust forces and the changes in plate thickness and thickness wedge due to the same and reflecting the same in the screw-down setting positions so as to improve the dimensional accuracy of the product and eliminate passage trouble occurring due to the occurrence of snake and camber.

DISCLOSURE OF THE INVENTION

[0007] The present invention was made in order to achieve the above object. The gist is as follows:

(1) A method of setting a screw-down position in flat rolling characterized by comprising predicting thrust forces between a rolled sheet and work rolls arising during rolling before the start of rolling and setting the screw-down position at the time of execution of rolling based on the expected value of the thrust forces and, at that time, individually setting screw-down positions at two points of the time of start of rolling and the time thrust counterforces arising at the supports of the thrust forces stabilize.

(2) A method of setting a screw-down position in flat rolling in a flat rolling method using a four-high or greater multi-roll rolling stand characterized by comprising predicting thrust forces between a rolled sheet and work rolls and/or a thrust force at a contact interface between rolls at least at one location arising during rolling before the start of rolling and setting the screw-down position at the time of execution of rolling based on the predicted value of the thrust forces and, at that time, individually setting screw-down positions at two points of the time of start of rolling and the time thrust counterforces arising at the supports of the thrust forces stabilize.

(3) A method of setting a screw-down position in flat rolling as set forth in item (2), wherein the screw-down positions are individually set at two points of time of the time of start of rolling and the time the thrust counterforces stabilize, characterized by determining a setting based on the predicted value of the thrust forces between the rolled sheet and work rolls when setting the screw-down position at the time of start of rolling and by determining a setting based on the predicted value of the thrust forces between the rolled sheet and work rolls and the thrust force at the contact interface between rolls at least at one location when setting the screw-down position at the time the thrust counterforces stabilize.

(4) A method of setting a screw-down position in flat rolling as set forth in any one of item (1) to item (3), characterized by making the time when the thrust counterforces stabilize the time when a predetermined certain time from the time of the start of rolling elapses, setting the screw-down position to the screw-down position at the time of start of rolling, and resetting the screw-down position to the screw-down position at the time said thrust counterforces stabilize at the time said certain time elapses from the start of rolling.

(5) A method of setting a screw-down position in flat rolling characterized by predicting the thrust forces between a rolled sheet and work rolls and/or the thrust force at a contact interface between rolls at least at one location arising during rolling before the start of rolling, setting the screw-down position based on predicted values of the thrust forces at the time of start of rolling, and setting the screw-down position based on the predicted value of the thrust forces and/or the measured value of the thrust counterforces during rolling and/or left/right rolling load after the time when the thrust counterforces arising at the supports of the thrust forces stabilize after the start of rolling.

(6) A method of setting a screw-down position in flat rolling as set forth in item (4) or (5), characterized by making the time when a predetermined certain time from the time of the start of rolling elapses the time when at least 0.2 second elapses from the start of rolling.

(7) A method of setting a screw-down position in flat rolling as set forth in any one of items (4) to (6), characterized by determining said predetermined certain time from the time of start of rolling based on the skew angle between the top and bottom work rolls and the rotational distance of the surface of the work rolls after threading of the rolled sheet.

(8) A method of setting a screw-down position in flat rolling as set forth in any one of items (4) to (7), characterized by determining said predetermined certain time from the time of start of rolling based on rolling results up to the previous rolled material or previous rolling pass.

(9) A method of setting a screw-down position in flat rolling as set forth in any one of items (1) to (3) or item (5), characterized by monitoring the stability of thrust counterforces detected using means for detecting thrust counterforces in a rolling stand having a thrust counterforce detecting means after the start of rolling and making the time when it is judged that said thrust counterforces have stabilized the time when the thrust counterforces stabilize.

(10) A method of setting a screw-down position in flat rolling as set forth in any one of items (1) to (3) or item (5), characterized by monitoring the stability of a top and/or bottom left/right rolling load difference processed from the detected value of rolling load detecting means after the start of rolling in a rolling stand having independent left/right rolling load detecting means at the top and/or bottom and making the time when it is judged that said rolling load difference has stabilized the time when the thrust counterforces stabilize.

(11) A method of setting a screw-down position in flat rolling as set forth in any one of items (1) to (3) or item (5) characterized by monitoring the stability of thrust counterforces detected using means for detecting thrust counterforces after the start of rolling and the stability of a left/right rolling load difference processed from the detected value of rolling load detecting means after the start of rolling in a rolling stand having a thrust counterforce detecting means and independent left/right rolling load detecting means and making the time when it is judged that said thrust counterforces and said rolling load difference have stabilized the time when the thrust counterforces stabilize.

(12) A method of setting a screw-down position in flat rolling as set forth in item (9) or item (11), characterized by evaluating the stability of said thrust counterforces by the rate of change over time of said thrust counterforces or said rate of change over time divided by the rotational speed of the work rolls and making the point of time when said rate of change over time or said rate of change over time divided by the rotational speed of the work rolls becomes not more than a predetermined numerical value the time when it is judged that the thrust counterforces stabilize.

(13) A method of setting a screw-down position in flat rolling as set forth in item (10) or item (11), characterized by evaluating the stability of said left/right rolling load difference by the rate of change over time of said rolling load difference or said rate of change over time divided by the rotational speed of the work rolls and making the time when said rate of change over time or said rate of change over time divided by the rotational speed of the work rolls becomes not more than a predetermined numerical value the time when it is judged that said rolling load difference stabilizes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

FIG. 1 is a schematic view of an embodiment of the method of item (1) or item (2) of the present invention.

FIG. 2 is a view of an example of the change of time in measured values of the thrust counterforces and left/right rolling load difference after threading of the leading end of the rolled sheet sampled when devising the method of the present invention.

FIG. 3 is a schematic view of an example of the structure of a flat rolling stand using the method of the present invention.

FIG. 4 is a schematic view of the definitions of various physical quantities used when explaining the action of the method of the present invention.

FIG. 5 is a schematic view of an embodiment of item (9) of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0009] The present inventors engaged in detailed investigations, analysis, and studies and as a result discovered that even when adjusting to certain thrust forces (thrust forces between rolled sheet and work rolls and/or between work rolls and backup rolls) (for example, strictly adjusting the skew angles between the top and bottom work rolls and/or the fine skew angles between the work rolls and backup rolls), as shown by way of an example in FIG. 2, the measured values of the thrust counterforces directly after threading of the leading end of the rolled sheet (in the figure, measured by load detectors attached to the thrust bearings of the work rolls) and the left/right rolling load difference (in the figure, displayed by smoothing the fluctuation along with the impact force at the time of threading etc.) remarkably changed and stabilized after the elapse of a certain time. Further, they confirmed that the plate thickness and thickness wedge of the leading end part of the rolled sheet after rolling changes mimicking the change in the measured values.

[0010] This phenomenon is understood as being due to the fact that, in general, there is a significant clearance in the θ_1 axis direction (hereinafter called "thrust direction clearance"), or elastic (contact) deformation of that location for example between the work roll chocks and the keeper plates (in the case of a rolling stand having axial direction shift devices of work rolls, chock support parts of the shift devices), so the roll chocks start to move from the positions of idle operation (where thrust forces are zero or small) before rolling in the direction of action of the thrust forces (or the combined force of the thrust forces between the rolled sheet and work rolls and the thrust forces between the work rolls and backup rolls in the case of for example a four-high rolling stand) after the start of rolling, the thrust counterforces start to increase from the time of contact with the keeper plates, the axial direction movements of the rolls stop at the time when reaching thrust counterforces sufficient for supporting the axial direction movements of the roll chocks due to that thrust forces (or combined force), and the thrust counterforces stabilize. Further, even when the thrust forces are constant, the moments acting on the rolls differ due to the change of the thrust counterforces, so it is understood that the left/right rolling load difference also fluctuates. That is, the changes in the thrust counterforces or the left/right rolling load difference after the start of rolling and the fluctuations in the plate thickness and thickness wedge of the leading end of the rolled sheet due to the same inherently occur so long as there is thrust direction clearance or elastic

deformation of the axial direction supports of the roll chocks. The inventors concluded that setting the screw-down positions considering in advance changes after the start of rolling, that is, individually setting the screw-down positions at the two times of the time of start of rolling and the time when the thrust counterforces stabilize for establishing the most suitable screw-down positions for those times, is essential.

[0011] The present invention was made based on the above discovery.

[0012] Embodiments of the present invention will be explained in detail below with reference to the attached drawings.

[0013] FIG. 3 is a schematic view of an embodiment of a flat rolling stand covered by the method of the present invention explained with reference to the example of a four-high rolling stand. The rolled sheet 3 is rolled between top and bottom work rolls 4a, 4b supported by top and bottom backup rolls 5a, 5b. The top and bottom backup rolls 5a, 5b are supported at their two ends by backup roll chocks 7a, 7b, 7c, and 7d. The top and bottom work rolls 4a, 4b are supported at their two ends by the work roll chocks 6a, 6b, 6c, and 6d and are adjusted in position in the roll axis direction by the top and bottom roll shift mechanisms 10a, 10b. The screw-down position settings calculated by a screw-down position setting calculator 1 are sent to the screw-down apparatuses 2a, 2b, and the screw-down positions are adjusted to the settings. The thrust counterforce detectors 8a, 8b and the rolling load detectors 9a, 9b, 9c, and 9d are used for judgment of the rate of change (stability) of the thrust counterforces after the start of rolling, explained later, in the method of the present invention. Note that in the present invention, the "top" and "bottom" mean above and below the rolled sheet. Further, FIG. 4 is a schematic view of the forces (including counterforces and loads, where a force in the arrow direction in the figure is defined as "positive") and dimensions used in the following explanation. The physical quantities represented by the symbols are as follows:

T_{WM} : Thrust forces acting between rolled sheet and work rolls

T_{WB} , T_{WB}^T , T_{WB}^B : Thrust forces acting between work rolls and backup rolls. Here, the superscript T indicates the "top side" and B the "bottom side", the same below.

T_W , T_W^T , T_W^B : Thrust counterforces acting on work rolls

T_B , T_B^T , T_B^B : Thrust counterforces acting on backup rolls

P_W , P_D , P_W^T , P_D^T , P_W^B , P_D^B : Rolling counterforces (rolling loads) acting on backup roll support points. Here, the subscript W indicates the "work side" and D the "drive side".

P_{df} , P_{df}^T , P_{df}^B : Left/right rolling counterforce (load) differences. (For example, $P_{df}^T = P_W^T - P_D^T$)

h_B , h_B^T , h_B^B : Distances between positions of working points of thrust counterforces acting on backup rolls and positions of working points of thrust forces acting between work rolls and backup rolls.

[0014] Below, the left/right difference in a physical quantity will be defined as [physical quantity of work side] - [physical quantity of drive side].

[0015] FIG. 1 is a schematic view of an embodiment of the method shown in item (1) or item (2) of the present invention. Before the start of rolling, first, the thrust forces between the rolled sheet and the work rolls and/or the thrust forces between the work rolls and backup rolls occurring during rolling are predicted. For predicting the thrust forces T_{WM} between the rolled sheet and the work rolls, for example, it is sufficient to use the prior art disclosed in Japanese Unexamined Patent Publication (Kokai) No. 6-154832. Further, for predicting the thrust forces T_{WB} between the work rolls and the backup rolls, for example, it is sufficient to use the prior art disclosed in Japanese Unexamined Patent Publication (Kokai) No. 10-263656, identify the thrust forces of the previous pass (in the case of single-stand multi pass rolling) or during rolling the previous rolled material (in the case of tandem rolling), and predict forces based on the identified values using for example the following formula (1):

$$T_{WB}^{pred} = F_1(T_{WB}^{idnt}, P_t^{meas}, P_t^{pred}, R^{old}, R^{new}, D, K) \quad <1>$$

where,

T_{WB}^{pred} : Predicted value of thrust forces between work rolls and backup rolls,

T_{WB}^{idnt} : Identified value of thrust forces between work rolls and backup rolls in previous pass or while rolling previous material,

P_t^{meas} : Measured value of rolling load (left/right total force) of previous pass or while rolling previous rolled material,

P_t^{pred} : Predicted value of rolling load (left/right total force) of rolling pass using method of present invention,

R^{old} : Rolling conditions of previous pass or previous rolled material (for example, plate thickness, plate width, rolling reduction, etc.),

R^{new} : Rolling conditions of rolling pass using method of present invention,
D: Group of dimension parameters of rolling stand, and
K: Group of rigidity parameters of rolling stand.

[0016] Next, based on the predicted value T_{WM}^{pred} of the thrust forces between the rolled sheet and work rolls and/or the predicted value T_{WB}^{pred} of the thrust forces between work rolls and backup rolls and the rolling conditions R^{new} at the rolling pass using the method of the present invention etc., the screw-down setting positions S^1 (screw-down setting position, that is, left/right mean value component of screw-down setting position) and S_{df}^1 (screw-down setting position, that is, left/right difference component of screw-down setting position) at the time of start of rolling and the screw-down setting positions S^2 and S_{df}^2 at the time the thrust counterforces T_W acting on the work rolls (hereinafter abbreviated as the "thrust counterforces" unless otherwise indicated) stabilize.

[0017] The screw-down setting positions of the two points of time may be calculated for example using the following formula <2> to formula <5>:

$$S^1 = F_2(T_{WM}^{pred}, T_{WB}^{pred}, P_t^{pred}, h_{df}^{aim}, R^{new}, D, K,) \quad <2>$$

$$S_{df}^1 = F_3(T_{WM}^{pred}, T_{WB}^{pred}, P_t^{pred}, P_{df}^{pred}, h_{df}^{aim}, R^{new}, D, K) \quad <3>$$

$$S^2 = F_4(T_{WM}^{pred}, T_{WB}^{pred}, P_t^{pred}, h_{df}^{aim}, R^{new}, D, K,) \quad <4>$$

$$S_{df}^2 = F_5(T_{WM}^{pred}, T_{WB}^{pred}, P_t^{pred}, P_{df}^{pred}, h_{df}^{aim}, R^{new}, D, K) \quad <5>$$

where,

P_{df}^{pred} : Left/right difference in contact pressure between rolled sheet and work rolls predicted in rolling pass using method of present invention,

h_{df}^{aim} : Target value of plate thickness after rolling (either plate thickness at center of width or mean plate thickness in width direction. Provided, however, that in the following explanation, defined as the plate thickness at the center of width), and

h_{df}^{aim} : Target value of left/right difference of plate thickness (thickness wedge) after rolling

[0018] The predicted value P_{df}^{pred} of the left/right difference of the contact pressure between the rolled sheet and work rolls may for example be calculated based on the left/right temperature difference of the rolled sheet, the thickness wedge before rolling, etc.

[0019] The screw-down setting positions S^1 and S_{df}^1 at the time of the start of rolling calculated and stored using the screw-down position setting calculator 1 according to the above formula <2> and formula <3> are sent to the screw-down apparatuses 2a, 2b, the screw-down positions are adjusted before the start of rolling to give the setting positions, and then the rolling is started. As explained above, after the start of rolling, the thrust counterforces start to change and change until a stable state. At the time when it is judged by the later explained method that the thrust counterforces are stable, the screw-down position setting calculator 1 sends the screw-down setting positions S^2 and S_{df}^2 at the time the thrust counterforces stabilize, calculated and stored in accordance with the above formula <4> and formula <5>, to the screw-down apparatuses 2a and 2b, then the corrects the screw-down positions to the setting positions.

[0020] When the thrust forces between the rolled sheet and work rolls are expected to be substantially zero such as when no significant skew angle is caused between the top and bottom work rolls, the term of the effect of the thrust force predicted value T_{WM}^{pred} at the right side of the above formula <2> to formula <5> may be omitted.

[0021] when the thrust forces T_{WM} between the rolled sheet and work rolls and the thrust forces T_{WB} between the work rolls and backup rolls can be individually predicted at the time of start of rolling and the time where the thrust counterforces become stable, it is possible to use the predicted value T_{WM}^{pred-1} of the thrust forces between the rolled sheet and the work rolls and the predicted value T_{WB}^{pred-1} of the thrust forces between the work rolls and the backup rolls at the time of start of rolling in the calculation of formula <2> and formula <3> and use the predicted value T_{WM}^{pred-2} of the thrust forces between the rolled sheet and the work rolls and the predicted value T_{WB}^{pred-2} of the thrust forces between the work rolls and the backup rolls at the time the thrust counterforces stabilize in the calculation of formula <4> and formula <5> so as to calculate the screw-down setting positions at the two points of time.

[0022] As in the four-high rolling stand shown in FIG. 3, when there are contact interfaces between the work rolls and backup rolls at top and bottom, instead of the above formula <2> to formula <5>, it is also possible to use predicted values of the thrust forces between the top and bottom work rolls and backup rolls, for example, use the following formula <2-I> to formula <5-I>:

$$S^1 = F_2^I(T_{WM}^{pred}, T_{WB}^{T:pred}, T_{WB}^{B:pred}, P_t^{pred}, h^{aim}, R^{new}, D, K,) \quad <2-I>$$

$$S_{df}^1 = F_3^I(T_{WM}^{pred}, T_{WB}^{T:pred}, T_{WB}^{B:pred}, P_t^{pred}, P_{df}^{pred}, h_{df}^{aim}, R^{new}, D, K,) \quad <3-I>$$

$$S^2 = F_4^I(T_{WM}^{pred}, T_{WB}^{T:pred}, T_{WB}^{B:pred}, P_t^{pred}, h^{aim}, R^{new}, D, K,) \quad <4-I>$$

$$S_{df}^2 = F_5^I(T_{WM}^{pred}, T_{WB}^{T:pred}, T_{WB}^{B:pred}, P_t^{pred}, P_{df}^{pred}, h_{df}^{aim}, R^{new}, D, K,) \quad <5-I>$$

where,

$T_{WB}^{T:pred}$: Predicted value of thrust force T_{WB}^T between top work roll 4a and top backup roll 5a, and
 $T_{WB}^{B:pred}$: Predicted value of thrust force T_{WB}^B between bottom work roll 4b and bottom backup roll 5b.

[0023] Further, similarly, in a four-high or greater multi-roll rolling stand of a type having a plurality of contact interfaces between rolls, when predicted values of the thrust forces between rolls defined for each contact interface between rolls can be obtained, it is also possible to for example use the following formula (2-II) to formula (5-II):

$$S^1 = F_2^{II}(T_{WM}^{pred}, T_{WB}^{1:pred}, \dots, T_{WB}^{i:pred}, \dots, T_{WB}^{N:pred}, P_t^{pred}, h^{aim}, R^{new}, D, K,) \quad <2-II>$$

$$S_{df}^1 = F_3^{II}(T_{WM}^{pred}, T_{WB}^{1:pred}, \dots, T_{WB}^{i:pred}, \dots, T_{WB}^{N:pred}, P_t^{pred}, P_{df}^{pred}, h_{df}^{aim}, R^{new}, D, K,) \quad <3-II>$$

$$S^2 = F_4^{II}(T_{WM}^{pred}, T_{WB}^{1:pred}, \dots, T_{WB}^{i:pred}, \dots, T_{WB}^{N:pred}, P_t^{pred}, h^{aim}, R^{new}, D, K,) \quad <4-II>$$

$$S_{df}^2 = F_5^{II}(T_{WM}^{pred}, T_{WB}^{1:pred}, \dots, T_{WB}^{i:pred}, \dots, T_{WB}^{N:pred}, P_t^{pred}, P_{df}^{pred}, h_{df}^{aim}, R^{new}, D, K,)$$

<5-II>

where,

$T_{WB}^{i:pred}$: Predicted value of thrust force of i-th (i being whole number from 1 to N) contact interface between rolls.

[0024] Of course, when not considering the thrust forces at contact interfaces between some rolls due to various constraint conditions (for example, prediction of thrust forces at contact interfaces between specific rolls is impossible) or preconditions (for example, the contact interfaces between specific rolls are sufficiently -- lubricated and substantially no thrust forces occur), it is sufficient to use formulas omitted the terms related to the thrust forces of the contact interfaces between rolls. In the case where there are no contact interfaces between rolls such as with a two-high rolling stand, when the gaps from the roll chocks to housing post is sufficiently managed or no thrust force substantially occurs at the contact interface between any rolls due to sufficient lubrication of the contact interface between rolls, when the thrust force of the contact interface between any rolls cannot be predicted due to equipment restrictions, or otherwise when not considering the thrust forces at the contact interfaces of all rolls, it is sufficient to use the method described in item (1) of the present invention and for example use the following formula <2-III> to formula <5-III> instead of the above formula <2> to <5>:

$$S^1 = F_2^{III}(T_{WM}^{pred}, P_t^{pred}, h_{df}^{aim}, R^{new}, D, K,)$$

<2-III>

$$S_{df}^1 = F_3^{III}(T_{WM}^{pred}, P_t^{pred}, P_{df}^{pred}, h_{df}^{aim}, R^{new}, D, K,)$$

<3-III>

$$S^2 = F_4^{III}(T_{WM}^{pred}, P_t^{pred}, h_{df}^{aim}, R^{new}, D, K,)$$

<4-III>

$$S_{df}^2 = F_5^{III}(T_{WM}^{pred}, P_t^{pred}, P_{df}^{pred}, h_{df}^{aim}, R^{new}, D, K,)$$

<5-III>

[0025] When the thrust counterforces at the time of start of rolling are envisioned to be substantially zero such as schematically shown in the above FIG. 2, from the equilibrium condition of forces in the roll axial direction acting on the work rolls shown in the following formula <6>, the thrust forces T_{WB} between work rolls and backup rolls at that point of time can be unambiguously found from the predicted value of the thrust forces T_{WM} between the rolled sheet and the work rolls, so in setting the screw-down positions at the time of start of rolling, the predicted value of the thrust forces between work rolls and backup rolls become unnecessary and the method described in item (3) of the present invention can be used:

$$T_{WB}^T - T_{WM}^T = T_W^T = 0 \text{ (top work roll),}$$

$$T_{WM}^B - T_{WB}^B = T_W^B = 0 \text{ (bottom work roll)}$$

<6>

[0026] However, the counterforces at the time when the thrust counterforces are stable are generally not zero, so

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the predicted values of the two thrust forces of the thrust forces T_{WM} between the rolled sheet and work rolls and the thrust forces T_{WB} between the work rolls and backup rolls become necessary for calculation of the screw-down setting positions at that point of time. Further, if considering the equilibrium condition of the moments, since the left/right rolling load difference P_{df} can be found based on the predicted values of the thrust forces, it is possible to use the following relatively simple formula <2-IV> to formula <5-IV> instead of the above formula <2> to formula <5>:

$$S^1 = h^{aim} - \Delta S(P_t^{pred}) - P_{df}^{pred-1} \{C_W(P_t^{pred}/2) - C_D(P_t^{pred}/2)\} / 4 \quad <2-IV>$$

$$S_{df}^1 = [h_{df}^{aim} - \{\Delta S_W(P_t^{pred}/2) - \Delta S_D(P_t^{pred}/2)\} - P_{df}^{pred-1} \{C_W(P_t^{pred}/2) + C_D(P_t^{pred}/2)\} / 2] a_B / b \quad <3-IV>$$

$$S^2 = h^{aim} - \Delta S(P_t^{pred}) - P_{df}^{pred-2} \{C_W(P_t^{pred}/2) - C_D(P_t^{pred}/2)\} / 4 \quad <4-IV>$$

$$S_{df}^2 = [h_{df}^{aim} - \{\Delta S_W(P_t^{pred}/2) - \Delta S_D(P_t^{pred}/2)\} - P_{df}^{pred-2} \{C_W(P_t^{pred}/2) + C_D(P_t^{pred}/2)\} / 2] a_B / b \quad <5-IV>$$

where,

- $\Delta S(P)$: Mill stretch (defined at center of sheet width) when rolling load (left/right total force) is P ,
- $\Delta S_W(P)$: Change of work side roll opening (defined at width edge position at work side of rolled sheet) when rolling load acting on support points of work side backup roll is P ,
- $\Delta S_D(P)$: Change of drive side roll opening (defined at width edge position at drive side of rolled sheet) when rolling load acting on support points of drive side backup roll is P ,
- $C_W(P)$: Compliance of $\Delta S_W(P)$ when rolling load acting on support points of work side backup roll is P ,
- $C_D(P)$: Compliance of $\Delta S_D(P)$ when rolling load acting on support points of drive side backup roll is P ,
- b : Plate width, and
- a_B : Distance between left/right support points of backup roll

[0027] The $\Delta S(P)$, $\Delta S_W(P)$, and $\Delta S_D(P)$ in the above formula can be determined for example from the results of measurement of the squeeze-down load under the kiss roll conditions, the rolling conditions, the dimensional parameters of the rolling stand, etc. Further, P_{df}^{pred-1} is the predicted value of the left/right rolling load difference at the time of start of rolling, while P_{df}^{pred-2} is the predicted value of the left/right rolling load difference at the time when the thrust counterforces stabilize. As explained above, these are calculated using the following formula <7> and formula <8> from the equilibrium condition of the moments:

$$P_{df}^{pred-1}: 2T_{WM}^{pred}(D_W+h_B^T)/a_B + \{b^2/(6a_B)\}p_{df}^{pred} \quad <7>$$

$$P_{df}^{pred-2}: \{T_{WM}^{pred}D_W+T_{WB}^{pred}(D_W+2h_B^T)/a_B+\{b^2/(6a_B)\}p_{df}^{pred} \quad <8>$$

where,

D_W : Diameter of work rolls

[0028] The stability of thrust counterforces may be judged using the time when a certain time determined in advance elapses from the start of rolling. At this time, to avoid the effect of the impact force accompanying threading of the leading end of the rolled sheet or the effect of the response times of the screw-down apparatuses 2a, 2b, this is made the time when at least 0.2 second elapses from the start of rolling. In the case of an ordinary flat rolling stand, if less than 0.2 second, there is a good chance of the rolling load or thrust counterforces remarkably fluctuating due to the effect of the impact force or the response times of the screw-down apparatuses. For example, when using the method described in item (5) of the present invention, the screw-down position settings greatly fluctuate and the risk of passage trouble increases, so setting the time to at least 0.2 second is a requirement. The time until the thrust counterforces stabilize is expected to be substantially proportional to the relative (rolling) slip distance in the roll axial direction between the rolled sheet and work rolls after the start of rolling. Based on the skew angle between top and bottom work rolls (that is, the relative slip angle $\theta_{slip} \times 2$ between the rolled sheet and work rolls) and rotational distance of the surface of work rolls after threading of the rolled sheet (L: time integrated value of work roll peripheral speed from the time of start of rolling), it is possible to use the time when the relative slip distance ($= L \times (\sin\theta_{slip})$) becomes a predetermined distance L_{stable} as the time when the thrust counterforces stabilize. Further, it is possible to apply so-called learning to set or sequentially adjust the elapsed time used for judgment based on the rolling results up to the previous rolled material or previous rolling pass.

[0029] Further, when the rolling stand used has a means for detecting thrust counterforces, for example, when it has thrust counterforce detectors 8a, 8b between the work rolls 4a, 4b and the roll shift mechanisms 10a, 10b such as with the rolling stand schematically shown in the above FIG. 3, it is also possible to use the method described in item (9) of the present invention (see FIG. 5), monitor the rate of change over time (speed of change) of the measured values of the thrust counterforce detectors 8a, 8b after the start of rolling as an indicator of the stability, and judge that the thrust counterforces have stabilized at the time when the absolute value of the rate of change becomes not more than a predetermined small numerical value. Even when using a rolling stand not having thrust counterforce detecting means, for example, if using the top rolling load detectors 9a, 9b to find the left/right rolling load difference P_{df}^T moment by moment, it is possible to judge that the thrust counterforces have stabilized by the point of time when the absolute value of the rate of change over time of the rolling load difference becomes not more than a predetermined small numerical value. This can be understood from the fact that when the external forces other than the thrust counterforces T_W acting on the work rolls substantially do not change, the relationship between the amount of change ΔP_{df} of the rolling load difference from the time of start of rolling ($= [P_{df}(t): P_{df} \text{ of current time}] - [P_{df}(0): P_{df} \text{ of time of start of rolling}]$) and the amount of change ΔT_W of the thrust counterforces ($= [T_W(t): T_W \text{ of current time}] - [T_W(0): T_W \text{ of time of start of rolling}]$) is expressed by the following formula <9> derived from the equilibrium condition of moment (amount of change) and that the rate of change over time is expressed by formula <9-1>.

[0030] Note that the two formulas stand at both of the top side and bottom side.

$$\Delta P_{df} = \Delta T_W(D_W+2h_B)/a_B \quad <9>$$

$$d(P_{df}(t))/dt = \{d(T_W(t))/dt\}$$

$$(D_W+2h_B)/a_B \quad <9-1>$$

where,

$d(P_{df}(t))/dt$: Rate of change over time of left/right rolling load difference at present time, and

$d(T_w(t))/dt$: Rate of change over time of thrust counterforces at present time.

[0031] However, to keep down the effects of the impact force accompanying threading of the leading end of the rolled sheet on the detected values of the rolling loads, it is preferable to use the above thrust counterforce detectors 8a, 8b. The rate of change over time of the measured values of the thrust counterforces and the left/right rolling load difference from the time of start of rolling are believed to be dependent on the rate of change over time of the relative slip distance in the roll axial direction between the rolled sheet and the work rolls, that is, the relative slip speed. When the roll rotational speed changes after the start of rolling, it is possible to use the rate of change over time of the measured value of the thrust counterforces or the rolling load difference divided by the roll rotational speed. Further, for example to deal with the case where the time when the thrust counterforces acting on the work rolls stabilize differs between the top and bottom, preferably the thrust counterforce detectors and/or rolling load detectors are arranged at both of the top side and bottom side and the stability of a thrust counterforces T_w is judged based on the two detected values (for example, it is judged that the thrust counterforces T_w have stabilized at the time when both of the top and bottom detected values satisfies the above condition), but it is also possible to arrange detectors and detect values at one of either the top and bottom. Of course, it is also possible to arrange both thrust counterforce detectors and rolling load detectors at the top and/or bottom or to arrange different detectors at the top and bottom (for example, the rolling load detectors at the bottom and the thrust counterforce detectors at the top). In the case of a five-high or greater multi-roll rolling stand, it is also possible to arrange thrust counterforce detectors at part or all of the group of intermediate rolls positioned between the work rolls and backup rolls. The thrust counterforce detecting means just need to be sufficient for judging the rate of change of the detected values. There is no need to use detectors superior in accuracy of the absolute values and resolution such as so-called load cells.

[0032] Further, in the case of a rolling stand having thrust counterforce detectors and/or independent left/right rolling load detectors, after the time when the thrust counterforces stabilize, it is also possible to adjust the screw-down positions based not only the predicted values of the thrust forces, but also the measured values from the detectors. For example, in this case, after the time when the thrust forces stabilize, it is believed that the equilibrium condition formula of moments described in the above formula <8> stands. If entering the measured value of the left/right rolling load difference at the left side of the formula, it is possible to make either of the predicted value T_{WM}^{pred} of the thrust forces between the rolled sheet and work rolls or the predicted value T_{WB}^{pred} of the thrust forces at the contact interface between the work rolls and backup rolls at the right side of the formula the estimated value (for the left/right difference in contact pressure between the rolled sheet and the work rolls, use the predicted value p_{df}^{pred}). By substituting the estimated value of the thrust forces based on the measured value with the corresponding predicted value of the thrust forces in the right side of the above formula <4> to formula <4-III> and/or formula <5> to formula <5-III> and calculating the screw-down setting positions, it can be easily imagined that higher accuracy adjustment of the screw-down positions than the case using only predicted values becomes possible. Of course, when the discrepancy with the predicted values before rolling is large, the possibility arises of the change in the screw-down positions at the time of adjustment becoming excessively large, so it is also possible to use both the predicted values and estimated values to adjust the screw-down positions.

[0033] It is naturally possible to use known control methods at the time of adjusting the screw-down positions in the present invention, for example, the so-called pattern control method of using a predetermined function having a elapsed time from the time of start of the rolling to the time when the thrust counterforces stabilize as an independent variable so as to smoothly change the screw-down positions between the two points of time and the so-called acceleration/deceleration processing of the amount of operation for using the screw-down setting positions based on the predicted values before rolling at the time the thrust counterforces stabilize and then gradually changing them to the screw-down setting positions calculated from the measured values at each moment (or estimated values of the thrust forces calculated from the measured values).

[0034] When the left/right housing rigidities are equal and the relationship between the line load along contact interfaces between rolls and amount of roll deformations (flattening, deflection, etc.) are equal at the left and right and other cases where the above thrust forces and thrust counterforces do not substantially affect the plate thickness after rolling, the present invention may be used only for calculation of the left/right differences S_{df}^1 , S_{df}^2 of the screw-down setting positions (calculation using the above formula <3> to formula <3-III> and formula <5> to formula <5-III>) and adjustment of the screw-down positions. In this case, the left/right mean values S^1 , S^2 of the screw-down setting positions may be calculated by for example the following formula <10> used in general since the past:

$$S^1 = S^2 = F_8(P_t^{pred}, R^{new}, D, K, \dots) \quad <10>$$

[0035] It is also possible to apply so-called learning to the method of the present invention, calculate for example the learning terms S^{1m-1} , S^{1m-2} , S_{df}^{1m-1} , and S_{df}^{1m-2} of the screw-down setting positions based on the rolling results of the previous pass or the previous rolling material, and, taking this into consideration as well (for example, adding corresponding learning terms to the right sides of the above-mentioned formula <2> to formula <5>, ..., formula <2-III> to formula <5-III>), calculate the screw-down setting positions.

Examples

[0036] The methods described in item (3) and item (9) of the present invention were used for a tandem mill having three pair cross rolling stands at the front stage. At that time, the thrust forces T_{WM} between the rolled sheet and the work rolls are predicted using the following formula <11> for the pair cross rolling stands and are made zero for the other rolling stands. Further, the thrust forces T_{WB} between work rolls and backup rolls are predicted by identifying the coefficient term β in the following formula <12> from the rolling results up to the previous rolled material and using that formula:

$$T_{WM}^{pred} = \alpha(\theta)P_t^{pred} \quad <11>$$

$$T_{WB}^{pred} = \beta P_t^{pred} \quad <12>$$

where, $\alpha(\theta)$ is a coefficient term determined for each skew angle θ . This is identified from rolling result data for various skew angles in advance. Further, the stability of a thrust counterforces after the start of rolling was judged by using the method described in item (12) of the present invention, entering the measured values obtained by the left/right rolling load detectors provided at top into the following formula <9-II> derived from the previously mentioned formula <9> to calculate the estimated value of the thrust forces, and judging the stability using the time when the value of the rate of change over time of the estimated value divided by the rotational speed of the work rolls (absolute value) falls below a judgment value determined in advance by various rolling result data:

$$\Delta T_W = \{P_{df}(t) - P_{df}(0)\}a_B / (D_W + 2h_B) \quad <9-II>$$

[0037] As a result, not only are the plate thickness and thickness wedge of the leading end of the rolled sheet after rolling improved, but also the amount of camber of the leading end is remarkably reduced and passage accidents arising due to snake of the leading end of the rolled sheet are substantially halved.

INDUSTRIAL APPLICABILITY

[0038] As explained above in detail, according to the method of the present invention, by suppressing the change in plate thickness and the change in thickness wedge of the leading end of the rolled sheet during flat rolling, it is possible to strikingly improve the dimensional accuracy of the rolled sheet and improve the rollability as much as possible.

Claims

1. A method of setting a screw-down position in flat rolling **characterized by** comprising predicting thrust forces between a rolled sheet and work rolls arising during rolling before the start of rolling and setting the screw-down position at the time of execution of rolling based on the expected value of the thrust forces and, at that time, individually setting screw-down positions at two points of the time of start of rolling and the time thrust counterforces arising at the supports of the thrust forces stabilize.
2. A method of setting a screw-down position in flat rolling in a flat rolling method using a four-high or greater multi-roll rolling stand **characterized by** comprising predicting thrust forces between a rolled sheet and work rolls and/or a thrust force at a contact interface between rolls at least at one location arising during rolling before the start of rolling and setting the screw-down position at the time of execution of rolling based on the predicted value of the thrust forces and, at that time, individually setting screw-down positions at two points of the time of start of

rolling and the time thrust counterforces arising at the supports of the thrust forces stabilize.

3. A method of setting a screw-down position in flat rolling as set forth in claim 2, wherein the screw-down positions are individually set at two points of time of the time of start of rolling and the time the thrust counterforces stabilize, **characterized by** determining a setting based on the predicted value of the thrust forces between the rolled sheet and work rolls when setting the screw-down position at the time of start of rolling and by determining a setting based on the predicted value of the thrust forces between the rolled sheet and work rolls and the thrust force at the contact interface between rolls at least at one location when setting the screw-down position at the time the thrust counterforces stabilize.
4. A method of setting a screw-down position in flat rolling as set forth in any one of claim 1 to claim 3, **characterized by** making the time when the thrust counterforces stabilize the time when a predetermined certain time from the time of the start of rolling elapses, setting the screw-down position to the screw-down position at the time of start of rolling, and resetting the screw-down position to the screw-down position at the time said thrust counterforces stabilize at the time said certain time elapses from the start of rolling.
5. A method of setting a screw-down position in flat rolling **characterized by** predicting the thrust forces between a rolled sheet and work rolls and/or the thrust force at a contact interface between rolls at least at one location arising during rolling before the start of rolling, setting the screw-down position based on predicted values of the thrust forces at the time of start of rolling, and setting the screw-down position based on the predicted value of the thrust forces and/or the measured value of the thrust counterforces during rolling and/or left/right rolling load after the time when the thrust counterforces arising at the supports of the thrust forces stabilize after the start of rolling.
6. A method of setting a screw-down position in flat rolling as set forth in claim 4 or 5, **characterized by** making the time when a predetermined certain time from the time of the start of rolling elapses the time when at least 0.2 second elapses from the start of rolling.
7. A method of setting a screw-down position in flat rolling as set forth in any one of claim 4 to claim 6, **characterized by** determining said predetermined certain time from the time of start of rolling based on the skew angle between the top and bottom work rolls and the rotational distance of the surface of the work rolls after threading of the rolled sheet.
8. A method of setting a screw-down position in flat rolling as set forth in any one of claims 4 to 7, **characterized by** determining said predetermined certain time from the time of start of rolling based on rolling results up to the previous rolled material or previous rolling pass.
9. A method of setting a screw-down position in flat rolling as set forth in any one of claims 1 to 3 or claim 5, **characterized by** monitoring the stability of thrust counterforces detected using means for detecting thrust counterforces in a rolling stand having a thrust counterforce detecting means after the start of rolling and making the time when it is judged that said thrust counterforces have stabilized the time when the thrust counterforces stabilize.
10. A method of setting a screw-down position in flat rolling as set forth in any one of claims 1 to 3 or claim 5, **characterized by** monitoring the stability of a top and/or bottom left/right rolling load difference processed from the detected value of rolling load detecting means after the start of rolling in a rolling stand having independent left/right rolling load detecting means at the top and/or bottom and making the time when it is judged that said rolling load difference has stabilized the time when the thrust counterforces stabilize.
11. A method of setting a screw-down position in flat rolling as set forth in any one of claims 1 to 3 or claim 5 **characterized by** monitoring the stability of thrust counterforces detected using means for detecting thrust counterforces after the start-of rolling and the stability of a left/right rolling load difference processed from the detected value of rolling load detecting means after the start of rolling in a rolling stand having a thrust counterforce detecting means and independent left/right rolling load detecting means and making the time when it is judged that said thrust counterforces and said rolling load difference have stabilized the time when the thrust counterforces stabilize.
12. A method of setting a screw-down position in flat rolling as set forth in claim 9 or claim 11, **characterized by** evaluating the stability of said thrust counterforces by the rate of change over time of said thrust counterforces or said rate of change over time divided by the rotational speed of the work rolls and making the point of time when said rate of change over time or said rate of change over time divided by the rotational speed of the work rolls

becomes not more than a predetermined numerical value the time when it is judged that the thrust counterforces stabilize.

- 5 **13.** A method of setting a screw-down position in flat rolling as set forth in claim 10 or claim 11, **characterized by** evaluating the stability of said left/right rolling load difference by the rate of change over time of said rolling load difference or said rate of change over time divided by the rotational speed of the work rolls and making the time when said rate of change over time or said rate of change over time divided by the rotational speed of the work rolls becomes not more than a predetermined numerical value the time when it is judged that said rolling load difference stabilizes.
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55

Fig.1

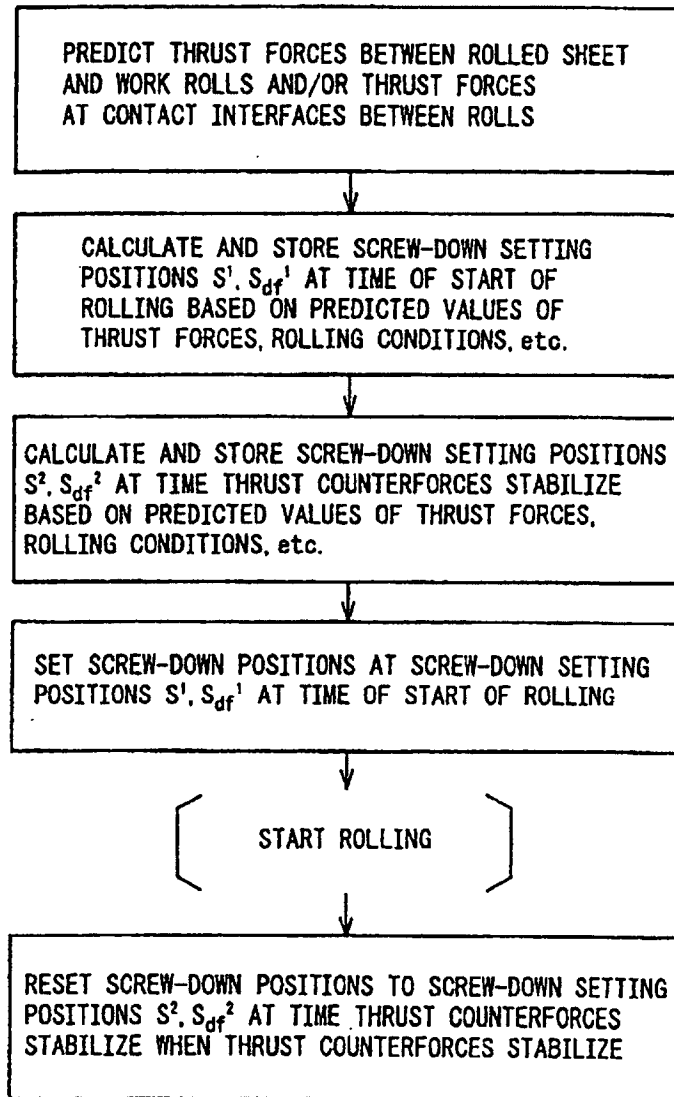


Fig.2

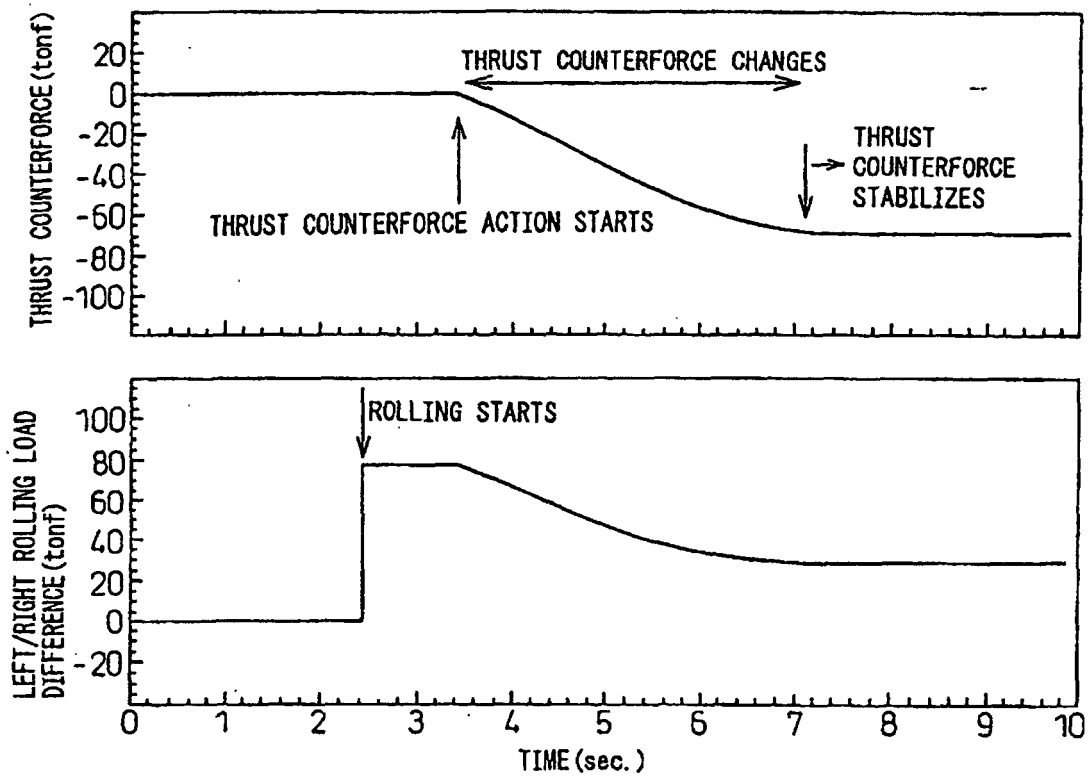


Fig.3

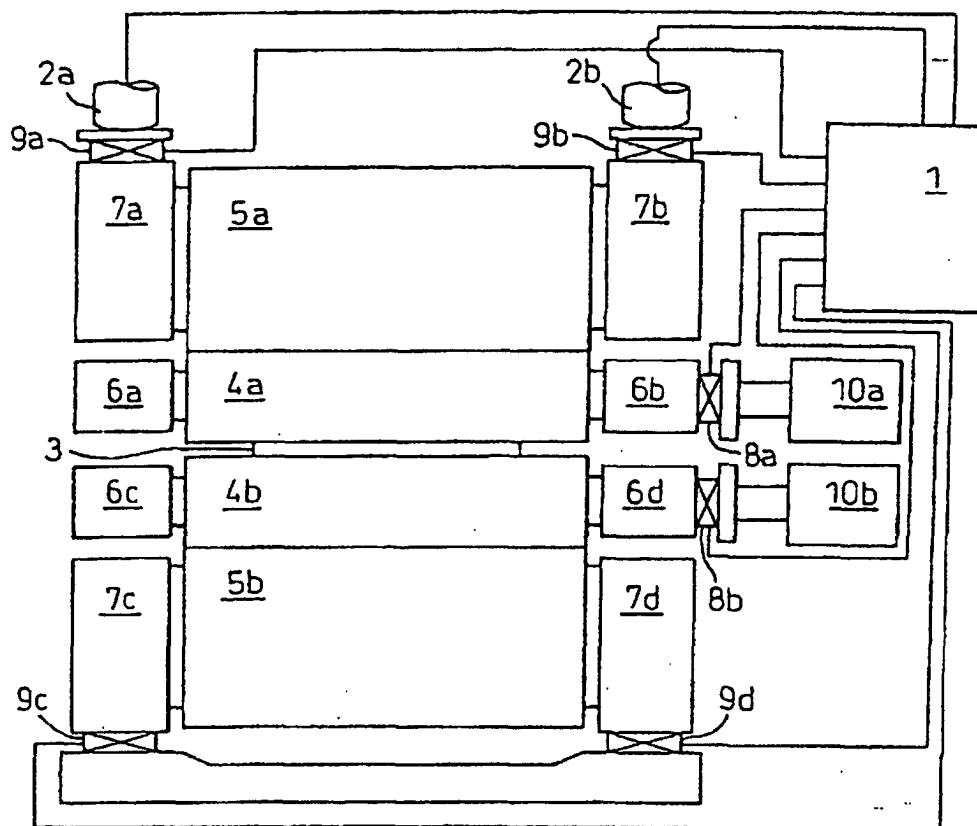


Fig.4

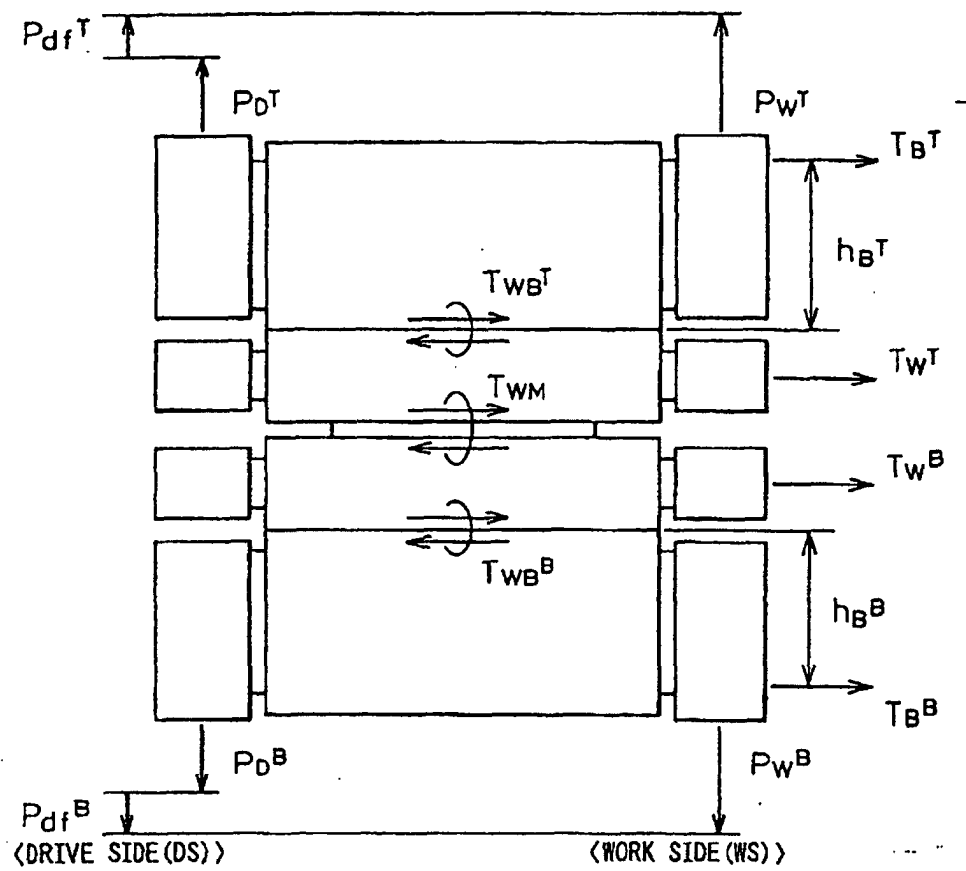
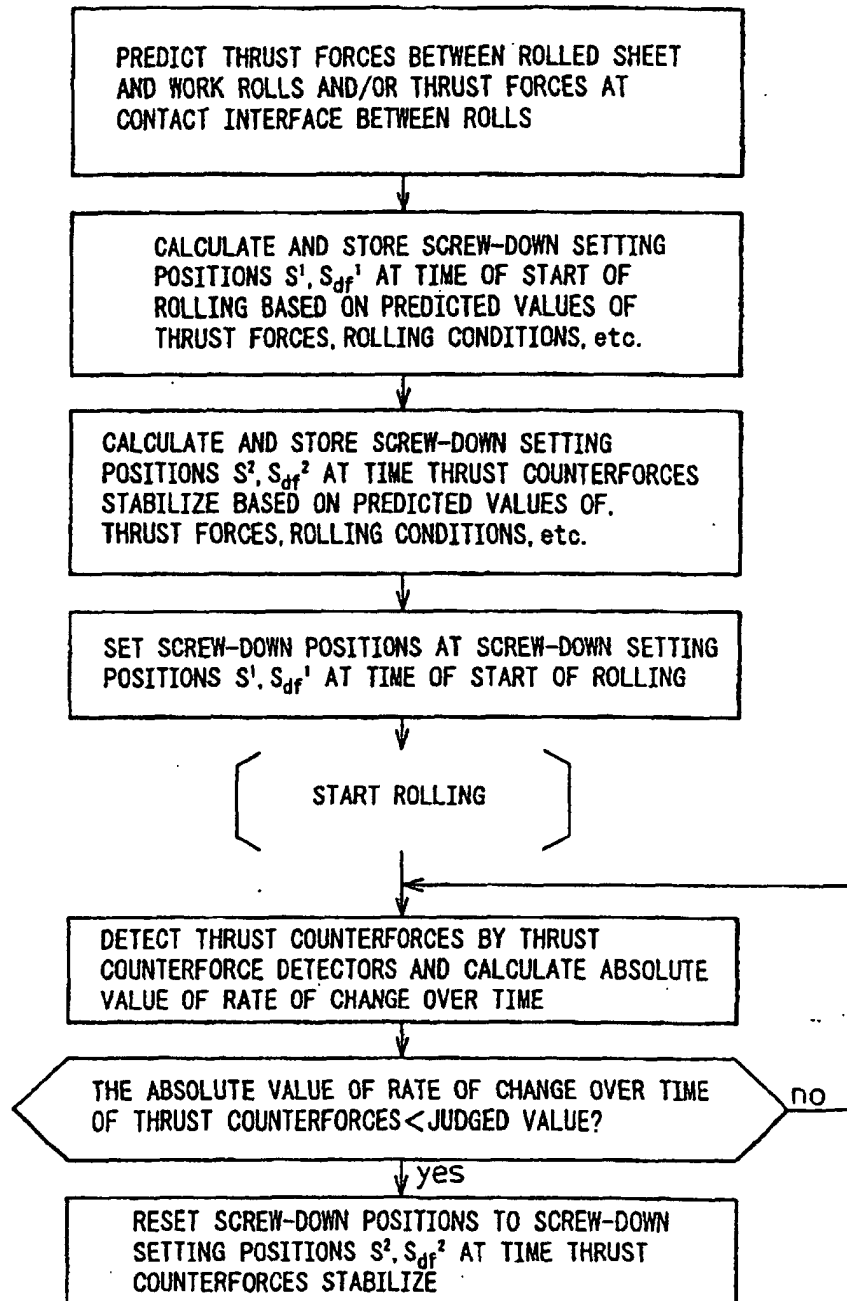


Fig.5



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP01/10064

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl ⁷ B21B37/00		
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 ⁷ B21B1/00-1/46, 37/00-37/78		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-2002 Kokai Jitsuyo Shinan Koho 1971-2002 Jitsuyo Shinan Toroku Koho 1996-2002		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 5-76915 A (Nippon Steel Corporation), 30 March, 1993 (30.03.1993), (Family: none)	1-13
A	JP 11-47814 A (Kawasaki Steel Corporation), 23 February, 1999 (23.02.1999), (Family: none)	1-13
☐ 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 document 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 12 February, 2002 (12.02.02)		Date of mailing of the international search report 19 February, 2002 (19.02.02)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

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