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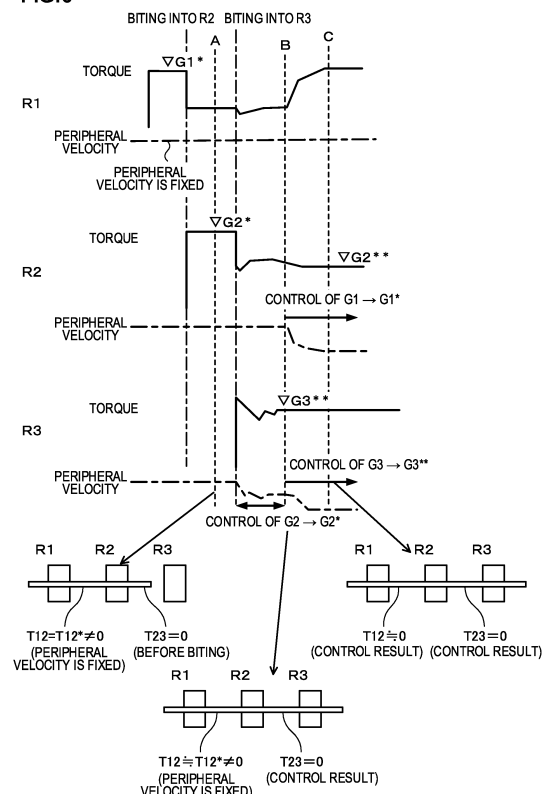
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(54) **SHAPED STEEL ROLLING METHOD, SHAPED STEEL MANUFACTURING LINE, AND SHAPED STEEL MANUFACTURING METHOD**

(57) Regarding each rolling mill, a rolling torque G_i before biting into a downstream stand is stored, the peripheral velocity of a most downstream stand R_n is controlled to be $G_{n-1} = G_{n-1}^*$ after biting into R_n , and a rolling torque G_n^{**} of R_n after tension is stabilized is stored. After that, the peripheral velocity of a rolling mill R_i is controlled to be $G_i = G_i^*$ toward an upstream side, and the peripheral velocity of a rolling mill R_k at a downstream side of the rolling mill R_i is controlled to keep $G_k = G_k^{**}$ ($k = i+1$ to n) so that a rolling torque of a most upstream rolling mill R_1 becomes equal to a stored G_1^* . Stabilization of material passage and improvement in accuracy of a product dimension are enabled by controlling tension between stands with high accuracy by using a simple control system without using table values or the like by each rolling condition even under a condition where a distance between stands is short.

FIG. 6



Description

[Technical Field]

5 (Cross-Reference to Related Applications)

[0001] This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2018-001784, filed in Japan on January 10, 2018, the entire contents of which are incorporated herein by reference.

10 **[0002]** The present invention relates to a rolling method of shaped steel which produces the shaped steel such as, for example, H-shaped steel, T-shaped steel, and I-shaped steel, a production line of the shaped steel, and a production method of the shaped steel.

[Background Art]

15 **[0003]** In a rolling process using a continuous rolling mill, material tension between respective rolling mills is an important element to determine dimensions such as thickness and width of material. It is therefore required to suitably control the tension between rolling mills to keep a product dimension good. In consideration of such circumstances, various techniques each performing tension control between rolling mills (these are also called a rolling stand or a stand) have been invented.

20 **[0004]** For example, Patent Document 1 discloses a technique of carrying out tension control between respective stands of a continuous rolling mill. Concretely, the control is performed by relating a relationship among a rolling torque, a rolling load, forward tension, and backward tension of respective rolling stands by a linear equation, estimating the forward tension and the backward tension based on measurement values of the rolling torque and the rolling load, and setting the estimated values as target values in Patent Document 1.

25 **[0005]** For example, Patent Document 2 discloses a technique of performing speed control by storing current of a roll driving motor when a material to be rolled is bitten into a reference rolling mill to compare with current of the roll driving motor when the material to be rolled is bitten into a next rolling mill in a continuous rolling mill having two or more rolling mills.

30 **[0006]** For example, Patent Document 3 discloses a technique of performing control of tension between respective stands by detecting only a torque fluctuation due to forward tension between a plurality of stands of a tandem rolling mill. Concretely, Patent Document 3 discloses a constitution where a no-tension torque of each arbitrary stand is found based on a rolling torque under a state where a material to be rolled is not bitten into a downstream side stand and a rolling torque of an upstream side stand at that timing at an arbitrary stand.

[Prior Art Document]

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[Patent Document]

[0007]

40 [Patent Document 1] Japanese Laid-open Patent Publication No. 2008-183594

[Patent Document 2] Japanese Patent Publication No. S53-34586

[Patent Document 3] Japanese Patent Publication No. S61-3564

[Disclosure of the Invention]

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[Problems to Be Solved by the Invention]

50 **[0008]** In a continuous rolling mill formed of a plurality of rolling mills, it is essential to control tension between stands (rolling mills), but according to the technique described in Patent Document 1, it is necessary to previously find the linear equation because the tension between stands is estimated from the linear equation, and creation of the linear equation based on wide range of experiments and numerical analysis is required.

[0009] Besides, the technique described in Patent Document 2 assumes that the tension between the reference rolling mill and a subsequent rolling mill can be controlled into a no-tension state before the material to be rolled is bitten into the subsequent stand (next rolling mill), and there is a possibility that the technique is not applicable when a distance between the stands becomes short.

55 **[0010]** It is considered that the technique described in Patent Document 3 assumes that a total sum of the rolling torques is constant regardless of tension, and when there is an error in this assumption, the error affects on the tension control between stands resulting in that the tension control with high accuracy is impossible. Further, the technique of

Patent Document 3 is invented basically on an assumption of rolling of wire materials or steel sheets, and some error may occur when it is applied to shaped steel which is rolled by using a universal rolling mill. Hereinafter, reasons thereof will be shortly explained in [0011] to [0016].

[0011] In Patent Document 3, the tension control between stands of the tandem rolling mill is performed by using Expressions (1), (2) described below.

[Mathematical Expression 1]

$$G_{i0} = \sum_{j=1}^i G_j - \sum_{j=1}^{i-1} G_{j0} \quad \dots (1)$$

where G_j : rolling torque of j stand

G_{j0} : rolling torque of j stand at no-tension time

$$G_{i, i+1} = \sum_{j=1}^i G_{j0} - \sum_{j=1}^{i-1} G_j \quad \dots (2)$$

[0012] It is considered that the above expression assumes that the total sum of the rolling torques at all stands is constant regardless of the tension. A case when the number of all stands is three (a first stand to a third stand) is considered as an example. Relationships expressed in Expressions (A1), (A2) described below are derived based on Expressions (1), (2) regarding a rolling torque G at each stand.

[Mathematical Expression 2]

$$G_{20} = G_{2*} + G_{1*} - G_{10} \Rightarrow G_{1*} + G_{2*} = G_{10} + G_{20} \quad \dots (A1)$$

$$G_{30} = (G_{1**} + G_{2**} + G_{3**}) - (G_{10} + G_{20}) \Rightarrow G_{1**} + G_{2**} + G_{3**} = G_{10} + G_{20} + G_{30} \dots (A2)$$

$$= (G_{1**} + G_{2**} + G_{3**}) - (G_{1*} + G_{2*})$$

*: timing after biting into second stand, **: timing after biting into third stand

[0013] Though these Expressions (A1), (A2) express relationships on the assumption that a total rolling torque of the total stand is constant regardless of a tension state, the total rolling torque changes in rolling of shaped steel such as, for example, H-shaped steel because a shape of a material to be rolled in a cross-section changes due to tension between stands. Concretely, there are reductions by a horizontal roll side surface and a vertical roll peripheral surface in universal rolling of shaped steel, and since different frictional forces act between the horizontal roll side surface and the vertical roll peripheral surface depending on positions, and the total rolling torque fluctuates in some cases when a dimension of the material to be rolled changes due to the tension between stands. Accordingly, it is reasonable to express the relationship between the tension and the rolling torque G by Expressions (B1) to (B3) described below each containing influence coefficients. In the following, tension between respective stands is set as tension T , tension between the first and second stands is denoted by T_{12} , tension between the second and third stands is denoted by T_{23} , and A_{12} , A_{23} , B_{12} , B_{23} each represent the influence coefficient between the respective stands.

[Mathematical Expression 3]

$$G_1 = G_{10} - A_{12} \cdot T_{12} \quad \dots (B1)$$

$$G_2 = G_{20} + B_{12} \cdot T_{12} - A_{23} \cdot T_{23} \quad \dots (B2)$$

$$G_3 = G_{30} + B_{23} \cdot T_{23} \quad \dots (B3)$$

[0014] In Expressions (B1) to (B3), the relationships expressed in Expressions (A1), (A2) are satisfied when $A_{12} = B_{12}$, $A_{23} = B_{23}$, but the relationships of $A_{12} = B_{12}$, $A_{23} = B_{23}$ are not satisfied in some cases when the total rolling

torque is not constant in the rolling of the shaped steel as stated above.

[0015] When Expression (A1) and Expressions (B1), (B2) are compared, Expression (B4) described below is derived by modifying Expressions (B1), (B2) at a timing before the material to be rolled is bitten into the third stand (that is, $T_{23} = 0$). [Mathematical Expression 4]

$$\begin{aligned} G_{20} &= G_2^* - B_{12} \cdot T_{12} \\ &= G_2^* - B_{12} / A_{12} (G_{10} - G_1^*) \\ &= G_2^* + G_1^* - G_{10} + (B_{12} / A_{12} - 1) \cdot (G_1^* - G_{10}) \quad \dots (B4) \end{aligned}$$

[0016] Expression (A1) and Expression (B4) which are the expressions to derive a second stand rolling torque G_{20} when the second stand is in no-tension are described together, further Expression (B4) is modified into Expression (B4)' to be compared.

[Mathematical Expression 5]

$$\begin{aligned} G_{20} &= G_2^* + G_1^* - G_{10} \quad (A1) \\ G_{20} &= G_2^* + G_1^* - G_{10} + (B_{12} / A_{12} - 1) \cdot (G_1^* - G_{10}) \quad \dots (B4) \\ &= G_2^* + G_1^* - G_{10} - (A_{12} - B_{12}) T_{12} \quad \dots (B4)' \end{aligned}$$

[0017] When the tension control in the rolling of the shaped steel is performed by using Expressions (1), (2) described in Patent Document 3 based on the comparison between Expression (A1) and Expression (B4) or between Expression (A1) and Expression (B4)', it can be seen that an error of $(B_{12}/A_{12} - 1)(G_1^* - G_{10}) = -(A_{12} - B_{12})T_{12}$ is contained.

[0018] The error becomes large as the tension between stands T_{12} is larger. In the rolling using a general rolling mill train, the second stand rolling torque G_{20} in no-tension is excessively figured out when $A_{12} > B_{12}$, and the second stand rolling torque G_{20} in no-tension is figured out too small when $A_{12} < B_{12}$ because the tension is set to be applied (that is, $T_{12} > 0$) to prevent poor material passage at a biting time.

[0019] Here, the numerical analysis showing that the total rolling torque is not constant when the shaped steel is rolled is explained with reference to FIGs. 9, 10. FIG. 9 is a schematic explanatory diagram of a universal intermediate rolling of the H-shaped steel, where (a) was a front view, and (b) is a plan view of two stands. In FIG. 9, the H-shaped steel with an inner size $B_i = 274$ mm, and a flange width $B_f = 150$ mm is rolled by using a tandem universal rolling mill with two stands. Rolling conditions were set as web thickness t of 11.4 mm $\rightarrow 10.0$ mm $\rightarrow 9.0$ mm, and a flange thickness t_f of 17.2 mm $\rightarrow 14.8$ mm $\rightarrow 13$ mm.

[0020] FIG. 10 is a graphic chart representing torque change amounts (ton·m) of respective stands through numerical analysis when tension (tonf) between a first stand R1 and a second stand R2 changes under the rolling conditions as stated above. When the influence coefficients A_{12} and B_{12} are the same, it is considered that positive and negative of the torque change amounts of the respective stands are reversed, and inclinations are the same. However, as represented in FIG. 10, the inclinations are different in the torque change amount of the first stand R1 and the torque change amount of the second stand R2, and it can be seen that $A_{12} > B_{12}$. That is, the second stand rolling torque G_{20} in no-tension is figured out to be too small when the tension control based on Patent Document 3 is performed under the rolling conditions of the shaped steel as stated above.

[0021] It is estimated that a shape of the material to be rolled changes due to the tension between stands, there are the reductions by the horizontal roll side surface and the vertical roll peripheral surface in the rolling of the shaped steel, and the total rolling torque fluctuates because different frictional forces act between the horizontal roll side surface and the vertical roll peripheral surface and the material to be rolled depending on positions as it can be seen from the numerical analysis result as stated above.

[0022] In the continuous rolling equipment where energy-saving and cost-saving are demanded, distances between stands of a plurality of stands are shortened in some cases to downsize the equipment. When the distance between stands is shortened in the tandem rolling, there is a possibility that a state where the material to be rolled is bitten into a downstream stand before upstream rolling stands are controlled into a no-tension state is generated, resulting in that the conventional art as described above cannot be applied as the tension control technique. For example, there is a possibility that the tension control does not make it in time before the material to be rolled is bitten into the downstream stand when the distance between stands is 1.5 m or less under conditions where recovery from lowering of the peripheral velocity just after the biting into each rolling stand (what is called an impact drop) is approximately 0.5 seconds and a biting speed of each rolling stand is 3 m/s.

[0023] In consideration of the above circumstances, an object of the present invention is to provide a rolling method of shaped steel capable of controlling tension between stands with high accuracy by using a simple control system without using table values or the like by each rolling condition even under a condition that a distance between stands is

short when rolling of the shaped steel is carried out by using a continuous rolling mill formed of three pieces or more of rolling mills in a tandem state, and improving stability of material passage and accuracy of product dimension, a production line of the shaped steel, and a production method of the shaped steel.

5 [Means for Solving the Problems]

[0024] To achieve the above-stated object, according to the present invention, there is provided a rolling method of shaped steel which carries out reduction between a horizontal roll side surface and a vertical roll peripheral surface by using one piece or more of rolling mill when tandem rolling is carried out in a rolling mill train formed of n-pieces of rolling mills of at least three pieces or more, the rolling method including: a first control step of fixing the peripheral velocity of a rolling mill R_i of the rolling mill train after a material to be rolled is bitten into the rolling mill R_i and before the material to be rolled is bitten into a rolling mill R_{i+1} positioning at a downstream side of the rolling mill R_i regarding each rolling mill R_i , storing a rolling torque G_i of the rolling mill R_i at that time as G_i^* , and controlling the peripheral velocity of a rolling mill R_n at a most downstream side of the rolling mill train so that a rolling torque G_{n-1} of a rolling mill R_{n-1} positioning at an upstream side of the rolling mill R_n becomes equal to G_{n-1}^* which is stored as a rolling torque of the rolling mill R_{n-1} before the material to be rolled is bitten into the rolling mill R_n , after the material to be rolled is bitten into the rolling mill R_n ; and a second control step of storing a rolling torque G_n^{**} of the rolling mill R_n after the first control step, subsequently controlling the peripheral velocity of the rolling mill R_{n-1} so that a rolling torque G_{n-2} of a rolling mill R_{n-2} positioning at an upstream side of the rolling mill R_{n-1} becomes equal to G_{n-2}^* which is stored as a rolling torque of the rolling mill R_{n-2} before the material to be rolled is bitten into the rolling mill R_{n-1} , and controlling the peripheral velocity of the rolling mill R_n so that the rolling torque G_n of the rolling mill R_n becomes equal to the stored rolling torque G_n^{**} , wherein the second control step is applied to all of the respective rolling mills R_i , and the peripheral velocity of each rolling mill R_i of the rolling mill train is controlled so that a rolling torque G_1 of a most upstream rolling mill R_1 becomes equal to G_1^* which is stored as the rolling torque of the rolling mill R_1 before the material to be rolled is bitten into a rolling mill R_2 positioning at a downstream side of the rolling mill R_1 . Note that i is an arbitrary integer number from 1 to n , and n is an integer number of 3 or more.

[0025] The control may be performed by using a torque arm coefficient (G/P) which is a value where a rolling torque of each rolling mill is divided by a rolling load of the rolling mill in place of a value of the rolling torque of each rolling mill of the rolling mill train.

[0026] The rolling may be carried out by fixing a ratio of the peripheral velocity of respective rolling mills R_i after all of the peripheral velocity of the respective rolling mills R_i of the rolling mill train are controlled.

[0027] A rolling speed of the rolling mill R_n at the most downstream side of the rolling mill train may be increased to a desired speed under a state where the ratio of the peripheral velocity of the respective rolling mills R_i is fixed.

[0028] According to another aspect of the present invention, there is provided a production line of shaped steel having a constitution where a rolling mill train formed of n-pieces of rolling mills of at least three-pieces or more and at least one piece or more of rolling mills or a rolling mill train are tandem-arranged in this order, and carrying out reduction between a horizontal roll side surface and a vertical roll peripheral surface by using one piece or more of rolling mill, in the production line, no-tension control of a material to be rolled is performed in the upstream rolling mill train, the upstream rolling mill train and the downstream rolling mills or rolling mill train are arranged under a state having sufficient distance for the material to be rolled to be bitten into the downstream rolling mills or rolling mill train after the no-tension control is completed, and the rolling method of the shaped steel described above is independently performed at the upstream rolling mill train and the downstream rolling mills or rolling mill train.

[0029] According to the present invention, there is provided a production method of shaped steel produced by carrying out reduction between a horizontal roll side surface and a vertical roll peripheral surface, the production method including: a first control step of fixing the peripheral velocity of a rolling mill R_i after a material to be rolled is bitten into the rolling mill R_i and before the material to be rolled is bitten into a rolling mill R_{i+1} positioning at a downstream side of the rolling mill R_i regarding each rolling mill R_i in a rolling mill train formed of n-pieces of rolling mills of at least three pieces or more and storing a rolling torque G_i of the rolling mill R_i at that time as G_i^* , and controlling the peripheral velocity of a most downstream rolling mill R_n of the rolling mill train after the material to be rolled is bitten into the rolling mill R_n so that a rolling torque G_{n-1} of a rolling mill R_{n-1} positioning at an upstream side of the rolling mill R_n becomes equal to G_{n-1}^* which is stored as a rolling torque of the rolling mill R_{n-1} before the material to be rolled is bitten into the rolling mill R_n ; and a second control step of storing a rolling torque G_n^{**} of the rolling mill R_n after the first control step, subsequently controlling the peripheral velocity of the rolling mill R_{n-1} so that a rolling torque G_{n-2} of a rolling mill R_{n-2} positioning at an upstream side of the rolling mill R_{n-1} becomes equal to G_{n-2}^* stored as a rolling torque of the rolling mill R_{n-2} before the material to be rolled is bitten into the rolling mill R_{n-1} , and controlling the peripheral velocity of the rolling mill R_n so that a rolling torque G_n of the rolling mill R_n becomes equal to the stored rolling torque G_n^{**} , wherein the shaped steel is produced by applying the second control step to all of the respective rolling mills R_i , and controlling the peripheral velocity of each rolling mill R_i of the rolling mill train so that a rolling torque G_1 of a most upstream rolling

mill R1 becomes equal to $G1^*$ which is stored as the rolling torque of the rolling mill R1 before the material to be rolled is bitten into a rolling mill R2 positioning at a downstream side of the rolling mill R1.

[Effect of the Invention]

[0030] According to the present invention, it becomes possible to enable stabilization of material passage and improvement in production dimension accuracy by controlling tension between stands with high accuracy by using a simple control system without using table values or the like by each rolling condition even under a condition where a distance between stands is short when shaped steel is rolled by using a continuous rolling mill formed of three pieces or more of rolling mills in a tandem state.

[Brief Description of the Drawings]

[0031]

[FIG. 1] FIG. 1 is a schematic explanatory diagram regarding a production line of H-shaped steel.

[FIG. 2] FIG. 2 is a schematic explanatory diagram of a universal rolling mill and an edger rolling mill.

[FIG. 3] FIG. 3 is a schematic plan view of a rolling mill train formed of three pieces of rolling mills of R1-R2-R3.

[FIG. 4] FIG. 4 is a schematic explanatory diagram regarding tension control when a distance between stands is long.

[FIG. 5] FIG. 5 is a schematic explanatory diagram in a case of applying conventional tension control when a distance between stands is extremely short.

[FIG. 6] FIG. 6 is a schematic explanatory diagram in a case of applying tension control according to the present invention when a distance between stands is extremely short.

[FIG. 7] FIG. 7 is a schematic explanatory diagram illustrating a combination of a rolling mill train formed of adjacent rolling mills R1 to R3 and a rolling mill at a downstream position which is sufficiently kept away from the rolling mill train.

[FIG. 8] FIG. 8 is a schematic explanatory diagram illustrating a combination of a rolling mill train formed of adjacent rolling mills R1 to R3 and a second rolling mill train formed of adjacent rolling mills R4 to R6 at a downstream position which is sufficiently kept away from the rolling mill train.

[FIG. 9] FIG. 9 is a schematic explanatory diagram of universal intermediate rolling of H-shaped steel.

[FIG. 10] FIG. 10 is a graphic chart representing a torque change amount of each stand through numerical analysis when tension between stands changes.

[Embodiments for Carrying out the Invention]

[0032] Hereinafter, embodiments of the present invention are explained with reference to the drawings. Note that in this description and the drawings, components having substantially the same functional configurations are denoted by the same numerals to omit duplicated explanation. In this description, a universal rolling mill and an edger rolling mill used when an H-shaped steel product is produced are illustrated as an example of the rolling mill forming a continuous rolling mill, but an application range of the present invention is not limited thereto. Besides, the "universal rolling mill" in this description indicates a rolling mill which carries out rolling accompanied by large extension at a shaped steel rolling time by using a horizontal roll and a vertical roll, and the "edger rolling" indicates a rolling mill which carries out extremely soft rolling by being used together with the universal rolling mill, and these rolling mills are sometimes called a "rolling stand" or just a "stand" in this description.

(Outline of production line and conventional point of issue)

[0033] FIG. 1 is an explanatory diagram regarding a production line L where a rolling method of shaped steel according to this embodiment is carried out. As illustrated in FIG. 1, a heating furnace 2, a rough rolling mill 4, two pieces of intermediate universal rolling mills 5, 6, and a finishing universal rolling mill 8 are sequentially arranged from an upstream side in the production line L. Further, an edger rolling mill 9 is provided between the two pieces of intermediate universal rolling mills 5, 6. Note that, in the following, a steel material in the production line L is collectively denoted as a "material to be rolled S" for explanation and its shape is sometimes illustrated using broken lines, oblique lines and the like in each drawing.

[0034] As illustrated in FIG. 1, in the production line L, the material to be rolled S such as, for example, a slab 11 extracted from the heating furnace 2 is subjected to rough rolling in the rough rolling mill 4. Then, the material to be rolled S is subjected to intermediate universal rolling in the intermediate universal rolling mills 5, 6. Under a state where reverse rolling with this intermediate universal rolling is possible, reduction is carried out for end portions or the like of the material to be rolled (flange corresponding portions 12) by the edger rolling mill 9. In a normal case, approximately

four to six pieces of calibers in total are engraved on rolls of the rough rolling mill 4 (a plurality of rough rolling mills are sometimes provided), an H-shaped raw blank 13 in a dog-bone shape is shaped by reverse rolling in a plurality of passes through those calibers, and the H-shaped raw blank 13 is subjected to application of reduction in a plurality of passes using a rolling mill train formed of the first intermediate universal rolling mill 5-the edger rolling mill 9-the second intermediate universal rolling mill 6, whereby an intermediate material 14 is shaped. The intermediate material 14 is subjected to finish rolling into a product shape in the finishing universal rolling mill 8, whereby an H-shaped steel product 16 is produced.

[0035] In the production line L illustrated in FIG. 1, when the H-shaped raw blank 13 is subjected to application of reduction in a plurality of passes using the rolling mill train formed of the first intermediate universal rolling mill 5-the edger rolling mill 9-the second intermediate universal rolling mill 6 to shape the intermediate material 14, a flange tip portion becomes an unreduced portion (refer to a broken line portion in the drawing) as it is illustrated in FIG. 2(a) in each universal rolling mill, and therefore, rolling to shape and reduce the unreduced portion is carried out by the edger rolling mill as illustrated in FIG. 2(b).

[0036] An example of a continuous rolling mill train carrying out rolling of a material to be rolled in a tandem state includes a constitution of the first intermediate universal rolling mill 5-the edger rolling mill 9-the second intermediate universal rolling mill 6 as stated above. In the rolling mill train having the constitution where a plurality of rolling stands are continuously arranged, when shaped steel is rolled as the material to be rolled S, tension control between rolling stands using a looper (tension control device) which is used when a steel strip is rolled or the like is difficult because stiffness of the material to be rolled is large. Besides, it has been general when the shaped steel is rolled to set the peripheral velocity so that tension between stands tends to be drawn at a biting time to secure stable material passage by preventing poor material passage such as turning up of the material to be rolled between the rolling stands. That is, it is required to suitably control the tension between stands after the material to be rolled is bitten to keep a product dimension good in the rolling of the shaped steel.

[0037] Further, a distance between stands of the plurality of stands is sometimes set to be short aiming at energy-saving, cost-saving, and downsizing of equipment in the continuous rolling mill train. However, if the distance between stands is shortened when the tandem rolling of the shaped steel is carried out, there is a possibility that the material to be rolled is bitten into a downstream stand before the tension between rolling stands at an upstream side is controlled into a no-tension state, resulting in that the conventional control to make the tension between stands tend to be drawn cannot be stably performed.

[0038] In consideration of such circumstances, there has been demanded a technique capable of controlling the tension between stands with high accuracy even in a constitution where the distance between stands is short, and enabling stable material passage, and improvement in product dimension accuracy in the continuous rolling mill train carrying out the tandem rolling of the shaped steel.

(Application example of tension control method)

[0039] In the production line L illustrated in FIG. 1, the constitution of the first intermediate universal rolling mill 5-the edger rolling mill 9-the second intermediate universal rolling mill 6 (refer to FIG. 2) was exemplified as the continuous rolling mill train, but the tension control method according to the present invention is applicable to any rolling mill as long as it has a constitution where a plurality of rolling mills (stands) are continuously arranged in the equipment carrying out the tandem rolling of the shaped steel. Hereinafter, cases, when the conventional tension control method and the tension control method according to the present invention are each applied to a rolling mill train where three pieces of stands of R1 to R3 are continuously arranged, are exemplified to be explained. This constitution is an example, and the tension control method according to the present invention is applicable to a rolling mill train of shaped steel where a plurality of rolling mills of at least three pieces or more are arranged in a tandem rolling state.

[0040] FIG. 3 is a schematic plan view of a rolling mill train 30 formed of three pieces of rolling mills R1-R2-R3, and for example, reverse rolling is carried out in this rolling mill train 30 as illustrated by a broken arrow in the drawing. Each distance between stands of the three pieces of rolling mills (rolling stands) of R1, R2, R3 is shorter than a longitudinal direction length of the material to be rolled S, and the rolling of the material to be rolled S is carried out in, what is called a tandem rolling state. When the tension control method according to the present invention is applied, superiority of the present invention to the conventional art is exhibited when the distance between these stands is a sufficiently short distance compared to a rolling speed of the material to be rolled S, that is, tension between respective stands cannot be made into a no-tension state before the material to be rolled S is bitten into a downstream stand. Note that the present invention can be applied also to a case when the distance between stands is long where, for example, Patent Document 2 (Japanese Patent Publication No. S53-34586) is applicable.

(Conventional tension control and problem thereof)

[0041] First, the tension control when the distance between stands is sufficiently long in the rolling mill train 30 formed of three pieces of rolling mills R1-R2-R3 is explained. Here, the constitution where "the distance between stands is sufficiently long" indicates that there is a sufficient distance to carry out and stabilize the no-tension control of the material to be rolled S between stands.

[0042] FIG. 4 is a schematic explanatory diagram regarding the tension control when the distance between stands is long, and is a schematic diagram illustrating a change of a rolling torque (solid line) and a change of the peripheral velocity (dot and dash line) of each of the rolling mills R1 to R3. In the following, respective rolling torques of R1 to R3 are defined as G1 to G3 as values which change with time, and each rolling torque value at a specific moment is denoted by an individual value such as "G1*". In FIG. 4, schematic diagrams each illustrating a position of the material to be rolled S in each of statuses A, B in the schematic diagram (FIG. 4) are also illustrated. The tension control when the distance between stands is long is explained with reference to FIG. 4.

1) At a preliminary stage of the status A illustrated in FIG. 4, a rolling torque G1* of R1 is stored just before the material to be rolled S is bitten into R2. After the material to be rolled S is bitten into R2 in the status A, the peripheral velocity of R1 is controlled so that $G1 = G1^*$ to put the tension between R1-R2 into a no-tension state (stable state), and a rolling torque G2* of R2 at that state is stored.

2) In the status B illustrated in FIG. 4, after the material to be rolled S is bitten into R3, the peripheral velocity of R2 is controlled so that the rolling torque G2 of R2 becomes $G2 = G2^*$. Both tensions between R1-R2 and between R2-R3 are thereby controlled into the no-tension states.

[0043] Next, in the rolling mill train 30 formed of the three pieces of rolling mills R1-R2-R3, a case when the conventional tension control is applied to the constitution where the distance between stands is extremely short is explained. Here, "the constitution where the distance between stands is extremely short" indicates a constitution where the material to be rolled S is bitten into a downstream stand before the tension between upstream rolling stands is controlled into the no-tension state.

[0044] FIG. 5 is a schematic explanatory diagram when the conventional tension control is applied to the case when the distance between stands is extremely short, and is a schematic diagram illustrating a change of a rolling torque (solid line) and a change of the peripheral velocity (dot and dash line) of each of the rolling mills R1 to R3. Also in FIG. 5, schematic diagrams each showing a position of the material to be rolled S in each of statuses A, B in the schematic diagram (FIG. 5) are also illustrated. The case of applying the conventional tension control to the constitution where the distance between stands is extremely short is explained with reference to FIG. 5.

1) At a preliminary stage of the status A illustrated in FIG. 5, the rolling torque G1* of R1 is stored just before the material to be rolled S is bitten into R2. After the material to be rolled S is bitten into R2 in the status A, the peripheral velocity of R1 is controlled so that $G1 = G1^*$, but the material to be rolled S is bitten into R3 before the control is completed. Even if a rolling torque G2* of R2 is stored under this state, the stored G2* is a value of a state where backward tension is applied.

2) In the status B illustrated in FIG. 5, even if the control to be $G2 = G2^*$ and $G1 = G1^*$ is performed, the tension between R2-R3 does not become the no-tension state because the stored G2* is the value of the state where the backward tension is applied as stated above, and the suitable tension control is not enabled.

[0045] As it has been explained with reference to FIG. 4 and Fig. 5, there is a problem that though the suitable tension control is possible by applying the conventional tension control technique when the distance between stands is sufficiently long (refer to FIG. 4), the suitable tension control cannot be enabled through the conventional tension control technique in the constitution where the distance between stands is extremely short (refer to FIG. 5) in the rolling mill train 30 formed of the three pieces of rolling mills R1-R2-R3.

[0046] In consideration of the above-stated problem, the present inventors invented a tension control method and a rolling method using the tension control method of fixing the peripheral velocity under a state where forward tension is zero (before the material to be rolled S is bitten into a downstream rolling mill), and sequentially setting the tension between stands to be zero by tracing back after the material to be rolled S is bitten into all of the rolling mills to be objects when tension control is performed in a rolling mill train formed of a plurality of rolling mills. Hereinafter, the rolling method according to the present invention is explained.

(Rolling method and tension control according to the present invention)

[0047] Here, a case is explained when a tension control technique according to the present invention is applied to the

constitution where the distance between stands is extremely short in the rolling mill train 30 formed of the three pieces of rolling mills R1-R2-R3. The tension control technique according to the present invention is applicable to a case when tandem rolling is carried out in a rolling mill train formed of an arbitrary n-pieces (n is an arbitrary integer number of three or more) of rolling mills, and here, it is explained by using the rolling mill train 30 formed of the three pieces of rolling mills R1-R2-R3 to simplify the explanation.

[0048] FIG. 6 is a schematic explanatory diagram when the tension control according to the present invention is applied to the case when the distance between stands is extremely short, and is a schematic diagram illustrating a change of a rolling torque (solid line) and a change of the peripheral velocity (dot and dash line) of each of the rolling mills R1 to R3. In FIG. 6, schematic diagrams each showing a position of the material to be rolled S in each of statuses A to C in the schematic diagram (FIG. 6) are also illustrated. The case applying the tension control according to the present invention to the constitution where the distance between stands is extremely short is explained with reference to FIG. 6.

1) At a preliminary stage of the status A illustrated in FIG. 6, the rolling torque $G1^*$ of R1 is stored just before the material to be rolled S is bitten into R2.

2) In the status A illustrated in FIG. 6, that is, just before the material to be rolled S is bitten into R3, the rolling torque $G2^*$ of R2 is stored, and the peripheral velocity of R1 is fixed in this stage.

3) In the status B illustrated in FIG. 6, that is, after the material to be rolled S is bitten into R3, the peripheral velocity of R3 is controlled so that the rolling torque $G2$ of R2 becomes equal to the stored $G2^*$ ($G2 = G2^*$). After the control is stabilized, tension between R2-R3 becomes no-tension. A rolling torque $G3^{**}$ of R3 under this state is stored.

4) The peripheral velocity of R2 is controlled so that $G1 = G1^*$ (that is, the tension between R1-R2 becomes no-tension) between the status B and the status C illustrated in FIG. 6. By controlling the peripheral velocity of R2 (the peripheral velocity changes), tension or compressive force acts between R2-R3, and at that time, the peripheral velocity of R3 is controlled so that $G3 = G3^{**}$ is kept.

5) In the status C illustrated in FIG. 6, the rolling torque $G2^{**}$ of R2 is stored at a timing when the tensions between R1-R2 and R2-R3 are stabilized.

6) Since the stored $G1^*$, $G2^{**}$, $G3^{**}$ during the above-stated processes are the rolling torques when forward tension and backward tension are zero, it is possible to keep the no-tension state over a whole length of the rolling mill train by controlling the peripheral velocity of the respective rolling mills so that $G1 = G1^*$, $G2 = G2^{**}$, and $G3 = G3^{**}$.

[0049] As mentioned above, the tension control is performed with high accuracy between respective rolling stands (between R1-R2 and between R2-R3) and it becomes possible to carry out the rolling while keeping the no-tension state by applying the tension control method explained by 1) to 6) with reference to FIG. 6 to the tandem rolling at the rolling mill train 30. A material passing property of the material to be rolled between rolling stands thereby improves, and deterioration of dimensional accuracy, slip, turning up due to the compressive force, and so on are prevented.

[0050] In the present embodiment, table values or the like by each rolling condition are not used, the rolling torques which can be measured are stored, and the tension control over the whole length of the rolling mill train 30 formed of R1-R2-R3 can be performed with high accuracy by using a simple control system.

(Application to rolling mill train formed of arbitrary plurality of mills)

[0051] In the explanation with reference to FIG. 6, there is explained the case when the tension control according to the present invention is applied to the rolling mill train 30 formed of three pieces of rolling mills R1-R2-R3, but an application range of the present invention is not limited thereto. That is, the technique of the present invention is applicable to a rolling mill train formed of three pieces or more of arbitrary plurality of rolling mills. Hereinafter, there is explained the tension control method when the tandem rolling is carried out by using a rolling mill train formed of arbitrary n-pieces of rolling mills of three pieces or more. In the following, respective rolling mills forming the rolling mill train formed of the n-pieces rolling mills are set as R1, R2, ... Rn, an i-th rolling mill is set as Ri, and a rolling torque of Ri is defined as Gi for the sake of explanation. That is, "i" is an arbitrary integer number from one to n, and n is an integer number of three or more.

1) In each of the rolling mills Ri other than the most downstream rolling mill Rn, a rolling torque Gi^* of Ri after the material to be rolled is bitten into Ri and just before bitten into the downstream rolling mill $Ri+1$ is stored and the peripheral velocity of Ri is fixed in this stage.

2) After the material to be rolled is bitten into the most downstream rolling mill Rn, the peripheral velocity of the most downstream rolling mill Rn is controlled so that the rolling torque $Gn-1$ of the rolling mill Rn-1 just before the most downstream rolling mill becomes equal to the rolling torque $Gn-1^*$ which is stored before biting into Rn (first control step). A tension state of Rn-1 becomes an equal state to a tension state just before the material to be rolled is bitten into the most downstream rolling mill Rn (forward tension = 0) by the control.

3) The rolling torque G_n^{**} of the rolling mill R_n after the tension control by the first control step is stabilized is stored.

4) The peripheral velocity of the rolling mill R_{n-1} is controlled so that the rolling torque G_{n-2} of the rolling mill R_{n-2} positioning at an upstream side of the rolling mill R_{n-1} becomes equal to G_{n-2}^* which is stored as the rolling torque of the rolling mill R_{n-2} before the material to be rolled is bitten into the rolling mill R_{n-1} , and the peripheral velocity of the rolling mill R_n is controlled so that the rolling torque G_n of the rolling mill R_n keeps the rolling torque G_n^{**} which is stored by the 3) step (second control step). Here, the rolling torque G_{n-1}^{**} of the rolling mill R_{n-1} is stored after the tension control is stabilized.

5) Subsequently, the second control step is sequentially performed for each of the rolling mills toward an upstream side so as to trace back through a similar method. That is, the no-tension state is similarly enabled between respective rolling mills after control by controlling the peripheral velocity of each rolling mill so that the rolling torque G_i of the rolling mill just before the rolling mill becomes equal to the rolling torque G_i^* which is stored before biting into the rolling mill, and controlling the peripheral velocity of R_{i+1} to R_n so that the rolling torques G_{i+1} to G_n of the rolling mills R_{i+1} to R_n at the downstream side of the rolling mill keep the rolling torques G_{i+1}^{**} to G_n^{**} which are stored after tension is stabilized, regarding each of the rolling mills R_{n-1} , R_{n-2} , ... R_1 .

6) Finally, the peripheral velocity of each rolling mill R_i of the rolling mill train is controlled so that the rolling torque G_1 of the most upstream rolling mill R_1 becomes equal to G_1^* which is stored as the rolling torque of the rolling mill R_1 before the material to be rolled is bitten into the rolling mill R_2 positioning at a downstream side of the rolling mill R_1 .

[0052] The first control step in the above-stated tension control method is a step of controlling the peripheral velocity of the rolling mill R_n so that $G_{n-1} = G_{n-1}^*$, and it is an independent control step of R_n . Besides, the second control step is an interlocking control step where the peripheral velocity of the rolling mill R_i is controlled so that $G_i = G_i^*$, and the peripheral velocity is controlled so that $G_k = G_k^{**}$ ($k = i+1$ to n) is kept for the rolling mill R_k at a downstream side of the rolling mill R_i . The tension state among all rolling mills can be controlled by sequentially applying this second control step from the rolling mill R_{n-1} toward the upstream side.

[0053] It becomes possible to perform the tension control so that the tensions between respective rolling mills become the no-tension state over the whole of the rolling mill train by sequentially performing the tension control so as to trace back toward the upstream side after the material to be rolled is bitten into the most downstream rolling mill R_n to finally control up to the most upstream rolling mill R_1 .

[0054] One example of the embodiment of the present invention has been explained above, but the present invention is not limited to the illustrated embodiments. It should be understood that various changes and modifications are readily apparent to those skilled in the art within the scope of the spirit as set forth in claims, and those should also be covered by the technical scope of the present invention.

[0055] In the rolling method according to the present invention explained in the above embodiments, temperature change at the rolling time of the material to be rolled S is not particularly mentioned. However, when a dimension of the material to be rolled S is long in a longitudinal direction, there is a possibility that the temperature of the material to be rolled S changes with time and the rolling torque of each rolling mill fluctuates in accordance with the temperature change when tandem rolling is carried out with a rolling mill train formed of a plurality of rolling mills such as, for example, R_1 - R_2 - R_3 . There is a possibility that error in accordance with the fluctuation may occur if the tension control method is applied without taking the fluctuation of the rolling torque due to the temperature change into consideration.

[0056] In consideration of such circumstances, a torque arm coefficient (G/P) being a value where a rolling torque (G) is divided by load (P) may be used in place of a value of the rolling torque (G) when the tension control technique described in the above embodiment is applied. It is possible to exclude an effect of the rolling torque change in accordance with the temperature change of the material to be rolled S and perform the control of the tension between stands by performing the tension control method according to the present invention by using the torque arm coefficient (G/P) instead of the rolling torque.

[0057] When mill rigidity of the rolling mill train is sufficiently large with respect to the temperature change and a dimensional change of a whole length of the rolling mill train is small when the no-tension state (stable state) in the rolling mill train is enabled by the rolling method explained in the above embodiment, a ratio of the peripheral velocity of the respective rolling mills under the stable state may be fixed. For example, when the rolling speed is increased after the stable state, the rolling speed of the whole of the rolling mill train is necessary to be increased. At this time, the no-tension state (stable state) can be kept by increasing the speed under the state where the fixed ratio of the peripheral velocity is kept as it is. At this time, the most downstream rolling mill at the rolling downstream is set to be a desired speed, and the rolling speeds of other rolling mills may be defined such that the ratio of the peripheral velocity becomes as it is in accordance with the rolling speed of the most downstream rolling mill.

(Modification example of the present invention)

[0058] FIG. 7 is a schematic explanatory diagram illustrating a combination of the rolling mill train 30 formed of adjacent

rolling mills (stands) R1 to R3 and a rolling mill F1 which is at a downstream position sufficiently kept away from the rolling mill train 30. In a constitution illustrated in FIG. 7, the tension control method explained in the above embodiment is applied to the rolling mill train formed of R1 to R3 to stabilize the tensions from R1 to R3, and then, after the material to be rolled S is bitten into F1, the peripheral velocity of F1 may be controlled so that a value of the rolling torque G3 of R3 becomes $G3 = G3^{**}$ (the rolling torque of R3 after stabilization). It is thereby also possible to enable the no-tension state between R3-F1.

[0059] FIG. 8 is a schematic explanatory diagram illustrating a combination of the rolling mill train 30 formed of the adjacent rolling mills R1 to R3 and a second rolling mill train 50 formed of rolling mills F1 to F3 adjacent with each other which are at a downstream position sufficiently kept away from the rolling mill train 30. In a constitution illustrated in FIG. 8, the tension control method explained in the above embodiment is applied to the rolling mill train 30 formed of R1 to R3 to stabilize each tension from R1 to R3, and the peripheral velocity of R1 to R3 are fixed before the material to be rolled S is bitten into F1. Under the state where the peripheral velocity of R1 to R3 are fixed, the tension control method explained in the above embodiment is similarly applied to the second rolling mill train 50 to stabilize the tension states of F1 to F3. The tension control between the rolling mill train 30 and the second rolling mill train 50 may be controlled through an arbitrary control method, and for example, the peripheral velocity of F1 may be controlled so that $G3 = G3^{**}$ (the rolling torque of R3 after stabilization).

[EXAMPLES]

[0060] When tandem rolling with a total reduction ratio of 40% and a rolling speed on a rolling mill train exit side of 4.0 m/s was performed at a rolling mill train formed of four mills (R1 to R4 from an upstream side) with each distance between the rolling mills of 2.0 m, there were compared a case when tension between stands was controlled by using the present invention (Example) and a case when it was controlled by using the conventional arts (Comparative Examples 1, 2).

[0061] In Comparative Example 1, the technique disclosed in Patent Document 2 (Japanese Patent Publication No. S53-34586) was used as the conventional art, the rolling torque was stored at 0.1 seconds before biting into a downstream stand, and the peripheral velocity was controlled so that the rolling torque became a value which was stored before the biting into the downstream stand after 0.5 seconds have passed since the biting into the downstream stand. Here, a reason why the timing when the rolling torque was stored was set at 0.1 seconds before the biting into the downstream stand was that a rolling speed was estimated from a distance between stands and a roll speed and an estimation error was taken into consideration to estimate the time required for the material to be rolled to be bitten into the downstream stand, to avoid that the storing timing of the rolling torque was after the biting into the downstream stand. A reason why the start of the control was set as 0.5 seconds after the biting into the downstream stand is that it was the time necessary to avoid a transient state such as recovery from lowering of the peripheral velocity due to the biting (impact drop).

[0062] Besides, in Comparative Example 2, the technique disclosed in Patent Document 3 (Japanese Patent Publication No. S61-3564) was used as the conventional art, arithmetic operation of a no-tension torque $Gj0$ of a stand was performed at 0.1 seconds before biting into a downstream stand, and control was performed so that tension between stands becomes zero after a material to be rolled was bitten into all of the stands. Here, a reason why the arithmetic operation timing of the no-tension torque $Gj0$ was set at 0.1 seconds before the biting into the downstream stand was that a rolling speed was estimated from a distance between stands and a roll speed and an estimation error was taken into consideration to estimate the time required for the material to be rolled to be bitten into the downstream stand, to avoid that the storing timing of the rolling torque was after the biting into the downstream stand.

[0063] When the present invention was applied (Example), the rolling without turning up of the material to be rolled was possible. On the other hand, in Comparative Example 1, there were only 0.07 seconds to perform the tension control of R1-R2 until the rolling torque of R2 was stored, and the rolling torque $G1$ of R1 could not be stabilized into a value which was stored before biting into R2. Further, regarding R3, the storing timing of the rolling torque was overlapped with the transient state after biting, and the material to be rolled was bitten into R4 without controlling the tension between R2-R3. As a result, significant comparative force was generated between R3-R4, resulting in that the material to be rolled was turned up between stands.

[0064] In Comparative Example 2, though a steady portion could be rolled without occurrence of turning up or the like, the rolling torque of R3 decreased rapidly just after ejection from R2, then a control command to increase the speed of R3 was issued, resulting in that the material to be rolled was turned up between R3-R4.

[Industrial Applicability]

[0065] The present invention is applicable to a rolling method of shaped steel which produces the shaped steel such as, for example, H-shaped steel, T-shaped steel, or I-shaped steel, a production line of the shaped steel, and a production method of the shaped steel.

[Explanation of Codes]

[0066]

5	2	heating furnace
	4	rough rolling mill
	5	(first) intermediate universal rolling mill (U1)
	6	(second) intermediate universal rolling mill (U2)
	8	finishing universal rolling mill
10	9	edger rolling mill (E)
	30	rolling mill train
	50	second rolling mill train
	S	material to be rolled
	L	production line

15

Claims

1. A rolling method of shaped steel which performs reduction between a horizontal roll side surface and a vertical roll peripheral surface by using one piece or more of rolling mill when tandem rolling is carried out in a rolling mill train formed of n-pieces of rolling mills of at least three pieces or more, the rolling method comprising:
- a first control step of fixing the peripheral velocity of a rolling mill R_i of the rolling mill train after a material to be rolled is bitten into the rolling mill R_i and before the material to be rolled is bitten into a rolling mill R_{i+1} positioning at a downstream side of the rolling mill R_i , and storing a rolling torque G_i of the rolling mill R_i at that time as G_i^* regarding each rolling mill R_i , and
- controlling the peripheral velocity of a most downstream rolling mill R_n of the rolling mill train after the material to be rolled is bitten into the rolling mill R_n so that a rolling torque G_{n-1} of a rolling mill R_{n-1} positioning at an upstream side of the rolling mill R_n becomes equal to G_{n-1}^* which is stored as a rolling torque of the rolling mill R_{n-1} before the material to be rolled is bitten into the rolling mill R_n ;
- a second control step of storing a rolling torque G_n^{**} of the rolling mill R_n after the first control step, and subsequently, controlling the peripheral velocity of the rolling mill R_{n-1} so that a rolling torque G_{n-2} of a rolling mill R_{n-2} positioning at an upstream side of the rolling mill R_{n-1} becomes equal to G_{n-2}^* which is stored as a rolling torque of the rolling mill R_{n-2} before the material to be rolled is bitten into the rolling mill R_{n-1} , and
- controlling the peripheral velocity of the rolling mill R_n so that a rolling torque G_n of the rolling mill R_n becomes equal to the stored rolling torque G_n^{**} , wherein
- the second control step is applied to all of the rolling mills R_i , and the peripheral velocity of each rolling mill R_i of the rolling mill train is controlled so that a rolling torque G_1 of a most upstream rolling mill R_1 becomes equal to G_1^* which is stored as a rolling torque of the rolling mill R_1 before the material to be rolled is bitten into a rolling mill R_2 positioning at a downstream side of the rolling mill R_1 ,
- here, i is an arbitrary integer number from one to n , and n is an integer number of three or more.
2. The rolling method of the shaped steel according to claim 1, wherein the control is performed by using a torque arm coefficient (G/P) which is a value where a rolling torque of each rolling mill is divided by a rolling load of the rolling mill in place of a value of the rolling torque of each rolling mill of the rolling mill train.
3. The rolling method of the shaped steel according to claim 1 or claim 2, wherein after controlling all of the peripheral velocity of the respective rolling mills R_i of the rolling mill train, rolling is carried out by fixing a ratio of the peripheral velocity of the respective rolling mills R_i .
4. The rolling method of the shaped steel according to claim 3, wherein a rolling speed of the most downstream rolling mill R_n of the rolling mill train is increased to a desired speed under a state where the ratio of the peripheral velocity of the respective rolling mills R_i is fixed.
5. A production line of shaped steel having a constitution where a rolling mill train formed of n-pieces of rolling mills of at least three pieces or more and at least one piece or more of rolling mills or a rolling mill train are tandem arranged in this order and carrying out reduction between a horizontal roll side surface and a vertical roll peripheral surface

by using one piece or more of rolling mill, wherein

in the production line, no-tension control of a material to be rolled is performed at the upstream rolling mill train, the upstream rolling mill train and the downstream rolling mills or rolling mill train are arranged in a state where there is a sufficient distance for the material to be rolled to be bitten into the downstream rolling mills or rolling mill train after the no-tension control is completed, and

the rolling method of the shaped steel according to any one of claims 1 to 4 is independently performed at the upstream rolling mill train and the downstream rolling mills or rolling mill train.

6. A production method of shaped steel produced by carrying out reduction between a horizontal roll side surface and a vertical roll peripheral surface, the production method comprising:

a first control step of fixing the peripheral velocity of a rolling mill R_i after a material to be rolled is bitten into the rolling mill R_i and before the material to be rolled is bitten into a rolling mill R_{i+1} positioning at a downstream side of the rolling mill R_i , and storing a rolling torque G_i of the rolling mill R_i at that time as G_i^* regarding each rolling mill R_i in a rolling mill train formed of n -pieces of rolling mills of at least three pieces or more, and controlling the peripheral velocity of a most downstream rolling mill R_n of the rolling mill train after the material to be rolled is bitten into the rolling mill R_n so that a rolling torque G_{n-1} of a rolling mill R_{n-1} positioning at an upstream side of the rolling mill R_n becomes equal to G_{n-1}^* which is stored as a rolling torque of the rolling mill R_{n-1} before the material to be rolled is bitten into the rolling mill R_n ;

a second control step of storing a rolling torque G_n^{**} of the rolling mill R_n after the first control step, and subsequently, controlling the peripheral velocity of the rolling mill R_{n-1} so that a rolling torque G_{n-2} of a rolling mill R_{n-2} positioning at an upstream side of the rolling mill R_{n-1} becomes equal to G_{n-2}^* which is stored as a rolling torque of the rolling mill R_{n-2} before the material to be rolled is bitten into the rolling mill R_{n-1} , and controlling the peripheral velocity of the rolling mill R_n so that a rolling torque G_n of the rolling mill R_n becomes equal to the stored rolling torque G_n^{**} , wherein

the shaped steel is produced by applying the second control step to all of the rolling mills R_i , and controlling the peripheral velocity of each rolling mill R_i of the rolling mill train so that a rolling torque G_1 of a most upstream rolling mill R_1 becomes equal to G_1^* which is stored as a rolling torque of the rolling mill R_1 before the material to be rolled is bitten into a rolling mill R_2 positioning at a downstream side of the rolling mill R_1 .

FIG.1

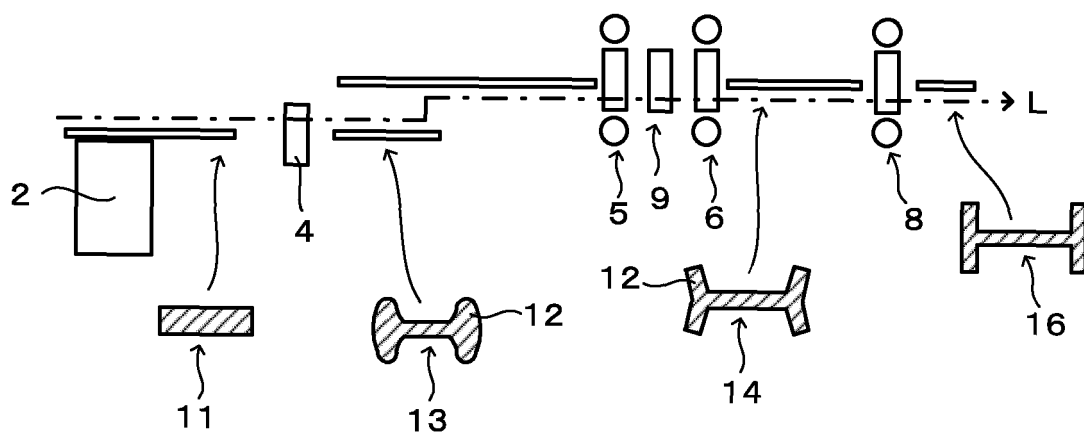


FIG.2

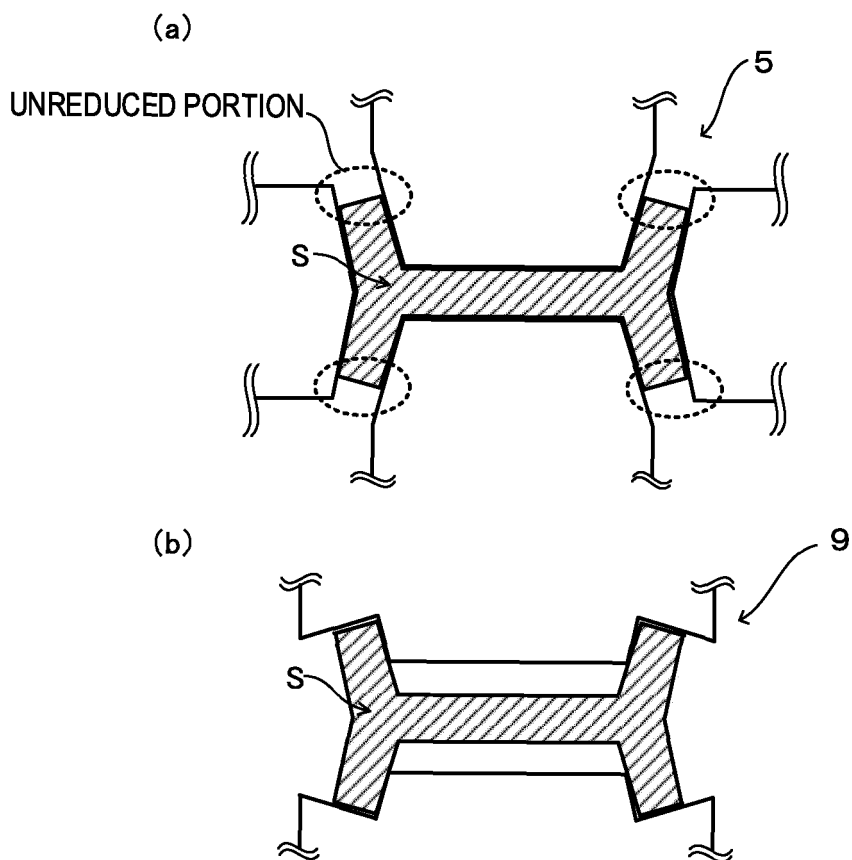


FIG.3

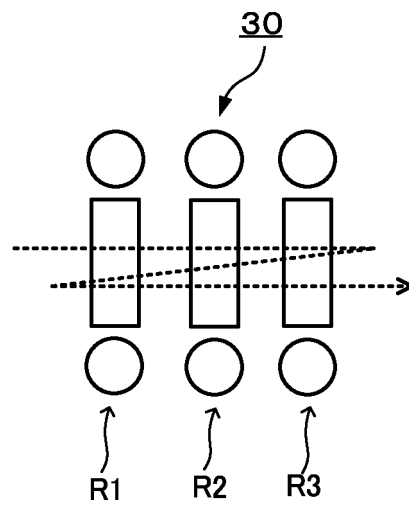


FIG.4

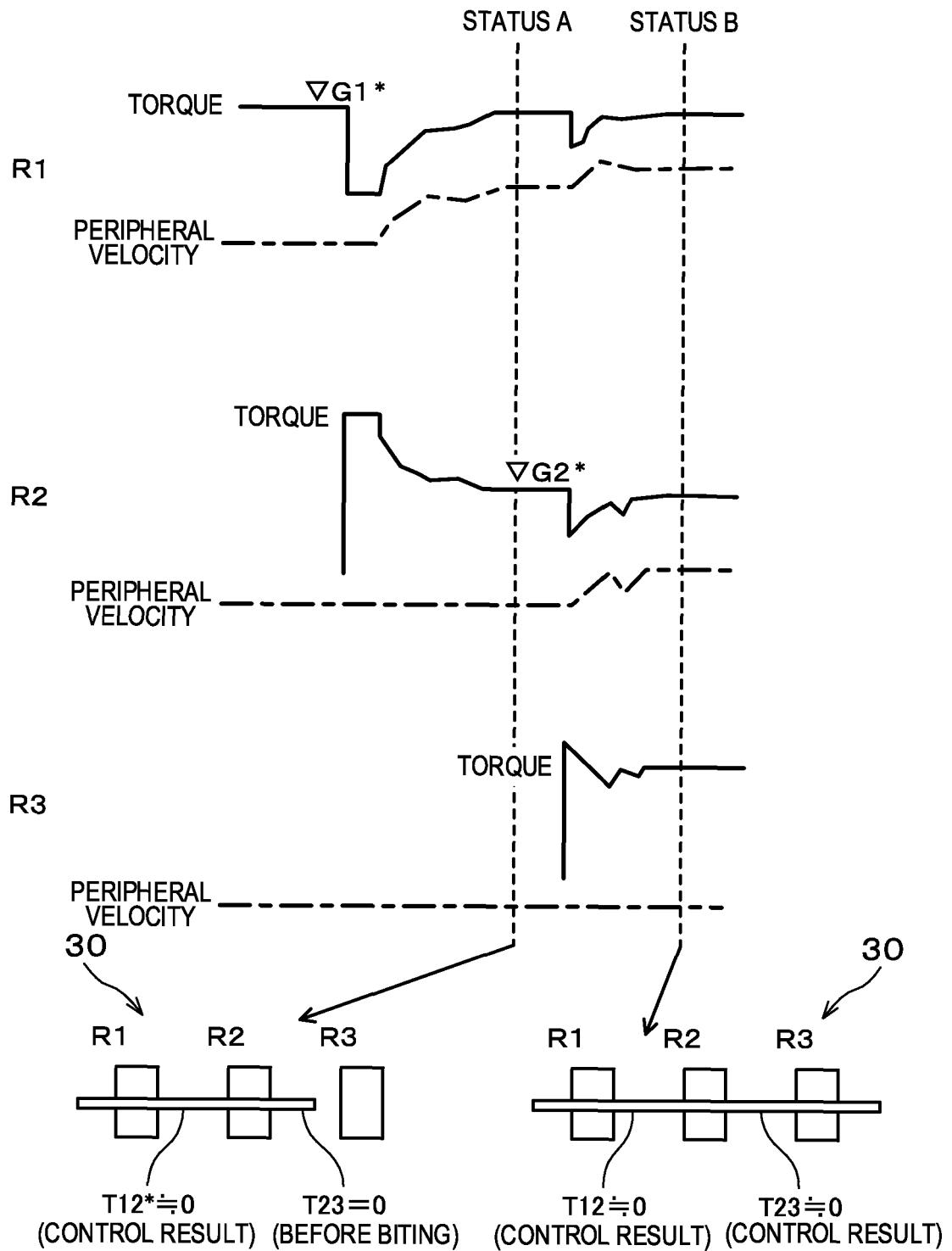


FIG.5

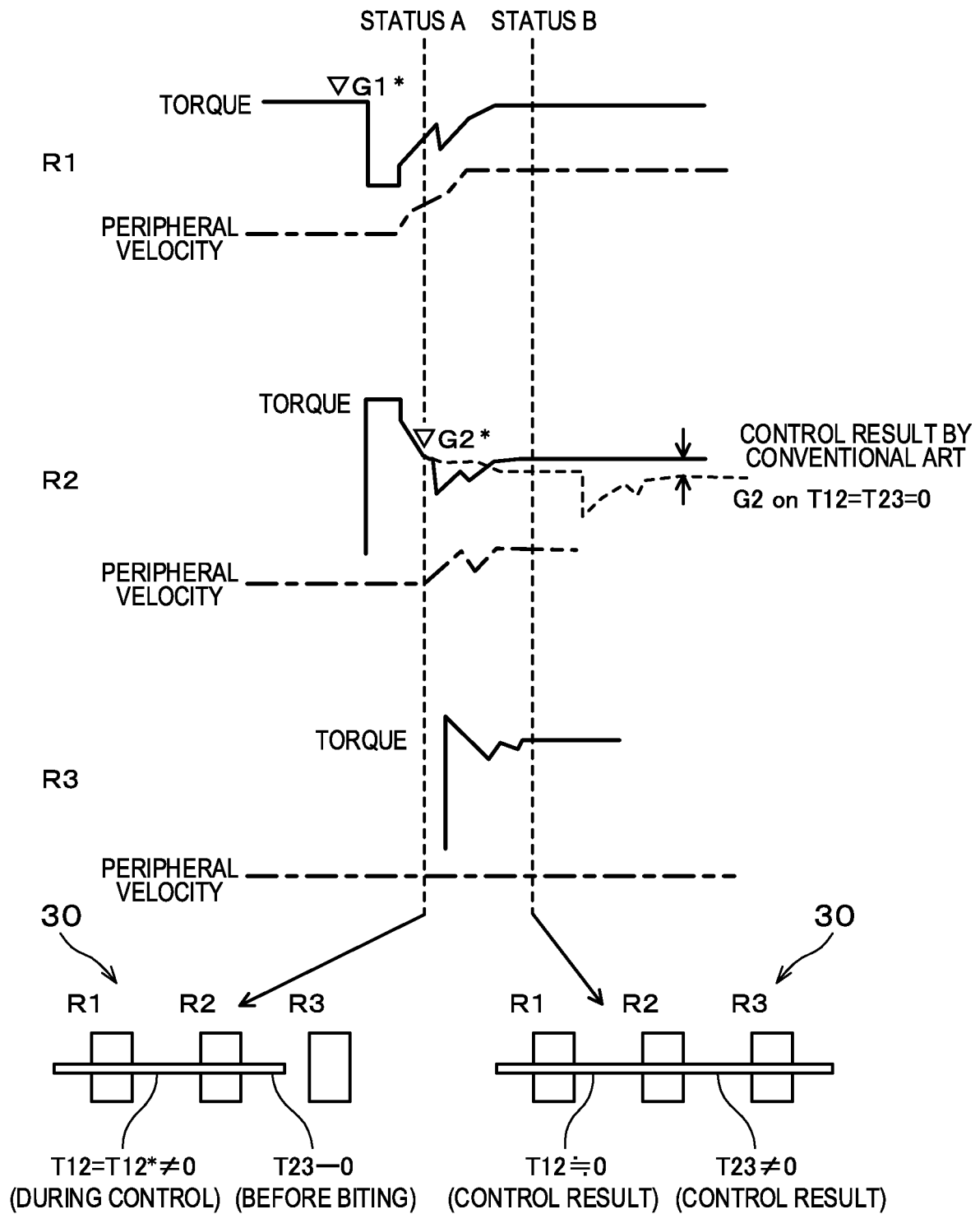


FIG.6

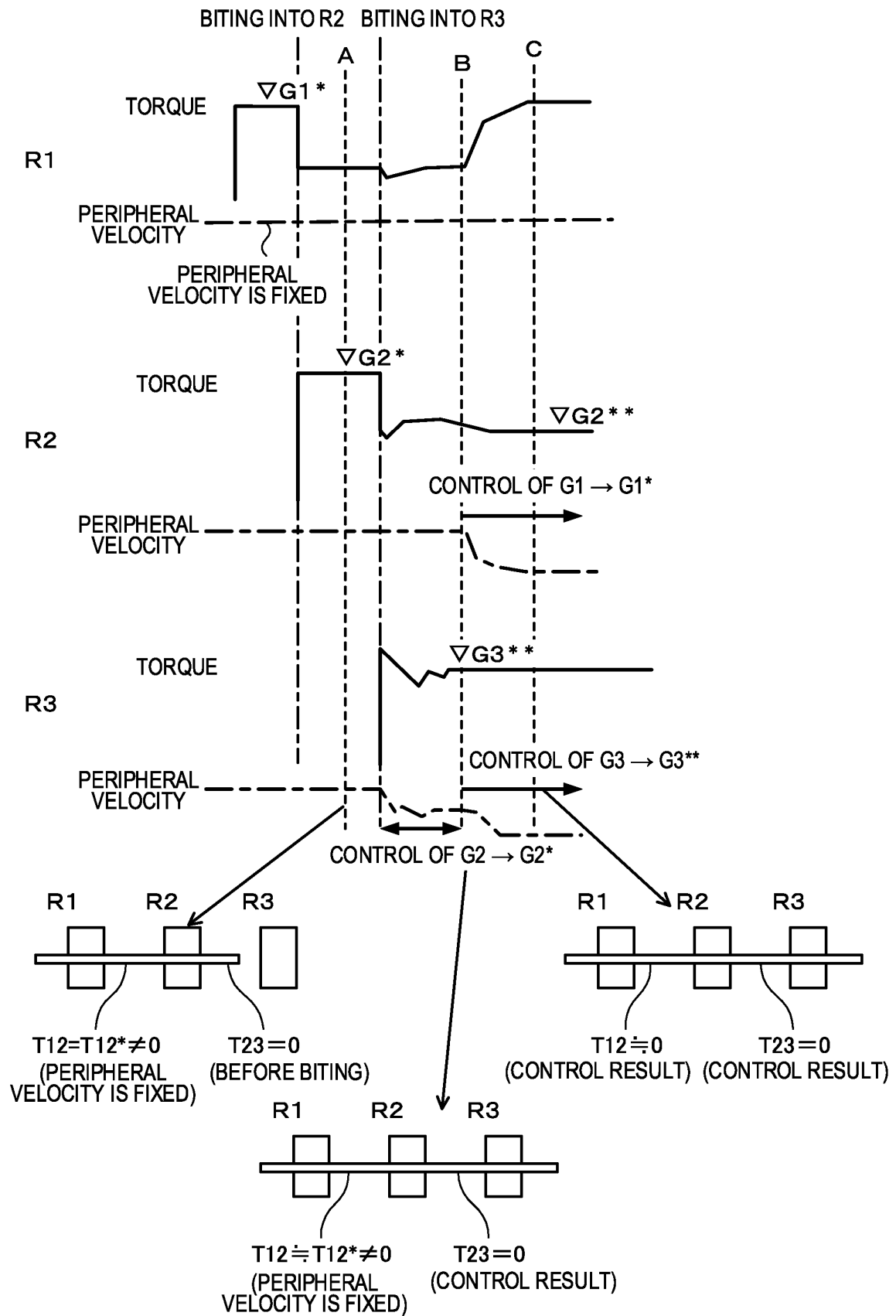


FIG.7

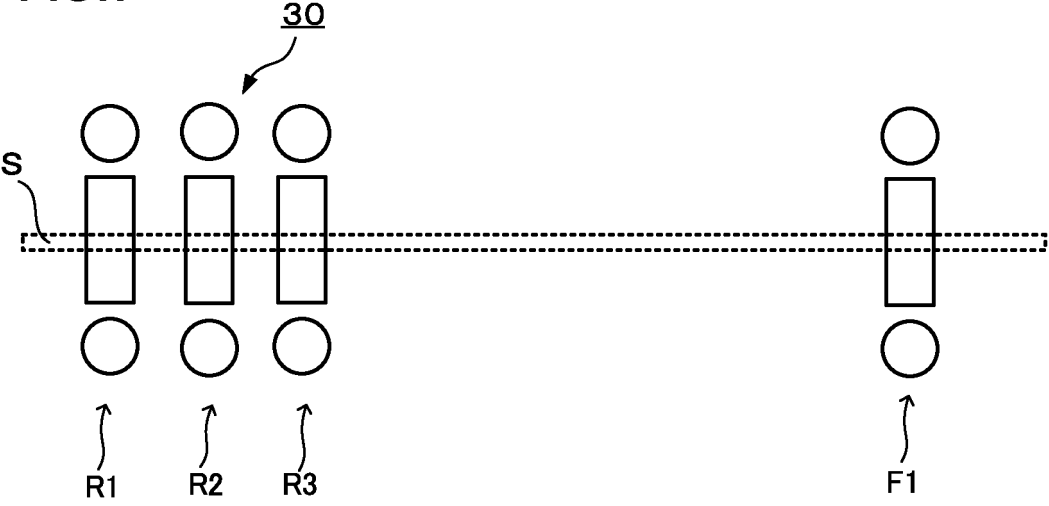


FIG.8

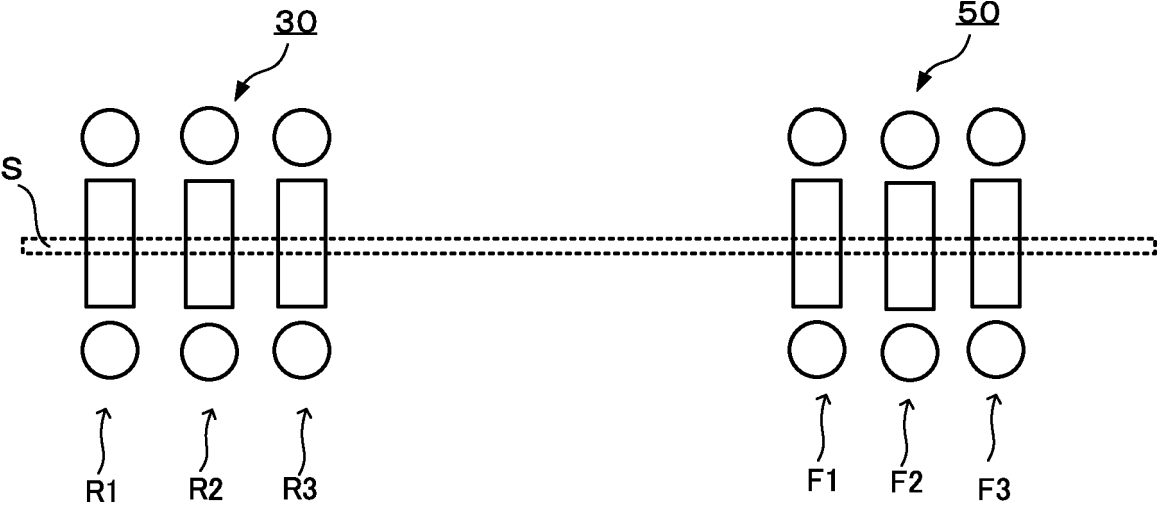


FIG.9

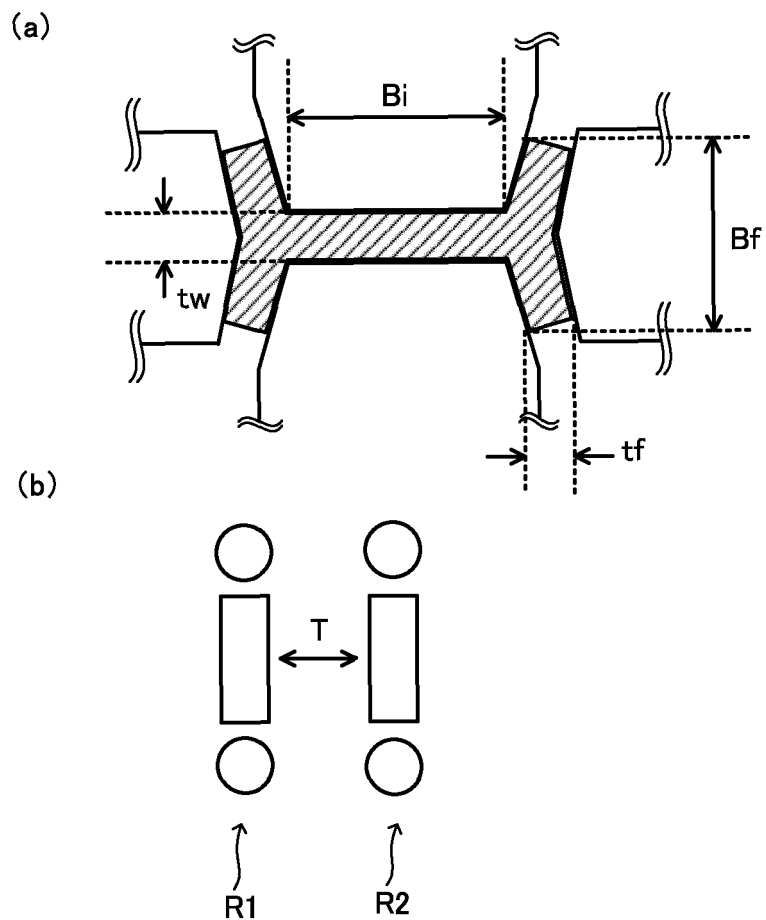
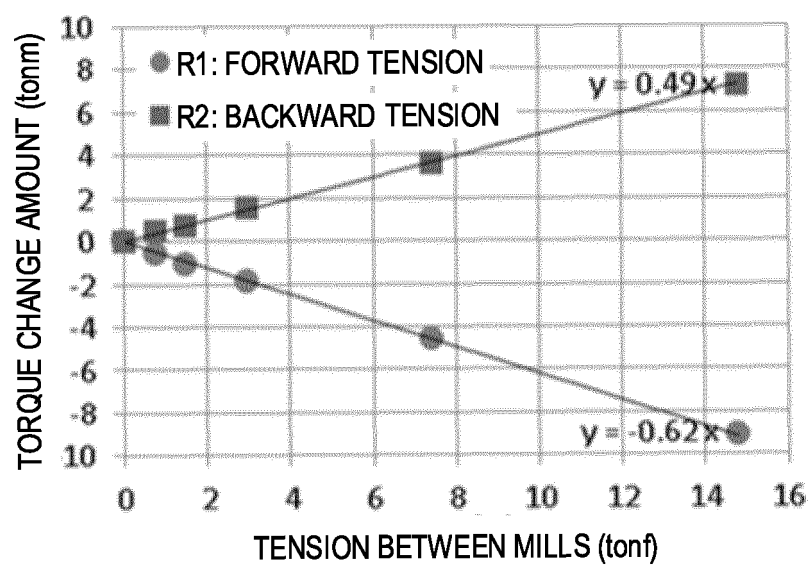


FIG.10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/048177

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. B21B37/00 (2006.01) i, B21B1/12 (2006.01) i, B21B37/52 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. B21B37/00, B21B1/12, B21B37/52

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2019

Registered utility model specifications of Japan 1996-2019

Published registered utility model applications of Japan 1994-2019

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 2005-262256 A (JFE STEEL CORPORATION) 29 September 2005 (Family: none)	1-6
A	JP 2008-183594 A (JFE STEEL CORPORATION) 14 August 2008 (Family: none)	1-6

☐

Further documents are listed in the continuation of Box C.

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See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"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

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Date of the actual completion of the international search
17.01.2019Date of mailing of the international search report
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