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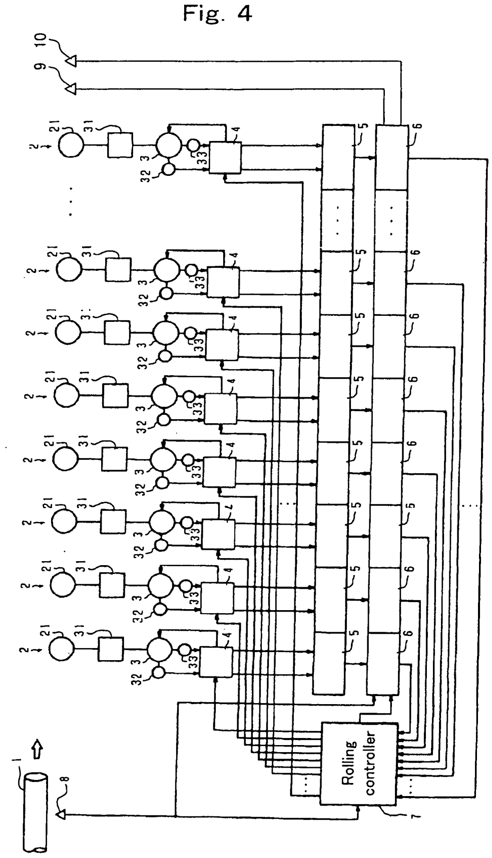
(54) Method and device for controlling sizing mill of pipe or tube

(57) There is provided a method for controlling sizing mill of a pipe or tube in which, when a front or rear end of a pipe or tube 1 is rolled by each stand 2 of a sizing mill, the rotational speed of rolling rolls 21 provided to each stand is controlled. The rotational speed control start timing of rolling rolls provided to a predetermined stand is corrected based on the thickness measured value of the front or rear end of the pipe or tube measured at the output side of the sizing mill.

Fig. 4



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Description

TECHNICAL FIELD

[0001] The present invention relates to a method and device for controlling sizing mill of pipes or tubes, and in particular, to a method and device for controlling a sizing mill capable of suppressing defective thickness of a front or rear end (longitudinal end) of a pipe or tube rolled by the sizing mill effectively.

BACKGROUND ART

[0002] Generally, in a step of finishing the outer diameter of a pipe or tube so as to have a predetermined value, there is used a sizing mill (sizer, stretch reducer or the like) comprising a plurality of stands each of which is provided with two or three grooved rolls (hereinafter referred to as rolling rolls). A sizing mill applies a tensile force in a pipe or tube axis direction of the pipe or tube being rolled by giving a difference to the circumferential speeds of the rolling rolls between adjacent stands to thereby control the thickness of a pipe or tube.

[0003] In a case of rolling a front or rear end of a pipe or tube, the tensile force in the pipe or tube axis direction is not applied sufficiently comparing with the case of rolling the intermediate portion of the pipe or tube, whereby there is caused a phenomenon where the thickness of the front or rear end of the pipe or tube is thicker than the thickness of the pipe or tube intermediate portion. Therefore, the front or rear end of the pipe or tube is cut off as being a part of defective dimension, which result in a lower yield.

[0004] In order to prevent such a lower yield due to an increase in the thickness of the front or rear end of the pipe, there is considered a method of controlling the circumferential speed (specifically, rotational speed) of rolling rolls when rolling the front or rear end of the pipe or tube(reducing the rotational speed when rolling the front or rear end of the pipe or tube). However, in order to activate such a method effectively, it is important that the timing of starting control of the rotational speed of rolling rolls must be accurate.

[0005] As shown in Fig. 1, assuming that, with respect to a timing when a front or rear end of a pipe or tube 1 is detected by a pipe end detector 8 such as an HMD, a period until the front or rear end of the pipe or tube reaches a first stand is To, and a period from the front or rear end of the pipe or tube leaves an $(i-1)^{th}$ stand until it reaches an i^{th} stand $(i \geq 2)$ is T_{i-1}, after the period To has passed from the timing the front or rear end of the pipe or tube 1 is detected by the pipe end detector 8, a rotational speed control of a rolling roll 2 provided to the first stand must be started, and after the period of $To + \Sigma T_j$ ($j = 1$ to $i-1$, $i \geq 2$) has passed, the rotational speed control of a rolling roll 21 provided to the i^{th} stand must be started.

[0006] In order to grasp the period To and the period T_{i-1} accurately, a high precision sensor such as a load measuring device may be disposed at each stand, but it requires enormous capital investment. The present invention is based on the premise of using a method of predicting the time period To and the time period T_{i-1} $(i \geq 2)$ without using a high precision sensor.

[0007] However, due to various factors, there is caused an error between the predicted periods of the period To and the period T_{i-1} $1 \geq 2)$ and the period that the front or rear end of the pipe or tube 1 actually reaches (hereinafter, referred to as "prediction error"). Therefore, there is a problem that an accurate control is impossible if the rotational speed control of the rolling roll 21 is started only based on the estimated periods, whereby an increase in the thickness of the front or rear end of the pipe or tube cannot be controlled effectively.

[0008] In Japanese Patent No. 2541311, there is proposed a method in which a rolling torque is calculated from the driving current and the rotational speed of a motor for driving rolling rolls, and a timing when an front or rear end of the pipe or tube actually reaches each stand (a timing when a front end bites into rolling rolls or rear end passes out of rolling rolls) is detected from the fluctuating state of the calculated rolling torque, and the rotational speed control start timing (the timing when the rotational speed control starts) of the rolling rolls for the next rolling of the pipe or tube is corrected such that the prediction error in each stand comes into a predetermined range.

[0009] In the method described in the above-mentioned publication, there is no analysis for a factor causing a prediction error at the rotational speed control start timing of rolling rolls which have been set with respect to each stand. Based on the prediction error calculated for each stand, the rotational speed control start timing of rolling rolls in the next rolling of the pipe or tube is corrected uniformly. Even if the timing when the front or rear end of the pipe or tube actually reaches is detected accurately, it is impossible to correct the rotational speed control start timing of rolling rolls for the pipe or tube to be rolled next, in the state where the prediction error varies at random.

[0010] In other words, a prediction error for rolling one pipe or tube is not always the same for the next pipe or tube to be rolled. Accordingly, it is impossible to correct the rotational speed control start timing of rolling rolls accurately for the next pipe or tube to be rolled. As a result, it is impossible to suppress the defective thickness of the front or rear end of the pipe or tube effectively.

[0011] Further, the pattern of the thickness fluctuation of a front or rear end of the pipe or tube is not always the same, so defective thickness of a front or rear end of the pipe or tube cannot be suppressed fundamentally only by grasping the timing when the front or rear end of the pipe or tube reaches each stand accurately to thereby control the rotational speed of the rolling rolls.

DISCLOSURE OF THE INVENTION

[0012] The present invention has been developed to solve such a problem in the conventional art. An object of the present invention is to provide a method and device for controlling a sizing mill, capable of suppressing defective thickness of a front or rear end of a pipe or tube to be rolled by the sizing mill effectively.

[0013] In order to solve the above-described problem, the present invention provides a method for controlling sizing mill of a pipe or tube, wherein a rotational speed control start timing of rolling rolls set with respect to a predetermined stand of a sizing mill is corrected based on a thickness measured value of a front or rear end of the pipe or tube measured at an output side of the sizing mill.

[0014] According to such an invention, the rotational speed control start timing of rolling rolls set with respect to a predetermined stand is corrected based on the thickness measured values of the front or rear end of the pipe or tube measured at the output side of the sizing mill, whereby it is expected to correct the rotational speed control start timing of the rolling rolls appropriately according to the actual thickness fluctuation of the front or rear end of the pipe or tube, so it is possible to effectively suppress defective thickness of the front or rear end of the pipe or tube rolled by the sizing mill.

[0015] It is preferable that the method for controlling sizing mill comprises:

a first step of calculating a prediction error between the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand and a timing when the front or rear end of the pipe or tube actually reaches the predetermined stand; and a second step of correcting the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand, based on the prediction error calculated and the thickness measured value of the front or rear end of the pipe or tube measured at the output side of the sizing mill.

[0016] According to such a preferable configuration, the rotational speed control start timing of the rolling rolls is corrected by using not only the thickness of the front or rear end of the pipe or tube actually measured but also a prediction error between the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand and the timing when the front or rear end of the pipe or tube actually reaches the predetermined stand. Therefore, it is expected to correct the rotational speed control start timing of the rolling rolls appropriately and accurately, so it is possible to suppress defective thickness of the front or rear end of the pipe or tube rolled by the sizing mill, more effectively.

[0017] In order to solve the problem described above, the inventors of the present invention intensively studied about factors causing a prediction error between the rotational speed control start timing of the rolling rolls set with respect to each stand and the timing when the front or rear end of the pipe or tube actually reached the stand. As a result, it was anticipated that a prediction error for a predicted period To until the front or rear end of the pipe or tube reaches a first stand, and a prediction error for the predicted period ΣT_j ($j = 1$ to $i-1$, $i \geq 2$) until the front or rear end of the pipe or tube reaches the i^{th} stand from the first stand were caused due to different factors.

[0018] That is, a prediction error for the predicted period To until the front or rear end of the pipe or tube reaches the first stand is caused due to a difference between the predicted carried speed and the actual carried speed of the pipe or tube due to the cross-sectional shape and a bend of the pipe or tube as well as abrasion of the carrying conveyor. The prediction error for the predicted period T_0 is a component included in common in the prediction error between the rotational speed control start timing of the rolling rolls set with respect to each stand and the timing when the front or rear end of the pipe or tube actually reaches the stand. On the other hand, a prediction error for the predicted period ΣT_j ($j = 1$ to $i-1$, $i \geq 2$) until the front or rear end of the pipe or tube reaches the i^{th} stand from the first stand is caused by fluctuations in the rolling state of each stand (for example, the extension rate of the pipe or tube in sizing mill is different from predicted values due to fluctuation factors on the sizing mill side such as actual rotational speed of rolling rolls being different from the set value and abrasion of the rolling rolls and surface irregularity of the rolling rolls being not uniform, as well as fluctuation factors on the pipe or tube side such as material, dimensions and temperature of the pipe or tube).

[0019] Next, the inventors of the present invention calculated through experimentations a prediction error between the rotational speed control start timing of the rolling rolls set with respect to each stand and the timing when the front or rear end of the pipe or tube actually reached the stand, and divided the calculated prediction error into a prediction error for the predicted period To until the front or rear end of the pipe or tube reaches the first stand (hereinafter, referred to as "prediction error component of a factor outside the stand" as appropriate), and a prediction error for the predicted period ΣT_j ($j = 1$ to $i-1$, $i \geq 2$) until the front or rear end of the pipe or tube reaches the i^{th} stand from the first stand (hereinafter, referred to as "prediction error component of a factor inside the stand" as appropriate), whereby analyzed the dispersion states of the both prediction error components. As a result, the inventors found that a tendency shown in Fig. 2 was obtained. Note that in Fig. 2, the horizontal axis shows the sequence of pipes or tubes rolled, and the vertical axis shows the ratio of each prediction error component to the predicted period.

[0020] Hereinafter, Fig. 2 will be described in detail. First, for each rolled pipe or tube, as shown in Fig. 3, the stand number was plotted in the horizontal axis X, and a prediction error (prediction error between the rotational speed control start timing of the rolling rolls set with respect to each stand and the timing when the front or rear end of the pipe or tube actually reaches the stand) in each stand calculated as described above was plotted in the vertical axis Y Then, based on the plotted data (i, Yi), a primary regression equation of Y in which X was a variable was calculated, and a Y section of the primary regression equation (value at a point intersecting the vertical axis) was defined as a prediction error component T_0' of the predicted period T_0 until a front or rear end of the pipe or tube reaches the first stand, and a value obtained by subtracting the prediction error component T_0' from the Y coordinate Y_i' in the primary regression equation, where X = i, was defined as a prediction error component ΣT_j' for the predicted period ΣT_j (j = 1 to i-1, i ≥ 2) until the front or rear end of the pipe or tube reached the i^{th} stand from the first stand. In Fig. 2, "○" indicates a value obtained by dividing the prediction error component T_0' calculated as described above by the predicted period T_0, and "□" indicates a value obtained by dividing the prediction error component ΣT_j' calculated as described above by the predicted period ΣT_j, respectively. Note that data shown in Fig. 2 indicates cases where pipes or tubes of different materials were rolled (in a chance 1, A1 indicates that carbon steel is rolled and A2 indicates that 2Cr steel is rolled, and in a chance 2, B1 indicates that low alloy steel is rolled and B2 indicates that carbon steel is rolled) in two manufacturing chances (chance 1 and chance 2) where the dates of rolling the pipes or tubes were different (accordingly, various settings of the rolling mill are often different).

[0021] As shown in Fig. 2, the dispersion tendency of the prediction error components T_0' for the predicted period T_0 (prediction error components of factors outside the stand) does not change a lot even though the manufacturing chance and the material of the pipe or tube differ. However, the dispersion tendency of the prediction error components ΣT_j' for the predicted period ΣT_j (prediction error components of factors inside the stand) changes when the material of the pipe or tube differs. This is due to the fact that the generating factors of the prediction error components of factors outside the stand and the prediction error components of factors inside the stand are different as described above.

[0022] As described above, the dispersion tendencies in the prediction error components of factors outside the stand and the prediction error components of factors inside the stand are different since their generation factors are different. Therefore, if the both prediction error components are divided and are provided separately (e.g., while being weighted differently) for correcting the rotational speed control start timing of the rolling rolls, it is expected that the rotational speed control start timing of the rolling rolls can be corrected appropriately even in a state where the prediction error between the rotational speed control start timing of the rolling rolls set with respect to each stand and the timing when a front or rear end of the pipe or tube actually reaches the stand varies at random, due to the fluctuations of the generation factors.

[0023] Accordingly, it is preferable that the second step includes the steps of: extracting a first prediction error component until the front or rear end of the pipe or tube reaches a first stand and a second prediction error component after the front or rear end of the pipe or tube reaches the first stand, from the prediction error calculated; applying a first weight to the first prediction error component extracted, and based on the first prediction error component applied with the first weight, correcting the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand; applying a second weight to the second prediction error component extracted, and based on the second prediction error component applied with the second weight, correcting the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand; and based on the thickness measured value of the front or rear end of the pipe or tube measured at the output side of the sizing mill, correcting the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand.

[0024] According to such a preferable configuration, a prediction error between the rotational speed control start timing of the rolling rolls set with respect to a predetermined stand and the timing when the front or rear end of the pipe or tube actually reaches the predetermined stand is calculated, and from the prediction error calculated, a first prediction error component (prediction error component of a factor outside the stand) until the front or rear end of the pipe or tube reaches the first stand and a second prediction error component (prediction error component of a factor inside the stand) after the front or rear end of the pipe or tube reached the first stand are extracted. Next, a first weight set to a value of 0 to 1 for example, is applied to the prediction error component of the factor outside the stand, and based on the prediction error component of the factor outside the stand applied with the first weight, the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand is corrected. Further, a second weight set to a value of 0 to 1 for example, is applied to the prediction error component of the factor inside the stand, and based on the prediction error component of the factor inside the stand applied with the second weight, the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand is corrected.

[0025] In other words, the rotational speed control start timing of the rolling rolls is corrected in such a manner that two prediction error components where the generation factors are different (accordingly, tendency of variation may differ) are divided, and each of the components is weighted separately (each of the prediction error components may be weighted differently). Therefore, even in such a state that a prediction error between the rotational speed control start timing of rolling rolls set with respect to each stand and the timing when the front or rear end of the pipe or tube actually reaches the stand varies at random according to the fluctuations of the generation factors of the prediction error, the rotational speed control start timing of the rolling rolls can be corrected appropriately, whereby it is possible to suppress defective thickness of a front or rear end of the pipe or tube rolled by the sizing mill more effectively.

[0026] Further, the present invention is also provided as a method for controlling sizing mill of a pipe or tube, comprising the steps of: calculating a prediction error between a rotational speed control start timing of rolling rolls set with respect to a predetermined stand of a sizing mill and a timing when a front or rear end of the pipe or tube actually reaches the predetermined stand; extracting a first prediction error component until the front or rear end of the pipe or tube reaches a first stand and a second prediction error component after the front or rear end of the pipe or tube reaches the first stand, from the prediction error calculated; applying a first weight to the first prediction error component extracted, and based on the first prediction error component applied with the first weight, correcting the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand; and applying a second weight to the second prediction error component extracted, and based on the second prediction error component applied with the second weight, correcting the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand.

[0027] Further, in order to solve the above-described problem, the present invention is provided as a device for controlling sizing mill of a pipe or tube, comprising: a thickness gauge provided at an output side of a sizing mill; a timing computing unit for correcting a rotational speed control start timing of rolling rolls set with respect to a predetermined stand, based on a thickness measured value of a front or rear end of a pipe or tube measured by the thickness gauge; and a rolling controller for controlling a rotational speed of rolling rolls provided to each stand, based on the rotational speed control start timing corrected by the timing computing unit.

[0028] It is preferable that the device for controlling sizing mill further comprises a detecting unit for detecting that a front or rear end of the pipe or tube reaches the predetermined stand, wherein the timing computing unit executes a computation including: a first step of calculating a prediction error between the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand and a timing when the front or rear end of the pipe or tube actually reaches the predetermined stand detected by the detecting unit; and a second step of correcting the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand, based on the prediction error calculated and the thickness measured value of the front or rear end of the pipe or tube measured by the thickness gauge.

[0029] Further, it is preferable that the second step includes the steps of:

extracting a first prediction error component until the front or rear end of the pipe or tube reaches a first stand and a second prediction error component after the front or rear end of the pipe or tube reaches the first stand, from the prediction error calculated; applying a first weight to the first prediction error component extracted, and based on the first prediction error component applied with the first weight, correcting the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand; applying a second weight to the second prediction error component extracted, and based on the second prediction error component applied with the second weight, correcting the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand; and based on the thickness measured value of the front or rear end of the pipe or tube measured by the thickness gauge, correcting the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand.

[0030] Further, in order to solve the above-described problem, the present invention is also provided as a device for controlling sizing mill of a pipe or tube, comprising: a detecting unit for detecting that a front or rear end of the pipe or tube reaches a predetermined stand of a sizing mill; a timing computing unit for correcting a rotational speed control start timing of rolling rolls set with respect to a predetermined stand; and a rolling controller for controlling a rotational speed of rolling rolls provided to each stand based on the rotational speed control start timing corrected by the timing computing unit, wherein the timing computing unit executes a computation including the steps of: calculating a prediction error between the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand and a timing when the front or rear end of the pipe or tube actually reaches the predetermined stand detected by the detecting unit; extracting a first prediction error component until the front or rear end of the pipe or tube reaches a first stand and a second prediction error component after the front or rear end of the pipe or tube reaches the first stand, from the prediction error calculated; applying a first weight to the first prediction error component extracted, and based on the first prediction error component applied with the first weight, correcting the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand; and applying a second weight to the second prediction error component extracted, and based on the second prediction error component applied with the second weight, correcting the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand.

[0031] In a first aspect there is provided a method for controlling sizing mill of a pipe or tube, wherein a rotational speed control start timing of rolling rolls set with respect to a predetermined stand of a sizing mill is corrected based on a thickness measured value of a front or rear end of the pipe or tube measured at an output side of said sizing mill. Preferably the method further comprises a first step of calculating a prediction error between the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand and a timing when the front or rear end of the pipe or tube actually reaches said predetermined stand; and a second step of correcting the rotational speed control start timing of the rolling rolls set with respect to said predetermined stand, based on said prediction error calculated and the thickness measured value of the front or rear end of the pipe or tube measured at the output side of said sizing mill. Desirably said second step includes the steps of: extracting a first prediction error component until the front or rear end of the pipe or tube reaches a first stand and a second prediction error component after the front or rear end of said pipe or tube reaches the first stand, from said prediction error calculated; applying a first weight to said first prediction error component extracted, and based on the first prediction error component applied with the first weight, correcting the rotational speed control start timing of the rolling rolls set with respect to said predetermined stand; applying a second weight to said second prediction error component extracted, and based on the second prediction error component applied with the second weight, correcting the rotational speed control start timing of the rolling rolls set with respect to said predetermined stand; and based on the thickness measured value of the front or rear end of the pipe or tube measured at the output side of said sizing mill, correcting the rotational speed control start timing of the rolling rolls set with respect to said predetermined stand.

[0032] In a second aspect there is provided a device for controlling sizing mill of a pipe or tube, comprising: a thickness gauge provided at an output side of a sizing mill; a timing computing unit for correcting a rotational speed control start timing of rolling rolls set with respect to a predetermined stand, based on a thickness measured value of a front or rear end of a pipe or tube measured by said thickness gauge; and a rolling controller for controlling a rotational speed of rolling rolls provided to each stand, based on the rotational speed control start timing corrected by said timing computing unit. Desirably the device further comprises: a detecting unit for detecting that a front or rear end of the pipe or tube reaches the predetermined stand, wherein said timing computing unit executes a computation including: a first step of calculating a prediction error between the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand and a timing when the front or rear end of the pipe or tube actually reaches said predetermined stand detected by said detecting unit; and a second step of correcting the rotational speed control start timing of the rolling rolls set with respect to said predetermined stand, based on said prediction error calculated and the thickness measured value of the front or rear end of the pipe or tube measured by said thickness gauge. Desirably said second step includes the steps of: extracting a first prediction error component until the front or rear end of the pipe or tube reaches a first stand and a second prediction error component after the front or rear end of said pipe or tube reaches the first stand, from said prediction error calculated; applying a first weight to said first prediction error component extracted, and based on the first prediction error component applied with the first weight, correcting the rotational speed control start timing of the rolling rolls set with respect to said predetermined stand; applying a second weight to said second prediction error component extracted, and based on the second prediction error component applied with the second weight, correcting the rotational speed control start timing of the rolling rolls set with respect to said predetermined stand; and based on the thickness measured value of the front or rear end of the pipe or tube measured by said thickness gauge, correcting the rotational speed control start timing of the rolling rolls set with respect to said predetermined stand.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033]

Fig. 1 is an illustration for describing a method of previously setting control start timings of rotational speeds of rolling rolls provided to respective stands.

Fig. 2 shows exemplary results of analyzing dispersion states of prediction error components of factor outside a stand and prediction error components of factor inside the stand.

Fig. 3 is an illustration for describing the meaning of the prediction error components of factor outside a stand and the prediction error components of factor inside the stand, shown in Fig. 2.

Fig. 4 is a block diagram showing the schematic configuration of a sizing mill used for performing a method for controlling sizing mill, according to an embodiment of the present invention.

Figs. 5(a) and 5(b) are diagrams each showing an example of a thickness measured value of a pipe or tube outputted from a thickness gauge shown in Fig. 4.

Fig. 6 is a flowchart showing a process flow in a timing computing unit shown in Fig. 4.

Figs. 7(a) and 7(b) show an exemplary result of evaluating a prediction error between the rotational speed control start timing of rolling rolls corrected with respect to a predetermined stand and the timing when a front or rear end of the pipe or tube actually reached the predetermined stand, in a case where the method for controlling sizing mill according to an embodiment of the present invention is applied.

Fig. 8 shows an example of the increased thickness ratio of a front or rear end in a case where the method for controlling sizing mill according to an embodiment of the present invention is applied.

BEST MODE FOR CARRYING OUT THE INVENTION

[0034] Hereinafter, an embodiment of the present invention will be described with reference to the accompanying drawings.

First Embodiment

[0035] Fig. 4 is a block diagram showing the schematic configuration of a sizing mill used for performing a method for controlling sizing mill, according to an embodiment of the present invention. As shown in Fig. 4, a pipe or tube 1 to be rolled is carried in an axial direction (direction shown by the outlined arrow in Fig. 4) by carrying rolls (not shown), and is sized and rolled at each stand 2. In the vicinity of the input side of the sizing mill in the carrying path of the pipe or tube 1, a pipe or tube end detector 8 which consists of a photoelectric sensor and detects a front end and rear end of the pipe or tube 1 by the operation of the photoelectric sensor. Further, in the vicinity of the output side of the sizing mill in the carrying path of the pipe or tube 1, a γ-ray thickness gauge 9 and a length gauge 10 consisting of a photoelectric sensor or the like are disposed. An end detecting signal of the pipe or tube 1 outputted from the pipe or tube end detector 8 is inputted into a rolling controller 7 and a timing computing unit 6. Further, a thickness measured value of the pipe or tube 1 outputted from the thickness gauge 9 and a length measured value of the pipe or tube 1 outputted from the length gauge 10 are inputted into the timing computing unit 6.

[0036] A rolling roll 21 provided to each stand 2 is driven by a roll driving motor 3 via a reduction gear 31. Among a plurality of stands 2, a roll driving motor 3 of a stand 2 in, for example, odd-number order counted from the first stand (stand disposed at the most upstream side) is provided with a current detector 32 for detecting a drive current of the roll driving motor 3 and a rotational speed detector 33 for detecting the rotational speed (the present invention is not limited to this configuration, and it is possible to adopt configurations in which the current detector 32 and the rotational speed detector 33 are provided to another predetermined stand or to the roll driving motors 3 of all stands). Detection signals of the current detector 32 and the rotational speed detector 33 are inputted into a motor drive controller 4 for drive-controlling the roll driving motor 3, respectively. In the motor drive controller 4, a rotational speed control starting signal of the rolling roll 21 has been inputted from the rolling controller 7, and the motor drive controller 4 performs a rotational speed control of the roll driving motor 3 based on the rotational speed control starting signal. Further, the detection signals of the current detector 32 and the rotational speed detector 33 are also inputted into a rolling torque computing unit 5 via the motor drive controller 4.

[0037] The rolling torque computing unit 5 serves as a detecting unit for detecting that a front or rear end of the pipe or tube reaches a predetermined stand in the present invention. The rolling torque computing unit 5 calculates rolling torque based on the detection signals of the driving current and the rotational speed inputted from the motor drive controller 4, and outputs the calculated rolling torque signal to the timing computing unit 6. To the timing computing unit 6, there are inputted the calculated rolling torque signal, the end detection signal from the pipe or tube end detector 8, the thickness measured value of the pipe or tube 1 outputted from the thickness gauge 9, the length measured value of the pipe or tube 1 outputted from the length gauge 10, and the rotational speed control starting signal of the rolling roll 21 from the rolling controller 7. Based on these inputted signals, the timing computing unit 6 calculates the correction amount of the rotational speed control starting signal, and outputs the calculation result to the rolling controller 7 as a correction signal.

[0038] To the rolling controller 7, the end detection signal from the pipe or tube end detector 8 and the correction signal from the timing computing unit 6 are inputted. Timing is started at the time when the end detection signal from the pipe or tube end detector 8 is imputed, and when the timing result reaches a stored set value of the rotational speed control start timing of the rolling rolls 21 of each stand 2, the rolling controller 7 outputs a rotational speed control starting signal to each motor drive controller 4 and to each timing computing unit 6. Each motor drive controller 4 lowers the rotational speed of the roll driving motor 3 based on the rotational speed control starting signal inputted. Note that a set value of the rotational speed control start timing is corrected based on the correction signal inputted from the timing computing unit 6, and is stored as a set value used for rolling the next pipe or tube 1.

[0039] Hereinafter, a method of computing the correction amount of the rotational speed control starting signal (correction amount of the rotational speed control start timing) in the timing computing unit 6, based on the rolling torque signal from the rolling torque computing unit 5, the end detection signal from the pipe or tube end detector 8, the thickness measured value of the pipe or tube 1 outputted from the thickness gauge 9, the length measured value of the pipe or tube 1 outputted from the length gauge 10, and the rotational speed control starting signal of the rolling roll 21 from the rolling controller 7, will be described specifically with reference to Figs. 5 and 6 and Fig. 3 described above as appropriate. Note that the method for controlling sizing mill, according to this embodiment, is configured so as to compute the correction amount of the rotational speed control starting signal while taking into account both of the correction amount based on the thickness measured value of a front or rear end of the pipe or tube 1 (hereinafter, referred to as "correction amount based on thickness result" as appropriate) and the correction amount based on a prediction error between the rotational speed control start timing of the rolling rolls 21 and the timing when the front or rear end of the pipe or tube 1 actually reaches (hereinafter, referred to as "correction amount based on prediction error" as appropriate). Hereinafter, the respective correction amounts will be described in sequence.

(1) Correction Amount Based on Thickness Result

[0040] First, the correction amount based on a thickness result will be described. Fig. 5 is a diagram showing an example of a thickness measured value of the pipe or tube 1 (average thickness in a pipe or tube circumferential direction) outputted from the thickness gauge 9. The timing computing unit 6 first calculates an average thickness tm in a length Lm, in the intermediate portion of the pipe or tube 1, shown by the following equation (1), based on the thickness measured value of the pipe or tube 1 outputted from the thickness gauge 9 and the length measured value of the pipe or tube 1 outputted from the length gauge 10:

$$Lm = L - (Lct + Lt + Lcb + Lb) \ldots (1)$$

[0041] Here, in the equation (1) above, L means the length of the pipe or tube 1 at the output side of the sizing mill, Lct means the crop length at the front end of the pipe or tube 1 defined in advance according to the type and dimensions of the pipe or tube 1, Lt means the front end length of the product part of the pipe or tube 1 defined in advance, Lcb means the crop length at the rear end of the pipe or tube 1 defined in advance, and Lb means the rear end length of the product part of the pipe or tube 1 defined in advance. Note that the front end length Lt and the rear end length Lb of the product part are lengths in predetermined proportional to the length (or target length) of the pipe or tube 1 at the output side of the sizing mill, or are constant lengths irrespective of the length of the pipe or tube 1.

(1-1) When there is a thickness measured value exceeding the upper limit but no value below the lower limit

[0042] Next, when, among thickness measured values of the pipe or tube 1 outputted from the thickness gauge 9, there is a value exceeding the upper limit (= tm + tup) but no value below the lower limit (= tm - tlo), within a part of the pipe or tube 1 corresponding to the front end length Lt of the product part, the timing computing unit 6 calculates the increased thickness length Lzt of the front end. Here, tup and tlo are values which have been determined beforehand. Further, the increased thickness length Lzt of the front end means the length from a portion where the thickness first increases from the average thickness tm by tup viewed from the most inner side of the portion corresponding to the front end length Lt of the product part of the pipe or tube 1, to a portion coming inside by the crop length Lct from the tip of the pipe or tube 1, as shown in Fig. 5(a). Similarly, if, among thickness measured values of the pipe or tube 1 outputted from the thickness gauge, there is a value exceeding the upper limit (= tm + tup) but no value below the lower limit (= tm - tlo), within a portion of the pipe or tube 1 corresponding to the rear end length Lb of the product part, the timing computing unit 6 calculates the increased thickness length Lzb of the rear end. The increased thickness length Lzb of the rear end means the length from a portion where the thickness first increases from the average thickness tm by tup viewed from the most inner side of the portion corresponding to the rear end length Lb of the product part of the pipe or tube 1, to a portion coming inside by the crop length Lcb from the rear end of the pipe or tube 1. The values of tup and tlo may take the same values in the front end and the rear end of the pipe or tube 1, or may be different.

[0043] Then, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the front end of the pipe or tube 1, the timing computing unit 6 outputs to the rolling controller 7 a correction signal in which ΔTt1 shown by the following equation (2) is set as the correction amount based on the thickness result:

$$\Delta Tt1 = Kt \cdot Lzt \cdot L0/L/V0 \ldots (2)$$

[0044] Here, in the equation (2), Kt means a constant (weight) set to a value of 0 to 1, L0 means the length of the pipe or tube 1 at the input side of the sizing mill (it is measurable by arranging a length gauge on the input side of the sizing mill or by measuring the length in the step of the previous stage of the sizing mill), and V0 means the speed of the pipe or tube 1 at the input side of the sizing mill (it is measurable by arranging a speed meter on the input side of the sizing mill, or by arranging two pipe or tube end detectors 8 described above and dividing the distance between the pipe or tube end detectors 8 by the difference between the detection times).

[0045] Since L/L0 means the elongation percentage of the pipe or tube 1 (percentage of the pipe or tube being elongated) by the sizing mill, a value, obtained by dividing the increased thickness length Lzt of the front end by L/L0 (= Lzt·L0/L), corresponds to the length of the increased thickness length of the front end at the input side of the sizing mill. A value, obtained by dividing the length of the increased thickness length of the front end at the input side of the sizing mill by the speed V0 of the pipe or tube 1 at the input side of the sizing mill (= Lzt·L0/L/V0) means a time period during which a portion corresponding to the increased thickness length of the front end is generated. Accordingly, it is possible to suppress generation of the portion corresponding to the increased thickness length of the front end by setting ΔTt1 shown by the above-mentioned equation (2) as the correction amount, and rolling the next pipe or tube 1 by uniformly adding the correction amount ΔTt1 to the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 (delaying the rotational speed control start timing by ΔTt1).

[0046] On the other hand, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the rear end of the pipe or tube 1, the timing computing unit 6 outputs to the rolling controller 7 a correction signal in which ΔTb1 shown by the following equation (3) is set as the correction amount based on the thickness result:

$$\Delta Tb1 = -Kb \cdot Lzb \cdot L0/L/V0 \ldots (3)$$

[0047] Here, in the equation (3), Kb means a constant (weight) set to a value of 0 to 1.

[0048] Similar to the aforementioned case of the front end of the pipe or tube 1, Lzb·L0/L/V0 means a time period in which a portion correspond to the increased thickness length Lzb of the rear end is generated.
Accordingly, it is possible to suppress generation of the portion corresponding to the increased thickness length of the rear end by setting ΔTb1 shown by the above-mentioned equation (3) as the correction amount, and rolling the next pipe or tube 1 by uniformly adding the correction amount Δtb1 to the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 (advancing the rotational speed control start timing by a period corresponding to the absolute value of ΔTt1).

(1-2) When there is a thickness measured value below the lower limit

[0049] On the other hand, when there is a value below the lower limit (= tm - tlo) among thickness measured values of the pipe or tube 1 outputted from the thickness gauge 9, in the portion of the pipe or tube 1 corresponding to the front end length Lt of the product part, the timing computing unit 6 calculates the reduced thickness length Lgt of the front end. Here, as shown in Fig. 5(b), the reduced thickness length Lgt of the front end means the length from a portion where the thickness is first reduced from the average thickness tm by tlo viewed from the most inner side of the portion corresponding to the front end length Lt of the product part of the pipe or tube 1, to a portion coming inside by the crop length Lct from the tip of the pipe or tube 1. Similarly, when there is a value below the lower limit (= tm - tlo) among thickness measured values of the pipe or tube 1 outputted from the thickness gauge 9, in the portion of the pipe or tube 1 corresponding to the rear end length Lb of the product part, the timing computing unit 6 calculates the reduced thickness length Lgb of the rear end. The reduced thickness length Lgb of the rear end means the length from a portion where the thickness is first reduced from the average thickness tm by tlo viewed from the most inner side of the portion corresponding to the rear end length Lb of the product part of the pipe or tube 1, to a portion coming inside by the crop length Lcb from the rear end of the pipe or tube 1.

[0050] Then, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the front end of the pipe or tube 1, the timing computing unit 6 outputs to the rolling controller 7 a correction signal in which ΔTt1 shown by the following equation (4) is set as the correction amount based on the thickness result:

$$\Delta Tt1 = -Kt \cdot Lgt \cdot L0/L/V0 \ldots (4)$$

[0051] On the other hand, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the rear end of the pipe or tube 1, the timing computing unit 6 outputs to the rolling controller 7 a correction signal in which ΔTb1 shown by the following equation (5) is set as the correction amount based on the thickness result:

$$\Delta Tb1 = Kb \cdot Lgb \cdot L0/L/V0 \ldots (5)$$

(1-3) When there is no value exceeding the upper limit and no value below the lower limit in thickness measured value

[0052] When there is no value exceeding the upper limit (= tm + tup) and no value below the lower limit (= tm - tlo) in thickness measured values of the pipe or tube 1 outputted from the thickness gauge 9 within the portion of the pipe or tube 1 corresponding to the front end length Lt of the product part, the timing computing unit 6 ends the computation since there is no need to correct the rotational speed control starting signal relating to the correction amount based on the thickness result (that is, a correction signal of the correction amount Δtb1 = 0 based on the thickness result is outputted to the rolling controller 7). Similarly, when there is no value exceeding the upper limit (= tm + tup) and no value below the lower limit (= tm - tlo) in thickness measured values of the pipe or tube 1 outputted from the thickness gauge 9 within the portion of the pipe or tube 1 corresponding to the rear end length Lb of the product part, the timing computing unit 6 ends the computation since there is no need to correct the rotational speed control starting signal relating to the correction amount based on the thickness result (that is, a correction signal of the correction amount ΔTb1 = 0 based on the thickness result is outputted to the rolling controller 7).

(2) Correction Amount Based on Prediction Error

[0053] Next, the correction amount based on a prediction error will be described. The timing computing unit 6 starts timing at a timing where an end (front end or rear end) detection signal is imputed from the pipe or tube end detector 8 to the timing computing unit 6 as a starting point, and based on the fluctuation state of a rolling torque signal inputted from the rolling torque computing unit 5, detects the timing where the end (front end or rear end) of the pipe or tube 1 actually reaches the predetermined stand 2 (stand in odd-number order in this embodiment) (that is, an elapsed time period starting from the time when the end detecting signal is imputed, hereinafter referred to as a "measured period" as appropriate). A specific method of detecting the timing when the front or rear end of the pipe or tube 1 actually reaches the predetermined stand 2, based on the fluctuation state of the rolling torque signal inputted, is similar to that described in Patent Document 1 described above, so the detailed description thereof is omitted in the present specification. On the other hand, the timing computing unit 6 detects an elapsed time period starting from the time when the end detecting signal is inputted from the pipe or tube end detector 8 to the timing computing unit 6, to the time when the rotational speed control starting signal of the rolling roll 21 is inputted from the rolling controller 7 (hereinafter, referred to as "predicted period" as appropriate), and calculates the prediction error Y_j between the predicted period and the measured period.

[0054] In the timing computing unit 6, first, based on plural pieces of data (i, Y_i) plotted by assuming the horizontal axis X being the stand number and the vertical axis Y being the prediction error between the predicted period and the measured period (see Fig. 3), the correlation coefficient R between X and Y is calculated (S1 in Fig. 6), and the calculated correlation coefficient R is determined whether it is below the predetermined value (S2 in Fig. 6).

[0055] Here, if the correlation coefficient R is below the predetermined value, it is determined that the prediction error Y_i only includes a prediction error component of the factor outside the stand, and based on (i, Y_i), a primary regression equation of Y, where X is a variable, is calculated (S3 in Fig. 6). Then, a Y section of the primary regression equation is defined as a prediction error T_0' between the predicted period and the measured period in the first stand (see S4 in Fig. 6, and Fig. 3). Next, for the stand in which the measured period has been detected, the sum of squares $\Sigma(Y_i - T_0')^2$ of the difference between the prediction error Y_i and the prediction error T_0' and the sum of squares $\Sigma(Y_i)^2$ of the prediction error Y_i are compared (S5 in Fig. 6), and if $\Sigma(Y_i - T_0')^2 \geq \Sigma(Y_i)^2$, the computation ends since there is no need to correct the rotational speed control starting signal relating to the correction amount based on the prediction error. More specifically, if the prediction error Y_i for the front end of the pipe or tube 1 satisfies the conditions described above, the timing computing unit 6 outputs a correction signal where the correction amount based on the prediction error is ΔTt2 = 0, to the rolling controller 7, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the front end of the pipe or tube 1. Similarly, if the prediction error Y_i for the rear end of the pipe or tube 1 satisfies the conditions described above, the timing computing unit 6 outputs a correction signal where the correction amount based on the prediction error is ΔTb2 = 0, to the rolling controller 7, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the rear end of the pipe or tube 1.

[0056] On the other hand, if $\Sigma(Y_i - T_0')^2 < \Sigma(Y_i)^2$, the timing computing unit 6 multiplies the prediction error T_0' by a first weight (value of 0 to 1, e.g., 0.5), and outputs a correction signal in which the prediction error T_0' multiplied by the first weight is set as the correction amount to the rolling controller 7 (S6 in Fig. 6). More specifically, if the prediction error Y_i for the front end of the pipe or tube 1 satisfies the conditions described above, the timing computing unit 6 outputs a correction signal where the correction amount based on the prediction error is ΔTt2 = -(first weight)·T_0', to the rolling controller 7, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the front end of the pipe or tube 1. In the rolling controller 7, the correction amount ΔTt2 based on the prediction error is added to the rotational speed control start timing of the rolling rolls 21 of each stand 2 uniformly (subtracting the prediction error T_0' multiplied by the first weight), which is used for rolling the next pipe or tube 1 (S6 in Fig. 6). Similarly, if the prediction error Y_i for the rear end of the pipe or tube 1 satisfies the conditions described above, the timing computing unit 6 outputs a correction signal where the correction amount based on the prediction error is ΔTb2 = -(first weight)·T_0', to the rolling controller 7, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the rear end of the pipe or tube 1.

[0057] On the other hand, if the correlation coefficient R is larger than the predetermined value, it is determined that the prediction error Y_i includes both of the prediction error component of the factor outside the stand and the prediction error component of the factor inside the stand, whereby the timing computing unit 6 calculates a primary regression equation based on (i, Y_i) similar to that described above (S7 in Fig. 6), and sets the calculated Y section of the of the primary regression equation as the prediction error T_0' between the predicted period and the measured period in the first stand (see S8 in Fig. 6 and Fig. 3). Next, the prediction error T_0' is multiplied by a first weight (value of 0 to 1, e.g., 0.5), and a correction signal in which the prediction error T_0' multiplied by the first weight is set as the correction amount is outputted to the rolling controller 7 (S9 in Fig. 6). In the rolling controller 7, the correction amount is subtracted from the rotational speed control start timing of the rolling rolls 21 of each stand 2 uniformly (S9 in Fig. 6). In other words, through the processing shown in S9 of Fig. 6, the prediction error component of the factor outside the stand included in the prediction error Y_i is corrected. Further, in the timing computing unit 6, a prediction error Y_i' between the predicted period and the measured period in each stand (i^{th} stand) after the second stand is calculated based on the primary regression equation (see S10 in Fig, 6 and Fig. 3), and a value obtained by subtracting T_0' from Y_i' (this value corresponds to a prediction error component ΣT_j' for a predicted period ΣT_j(j = 1 to i-1, i ≥ 2) until the front or rear end of the pipe or tube reaches i^{th} stand from the first stand) is multiplied by a second weight (values of 0 to 1, e.g., 0.5), and a correction signal where the value multiplied by the second weight is set as the correction amount is outputted to the rolling controller (S11 in Fig. 6). In the rolling controller 7, the correction amount is further subtracted from the rotational speed control start timing, for the next pipe or tube, of the rolling roll 21 in each stand (i^{th} stand) (S11 in Fig. 6). In other words, through the processing shown in S11 of Fig. 6, the prediction error component of the factor inside the stand, included in the prediction error Y_i, is corrected.

[0058] Namely, when the correlation coefficient R for the front end of the pipe or tube 1 is larger than the predetermined value, the timing computing unit 6 outputs a correction signal where the correction amount based on the prediction error is ΔTt2 = -(first weight)·T_0' - (second weight)·(Y_i'- T_0') is outputted to the rolling controller 7, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the front end of the pipe or tube 1. Similarly, when the correlation coefficient R for the rear end of the pipe or tube 1 is larger than the predetermined value, the timing computing unit 6 outputs a correction signal where the correction amount based on the prediction error is ΔTb2 = -(first weight)·T_0' - (second weight)·(Y_i'-T_0') is outputted to the rolling controller 7, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the rear end of the pipe or tube 1.

[0059] Note that this embodiment has described such a configuration that, based on the data (i, Y_i) plotted on the premise that the horizontal axis X shows the stand number i and the vertical axis Y shows the prediction error Y_i between the predicted period and the measured period, a primary regression equation ofY where X is variable is calculated, and with the primary regression equation, a prediction error component of a factor outside the stand and a prediction error component of a factor inside the stand are separated. However, the present invention is not limited to this configuration. It is possible to adopt such a configuration that an N^{th} (integer of N > 1) regression equation ofY where X is variable is calculated based on data (i, Y_i), and a prediction error component of a factor outside the stand and a prediction error component of a factor inside the stand are separated. Further, as the first weight and the second weight, the same values may be adopted in the front end and the rear end of the pipe or tube 1, or different values may be adopted.

(3) Total Correction Amount

[0060] The method of controlling thicknesses of the front and rear end of the pipe or tube according to this embodiment is so configured as to compute the correction amount of the rotational speed control start timing of the rolling rolls 21 set at the current rolling time with respect to each stand 2, taking into account both (1) correction amount based on the thickness result and (2) the correction amount based on the prediction error, as described above. That is, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the front end of the pipe or tube 1, ΔTt shown by the following equation (6) is considered as the total correction amount, and is stored in the rotating controller 7:

$$\Delta Tt = \alpha t \cdot \Delta Tt1 + \beta t \cdot \Delta Tt2 \ldots (6)$$

[0061] Here, αt is a constant of 0 to 1, and βt is a constant of 1 - αt.

[0062] Further, the set value of the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the front end of the pipe or tube 1 is corrected based on the correction amount ΔTt stored (correction amount ΔTt is added), which is used as a set value for rotating the next pipe or tube 1.

[0063] Similarly, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the rear end of the pipe or tube 1, ΔTb shown by the following equation (7) is considered as the total correction amount, and is stored in the rotating controller 7:

$$\Delta Tb = \alpha b \cdot \Delta Tb1 + \beta b \cdot \Delta Tb2 \ldots (7)$$

[0064] Here, αb is a constant of 0 to 1, and βb is a constant of 1- αb.

[0065] Further, the set value of the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the rear end of the pipe or tube 1 is corrected based on the correction amount ΔTb stored (correction amount ΔTb is added), which is used as a set value for rotating the next pipe or tube 1.

[0066] Although, in this embodiment, descriptions have been given in the order of (1) the correction amount based on the thickness result and (2) the correction amount based on the prediction error, it is not necessary to perform computation in this order. A configuration in which ether correction amount is computed first may be applied.

[0067] As described above, according to the method for controlling sizing mill of this embodiment, the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 is corrected based on the thickness measured values of the front and rear end of the pipe or tube 1 measured at the output side of the sizing mill. Therefore, it is expected that the rotational speed control start timing of the rolling rolls 21 is corrected so as to be appropriate for the actual thickness fluctuations of the front and rear end of the pipe or tube. Further, since the prediction error is divided into two prediction error components of different factors (a prediction error component of a factor outside the stand and a prediction error component of a factor inside the stand) which are weighted respectively (it is possible to differ first and second weights applied to the both prediction error components respectively) and are provided to correct the rotational speed control start timing of the rolling rolls 21, it is possible to correct the rotational speed control start timing of the rolling rolls 21 appropriately in a state where the prediction error between the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 and the timing when a front or rear end of the pipe or tube 1 reaches each stand 2 varies at random along with the fluctuation of the generation factors of the prediction error. Accordingly, it is possible to suppress defective front and rear end thickness of the pipe or tube 1 rolled by the sizing mill, effectively.

Second Embodiment.

[0068] A method for controlling sizing mill, according to this embodiment, is configured to use only the correction amount based on the thickness result in the first embodiment. That is, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the front end of the pipe or tube 1, $\Delta Tt = \Delta Tt1$ (that is, $\alpha t = 1$, $\beta t = 0$ in the equation (6) above) is considered as the total correction amount, and is stored in the rolling controller 7. Further, the set value of the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the front end of the pipe or tube 1 is corrected based on the stored correction amount ΔTt (correction amount ΔTt is added), which is used as a set value for rolling the next pipe or tube 1. Similarly, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the rear end of the pipe or tube 1, $\Delta Tb = \Delta Tb1$ (that is, $\alpha b = 1$, $\beta b = 0$ in the equation (7) above) is considered as the total correction amount, and is stored in the rolling controller 7. Further, the set value of the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the rear end of the pipe or tube 1 is corrected based on the stored correction amount ΔTb (correction amount ΔTb is added), which is used as the set value for rolling the next pipe or tube 1.

[0069] According to the method for controlling sizing mill of this embodiment, the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 is corrected based on the thickness measured values of the front and rear end of the pipe or tube 1 measured at the output side of the sizing mill, so it is expected that the rotational speed control start timing of the rolling rolls 21 can be corrected so as to be appropriate for the actual thickness fluctuations of the front and rear ends of the pipe or tube. Thereby, it is possible to suppress defective thicknesses in the front and rear ends of the pipe or tube 1 rolled by the sizing mill, effectively.

Third Embodiment

[0070] A method for controlling sizing mill, according to this embodiment, is configured to use a prediction error Yi between the predicted period and the measured period in each stand 2 as it is. The correction amounts based on the prediction errors are $\Delta Tt2$ and $\Delta Tb2$ (in this embodiment, however, measured periods must be detected not only for the stands in odd-number order but for all stands, different from the first embodiment). In other words, the correction amount is computed based on the equations (6) and (7) above, where $\Delta Tt2 = -Yi$ (prediction error for the front end) and $\Delta Tb2 = -Yi$ (prediction error for the rear end).

[0071] According to the method for controlling sizing mill of this embodiment, the rotational speed control start timing of the rolling rolls 21 is corrected by using not only the thickness measured values of the front and rear ends of the pipe or tube 1 measured at the output side of the sizing mill but also the prediction errors between the rotation speed control start timings of the rolling roll set with respect to each stand 2 and the timing when the front or rear end of the pipe or tube 1 actually reach each stand 2. Therefore it is expected that the rotational speed control start timing of the rolling rolls 21 can be corrected so as to be more appropriate than the case of the second embodiment, whereby it is possible to suppress defective thicknesses in front and rear ends of the pipe or tube 1 rolled by the sizing mill, effectively.

Fourth Embodiment

[0072] A method for controlling sizing mill, according to this embodiment, is configured to only use the correction amount based on the prediction error in the first embodiment. That is, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the front end of the pipe or tube 1, $\Delta Tt = \Delta Tt2$ (that is, $\alpha t = 0$, $\beta t = 1$ in the equation (6) above) is considered as the total correction amount, and is stored in the rolling controller 7. Then, the set value of the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the front end of the pipe or tube 1 is corrected based on the stored correction amount ΔTt (the correction amount ΔTt is added), which is used as the set value for rolling the next pipe or tube 1. Similarly, as for the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the rear end of the pipe or tube 1, $\Delta Tb = \Delta Tb2$ (that is, $\alpha b = 0$, $\beta b = 1$ in the equation (7) above) is considered as the total correction amount, and is stored in the rolling controller 7. Then, the set value of the rotational speed control start timing of the rolling rolls 21 set with respect to each stand 2 relating to the rear end of the pipe or tube 1 is corrected based on the stored correction amount ΔTb (the correction amount ΔTb is added), which is used as the set value for rolling the next pipe or tube 1.

[0073] According to the method for controlling sizing mill of this embodiment, since the prediction error is divided into two prediction error components of different factors (a prediction error component of a factor outside the stand and a prediction error component of a factor inside the stand) which are weighted respectively (it is possible to differ first and second weights applied to the both prediction error components respectively) and are provided to correct the rotational speed control start timing of the rolling rolls 21, it is possible to correct the rotational speed control start timing of the rolling rolls 21 appropriately in a state where the prediction errors between the rotational speed control start timings of the rolling roll 21 set to each stand 2 and the timings when front and rear ends of the pipe or tube 1 reach each stand 2 varies at random along with the fluctuations of the generation factors of the prediction errors. Accordingly, it is possible to suppress defective thicknesses in the front and rear ends of the pipe or tube 1 rolled by the sizing mill, effectively.

[0074] Figs. 7(a) and 7(b) show exemplary results of evaluating prediction error between the rotational speed control start timing of the rolling rolls 21 corrected with respect to a predetermined stand 2 and the timing when a front or rear end of the pipe or tube 1 actually reaches the predetermined stand 2, in the case of applying the method for controlling sizing mill (method for correcting rotational speed control start timing of rolling roll 21) according to the fourth embodiment of the present invention. Fig. 7(a) shows a prediction error in the case of applying the method according to the fourth embodiment of the present invention, and Fig. 7(b) shows a prediction error in the case of applying the conventional method (prediction error between the rotational control start timing of the rolling rolls 21 which has been set beforehand with respect to the predetermined stand 2

(including a case where correction is performed manually by the operator) and the timing when the front or rear end of the pipe or tube 1 actually reaches the predetermined stand 2). As shown in Fig. 7(a), it was found that according to the method of this embodiment, the absolute value of the average value of prediction errors becomes small and the dispersion also becomes small comparing with the case of applying the conventional method (Fig. 7(b)), whereby it was possible to correct the rotational speed control start timing of the rolling rolls 21, appropriately.

[0075] Thereby, as shown in Fig. 8, it is possible to suppress defective thickness (increased thickness ratio of end) of the front end (except for the crop part shown in Fig. 8) of the pipe or tube 1 rolled by the sizing mill more effectively comparing with the conventional case. The increased thickness ratio of end shown in Fig. 8 is a value indicated by (thickness at each portion of end - average thickness (tm))/average thickness (tm) $\times$ 100 (%).

[0076] Further, the tolerance failure ratio of the thickness of the pipe or tube 1 after being rolled was evaluated, in the case of applying the methods for controlling sizing mill according to the first to fourth embodiments of the present invention and methods of comparative examples. More specifically, 50 to 100 pipes or tubes for each manufacturing chance were sized and rolled for three manufacturing chances in total under the following conditions of (1) to (6), and the tolerance failure ratios were evaluated for the front ends (portions corresponding to the crop lengths Lct and the front end lengths Lt of the product parts) after being rolled, for each chance. Note that the tolerance failure ratio means the ratio of the number of pipes or tubes in which the average thicknesses of the front ends are out of the range of (tm - tlo) to (tm - tup) to the total number of rolled pipes or tubes:

(1) Pipe or tube dimensions at input side of sizing mill: outer diameter 100 mm, thickness 6.0 to 7.0 mm,
(2) Pipe or tube dimensions at output side of sizing mill: outer diameter 30.0 mm, thickness 5.0 to 6.0 mm,

(3) Pipe or tube temperature at input side of sizing mill: 900 to 950˚C,
(4) Pipe or tube temperature at output side of sizing mill: 810 to 860˚C,
(5) The number of stands in sizing mill: 25 stands, and
(6) Pipe or tube material: carbon steel.

[0077] Table 1 shows evaluation results. Note that Examples 1-1 and 1-2 in Table 1 show a method for controlling sizing mill, corresponding to the first embodiment. Example 1-1 shows an example in which coefficients αt and βt in the equation (6) described above are fixed (the first coefficients shown in Table 1 are $\alpha t = \beta t = 0.5$, the second coefficients shown in Table 1 are $\alpha t = \beta t = 0.5$) in all three manufacturing chances. Example 1-2 shows an example in which αt and βt are fixed (the first coefficients shown in Table 1 are $\alpha t = 0.3$ and $\beta t = 0.7$) in the same manufacturing chance, but at the timing of the manufacturing chance being changed, different coefficients (the second coefficients shown in Table 1 are $\alpha t = 0.7$ and $\beta t = 0.3$) are used. Further, Example 2, Example 3 and Example 4 are methods for controlling sizing and fixing, corresponding to the second embodiment, the third embodiment and the fourth embodiment, respectively. Comparative Example 1 is a method of using a prediction error between the predicted period and the measured period in each stand as the correction mount as it is, without performing thickness measurement. Comparative Example 2 is a method in which correction is performed manually by the operator, without performing thickness measurement.

Table 1

	Correction based on thickness result	Correction based on prediction error	The first coefficient		The second coefficient		Tolerance failure ratio (%)		
			αt	βt	αt	βt	Chance 1	Chance 2	Chance 3
Example 1-1	○	○ (Primary regression equation)	0.5	0.5	0.5	0.5	3.5	1.5	1.2
Example 1-2	○	○ (Primary regression equation)	0.3	0.7	0.7	0.3	3.8	1.0	0.7
Example 2	○	×	1.0	0.0	1.0	0.0	4.0	3.5	3.2
Example 3	○	○ (Prediction error in each stand)	0.5	0.5	0.5	0.5	5.0	3.5	2.5
Example 4	×	○ (Primary regression equation)	0.0	1.0	0.0	1.0	6.5	4.5	4.0
Comparative Example 1	×	○ (Prediction error in each stand)	0.0	1.0	0.0	1.0	8.0	7.5	6.5
Comparative Example 2	×	△ (Manual)	0.0	(1.0)	0.0	(1.0)	10.0	9.0	8.5

[0078] As shown in Table 1, the tolerance failure ratio was lowered in the method of Example 4, comparing with Comparative Examples 1 and 2. In particular, in the method of Comparative Example 1, the prediction error between the predicted period and the measured period in each stand was used as it was as the correction amount, so an influence of the measurement error of the measured period directly affected, whereby the prediction error was difficult to be solved. On the other hand, in the method of Example 4, the correction amount was approximated by a primary regression equation, whereby it was less likely to be affected by the measurement error of the measured period, so it was considered that the tolerance failure ratio was lowered consequently. Further, in the method of Example 3, correction based on the thickness result was added to the method of Comparative Example 1, whereby it was possible to reduce the tolerance failure ratio comparing with the methods of Comparative Examples 1 and 2. However, since the prediction error in each stand was defined as the correction amount based on the prediction error as it was, similar to the method of Comparative Example 1, it was difficult to solve the prediction error, so the tolerance failure ratio was also somewhat difficult to be solved, consequently. Further, as for the method of Example 2, it was possible to reduce the tolerance failure ratio comparing with the methods of Comparative Examples 1 and 2, since a correction based on the thickness result was performed. However, since a correction based on the prediction error was not performed, the tolerance failure ratio was less likely to be solved comparing with the methods of Examples 1-1, 1-2 and 3. In the method of Example 1-1, since a correction based on the thickness result and a correction based on the prediction error based on a primary regression equation are performed, the tolerance failure ratio was lowered and was possible to be solved quickly, comparing with not only Comparative Examples 1 and 2 but also Examples 2 to 4. Further, in the methods of Example 1-2, since different coefficients were used in the case of the same manufacturing chance and in the case of the manufacturing chance being changed (at the timing where the manufacturing chance is changed, the value of αt is increased such that the correction amount based on the thickness result contributes more), it was possible to solve the tolerance failure ratio more quickly than the method of Example 1-1. This is because the correction amount based on the thickness result may depend more on the dimensions of the pipe or tube than the manufacturing chances. That is, in the case where the dimensions of the pipe or tube at respective chances are the same as in this example, it is considered that the correction result in the prior manufacturing chance can be utilized in a more effective manner by setting coefficients such that the correction amount based on the thickness result contributes more at timing when the manufacturing chance is changed.

Claims

1. A method for controlling sizing mill of a pipe or tube, comprising the steps of:

calculating a prediction error between a rotational speed control start timing of rolling rolls set with respect to a predetermined stand of a sizing mill and a timing when a front or rear end of the pipe or tube actually reaches said predetermined stand;
extracting a first prediction error component until the front or rear end of the pipe or tube reaches a first stand and a second prediction error component after the front or rear end of said pipe or tube reaches the first stand, from said prediction error calculated;
applying a first weight to said first prediction error component extracted, and based on the first prediction error component applied with the first weight, correcting the rotational speed control start timing of the rolling rolls set with respect to said predetermined stand; and
applying a second weight to said second prediction error component extracted, and based on the second prediction error component applied with the second weight, correcting the rotational speed control start timing of the rolling rolls set with respect to said predetermined stand.

2. A device for controlling sizing mill of a pipe, comprising:

a detecting unit for detecting that a front or rear end of the pipe or tube reaches a predetermined stand of a sizing mill;
a timing computing unit for correcting a rotational speed control start timing of rolling rolls set with respect to a predetermined stand; and
a rolling controller for controlling a rotational speed of rolling rolls provided to each stand based on the rotational speed control start timing corrected by said timing computing unit, wherein

said timing computing unit executes a computation including the steps of:

calculating a prediction error between the rotational speed control start timing of the rolling rolls set with respect to the predetermined stand and a timing when the front or rear end of the pipe or tube actually reaches said predetermined stand detected by said detecting unit;
extracting a first prediction error component until the front or rear end of the pipe or tube reaches a first stand and a second prediction error component after the front or rear end of said pipe or tube reaches the first stand, from said prediction error calculated;
applying a first weight to said first prediction error component extracted, and based on the first prediction error component applied with the first weight, correcting the rotational speed control start timing of the rolling rolls set with respect to said predetermined stand; and
applying a second weight to said second prediction error component extracted, and based on the second

prediction error component applied with the second weight, correcting the rotational speed control start timing of the rolling rolls set with respect to said predetermined stand.

Fig. 1

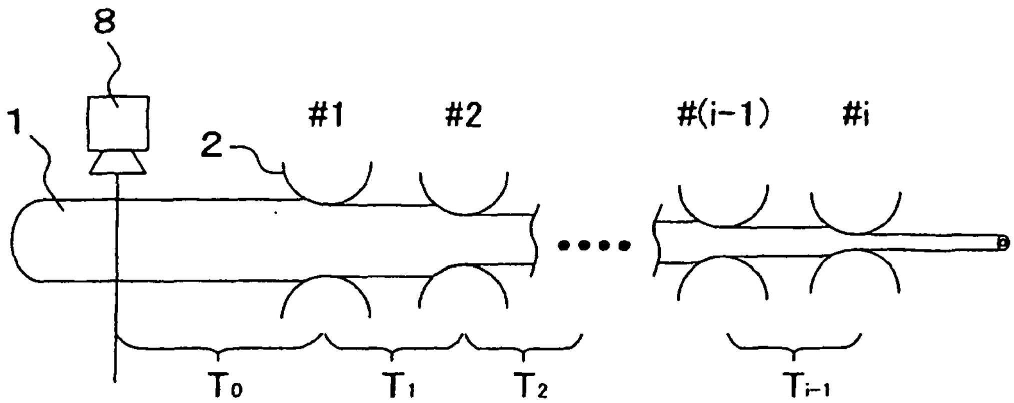


Fig. 2

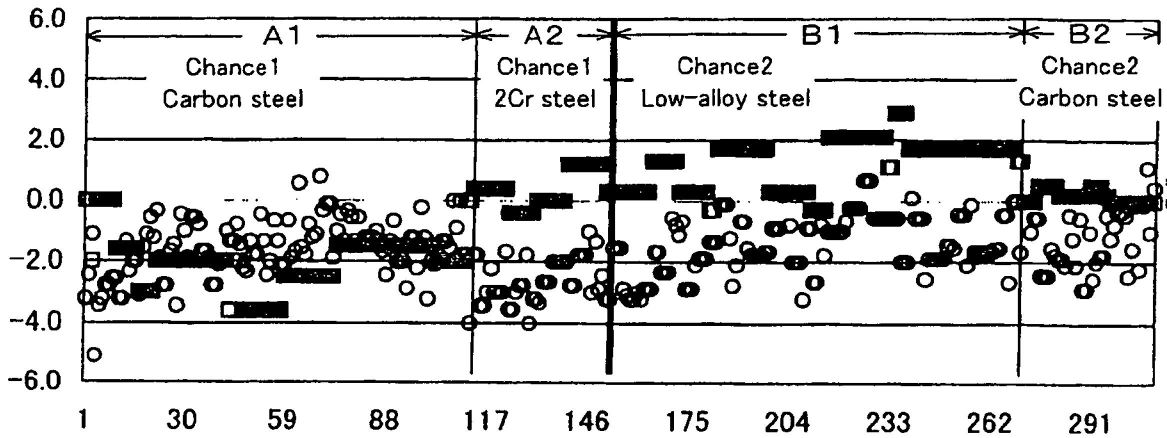

6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
A1
Chance1
Carbon steel
A2
Chance1
2Cr steel
B1
Chance2
Low-alloy steel
B2
Chance2
Carbon steel
1
30
59
88
117
146
175
204
233
262
291

Fig. 3

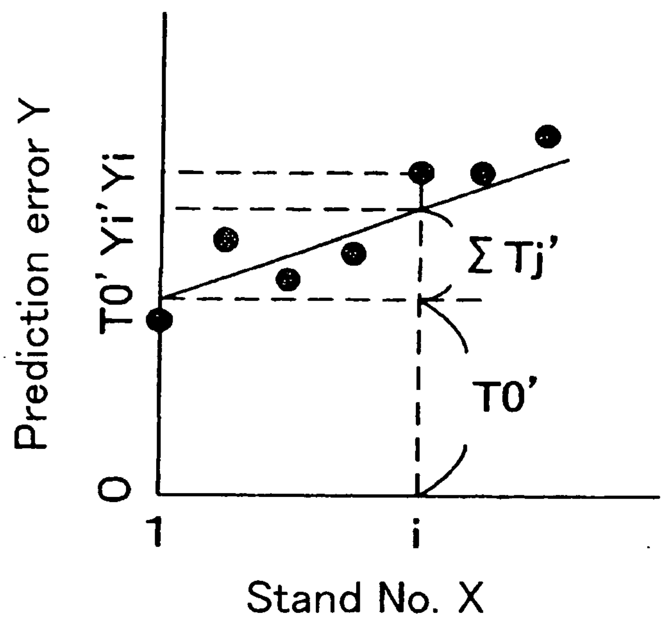


Fig. 4

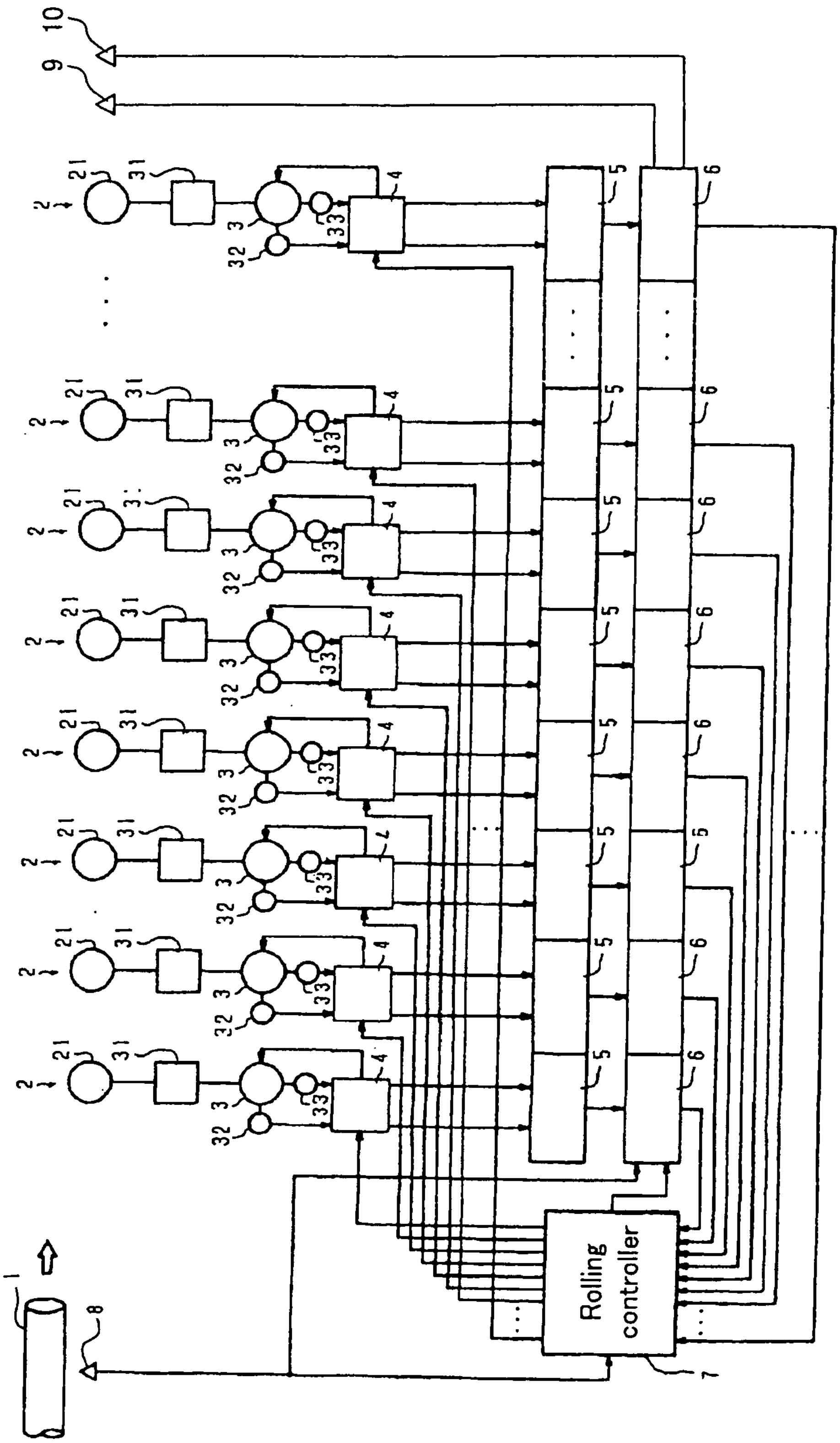


Fig. 5

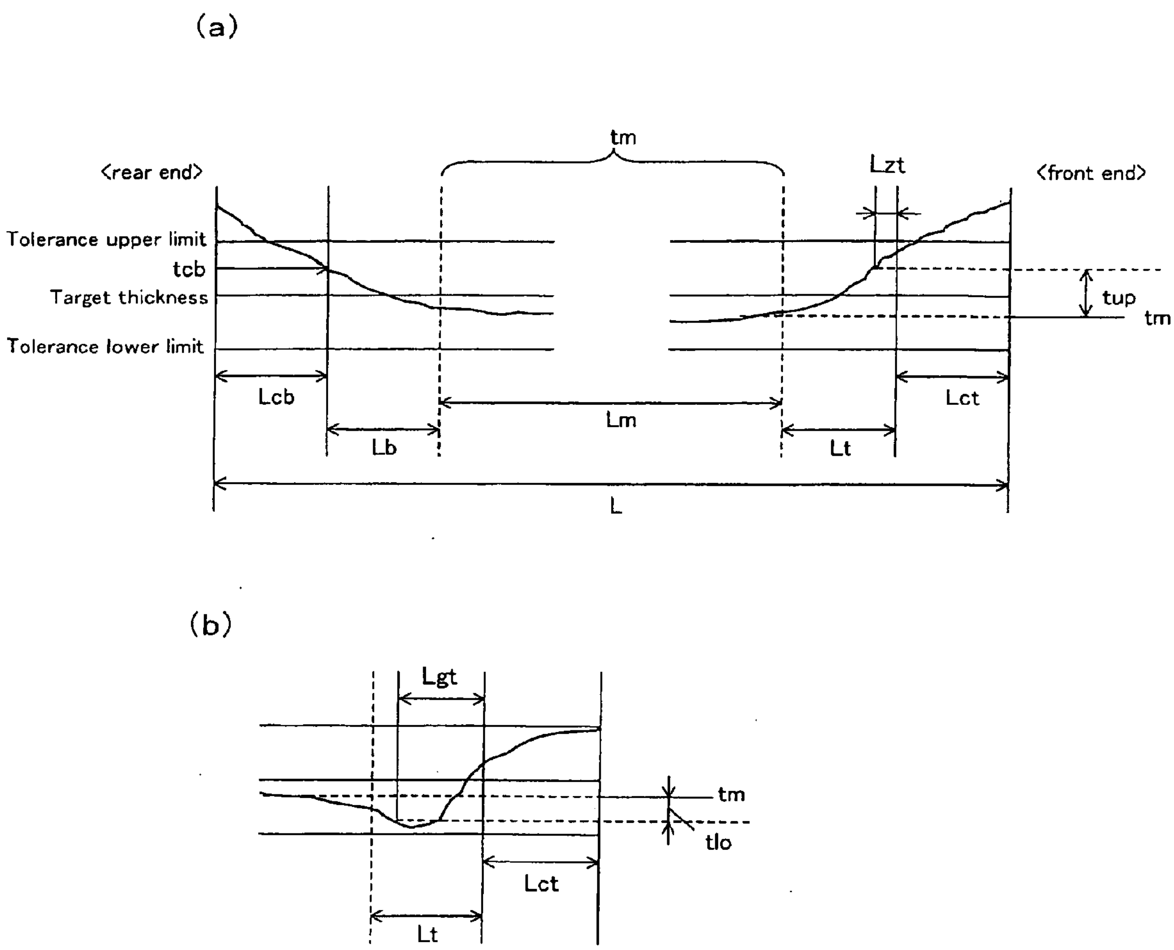

(a)
tm
<rear end>
Lzt
<front end>
Tolerance upper limit
tcb
Target thickness
tup
tm
Tolerance lower limit
Lcb
Lct
Lm
Lb
Lt
L
(b)
Lgt
tm
tlo
Lct
Lt

Fig. 6

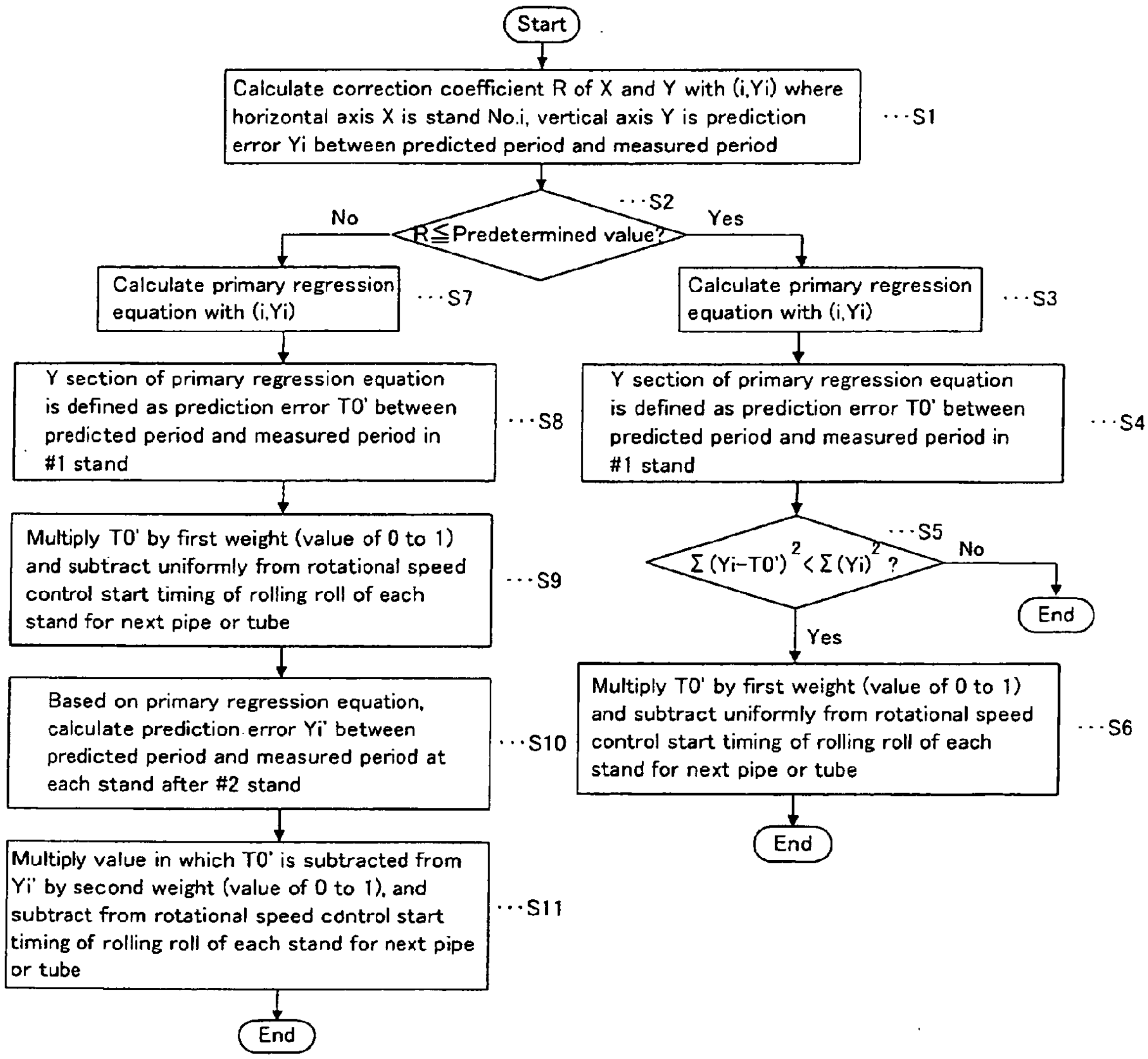

Start
Calculate correction coefficient R of X and Y with (i,Yi) where horizontal axis X is stand No.i, vertical axis Y is prediction error Yi between predicted period and measured period
···S1
···S2
R≦Predetermined value?
No
Yes
Calculate primary regression equation with (i,Yi)
···S7
Calculate primary regression equation with (i,Yi)
···S3
Y section of primary regression equation is defined as prediction error T0' between predicted period and measured period in #1 stand
···S8
Y section of primary regression equation is defined as prediction error T0' between predicted period and measured period in #1 stand
···S4
Multiply T0' by first weight (value of 0 to 1) and subtract uniformly from rotational speed control start timing of rolling roll of each stand for next pipe or tube
···S9
···S5
Σ(Yi−T0')² < Σ(Yi)² ?
No
End
Yes
Based on primary regression equation, calculate prediction error Yi' between predicted period and measured period at each stand after #2 stand
···S10
Multiply T0' by first weight (value of 0 to 1) and subtract uniformly from rotational speed control start timing of rolling roll of each stand for next pipe or tube
···S6
End
Multiply value in which T0' is subtracted from Yi' by second weight (value of 0 to 1), and subtract from rotational speed control start timing of rolling roll of each stand for next pipe or tube
···S11
End

Fig. 7

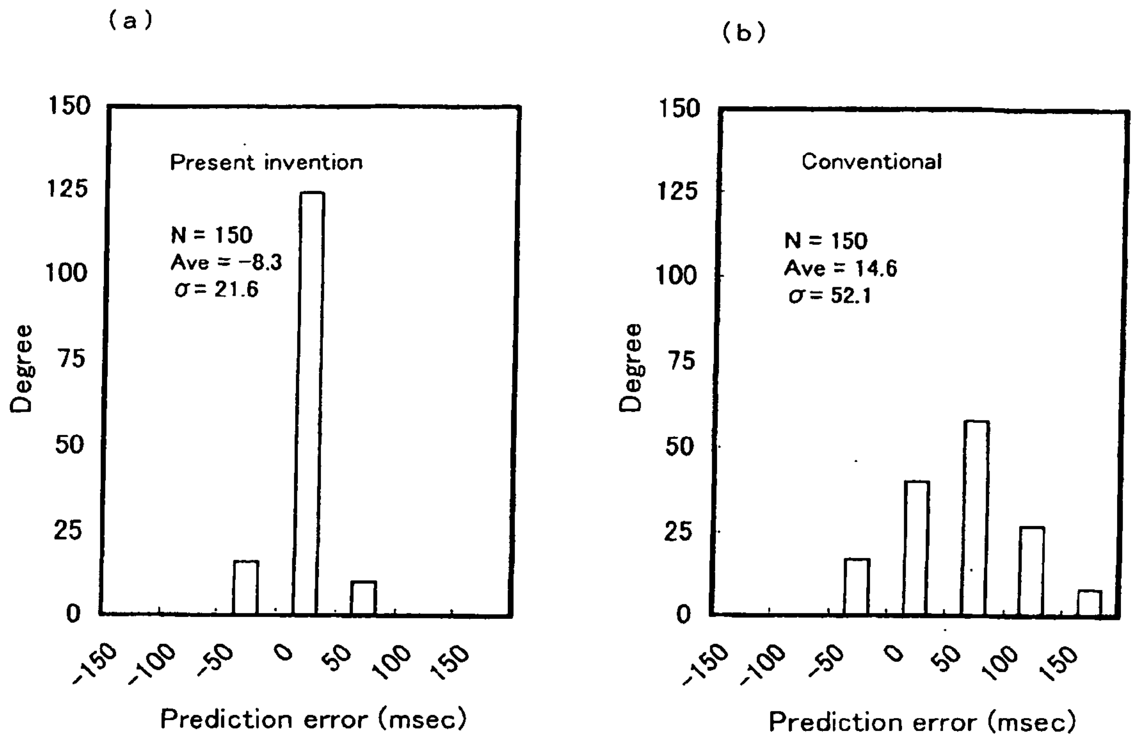
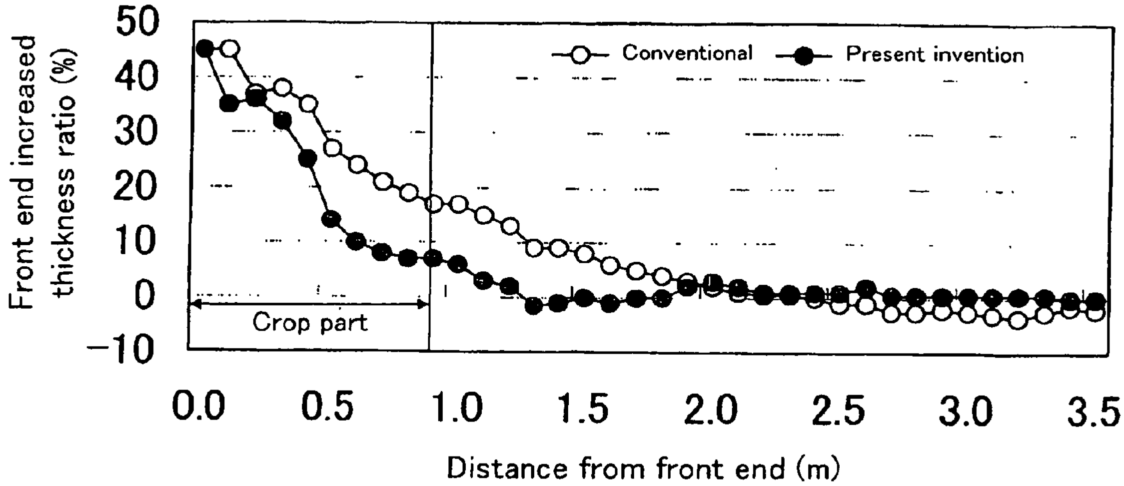

(a)
Present invention
N = 150
Ave = −8.3
σ = 21.6
Degree
Prediction error (msec)
(b)
Conventional
N = 150
Ave = 14.6
σ = 52.1
Degree
Prediction error (msec)

Fig. 8


Front end increased thickness ratio (%)
50
40
30
20
10
0
−10
Conventional
Present invention
Crop part
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Distance from front end (m)

Europäisches Patentamt
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Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 08 02 1885

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	JP 07 246414 A (NIPPON KOKAN KK) 26 September 1995 (1995-09-26) * abstract * -----	1,2	INV. B21B37/78 B21B17/14
A	JP 58 196111 A (KAWASAKI STEEL CO) 15 November 1983 (1983-11-15) * abstract * -----	1,2	
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TECHNICAL FIELDS SEARCHED (IPC)

B21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	13 February 2009	Forciniti, Marco

2

CATEGORY OF CITED DOCUMENTS

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The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

13-02-2009

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		JP 63057122 B	10-11-1988
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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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