



(11)

EP 4 212 260 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
19.07.2023 Bulletin 2023/29

(51) International Patent Classification (IPC):
B21B 37/28 (2006.01) **B21B 37/40** (2006.01)

(21) Application number: **21866765.7**

(52) Cooperative Patent Classification (CPC):
B21B 37/28; B21B 37/40

(22) Date of filing: **07.09.2021**

(86) International application number:
PCT/JP2021/032889

(87) International publication number:
WO 2022/054806 (17.03.2022 Gazette 2022/11)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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(30) Priority: **10.09.2020 JP 2020152348**

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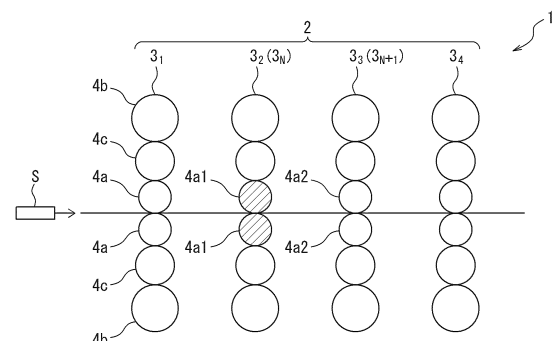
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(54) **COLD ROLLING METHOD, COLD ROLLING EQUIPMENT, AND COLD-ROLLED STEEL SHEET MANUFACTURING METHOD**

(57) A cold rolling method, cold rolling equipment, and a cold-rolled steel sheet manufacturing method capable of preventing sheet breakage by sufficiently suppressing occurrence of an edge crack of a material to be rolled during cold rolling are provided. In the cold rolling method, a rolling mill (2) including a plurality of stands (3₁) to (3₄) cold-rolls a material to be rolled (S). An N-th stand (3_N) (N is a natural number equal to or greater than 2) arranged in an N-th position from an upstream side of the material to be rolled (S) in a transfer direction among the plurality of stands (3₁) to (3₄), includes a tapered work roll (4a1) having a taper (4ab) formed on an end portion of a roll (4aa) having a uniform diameter. The N-th stand (3_N) rolls the material to be rolled (S) with a linear load of 0.8 t/mm or more.

FIG. 1



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Description

Technical Field

5 **[0001]** The present invention relates to a cold rolling method for cold-rolling a material to be rolled, cold rolling equipment, and a cold-rolled steel sheet manufacturing method.

Background Art

10 **[0002]** In a cold-rolled steel sheet manufacturing line, sheet breakage may occur due to various factors during cold rolling of a material to be rolled. One of the reasons for the sheet breakage is occurrence of an edge crack based on a crack which occurred due to a tension applied to an edge portion increased due to a defective sheet thickness distribution (for example, edge drop) in a sheet width direction of the material to be rolled, and this may lead to the sheet breakage. In order to reduce such sheet breakage, it is important to suppress the generation of cracks and an increase of the
15 generated cracks in their size. The edge drop refers to a phenomenon of rapid sheet thickness reduction particularly at both end portions in a sheet width direction in a sheet thickness deviation in the sheet width direction that occurs on a sheet material during the rolling.

[0003] In the related art, a method for controlling a sheet thickness of a sheet material in a width direction disclosed in PTL 1 has been proposed as, for example, a method for reducing the amount of the edge drop and improving the
20 sheet thickness distribution in the sheet width direction.

[0004] In the method for controlling the sheet thickness in the width direction of a sheet material disclosed in PTL 1, the sheet thickness of the sheet material in the width direction is controlled by a rolling mill including a mechanism of shifting and a mechanism of crossing a work roll having a tapered roll end portion in a plurality of stands.

[0005] According to the method for controlling the sheet thickness of the sheet material in the width direction disclosed
25 in PTL 1, it is possible to accurately perform the control in a divided manner using the plurality of stands. Accordingly, it is possible to obtain an excellent sheet thickness distribution over the entire sheet width from a sheet thickness deviation that is gently generated from a sheet width center toward a sheet end side to a sheet thickness deviation sharply generated on a sheet width end portion (edge drop) .

30 Citation List

Patent Literature

[0006] PTL 1: JP H10-29010 A
35

Summary of Invention

Technical problem

40 **[0007]** However, the method for controlling the sheet thickness of the sheet material in the width direction disclosed in PTL 1 has the following problems.

[0008] That is, in the method for controlling the sheet thickness of the sheet material in the width direction disclosed in PTL 1, the excellent sheet thickness distribution is obtained over the entire sheet width, but according to a test of the inventors, it was found that the occurrence of edge cracks of a material to be rolled during cold rolling cannot be sufficiently suppressed and sheet breakage during the cold rolling cannot be sufficiently suppressed.
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[0009] Therefore, the present invention has been made to solve the problems of the related art, and an object thereof is to provide a cold rolling method capable of preventing sheet breakage by sufficiently suppressing occurrence of an edge crack of a material to be rolled during cold rolling, cold rolling equipment, and a cold-rolled steel sheet manufacturing method.
50

Solution to Problem

[0010] In order to achieve the aforementioned object, there is provided a cold rolling method according to an aspect of the present invention for cold-rolling a material to be rolled by a rolling mill including a plurality of stands, in which an
55 N-th stand (N is a natural number equal to or greater than 2) arranged in an N-th position from an upstream side of the material to be rolled in a transfer direction among the plurality of stands, includes a tapered work roll having a taper formed on an end portion of a roll having a uniform diameter, and the N-th stand rolls the material to be rolled with a linear load of 0.8 t/mm or more.

[0011] In addition, there is provided a cold rolling method according to another aspect of the present invention for cold-rolling a material to be rolled by a rolling mill including a plurality of stands, in which an N-th stand (N is a natural number equal to or greater than 2) arranged in an N-th position from an upstream side of the material to be rolled in a transfer direction and an (N + 1)-th stand arranged in an (N + 1)-th position on a downstream side of the N-th stand among the plurality of stands, include a tapered work roll having a taper formed on an end portion of a roll having a uniform diameter, and each of the N-th stand and the (N + 1)-th stand rolls the material to be rolled with a linear load of 1.7 t/mm or more and a tapered rolling portion width $WR\delta$ which is a length, which faces the material to be rolled, of the taper formed on the tapered work roll of each of the N-th stand and the (N + 1)-th stand is set as -50 mm to -5 mm.

[0012] In addition, there is provided a cold rolling equipment according to still another aspect of the present invention having a rolling mill including a plurality of stands for rolling a material to be rolled, in which an N-th stand (N is a natural number equal to or greater than 2) arranged in an N-th position from an upstream side of the material to be rolled in a transfer direction among the plurality of stands, includes a tapered work roll having a taper formed on an end portion of a roll having a uniform diameter, and a linear load of the N-th stand is set as 0.8 t/mm or more.

[0013] In addition, there is provided a cold rolling equipment according to still another aspect of the present invention including a rolling mill having a plurality of stands for rolling a material to be rolled, in which each of an N-th stand (N is a natural number equal to or greater than 2) arranged in an N-th position from an upstream side of the material to be rolled in a transfer direction and an (N + 1)-th stand arranged in an (N + 1)-th position on a downstream side of the N-th stand among the plurality of stands, includes a tapered work roll having a taper formed on an end portion of a roll having a uniform diameter, and a linear load of each of the N-th stand and the (N + 1)-th stand is set as 1.7 t/mm or more, and a tapered rolling portion width $WR\delta$, which is a length, which faces the material to be rolled, of the taper formed on the tapered work roll of each of the N-th stand and the (N + 1)-th stand is set as -50 mm to -5 mm.

[0014] In addition, there is provided a cold-rolled steel sheet manufacturing method according to still another aspect of the present invention including cold-rolling a steel sheet to manufacture a cold-rolled steel sheet by the cold rolling method described above.

Advantageous Effects of Invention

[0015] According to the cold rolling method, the cold rolling equipment, and the cold-rolled steel sheet manufacturing method according to the present invention, it is possible to prevent sheet breakage by sufficiently suppressing occurrence of an edge crack of a material to be rolled during cold rolling.

Brief Description of Drawings

[0016]

FIG. 1 is a schematic configuration diagram of cold rolling equipment according to a first embodiment of the present invention;

FIG. 2 is a view for explaining a tapered work roll in the cold rolling equipment illustrated in FIG. 1;

FIG. 3 is a diagram for explaining an edge drop ratio;

FIG. 4 is a diagram for explaining edge-up;

FIG. 5 is a graph illustrating an edge drop ratio on each stand when each stand rolls a steel sheet with a linear load of 1.4 t/mm, in a case where a work roll of a second stand is set as a tapered work roll and work rolls of a first stand, a third stand, and a fourth stand are set as flat work rolls;

FIG. 6 is a graph illustrating sheet crowns of the second stand and the third stand on an outer side, in a case where the work rolls of the second stand and the third stand are set as the flat work rolls;

FIG. 7 is a graph illustrating tensions of the second stand and the third stand on an outer side, in a case where the work rolls of the second stand and the third stand are set as the flat work rolls;

FIG. 8 is a graph illustrating sheet crowns of the second stand and the third stand on an outer side, in a case where the work roll of the second stand is set as the tapered work roll and the work roll of the third stand is set as the flat work roll;

FIG. 9 is a graph illustrating tensions of the second stand and the third stand on an outer side, in a case where the work roll of the second stand is set as the tapered work roll and the work roll of the third stand is set as the flat work roll;

FIG. 10 is a graph illustrating comparison between a breakage occurrence ratio in a case where the work roll of the second stand is set as the tapered work roll and the work roll of the third stand is set as the flat work roll, and a breakage occurrence ratio in a case where the work rolls of the second stand and the third stand are set as the flat work rolls;

FIG. 11 is a graph illustrating comparison of the edge drop ratio on each stand when each stand rolls a steel sheet with a linear load of 1.25 t/mm by changing a tapered rolling portion width $WR\delta$ of the tapered work roll of the second

stand to +20 mm, +50 mm, -5 mm, and +60 mm, in a case where the work roll of the second stand is set as the tapered work roll and the work rolls of the first stand, the third stand, and the fourth stand are set as the flat work rolls; FIG. 12 is a graph illustrating comparison of the edge drop ratio on each stand when each stand rolls a steel sheet with a linear load of 1.35 t/mm by changing a tapered rolling portion width $WR\delta$ of the tapered work roll of the second stand to +20 mm, +50 mm, -5 mm, and +60 mm, in a case where the work roll of the second stand is set as the tapered work roll and the work rolls of the first stand, the third stand, and the fourth stand are set as the flat work rolls; FIG. 13 is a graph illustrating comparison of the edge drop ratio on each stand when each stand rolls a steel sheet with a linear load of 1.45 t/mm by changing a tapered rolling portion width $WR\delta$ of the tapered work roll of the second stand to -20 mm, -50 mm, +5 mm, and -60 mm, in a case where the work roll of the second stand is set as the tapered work roll and the work rolls of the first stand, the third stand, and the fourth stand are set as the flat work rolls; FIG. 14 is a graph illustrating comparison of the edge drop ratio on each stand when each stand rolls a steel sheet with a linear load of 1.60 t/mm by changing a tapered rolling portion width $WR\delta$ of the tapered work roll of the second stand to -20 mm, -50 mm, +5 mm, and -60 mm, in a case where the work roll of the second stand is set as the tapered work roll and the work rolls of the first stand, the third stand, and the fourth stand are set as the flat work rolls; FIG. 15 is a schematic configuration diagram of cold rolling equipment according to a second embodiment of the present invention; and FIG. 16 is a graph illustrating an edge drop ratio on each stand when each stand rolls a steel sheet with a linear load of 1.7 t/m, in a case where the work rolls of all the first stand to the fourth stand are set as the flat work rolls, in a case where only the work roll of the second stand is set as the tapered work roll and the work rolls of the other stands are set as the flat work rolls, and in a case where the work rolls of the second stand and the third stand are set as the tapered work rolls and the work roll of the other stands are set as the flat work rolls.

Description of Embodiments

[0017] Hereinafter, embodiments of the present invention will be described with reference to the drawings. The embodiments illustrated below are examples of a device or a method for implementing technical idea of the present invention and the technical idea of the present invention does not intend to specify materials, shapes, structures, arrangement, and the like of the constituent components to the following embodiments. Also, the drawings are schematically illustrated. Therefore, it should be noted that a relationship, a ratio, and the like between a thickness and a planar dimension are different from the actual ones, and the drawings include portions where the relationship or ratio thereof are different from each other.

(First Embodiment)

[0018] FIG. 1 illustrates a schematic configuration of cold rolling equipment according to a first embodiment of the present invention.

[0019] Cold rolling equipment 1 illustrated in FIG. 1 includes a rolling mill (tandem rolling mill) 2 including a plurality of (four in this embodiment) stands 3_1 to 3_4 . The rolling mill 2 cold-rolls a steel sheet S (see FIG. 2) as a material to be rolled. A steel sheet S is rolled by the rolling mill 2 while being transferred from an upstream side to a downstream side of the cold rolling equipment 1. The stands are configured with a first stand 3_1 arranged in a first position from an upstream side of the steel sheet S in a transfer direction, a second stand 3_2 arranged on a downstream side of the first stand 3_1 , a third stand 3_3 arranged on a downstream side of the second stand 3_2 , and a fourth stand 3_4 arranged on a downstream side of the third stand 3_3 . The number of stands is not limited to four and may be any number greater than 1. The subscript of each stand indicates the arrangement order from the upstream side of the steel sheet S in the transfer direction, and a stand arranged in an N-th position (N is a natural number equal to or greater than 2) from the upstream side of the steel sheet S in the transfer direction is referred to as an N-th stand 3_N , and a stand arranged in an (N + 1)-th position is referred to as an (N + 1)-th stand 3_{N+1} , In FIG. 1, for reference, the N-th stand 3_N is parenthesized and written together with the second stand 3_2 , and the (N + 1)-th stand 3_{N+1} is parenthesized and written together with the third stand 3_3 .

[0020] Each of the first stand 3_1 to the fourth stand 3_4 includes a pair of upper and lower work rolls 4a for rolling the steel sheet S as a material to be rolled, a pair of upper and lower back-up rolls 4b for supporting the work rolls 4a, and a pair of upper and lower intermediate rolls 4c arranged between each work roll 4a and each back-up roll 4b.

[0021] In addition, each work roll 4a of the second stand 3_2 is configured as a tapered work roll 4a1 (hatched in FIG. 1), and each work roll 4a of the first stand 3_1 , the third stand 3_3 , and the fourth stand 3_4 other than the second stand 3_2 is configured with a flat work roll 4a2 (not hatched in FIG. 1). The configurations of the tapered work roll 4a1 and the flat work roll 4a2 will be described later.

[0022] The reason why each work roll 4a of the second stand 3_2 is configured with the tapered work roll 4a1 as described above will be described below.

[0023] As illustrated in FIG. 1, the present inventors had conducted studies about a stand where an edge crack occurs when an electromagnetic steel sheet, as a material to be rolled, is cold-rolled by the rolling mill (tandem rolling mill) 2 including four stands which are first stand 3₁ to the fourth stand 3₄. In the rolling mill 2 used in this test, among the four stands which are the first stand 3₁ to the fourth stand 3₄, the work rolls 4a of the first stand 3₁ and the fourth stand 3₄ were set as the tapered work rolls 4a1, and the work rolls 4a of the second stand 3₂ and the third stand 3₃ were set as the flat work rolls 4a2.

[0024] As a result of investigating a starting point of a crack by rolling the electromagnetic steel sheet with the rolling mill 2, it was confirmed that the edge crack occurred on an outer side of the third stand 3₃. In order to identify the factor, an edge drop ratio of each of the first stand 3₁ to the fourth stand 3₄ was measured.

[0025] Here, the edge drop refers to a phenomenon of rapid sheet thickness reduction particularly at both end portions in a sheet width direction in a sheet thickness deviation in the sheet width direction that occurs on the steel sheet S during the rolling. The edge drop ratio is represented by the following equation, in a case where a sheet thickness at 5 mm from both end surfaces of the steel sheet S in the sheet width direction is defined as E5 and a sheet thickness at 20 mm from the both end surfaces is defined as E20, as illustrated in FIG. 3.

$$\text{Edge drop ratio } Ed = (E5 - E20)/E20$$

[0026] An edge-up known as a sheet thickness deviation in contrast to the edge drop refers to a phenomenon of a rapid sheet thickness increase particularly at both end portions in the sheet width direction in the sheet thickness deviation in the sheet width direction that occurs on the steel sheet S during the rolling. An edge-up amount is represented by the following equation, in a case where a sheet thickness at 5 mm from both end surfaces of the steel sheet S in the sheet width direction is defined as E5 and a sheet thickness at 20 mm from the both end surfaces is defined as E20, as illustrated in FIG. 4.

$$\text{Edge-up amount } Eu = E5 - E20$$

[0027] In FIGS. 3 and 4, a reference numeral CL represents a center line of the steel sheet S in a width direction.

[0028] As a result of measuring the edge drop ratio of each of the first stand 3₁ to the fourth stand 3₄, it was found that the edge drop ratio was greatly increased and exceeded a suitable range on the third stand 3₃, and then the edge drop ratio was decreased on the fourth stand 3₄. Here, an increase in the edge drop ratio means that a numerical value of the edge drop ratio increases on a negative side, and a decrease in the edge drop ratio means that a numerical value of the edge drop ratio decreases on a negative side.

[0029] In other words, it was found that, in a case where a difference between the edge drop ratio on the fourth stand 3₄ and the edge drop ratio on the third stand 3₃ is large (the difference is 0.02 or more on a + side), the sheet breakage easily occurs.

[0030] It was assumed that this was because an excessive tension was applied to both edge portions of an electromagnetic steel sheet in a sheet width direction in the third stand 3₃ and the edge crack occurred on the outer side of the third stand 3₃ due to a crack or the like on an edge portion occurred in the second stand 3₂ on the upstream side as a starting point.

[0031] For this reason, the present inventors make a uniform sheet thickness distribution of the steel sheet by setting the work roll 4a of the second stand 3₂ on the upstream side as the tapered work roll 4a1, and set the work roll 4a of the third stand 3₃ on the downstream side as the flat work roll 4a2. Accordingly, the present inventors acquired findings in that the edge drop ratio on the first stand 3₁, the second stand 3₂, the third stand 3₃, and the fourth stand 3₄ can be set in the suitable range, the difference between the edge drop ratio on the fourth stand 3₄ and the edge drop ratio on the third stand 3₃ is decreased, and the tension applied to the edge portion of the third stand 3₃ on the downstream side is decreased, thereby preventing the edge crack of the steel sheet.

[0032] For this reason, each work roll 4a of the second stand 3₂ was configured with the tapered work roll 4a1. Accordingly, it was found that, by performing the rolling with the tapered work roll 4a1 in the second stand 3₂, the occurrence of the excessive edge drop was suppressed, and even when the rolling is performed with the flat work roll in the subsequent third stand 3₃, the tension applied to the edge portion was decreased, thereby suppressing the occurrence of the crack. As a result of cold-rolling the electromagnetic steel sheet as the material to be rolled by the rolling mill 2 illustrated in FIG. 1, the breakage caused by the crack of the edge portion of the electromagnetic steel sheet was reduced.

[0033] FIG. 5 illustrates an edge drop ratio on each of the first stand 3₁ to the fourth stand 3₄ when each of the first stand 3₁ to the fourth stand 3₄ rolls the steel sheet S with a linear load of 1.4 t/mm, in a case where the work roll 4a of the second stand 3₂ is set as the tapered work roll 4a1 (although will be described later, a tapered rolling portion width

WR δ of the second stand 3₂ is -50 mm to -5 mm) and the work rolls 4a of the other stands 3₁, 3₃, and 3₄ are set as the flat work rolls 4a2. As illustrated in FIG. 5, it was found that, when the tapered work roll 4a1 was applied to the second stand 3₂, the edge drop ratio of the first stand 3₁ to the fourth stand 3₄ was in the suitable ranges, without significant increase, and the difference between the edge drop ratio on the fourth stand 3₄ and the edge drop ratio on the third stand 3₃ was less than 0.02.

[0034] FIG. 6 illustrates a sheet crown on an outer side of each of the second stand 3₂ and the third stand 3₃ in a case where the work rolls 4a of the second stand 3₂ and the third stand 3₃ were set as the flat work rolls 4a2. In addition, FIG. 7 illustrates a tension on an outer side of each of the second stand 3₂ and the third stand 3₃ in a case where the work rolls 4a of the second stand 3₂ and the third stand 3₃ were set as the flat work rolls 4a2.

[0035] As illustrated in FIG. 6, in a case where the flat work roll 4a2 is applied to the second stand 3₂ and the third stand 3₃, the excessive edge drop occurs in the second stand 3₂. Meanwhile, the edge drop ratio greatly increases from the second stand 3₂ to the third stand 3₃, and excessive tension is applied to the third stand 3₃, as illustrated in FIG. 7.

[0036] In addition, FIG. 8 illustrates a sheet crown on the outer side of each of the second stand 3₂ and the third stand 3₃, in a case where the work roll 4a of the second stand 3₂ is set as the tapered work roll 4a1 and the work roll 4a of the third stand 3₃ is set as the flat work roll 4a2. Further, FIG. 9 illustrates a tension on the outer side of each of the second stand 3₂ and the third stand 3₃, in a case where the work roll 4a of the second stand 3₂ is set as the tapered work roll 4a1 and the work roll 4a of the third stand 3₃ is set as the flat work roll 4a2.

[0037] As illustrated in FIG. 8, it is found that, when the tapered work roll 4a1 is applied to the second stand 3₂ and the flat work roll 4a2 is applied to the third stand 3₃, the excessive edge drop is suppressed on the second stand 3₂, the edge drop is suitably promoted on the third stand 3₃, and accordingly, an edge tension is suppressed from becoming an excessive tension as illustrated in FIG. 9.

[0038] When each breakage occurrence ratio is compared, the breakage occurrence ratio can be decreased by configuring the work roll 4a of the second stand 3₂ with the tapered work roll 4a1 as illustrated in FIG. 10, compared to a case where the work roll 4a of the second stand 3₂ is configured with the flat work roll 4a2.

[0039] From the above, by configuring the work roll 4a of the second stand 3₂ with the tapered work roll 4a1, it is possible to reinforce the findings in that the occurrence of the excessive edge drop on the second stand 3₂ on the upstream side can be suppressed and the tension applied to the edge portion of the steel sheet S on the third stand 3₃ on the downstream side can be decreased to suppress the occurrence of the edge crack.

[0040] The above result is obtained in a case where the second stand 3₂ having the tapered work rolls 4a1 rolls the steel sheet S with a linear load (rolling load/sheet width) of 1.4 t/mm.

[0041] As a result of further tests, as illustrated in Tables 1, FIG. 11, Table 2, and FIG. 12, it was found that, in a case where the linear load of the second stand 3₂ having the tapered work rolls 4a1 was set as less than 1.4 t/mm, the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ is preferably ± 0 mm to +50 mm. Although the tapered rolling portion width WR δ will be described in detail later, when the steel sheet S is rolled by setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as a value on a negative side, that is, by shifting the tapered work roll 4a1 of the second stand 3₂ to a negative direction, the steel sheet S is reversely edged up on the shifted second stand 3₂, thereby causing the occurrence of the edge crack or the breakage. Here, in a case of edge crack, the steel sheet S cannot pass through a next step (annealing step), and since there is a high possibility that the steel sheet S is broken due to the annealing, it is preferable to roll the steel sheet S by shifting the tapered work roll 4a1 of the second stand 3₂ to the positive direction. Even in a case where the tapered work roll 4a1 of the second stand 3₂ is shifted in the positive direction, when the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ is larger than +50 mm, there is a risk that the steel sheet S is edged up on the next third stand 3₃ after the shifted second stand 3₂ to cause the occurrence of the edge crack or the breakage. Accordingly, it is preferable that an upper limit of the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ is set as +50 mm.

[Table 1]

Linear load 1.25 (t/mm)					
WR δ (mm)	Edge drop ratio (-)				
	Base sheet	First stand	Second stand	Third stand	Fourth stand
+20	-0.001	-0.013	-0.043	-0.063	-0.083
+50	-0.001	-0.013	-0.063	-0.083	-0.088
-5	-0.001	-0.013	0.007	-0.013	-0.053
+60	-0.001	-0.013	-0.083	-0.053	-0.063

[Table 2]

Linear load 1.35 (t/mm)					
WR δ (mm)	Edge drop ratio (-)				
	Base sheet	First stand	Second stand	Third stand	Fourth stand
+20	-0.001	-0.013	-0.043	-0.073	-0.093
+50	-0.001	-0.013	-0.073	-0.103	-0.108
-5	-0.001	-0.013	-0.003	-0.033	-0.073
+60	-0.001	-0.013	-0.093	-0.073	-0.083

[0042] Table 1 and FIG. 11 illustrate comparison of the edge drop ratio on each stand when each stand rolls the steel sheet with a linear load of 1.25 t/mm by changing the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand to +20 mm, +50 mm, -5 mm, and +60 mm, in a case where the work roll 4a of the second stand 3₂ is set as the tapered work roll 4a1 and the work rolls 4a of the first stand 3₁, the third stand 3₃, and the fourth stand 3₄ are set as the flat work rolls 4a2.

[0043] As illustrated in Table 1 and FIG. 11, it is found that, when the second stand 3₂ having the tapered work roll 4a1 rolls the steel sheet S with a linear load of 1.25 t/mm, in a case where the steel sheet S is rolled by setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as -5 mm beyond the range, the second stand 3₂ shifted in the negative direction is edged up, and in a case where the steel sheet S is rolled by setting the tapered rolling portion width WR δ as +60 mm beyond the range, the next second stand 3₃ after the second stand 3₂ shifted in the positive direction is edged up. It is found that, in a case where the steel sheet S is rolled by setting the tapered rolling portion width WR δ as +20 mm and +50 mm in the range, the edge drop of the second stand 3₂, the third stand 3₃, the fourth stand 3₄ is suitably promoted.

[0044] In addition, Table 2 and FIG. 12 illustrate comparison of the edge drop ratio on each stand when each stand rolls the steel sheet with a linear load of 1.35 t/mm by changing the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand to +20 mm, +50 mm, -5 mm, and +60 mm, in a case where the work roll 4a of the second stand 3₂ is set as the tapered work roll 4a1 and the work rolls 4a of the first stand 3₁, the third stand 3₃, and the fourth stand 3₄ are set as the flat work rolls 4a2.

[0045] As illustrated in Table 2 and FIG. 12, it is found that, when the second stand 3₂ having the tapered work roll 4a1 rolls the steel sheet S with a linear load of 1.35 t/mm, in a case where the steel sheet S is rolled by setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as -5 mm beyond the range, the second stand 3₂ shifted in the negative direction is edged up, and in a case where the steel sheet S is rolled by setting the tapered rolling portion width WR δ as +60 mm beyond the range, the next second stand 3₃ after the second stand 3₂ shifted in the positive direction is edged up. It is found that, in a case where the steel sheet S is rolled by setting the tapered rolling portion width WR δ as +20 mm and +50 mm in the range, the edge drop of the second stand 3₂, the third stand 3₃, and the fourth stand 3₄ is suitably performed.

[0046] A lower limit value of the linear load at which the edge crack of the steel sheet S occurs is 0.8 t/mm, unless the second stand 3₂ is shifted in the positive direction. In other words, in a case where the steel sheet S is rolled with a linear load of less than 0.8 t/mm, the edge crack of the steel sheet S does not occur regardless of the shift direction of the second stand 3₂.

[0047] In addition, as a result of further tests, as illustrated in Tables 3, FIG. 13, Table 4, and FIG. 14, it was found that, in a case where the linear load of the second stand 3₂ having the tapered work rolls 4a1 was set as 1.4 t/mm or more, the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ is preferably -50 mm to -5 mm. When the steel sheet S is rolled by setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as a value on a positive side, that is, by shifting the tapered work roll 4a1 of the second stand 3₂ to a positive direction, the steel sheet S is edged up on the next stand (the third stand 3₃) or the stand after the next stand (the fourth stand 3₄) after the shifted second stand 3₂, thereby causing the occurrence of the edge crack or the breakage. The expression that "it was found that, in a case where a difference between the edge drop ratio on the fourth stand 3₄ and the edge drop ratio on the third stand 3₃ is large, the sheet breakage easily occurs" has the same meaning as the expression "the steel sheet S is edged up on the next stand (the fourth stand 3₄) after the shifted second stand 3₂, thereby causing the occurrence of the edge crack or the breakage". Here, in a case of the edge crack, the steel sheet S cannot pass through the next step (annealing step) and a possibility that the steel sheet S cracks due to the annealing is high. In addition, when the steel sheet S is rolled by shifting the tapered work roll 4a1 of the second stand 3₂ in the positive direction, the edge drop is excessively produced on the shifted second stand 3₂ (excessive edge drop occurs),

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and accordingly, a pressure of the edge of the steel sheet S cannot be decreased on the next stand (third stand 3_3) and the edge crack may occur due to an increase in tension. Therefore, it is preferable to roll the steel sheet S by shifting the second stand 3_2 in the negative direction. Even in a case where the second stand 3_2 is shifted in the negative direction, when the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand 3_2 is larger than -50 mm, there is a risk that the steel sheet S is edged up on the shifted second stand 3_2 to cause the occurrence of the edge crack or the breakage. Accordingly, it is preferable that a lower limit of the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand 3_2 is set as -50 mm.

[Table 3]

Linear load 1.45 (t/mm)					
$WR\delta$ (mm)	Edge drop ratio (-)				
	Base sheet	First stand	Second stand	Third stand	Fourth stand
+20	-0.001	-0.013	-0.033	-0.053	-0.073
+50	-0.001	-0.013	-0.023	-0.043	-0.048
-5	-0.001	-0.013	-0.113	-0.063	-0.103
+60	-0.001	-0.013	0.007	-0.013	-0.023

[Table 4]

Linear load 1.60 (t/mm)					
$WR\delta$ (mm)	Edge drop ratio (-)				
	Base sheet	First stand	Second stand	Third stand	Fourth stand
+20	-0.001	-0.013	-0.043	-0.073	-0.093
+50	-0.001	-0.013	-0.033	-0.043	-0.048
-5	-0.001	-0.013	-0.123	-0.053	-0.093
+60	-0.001	-0.013	0.047	-0.017	-0.007

[0048] Table 3 and FIG. 13 illustrate comparison of the edge drop ratio on each stand when each stand rolls the steel sheet with a linear load of 1.45 t/mm by changing the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand to -20 mm, -50 mm, +5 mm, and -60 mm, in a case where the work roll 4a of the second stand 3_2 is set as the tapered work roll 4a1 and the work rolls 4a of the first stand 3_1 , the third stand 3_3 , and the fourth stand 3_4 are set as the flat work rolls 4a2.

[0049] As illustrated in Table 3 and FIG. 13, it is found that, when the second stand 3_2 having the tapered work roll 4a1 rolls the steel sheet S with a linear load of 1.45 t/mm, in a case where the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ of the second stand 3_2 as +5 mm beyond the range, the excessive edge drop occurs on the second stand 3_2 shifted in the positive direction and the next third stand 3_2 is edged up, and in a case where the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ as -60 mm beyond the range, the second stand 3_2 shifted in the negative direction is edged up. It is found that, in a case where the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ as -20 mm and -50 mm in the range, the edge drop of the second stand 3_2 , the third stand 3_3 , the fourth stand 3_4 is suitably promoted.

[0050] In addition, Table 4 and FIG. 14 illustrate comparison of the edge drop ratio on each stand when each stand rolls the steel sheet with a linear load of 1.60 t/mm by changing the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand to -20 mm, -50 mm, +5 mm, and -60 mm, in a case where the work roll 4a of the second stand 3_2 is set as the tapered work roll 4a1 and the work rolls 4a of the first stand 3_1 , the third stand 3_3 , and the fourth stand 3_4 are set as the flat work rolls 4a2.

[0051] As illustrated in Table 4 and FIG. 14, it is found that, when the second stand 3_2 having the tapered work roll 4a1 rolls the steel sheet S with a linear load of 1.60 t/mm, in a case where the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand 3_2 as +5 mm beyond the range, the excessive edge drop occurs on the second stand 3_2 shifted in the positive direction and the next third stand 3_2 is edged up, and in a case where the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ as -60 mm beyond

the range, the second stand 3_2 shifted in the negative direction is edged up. It is found that, in a case where the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ as -20 mm and -50 mm in the range, the edge drop of the second stand 3_2 , the third stand 3_3 , the fourth stand 3_4 is suitably promoted.

[0052] From the above, the work roll 4a of the second stand 3_2 is configured with the tapered work roll 4a1, and the second stand 3_2 having the tapered work roll 4a1 rolls the steel sheet S with a linear load of 0.8 t/mm or more. When the second stand 3_2 rolls the steel sheet S with a linear load of less than 1.4 t/mm, the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand 3_2 as ± 0 mm to +50 mm. In addition, when the second stand 3_2 rolls the steel sheet S with a linear load of 1.4 t/mm or more, the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand 3_2 as -50 mm to -5 mm. It was found that by this, both edge drop and edge-up can be appropriately controlled, and the occurrence of edge crack can be suppressed.

[0053] The reason for determining whether to shift the tapered work roll 4a1 of the second stand 3_2 in the positive direction or shift the tapered work roll 4a1 in the negative direction based on the linear load, 1.4 t/mm, of the second stand 3_2 having the tapered work roll 4a1 is as described below. That is, in a case where the linear load of the second stand 3_2 having the tapered work roll 4a1 is set as 1.4 t/mm or more, the material to be rolled is a high-load material, and the tapered work roll 4a1 easily bend. Accordingly, by shifting the tapered work roll 4a1 in the negative direction, the excessive edge drop is suppressed. On the other hand, in a case where the linear load of the second stand 3_2 having the tapered work roll 4a1 is set as less than 1.4 t/mm, the material to be rolled is a low-load material, and the tapered work roll 4a1 is less likely to bend and the edge-up easily occurs. Accordingly, by shifting the tapered work roll 4a1 in the positive direction, it is held on the edge drop side.

[0054] Next, the configuration of the tapered work roll 4a1 will be described with reference to FIG. 2. In the tapered work roll 4a1, a taper 4ab which is tapered is formed on an end portion of a roll 4aa having a uniform diameter in a body length direction. The work roll 4a, which is the tapered work roll 4a1, is configured to be shifted in an axial direction (a roll body length direction, a sheet width direction of the steel sheet S).

[0055] The tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 is a length of the taper 4ab facing the steel sheet S, and is a length from a taper start end 4ac to a width direction end surface of the steel sheet S in FIG. 2. As described above, when the second stand 3_2 rolls the steel sheet S with a linear load of less than 1.4 t/mm, the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand 3_2 as ± 0 mm to +50 mm. That is, it is preferable to roll the steel sheet S by shifting the tapered work roll 4a1 of the second stand 3_2 in the positive direction.

[0056] In addition, as described above, when the second stand 3_2 rolls the steel sheet S with a linear load of 1.4 t/mm or more, the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand 3_2 as -50 mm to -5 mm. That is, it is preferable to roll the steel sheet S by shifting the tapered work roll 4a1 of the second stand 3_2 in the negative direction.

[0057] In a case where the width direction end surface of the steel sheet S protrudes from the taper start end 4ac, the tapered rolling portion width $WR\delta$ is a negative value, and in a case where the width direction end surface of the steel sheet S is recessed from the taper start end 4ac, the tapered rolling portion width $WR\delta$ is a positive value. A case where the tapered rolling portion width $WR\delta$ is a positive value is the same operation as a case where the flat work roll 4a2 is used.

[0058] In addition, an inclination of the taper 4ab is represented as L/H, in a case where a length from the taper start end 4ac to a taper final end surface (axial direction end surface of the tapered work roll 4a1) is defined as L and a difference in height between an outer peripheral surface of the roll 4aa and an outer periphery of the taper final end surface is defined as H. The inclination L/H of the taper 4ab is preferably 1/800 to 1/400. In a case where the inclination L/H of the taper 4ab is smaller than 1/800, there is a problem that the edge drop cannot be suppressed. On the other hand, in a case where the inclination L/H of the taper 4ab is larger than 1/400, there is a problem that the edge-up excessively occurs.

[0059] In addition, in the description of the configuration of the flat work roll 4a2, the flat work roll 4a2 is configured with a roll having a uniform diameter in the body length direction. The work roll 4a, which is the flat work roll 4a2, is configured to be shifted in an axial direction (a roll body length direction, a sheet width direction of the steel sheet S).

[0060] As described above, in the cold rolling equipment 1 according to the first embodiment, among the four stands of the first stands 3_1 to the fourth stands 3_4 , the second stand 3_2 arranged in the second position from the upstream side of the steel sheet S, as the material to be rolled, in the transfer direction includes the tapered work roll 4a1 having the taper 4ab formed on the end portion of the roll 4aa having a uniform diameter. A linear load of the second stand 3_2 is set as 0.8 t/mm or more. When the linear load of the second stand 3_2 is set as less than 1.4 t/mm, the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand 3_2 is ± 0 mm and +50 mm. In addition, when the linear load of the second stand 3_2 is set as 1.4 t/mm or more, the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand 3_2 is set as -50 mm to -5 mm.

[0061] Therefore, the edge drop ratio on the first stand 3_1 to the fourth stand 3_4 is kept within the appropriate range, and the occurrence of edge crack on the steel sheet S as the material to be rolled during the cold rolling is sufficiently

suppressed, thereby suppressing the sheet breakage.

[0062] In addition, in the cold rolling equipment 1 according to the first embodiment, among the four stands of first stands 3_1 to the fourth stand 3_4 , the third stand 3_3 arranged in the third position on the downstream side of the second stand 3_2 includes the flat work roll 4a2 having a uniform diameter of a roll.

[0063] Accordingly, the effect of promoting the edge drop is exhibited.

[0064] In addition, in the cold rolling equipment 1 according to the first embodiment, among the four stands of first stands 3_1 to the fourth stands 3_4 , the first stand 3_1 arranged on the uppermost stream side includes the flat work roll 4a2, but may include the tapered work roll 4a1.

[0065] Accordingly, the effect of suppressing the edge drop is exhibited.

[0066] In addition, in a cold rolling method according to the first embodiment, the steel sheet S as the material to be rolled is cold-rolled by the rolling mill 2 in the cold rolling equipment 1 illustrated in FIG. 1. In this case, among the four stands of the first stands 3_2 to the fourth stands 3_4 , the second stand 3_2 arranged in the second position from the upstream side of the steel sheet S in the transfer direction includes the tapered work roll 4a1 having the taper 4ab formed on the end portion of the roll 4aa having a uniform diameter, and the second stand 3_2 rolls the steel sheet S with a linear load of 0.8 t/mm or more.

[0067] When the second stand 3_2 rolls the steel sheet S with a linear load of less than 1.4 t/mm, the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ which is a length of the taper 4ab, facing the steel sheet S, which is formed on the tapered work roll 4a1 of the second stand 3_2 as ± 0 mm to +50 mm.

[0068] Meanwhile, when the second stand 3_2 rolls the steel sheet S with a linear load of 1.4 t/mm or more, the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ which is a length of the taper 4ab, facing the steel sheet S, which is formed on the tapered work roll 4a1 of the second stand 3_2 as -50 mm to -5 mm.

[0069] Therefore, the edge drop ratio on the first stand 3_1 to the fourth stand 3_4 is kept within the appropriate range, and the occurrence of edge crack on the steel sheet S as the material to be rolled during the cold rolling is sufficiently suppressed, thereby suppressing the sheet breakage.

[0070] In the cold-rolled steel sheet manufacturing method according to the first embodiment, the steel sheet S is cold-rolled by the cold rolling method according to the first embodiment to manufacture the cold-rolled steel sheet.

(Second Embodiment)

[0071] Next, cold rolling equipment according to a second embodiment of the present invention will be described with reference to FIG. 15. FIG. 15 illustrates a schematic configuration of cold rolling equipment according to a second embodiment of the present invention. In FIG. 15, the same reference numerals are used for the same members as the members of FIG. 1 and the description thereof may be omitted. In FIG. 15, for reference, the N-th stand 3_N is parenthesized and written together with the second stand 3_2 , the (N + 1)-th stand 3_{N+1} is parenthesized and written together with the third stand 3_3 , and the (N + 2)-th stand 3_{N+2} is parenthesized and written together with the fourth stand 3_4 .

[0072] Unlike the cold rolling equipment 1 illustrated in FIG. 1, in the cold rolling equipment 1 illustrated in FIG. 15, each work roll 4a of the second stand 3_2 is not only configured with the tapered work roll 4a1 (hatched in FIG. 15), but also each work roll 4a of the third stand 3_3 is configured with the tapered work roll 4a1. Each work roll 4a of the first stand 3_1 and the fourth stand 3_4 is configured with the flat work roll 4a2.

[0073] The reason why each work roll 4a of the second stand 3_2 and each work roll 4a of the third stand 3_3 is configured with the tapered work roll 4a1 as described above will be described below.

[0074] FIG. 16 illustrates an edge drop ratio on each stand when each stand rolls a steel sheet with a linear load of 1.7 t/m, in a case where the work rolls of all the first stand to the fourth stand are set as the flat work rolls, in a case where only the work roll of the second stand is set as the tapered work roll (the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand 3_2 is set as -50 mm to -5 mm) and the work rolls of the other stands are set as the flat work rolls, and in a case where the work rolls of the second stand and the third stand are set as the tapered work rolls (each of the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand 3_2 and the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the third stand 3_3 is set as -50 mm to -5 mm) and the work roll of the other stands are set as the flat work rolls.

[0075] As illustrated in FIG. 16, in a case where the second stand 3_2 having the tapered work rolls 4a1 (the tapered rolling portion width $WR\delta$ of the second stand 3_2 is set as -50 mm to -5 mm) rolls an electromagnetic steel sheet with a linear load of 1.7 t/mm, the edge drop ratio of the first stand 3_1 to the fourth stand 3_4 is set in the suitable range, without a great increase. The same effect is also exhibited in a case where the second stand 3_2 having the tapered work rolls 4a1 (the tapered rolling portion width $WR\delta$ of the second stand 3_2 is set as -50 mm to -5 mm) rolls the electromagnetic steel sheet with a large linear load of greater than 1.7 t/mm.

[0076] On the other hand, as illustrated in FIG. 16, in a case where the second stand 3_2 and the third stand 3_3 having two continuous tapered work rolls 4a1 (each of the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the second stand 3_2 and the tapered rolling portion width $WR\delta$ of the tapered work roll 4a1 of the third stand 3_3 is set as -50

mm to -5 mm) rolls the electromagnetic steel sheet with a linear load of 1.7 t/mm, an increase ratio from the edge drop ratio on the second stand 3₂ to the edge drop ratio on the third stand 3₃ can be suppressed to be smaller than that in a case where only the work roll 4a of the second stand 3₂ is set as the tapered work roll 4a1. The same effect is also exhibited in a case where the second stand 3₂ and the third stand 3₃ having the two continuous tapered work rolls 4a1 roll the electromagnetic steel sheet with a linear load greater than 1.7 t/mm.

[0077] Accordingly, a tension applied to an edge portion on the third stand 3₃ is further reduced, and edge crack of the steel sheet can be more appropriately suppressed.

[0078] Therefore, in the cold rolling equipment 1 illustrated in FIG. 15, by assuming that the steel sheet S as the material to be rolled is rolled with a linear load of 1.7 t/mm or more, each work roll 4a of the second stand 3₂ is not only configured with the tapered work roll 4a1, but also each work roll 4a of the third stand 3₃ is configured with the tapered work roll 4a1.

[0079] However, in a case where the linear load of the second stand 3₂ and the third stand 3₃ having the tapered work rolls 4a1 is set as 1.7 t/mm or more, the tapered rolling portion width WR δ of the tapered work rolls 4a1 of the second stand 3₂ and the third stand 3₃ is set as -50 mm to -5 mm, due to the same reason as described above in the first embodiment.

[0080] As described above, in the cold rolling equipment 1 according to the second embodiment, among the four stands of the first stands 3₁ to the fourth stands 3₄, the second stand 3₂ arranged in the second position from the upstream side of the steel sheet S, as the material to be rolled, in the transfer direction and the third stand 3₃ arranged in the third position on the downstream side of the second stand 3₂ include the tapered work roll 4a1 having the taper 4ab formed on the end portion of the roll 4aa having a uniform diameter. The linear load of the second stand 3₂ and the third stand 3₃ is set as 1.7 t/mm or more, and the tapered rolling portion width WR δ which is a length of the taper 4ab, facing the steel sheet S, which is formed on the tapered work roll 4a1 of each of the second stand 3₂ and the third stand 3₃ is set as -50 mm to -5 mm.

[0081] Therefore, the edge drop ratio on the first stand 3₁ to the fourth stand 3₄ is kept within the appropriate range, and the occurrence of edge crack on the steel sheet S as the material to be rolled during the cold rolling is more sufficiently suppressed, thereby suppressing the sheet breakage.

[0082] In addition, in the cold rolling equipment 1 according to the second embodiment, among the four stands of first stands 3₁ to the fourth stand 3₄, the fourth stand 3₄ arranged in the fourth position on the downstream side of the third stand 3₃ includes the flat work roll 4a2 having a uniform diameter.

[0083] Accordingly, the effect of promoting the edge drop is exhibited.

[0084] In addition, in the cold rolling equipment 1 according to the second embodiment, among the four stands of first stands 3₁ to the fourth stands 3₄, the first stand 3₁ arranged on the uppermost stream side includes the flat work roll 4a2, but may include the tapered work roll 4a1.

[0085] Accordingly, the effect of suppressing the edge drop is exhibited.

[0086] In addition, in a cold rolling method according to the second embodiment, the steel sheet S as the material to be rolled is cold-rolled by the rolling mill 2 in the cold rolling equipment 1 illustrated in FIG. 1. In this case, the second stand 3₂ and the third stand 3₃ among the four stands of first stands 3₁ to fourth stands 3₄ include the tapered work roll 4a1 having the taper 4ab formed on the end portion of the roll 4aa having a uniform diameter. The second stand 3₂ and the third stand 3₃ roll the steel sheet S with a linear load of 1.7 t/mm or more, and by setting the tapered rolling portion width WR δ which is a length of the taper 4ab, facing the steel sheet S, which is formed on the tapered work roll 4a1 of each of the second stand 3₂ and the third stand 3₃ as -50 mm to -5 mm.

[0087] Therefore, the edge drop ratio on the first stand 3₁ to the fourth stand 3₄ is kept within the appropriate range, and the occurrence of edge crack on the steel sheet S as the material to be rolled during the cold rolling is more sufficiently suppressed, thereby suppressing the sheet breakage.

[0088] Here, the configuration of the tapered work roll 4a1 is the same as that illustrated in FIG. 2, and on the tapered work roll 4a1, the taper 4ab which is tapered is formed on an end portion of the roll 4aa having a uniform diameter in a body length direction. The work roll 4a, which is the tapered work roll 4a1, is configured to be shifted in an axial direction (a roll body length direction, a sheet width direction of the steel sheet S).

[0089] When a case where the width direction end surface of the steel sheet S protrudes from the taper start end 4ac is set as negative, and when a case where the width direction end surface of the steel sheet S is recessed than the taper start end 4ac is set as positive, as described above, the steel sheet S is rolled by setting the tapered rolling portion width WR δ which is a length of the taper 4ab facing the steel sheet S as -50 mm to -5 mm. In addition, the inclination L/H of the taper 4ab is preferably 1/800 to 1/400 as described above.

[0090] By the way, even when the tapered work roll 4a1 is used, if the tapered rolling portion width WR δ is greater than 0 mm on the positive side, the flat work roll 4a2 can be used.

[0091] Therefore, in both the cold rolling equipment 1 of the first embodiment and the second embodiment, each work roll 4a of the second stand 3₂ and each work roll 4a of the third stand 3₃ are set as the tapered work roll 4a1, and the steel sheet can also be rolled in a preferred aspect by shifting each work roll 4a in the axial direction according to the

linear load.

[0092] That is, when the linear load is 0.8 t/mm or more and less than 1.4 t/mm, the tapered work roll 4a1 may be used as the flat work roll 4a2 by shifting each work roll 4a in the axial direction so that the tapered rolling portion width $WR\delta$ in the second stand 3₂ is set as ± 0 mm to +50 mm and the tapered rolling portion width $WR\delta$ in the third stand 3₂ is greater than 0 mm.

[0093] In addition, when the linear load is 1.4 t/mm or more and less than 1.7 t/mm, the work roll may be used as the flat work roll 4a2 by shifting each work roll 4a in the axial direction so that the tapered rolling portion width $WR\delta$ in the second stand 3₂ is set as -50 mm to -5 mm and the tapered rolling portion width $WR\delta$ in the third stand 3₃ is greater than 0 mm.

[0094] Furthermore, when the linear load is 1.7 t/mm or more, the work roll may be used as the tapered work roll 4a1 by shifting each work roll 4a in the axial direction so that the tapered rolling portion width $WR\delta$ of each of the second stand 3₂ and the third stand 3₃ is set as -50 mm to -5 mm.

[0095] In the cold-rolled steel sheet manufacturing method according to the second embodiment, the steel sheet S is cold-rolled by the cold rolling method according to the second embodiment to manufacture the cold-rolled steel sheet.

[0096] Although the embodiments of the present invention have been described above, the present invention is not limited thereto and can be modified and improved in various ways.

[0097] In the first embodiment and the second embodiment, the rolling mill (tandem rolling mill) 2 including the four stands of the first stands 3₁ to the fourth stands 3₄ was described as an example, but the number of stands is not limited thereto, and the rolling mill 2 including five or more stands may be used. When five or more stands are provided, in a case where the number of stands including the work roll 4a as the tapered work roll 4a1 is one as in the first embodiment, one stand may be selected from stands in a preceding stage, except a stand on the uppermost stream side. In addition, when the number of stands including the work roll 4a as the tapered work roll 4a1 is two continuously provided as in the second embodiment, at least one stand among these may be one stand selected from the stands in a preceding stage may be used, except for a stand on the uppermost stream side.

[0098] Further, in the first embodiment, the tapered work roll 4a1 is applied to the second stand 3₂, and this is because that, in the rolling mill 2 of the first embodiment, since the breakage occurs on the third stand 3₃, the stand on the upstream side thereof is selected. In the second embodiment, the tapered work roll 4a1 is applied to the second stand 3₂ and the third stand 3₃, and this is also because the breakage occurs on the third stand 3₃. In the first and second embodiments, the tapered work roll 4a1 may be applied to other stands according to the configuration of the rolling mill (tandem rolling mill) 2 or the like.

[0099] Based on the above, in the cold rolling method, the cold rolling equipment, and the cold-rolled steel sheet manufacturing method according to the present invention, among the plurality of stands 3₁ to 3₄, the N-th stand 3_N arranged in the N-th position (N is a natural number equal to or greater than 2) from the upstream side of the steel sheet S, as the material to be rolled, in the transfer direction includes the tapered work roll 4a1 having the taper 4ab formed on the end portion of the roll 4aa having a uniform diameter. Then, on the N-th stand 3_N, the steel sheet S as the material to be rolled is rolled with a linear load of 0.8 t/mm or more.

[0100] In addition, when the N-th stand 3_N rolls the steel sheet S with a linear load of less than 1.4 t/mm, it is preferable that the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ which is a length of the taper 4ab, facing the steel sheet S, which is formed on the tapered work roll 4a1 of the N-th stand 3_N as ± 0 mm to +50 mm.

[0101] Meanwhile, when the N-th stand 3_N rolls the steel sheet S with a linear load of 1.4 t/mm or more, it is preferable that the steel sheet S is rolled by setting the tapered rolling portion width $WR\delta$ which is a length of the taper 4ab, facing the steel sheet S, which is formed on the tapered work roll 4a1 of the N-th stand 3_N as -50 mm to -5 mm.

[0102] In the cold rolling method, the cold rolling equipment, and the cold-rolled steel sheet manufacturing method according to the present invention, it is preferable that, among the plurality of stands 3₁ to 3₄, the (N + 1)-th stand 3_{N+1} arranged in the (N + 1)-th position on the downstream side of the N-th stand 3_N includes the flat work roll 4a2 having a uniform diameter of the roll to roll the steel sheet S as the material to be rolled.

[0103] In addition, in the cold rolling method, the cold rolling equipment, and the cold-rolled steel sheet manufacturing method according to the present invention, among the plurality of stands 3₁ to 3₄, the N-th stand 3_N arranged in the N-th position (N is a natural number equal to or greater than 2) from the upstream side of the steel sheet S, as the material to be rolled, in the transfer direction and the (N + 1)-th stand 3_{N+1} arranged in the (N + 1)-th position on the downstream side of the N-th stand 3_N include the tapered work roll 4a1 having the taper 4ab formed on the end portion of the roll 4aa having a uniform diameter. The N-th stand 3_N and the (N + 1)-th stand 3_{N+1} rolls the steel sheet S with a linear load of 1.7 t/mm or more, and by setting the tapered rolling portion width $WR\delta$ which is a length of the taper 4ab, facing the steel sheet S, which is formed on the tapered work roll 4a1 of each of the N-th stand 3_N and the (N + 1)-th stand 3_{N+1} as -50 mm to -5 mm.

[0104] In the cold rolling method, the cold rolling equipment, and the cold-rolled steel sheet manufacturing method according to the present invention, it is preferable that, among the plurality of stands 3₁ to 3₄, the (N + 2)-th stand 3_{N+2} arranged in the (N + 2)-th position on the downstream side of the (N + 1)-th stand 3_{N+1} includes the flat work roll 4a2

having a uniform diameter of the roll to roll the steel sheet S as the material to be rolled.

[0105] In addition, in the first and second embodiments, the electromagnetic steel sheet was used as the material to be rolled in the test, but the steel type of the steel sheet S is not limited to the electromagnetic steel sheet. A stainless steel sheet, a high-carbon steel sheet, an electromagnetic steel sheet, and the like are known as steel types in which edge cracks are generally likely to occur on the edge portion, and a significant effect is exhibited by using the cold rolling method, the cold rolling equipment, and the cold-rolled steel sheet manufacturing method of the present invention.

Examples

[0106] In order to verify the effect of the present invention, the cold rolling was performed using the cold rolling equipment 1 under conditions illustrated in Tables 5 and 6. In Tables 5 and 6, a rolling reduction is calculated based on a sheet thickness of the material to be rolled on an inner side of the first stand 3₁ and a sheet thickness of the material to be rolled on the outer side of the fourth stand 3₄.

[Table 5]

	Material to be rolled	Rolling reduction	Tapered work roll				Edge drop ratio (-) of corresponding stand	Edge drop ratio (-) of next stand	Presence or absence of edge crack
			WR δ (mm)	Taper inclination	Applied STD	Linear load (t/mm)			
Invention Example 1	Electromagnetic steel sheet A	90.2%	-50	1/800	Second STD	1.45	-0.01	-0.02	Absent
Invention Example 2	Electromagnetic steel sheet A	90.2%	-30	1/800	Second STD	1.45	-0.02	-0.03	Absent
Invention Example 3	Electromagnetic steel sheet A	90.2%	-20	1/800	Second STD	1.45	-0.02	-0.02	Absent
Invention Example 4	Electromagnetic steel sheet A	90.2%	-5	1/800	Second STD	1.45	-0.04	-0.03	Absent
Comparative Example 1	Electromagnetic steel sheet A	90.2%	-60	1/800	Second STD	1.45	+0.02	-0.02	Present
Comparative Example 2	Electromagnetic steel sheet A	90.2%	+5	1/800	Second STD	1.45	-0.10	+0.05	Present
Comparative Example 3	Electromagnetic steel sheet A	90.2%	-	-	-	1.45	-0.07	+0.03	Present
Invention Example 5	Electromagnetic steel sheet B	90.2%	-50	1/800	Second STD	1.6	-0.02	-0.01	Absent
Invention Example 6	Electromagnetic steel sheet B	90.2%	-30	1/800	Second STD	1.6	-0.03	-0.04	Absent
Invention Example 7	Electromagnetic steel sheet B	90.2%	-20	1/800	Second STD	1.6	-0.03	-0.03	Absent
Invention Example 8	Electromagnetic steel sheet B	90.2%	-5	1/800	Second STD	1.6	-0.05	-0.02	Absent
Comparative Example 4	Electromagnetic steel sheet B	90.2%	-60	1/800	Second STD	1.6	+0.06	-0.03	Present
Comparative Example 5	Electromagnetic steel sheet B	90.2%	+5	1/800	Second STD	1.6	-0.11	+0.07	Present

(continued)

	Material to be rolled	Rolling reduction	Tapered work roll				Edge drop ratio (-) of corresponding stand	Edge drop ratio (-) of next stand	Presence or absence of edge crack
			WR δ (mm)	Taper inclination	Applied STD	Linear load (t/mm)			
Comparative Example 6	Electromagnetic steel sheet B	90.2%	-	-	-	1.6	-0.08	+0.02	Present
Invention Example 9	Electromagnetic steel sheet C	90.8%	-50	1/800	Second STD	1.65	-0.03	-0.02	Absent
Invention Example 10	Electromagnetic steel sheet C	90.8%	-30	1/800	Second STD	1.65	-0.04	-0.05	Absent
Invention Example 11	Electromagnetic steel sheet C	90.8%	-20	1/800	Second STD	1.65	-0.04	-0.04	Absent
Invention Example 12	Electromagnetic steel sheet C	90.8%	-5	1/800	Second STD	1.65	-0.06	-0.01	Absent
Comparative Example 7	Electromagnetic steel sheet C	90.8%	-60	1/800	Second STD	1.65	+0.04	-0.04	Present
Comparative Example 8	Electromagnetic steel sheet C	90.8%	+5	1/800	Second STD	1.65	-0.12	+0.07	Present
Comparative Example 9	Electromagnetic steel sheet C	90.8%	-	-	-	1.65	-0.09	+0.03	Present
Invention Example 13	Electromagnetic steel sheet A	90.2%	-30	1/400	Second STD	1.45	-0.01	-0.03	Absent
Invention Example 14	Electromagnetic steel sheet H	93.2%	-30	1/800	Second and third STDs	1.72	-0.01	-0.03	Absent
Invention Example 15	Stainless steel sheet	83.3%	-30	1/800	Second STD	1.68	-0.03	-0.02	Absent
Invention Example 16	High-carbon steel sheet	65.8%	-30	1/800	Second STD	1.69	-0.03	-0.03	Absent

[Table 6]

	Material to be rolled	Rolling reduction	Tapered work roll				Edge drop ratio (-) of corresponding stand	Edge drop ratio (-) of next stand	Presence or absence of edge crack
			WRδ (mm)	Taper inclination	Applied STD	Linear load (t/mm)			
Reference Example 1	Electromagnetic steel sheet D	511 %	-5	1/800	Second STD	0.75	+0.07	-0.02	Present
Reference Example 2	Electromagnetic steel sheet D	51.1%	0	1/800	Second STD	0.75	-0.01	-0.01	Absent
Reference Example 3	Electromagnetic steel sheet D	511 %	60	1/800	Second STD	0.75	-0.03	-0.02	Absent
Reference Example 4	Electromagnetic steel sheet D	51.1%	-	-	-	0.75	-0.02	-0.02	Absent
Invention Example 17	Electromagnetic steel sheet E	53.6%	0	1/800	Second STD	0.85	-0.01	-0.01	Absent
Invention Example 18	Electromagnetic steel sheet E	53.6%	+20	1/800	Second STD	0.85	-0.01	-0.02	Absent
Invention Example 19	Electromagnetic steel sheet E	53.6%	+30	1/800	Second STD	0.85	-0.01	-0.02	Absent
Invention Example 20	Electromagnetic steel sheet E	53.6%	+50	1/800	Second STD	0.85	-0.02	-0.01	Absent
Comparative Example 10	Electromagnetic steel sheet E	53.6%	+60	1/800	Second STD	0.85	-0.03	+0.02	Present
Comparative Example 11	Electromagnetic steel sheet E	53.6%	-5	1/800	Second STD	0.85	+0.04	-0.02	Present
Comparative Example 12	Electromagnetic steel sheet E	53.6%	-	-	-	0.85	-0.03	+0.01	Present
Invention Example 21	Electromagnetic steel sheet F	63.0%	0	1/800	Second STD	1.25	-0.02	-0.01	Absent
Invention Example 22	Electromagnetic steel sheet F	63.0%	+20	1/800	Second STD	1.25	-0.02	-0.02	Absent

(continued)

	Material to be rolled	Rolling reduction	Tapered work roll				Edge drop ratio (-) of corresponding stand	Edge drop ratio (-) of next stand	Presence or absence of edge crack
			WR δ (mm)	Taper inclination	Applied STD	Linear load (t/mm)			
Invention Example 23	Electromagnetic steel sheet F	63.0%	+30	1/800	Second STD	1.25	-0.03	-0.03	Absent
Invention Example 24	Electromagnetic steel sheet F	63.0%	+50	1/800	Second STD	1.25	-0.05	-0.02	Absent
Comparative Example 13	Electromagnetic steel sheet F	63.0%	+60	1/800	Second STD	1.25	-0.07	+0.03	Present
Comparative Example 14	Electromagnetic steel sheet F	63.0%	-5	1/800	Second STD	1.25	+0.02	-0.02	Present
Comparative Example 15	Electromagnetic steel sheet F	63.0%	-	-	-	1.25	-0.06	+0.02	Present
Invention Example 25	Electromagnetic steel sheet G	70.2%	0	1/800	Second STD	1.35	-0.03	-0.02	Absent
Invention Example 26	Electromagnetic steel sheet G	70.2%	+20	1/800	Second STD	1.35	-0.03	-0.03	Absent
Invention Example 27	Electromagnetic steel sheet G	70.2%	+30	1/800	Second STD	1.35	-0.04	-0.04	Absent
Invention Example 28	Electromagnetic steel sheet G	70.2%	+50	1/800	Second STD	1.35	-0.06	-0.03	Absent
Comparative Example 16	Electromagnetic steel sheet G	70.2%	+60	1/800	Second STD	1.35	-0.08	+0.02	Present
Comparative Example 17	Electromagnetic steel sheet G	70.2%	-5	1/800	Second STD	1.35	+0.01	-0.03	Present
Comparative Example 18	Electromagnetic steel sheet G	70.2%	-	-	-	1.35	-0.07	+0.01	Present

[0107] The rolling was performed by setting the material to be rolled as an electromagnetic steel sheet A in Invention Examples 1 to 4, setting the material to be rolled as an electromagnetic steel sheet B in Invention Examples 5 to 8, setting the material to be rolled as an electromagnetic steel sheet C in Invention Examples 9 to 12, applying the tapered work roll 4a1 to the second stand 3₂, setting the linear load of the second stand 3₂ as 1.4 t/mm or more, and setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as -50 mm to -5 mm which is in the range. In any of Invention Examples 1 to 12, the edge drop ratio of the stand (the second stand 3₂) and the next stand (the third stand 3₃) was within the suitable range, and there were no edge cracks in each of Invention Examples 1 to 12.

[0108] In addition, the rolling was performed by setting the material to be rolled as the electromagnetic steel sheet A in Comparative Example 1, setting the material to be rolled as the electromagnetic steel sheet B in Comparative Example 4, setting the material to be rolled as the electromagnetic steel sheet C in Comparative Example 7, applying the tapered work roll 4a1 to the second stand 3₂, setting the linear load of the second stand 3₂ as 1.4 t/mm or more, and setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as -60 mm which is beyond the range in the negative direction. In any of Comparative Examples 1, 4, and 7, the stand (the second stand 3₂) was edged up, and edge cracks were found in each of Comparative Examples 1, 4, and 7.

[0109] The rolling was performed by setting the material to be rolled as the electromagnetic steel sheet A in Comparative Example 2, setting the material to be rolled as the electromagnetic steel sheet B in Comparative Example 5, setting the material to be rolled as the electromagnetic steel sheet C in Comparative Example 8, applying the tapered work roll 4a1 to the second stand 3₂, setting the linear load of the second stand 3₂ as 1.4 t/mm or more, and setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as +5 mm which is beyond the range in the positive direction. In any of Comparative Examples 2, 5, and 8, the next stand (the third stand 3₃) of the stand (the second stand 3₂) was edged up, and edge cracks were found in each of Comparative Examples 2, 5, and 8.

[0110] In addition, the rolling was performed by setting the material to be rolled as the electromagnetic steel sheet A in Comparative Example 3, setting the material to be rolled as the electromagnetic steel sheet B in Comparative Example 6, setting the material to be rolled as the electromagnetic steel sheet C in Comparative Example 9, applying the flat work roll to all the first stand 3₁ to the fourth stand 3₄, and setting the linear load of the second stand 3₂ as 1.4 t/mm or more. In any of Comparative Examples 3, 6, and 9, the next stand (the third stand 3₃) of the stand (the second stand 3₂) including the flat work roll was edged up, and edge cracks were found in each of Comparative Examples 3, 6, and 9.

[0111] In addition, the rolling was performed by setting the material to be rolled as an electromagnetic steel sheet D in Reference Example 1, applying the tapered work roll 4a1 to the second stand 3₂, setting the linear load of the second stand 3₂ as 0.75 t/mm which is beyond the range, and setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as -5 mm. In addition, the rolling was performed by setting the material to be rolled as the electromagnetic steel sheet D in Reference Example 2, applying the tapered work roll 4a1 to the second stand 3₂, setting the linear load of the second stand 3₂ as 0.75 t/mm which is beyond the range, and setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as 0 mm. In addition, the rolling was performed by setting the material to be rolled as the electromagnetic steel sheet D in Reference Example 3, applying the tapered work roll 4a1 to the second stand 3₂, setting the linear load of the second stand 3₂ as 0.75 t/mm which is beyond the range, and setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as +60 mm. Furthermore, the rolling was performed by setting the material to be rolled as the electromagnetic steel sheet D in Reference Example 4, applying the flat work roll to all the first stand 3₁ to the fourth stand 3₄, and setting the linear load of the second stand 3₂ as 0.75 t/mm or more which is beyond the range. In a case of Reference Example 1, due to the shifting of the second stand 3₂ in the negative direction under ultra-light pressure, the second stand 3₂ was edged up and the edge crack occurred. In a case of Reference Examples 2 to 4, the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ was changed to ± 0 mm, +60 mm, and the work roll was changed to flat work roll. The edge drop ratio of the stand (the second stand 3₂) and the next stand (the third stand 3₃) was within the suitable range under ultra-light pressure, and in each of the Reference Examples 2 to 4, there were no edge cracks and the effect of setting the second stand 3₂ to the tapered work roll 4a1 was not exhibited.

[0112] In addition, the rolling was performed by setting the material to be rolled as an electromagnetic steel sheet E in Invention Examples 17 to 20, setting the material to be rolled as an electromagnetic steel sheet F in Invention Examples 21 to 24, setting the material to be rolled as an electromagnetic steel sheet G in Invention Examples 25 to 28, applying the tapered work roll 4a1 to the second stand 3₂, setting the linear load of the second stand 3₂ as 0.8 t/mm or more and less than 1.4 t/mm which is in the range, and setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as ± 0 mm to +50 mm which is in the range. In any of Invention Examples 17 to 25, the edge drop ratio of the stand (the second stand 3₂) and the next stand (the third stand 3₃) was within the suitable range, and there were no edge cracks in each of Invention Examples 1 to 12.

[0113] The rolling was performed by setting the material to be rolled as the electromagnetic steel sheet E in Comparative Example 10, setting the material to be rolled as the electromagnetic steel sheet F in Comparative Example 13, setting the material to be rolled as the electromagnetic steel sheet G in Comparative Example 16, applying the tapered work

roll 4a1 to the second stand 3₂, setting the linear load of the second stand 3₂ as 0.8 t/mm or more and less than 1.4 t/mm, and setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as +60 mm which is beyond the range in the positive direction. In any of Comparative Examples 10, 13, and 16, the next stand (the third stand 3₃) of the stand (the second stand 3₂) was edged up, and edge cracks were found in each of Comparative

Examples 12, 15, and 18.

[0114] In addition, the rolling was performed by setting the material to be rolled as the electromagnetic steel sheet E in Comparative Example 11, setting the material to be rolled as the electromagnetic steel sheet F in Comparative Example 14, setting the material to be rolled as the electromagnetic steel sheet G in Comparative Example 17, applying the tapered work roll 4a1 to the second stand 3₂, setting the linear load of the second stand 3₂ as 0.8 t/mm or more and less than 1.4 t/mm, and setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as -5 mm which is beyond the range in the negative direction. In any of Comparative Examples 11, 14, and 17, the stand (the second stand 3₂) was edged up, and edge cracks were found in each of Comparative Examples 11, 14, and 17.

[0115] In addition, the rolling was performed by setting the material to be rolled as the electromagnetic steel sheet E in Comparative Example 12, setting the material to be rolled as the electromagnetic steel sheet F in Comparative Example 15, setting the material to be rolled as the electromagnetic steel sheet G in Comparative Example 18, applying the flat work roll to all the first stand 3₁ to the fourth stand 3₄, and setting the linear load of the second stand 3₂ as 0.8 t/mm or more and less than 1.4 t/mm. In any of Comparative Examples 14, 17, and 20, the next stand (the third stand 3₃) of the stand (the second stand 3₂) including the flat work roll was edged up, and edge cracks were found in each of Comparative Examples 12, 15, and 18.

[0116] In addition, the rolling was performed by setting the material to be rolled as an electromagnetic steel sheet A in Invention Example 13, applying the tapered work roll 4a1 to the second stand 3₂, setting the linear load of the second stand 3₂ as 1.45 t/mm, and setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as -30 mm which is in the range. The inclination L/H of the taper 4ab of the tapered work roll 4a1 was set to 1/400, which is in the preferred range. In Invention Example 13, the edge drop ratio of the stand (the second stand 3₂) and the next stand (the third stand 3₃) was in the suitable range and there were no edge cracks.

[0117] In addition, the rolling was performed by setting the material to be rolled as an electromagnetic steel sheet H in Invention Example 14, applying the tapered work roll 4a1 to the second stand 3₂ and the third stand 3₃, setting the linear load of the second stand 3₂ and the third stand 3₃ as 1.72 t/mm, and setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of each of the second stand 3₂ and the third stand 3₃ as -30 mm which is in the range. In Invention Example 14, the edge drop ratio of the stand (the second stand 3₂) and the next stand (the third stand 3₃) was in the suitable range and there were no edge cracks.

[0118] In addition, the rolling was performed by setting the material to be rolled as a stainless steel sheet in Invention Example 15, setting the material to be rolled as a high-carbon steel sheet in Invention Example 16, applying the tapered work roll 4a1 to the second stand 3₂, setting the linear load of the second stand 3₂ as 1.4 t/mm or more, and setting the tapered rolling portion width WR δ of the tapered work roll 4a1 of the second stand 3₂ as -30 mm which is in the range. In any of Invention Examples 15 and 16, the edge drop ratio of the stand (the second stand 3₂) and the next stand (the third stand 3₃) was within the suitable range, and there were no edge cracks in each of Invention Examples 15 and 16.

Reference Signs List

[0119]

- 1 cold rolling equipment
- 2 rolling mill
- 3₁ first stand
- 3₂ second stand
- 3₃ third stand
- 3₄ fourth stand
- 3_N N-th stand
- 3_{N+1} (N + 1) -th stand
- 3_{N+2} (N + 2)-th stand
- 4a work roll
- 4a1 tapered work roll
- 4a2 flat work roll
- 4aa roll
- 4ab taper
- 4ac taper start end
- 4b back-up roll

4c intermediate roll
S steel sheet (material to be rolled)

5 Claims

1. A cold rolling method for cold-rolling a material to be rolled by a rolling mill including a plurality of stands,

wherein an N-th stand (N is a natural number equal to or greater than 2) arranged in an N-th position from an upstream side of the material to be rolled in a transfer direction among the plurality of stands, includes a tapered work roll having a taper formed on an end portion of a roll having a uniform diameter, and the N-th stand rolls the material to be rolled with a linear load of 0.8 t/mm or more.

2. The cold rolling method according to claim 1, wherein, in a case where the N-th stand rolls the material to be rolled with a linear load of less than 1.4 t/mm, the material to be rolled is rolled by setting a tapered rolling portion width $WR\delta$ which is a length, which faces the material to be rolled, of the taper formed on the tapered work roll of the N-th stand as ± 0 mm to +50 mm.

3. The cold rolling method according to claim 1 or 2, wherein, in a case where the N-th stand rolls the material to be rolled with a linear load of 1.4 t/mm or more, the material to be rolled is rolled by setting a tapered rolling portion width $WR\delta$ which is a length, which faces the material to be rolled, of the taper formed on the tapered work roll of the N-th stand as -50 mm to -5 mm.

4. The cold rolling method according to any one of claims 1 to 3, wherein, among the plurality of stands, an (N + 1) -th stand arranged in an (N + 1) -th position on a downstream side of the N-th stand rolls the material to be rolled with a flat work roll having a uniform diameter of a roll.

5. A cold rolling method for cold-rolling a material to be rolled by a rolling mill including a plurality of stands,

wherein an N-th stand (N is a natural number equal to or greater than 2) arranged in an N-th position from an upstream side of the material to be rolled in a transfer direction and an (N + 1) -th stand arranged in an (N + 1) -th position on a downstream side of the N-th stand among the plurality of stands, include a tapered work roll having a taper formed on an end portion of a roll having a uniform diameter, and each of the N-th stand and the (N + 1) -th stand rolls the material to be rolled with a linear load of 1.7 t/mm or more and a tapered rolling portion width $WR\delta$ which is a length, which faces the material to be rolled, of the taper formed on the tapered work roll of each of the N-th stand and the (N + 1) -th stand is set as -50 mm to -5 mm.

6. The cold rolling method according to claim 5, wherein, among the plurality of stands, an (N + 2) -th stand arranged in an (N + 2) -th position on a downstream side of the (N + 1) -th stand rolls the material to be rolled with a flat work roll having a uniform diameter of a roll.

7. The cold rolling method according to any one of claims 1 to 6, wherein, among the plurality of stands, a stand arranged on an uppermost stream side of the material to be rolled in the transfer direction rolls the material to be rolled with a flat work roll having a uniform diameter of a roll.

8. Cold rolling equipment including a rolling mill having a plurality of stands for cold-rolling a material to be rolled,

wherein an N-th stand (N is a natural number equal to or greater than 2) arranged in an N-th position from an upstream side of the material to be rolled in a transfer direction among the plurality of stands, includes a tapered work roll having a taper formed on an end portion of a roll having a uniform diameter, and a linear load of the N-th stand is set as 0.8 t/mm or more.

9. The cold rolling equipment according to claim 8, wherein, in a case where a linear load of the N-th stand is set as less than 1.4 t/mm, a tapered rolling portion width $WR5$ which is a length, which faces the material to be rolled, of the taper formed on the tapered work roll of the N-th stand is set as ± 0 mm to +50 mm.

10. The cold rolling equipment according to claim 8 or 9, wherein, in a case where a linear load of the N-th stand is set as 1.4 t/mm or more, a tapered rolling portion width $WR5$ which is a length, which faces the material to be rolled, of

the taper formed on the tapered work roll of the N-th stand is set as -50 mm to -5 mm.

11. The cold rolling equipment according to any one of claims 8 to 10, wherein, among the plurality of stands, an (N + 1) -th stand arranged in an (N + 1) -th position on a downstream side of the N-th stand includes a flat work roll having a uniform diameter of a roll.

12. Cold rolling equipment including a rolling mill having a plurality of stands for rolling a material to be rolled,

wherein each of an N-th stand (N is a natural number equal to or greater than 2) arranged in an N-th position from an upstream side of the material to be rolled in a transfer direction and an (N + 1) -th stand arranged in an (N + 1) -th position on a downstream side of the N-th stand among the plurality of stands, includes a tapered work roll having a taper formed on an end portion of a roll having a uniform diameter, and a linear load of each of the N-th stand and the (N + 1) -th stand is set as 1.7 t/mm or more, and a tapered rolling portion width $WR\delta$ which is a length, which faces the material to be rolled, of the taper formed on the tapered work roll of each of the N-th stand and the (N + 1) -th stand is set as -50 mm to -5 mm.

13. The cold rolling equipment according to claim 12, wherein, among the plurality of stands, an (N + 2)-th stand arranged in an (N + 2)-th position on a downstream side of the (N + 1) -th stand includes a flat work roll having a uniform diameter of a roll.

14. The cold rolling equipment according to any one of claims 8 to 13, wherein, among the plurality of stands, a stand arranged on an uppermost stream side of the material to be rolled in the transfer direction includes a flat work roll having a uniform diameter of a roll.

15. A cold-rolled steel sheet manufacturing method comprising:
cold-rolling a steel sheet to manufacture a cold-rolled steel sheet by the cold rolling method according to any one of claims 1 to 7.

FIG. 1

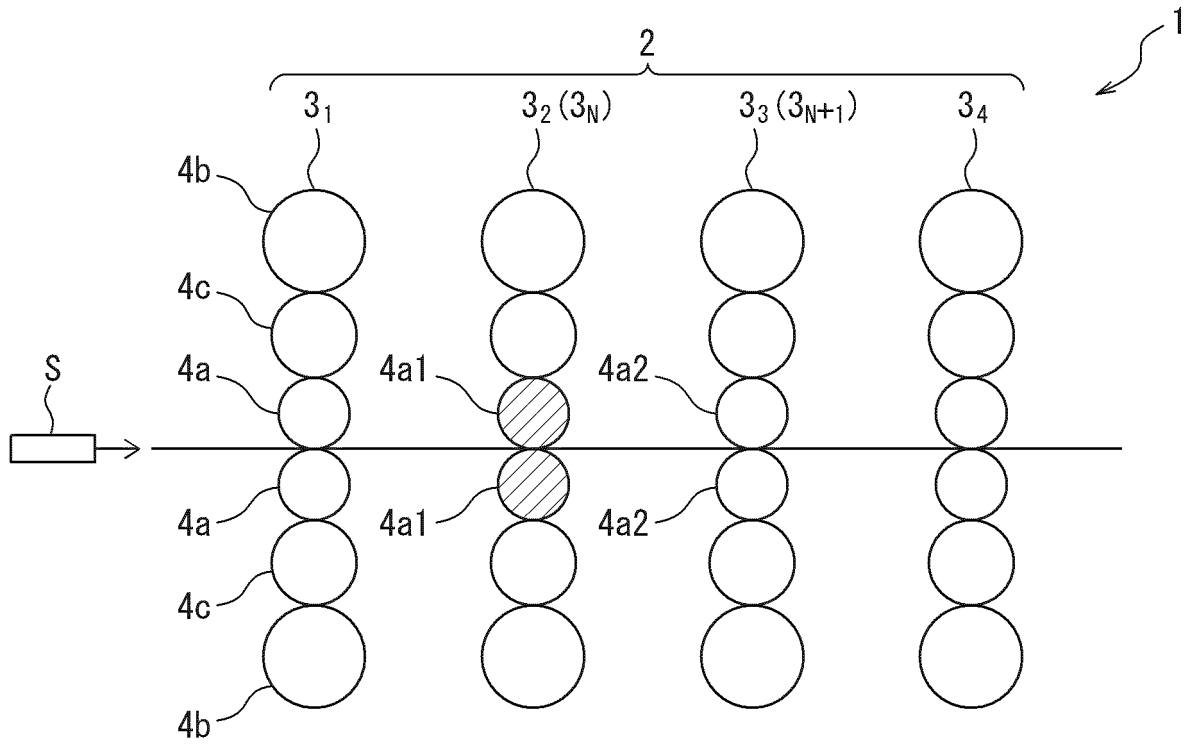


FIG. 2

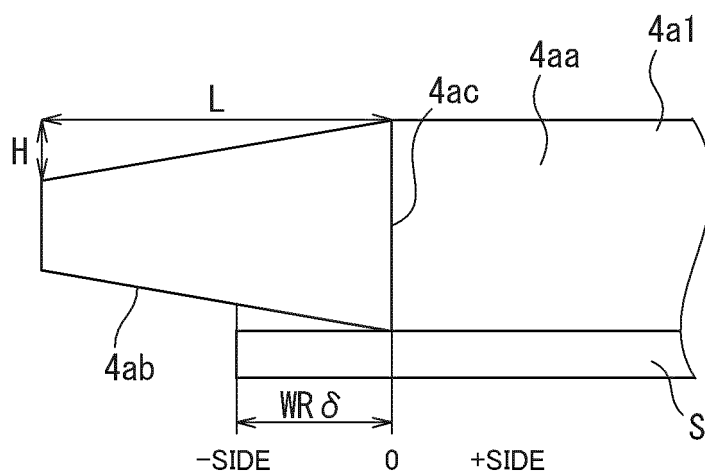


FIG. 3

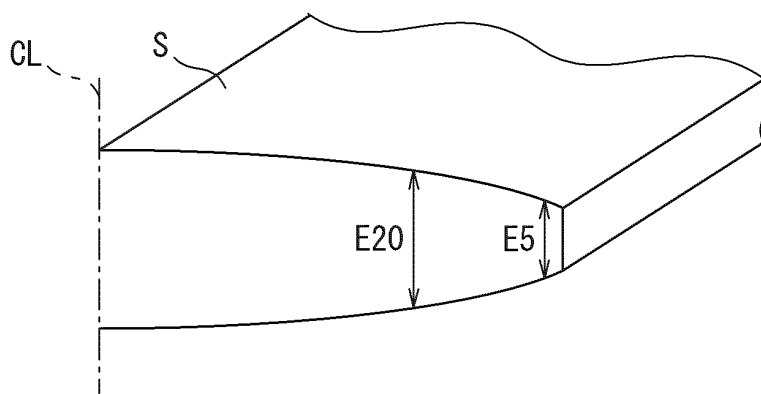


FIG. 4

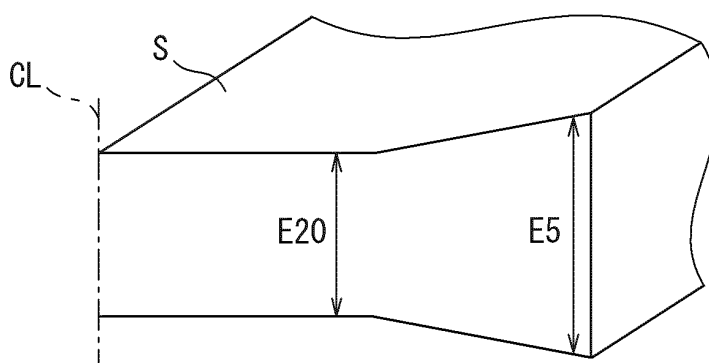


FIG. 5

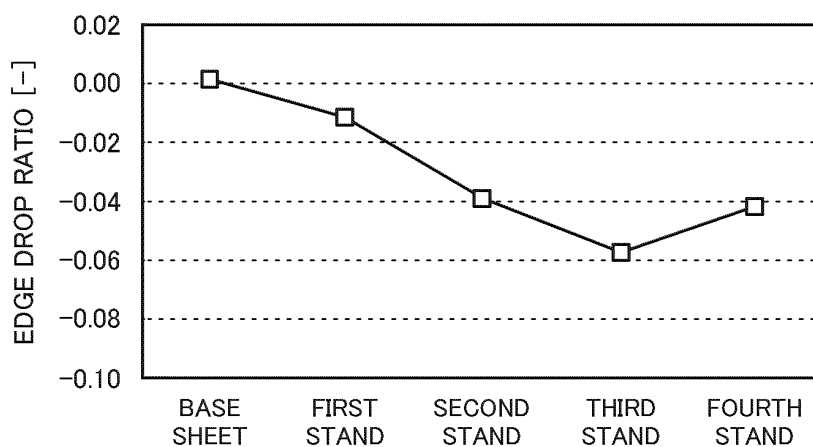


FIG. 6

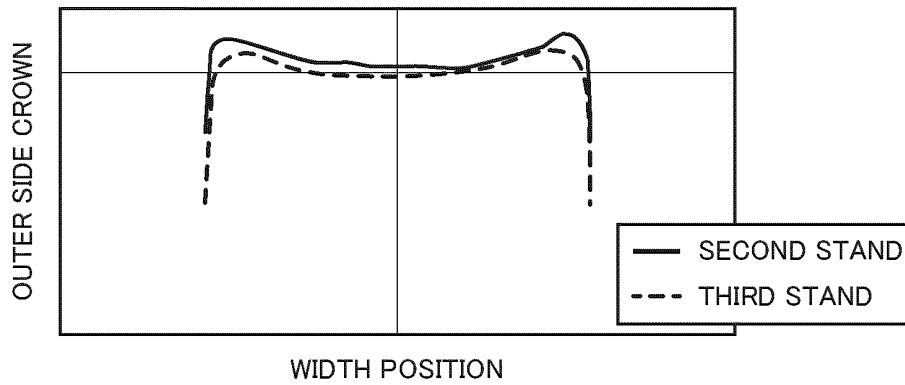


FIG. 7

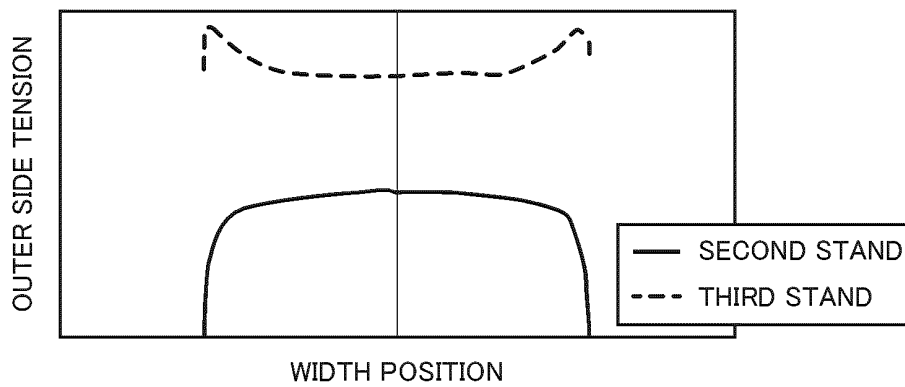


FIG. 8

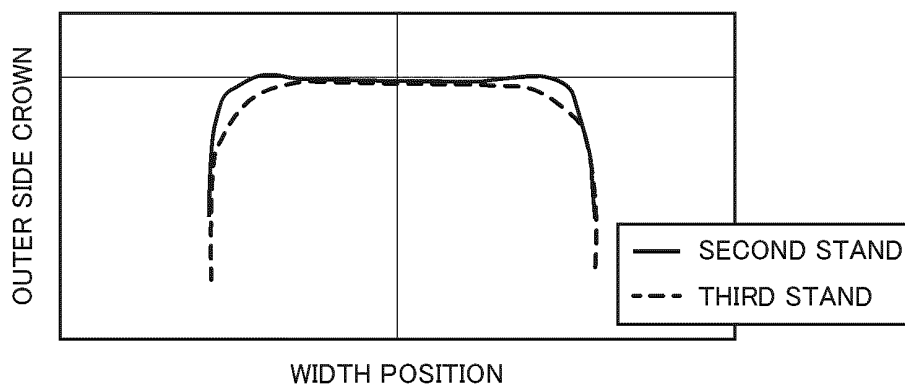


FIG. 9

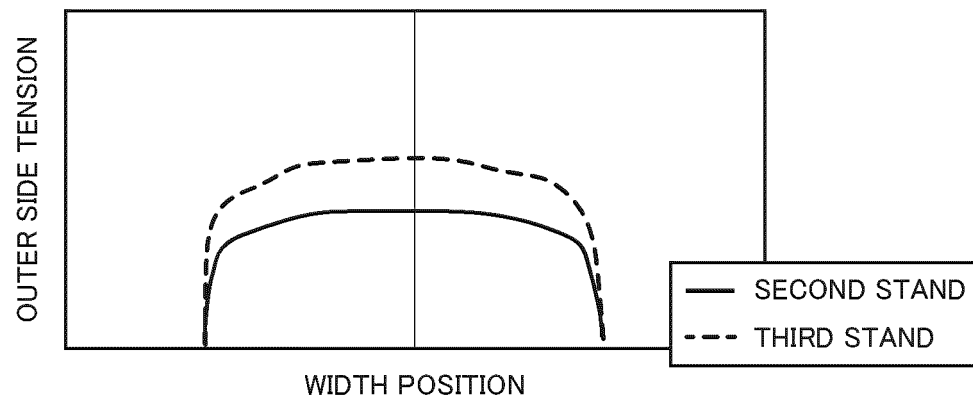


FIG. 10

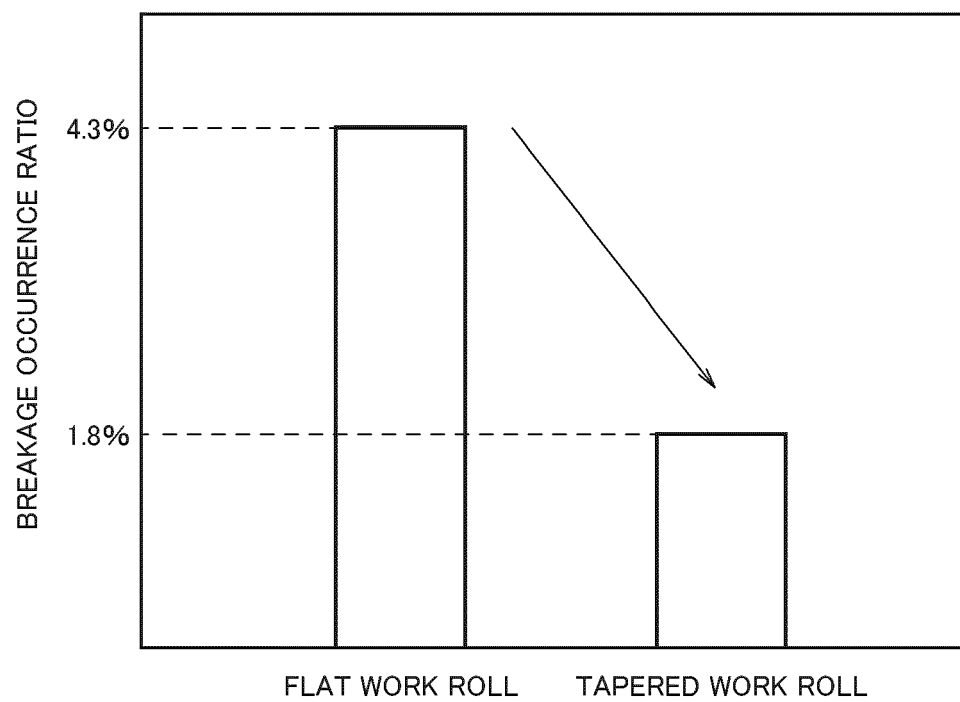


FIG. 11

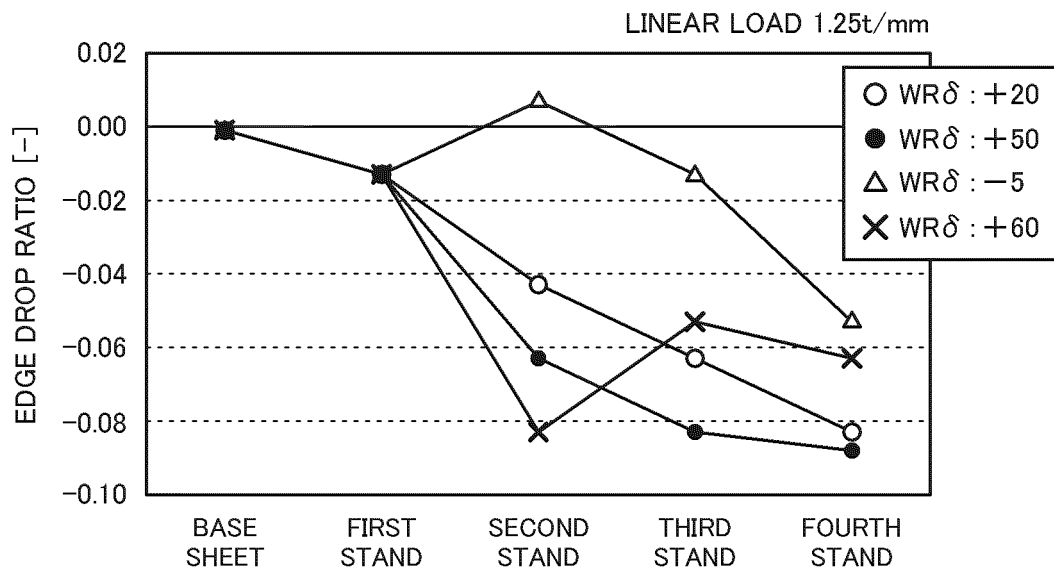


FIG. 12

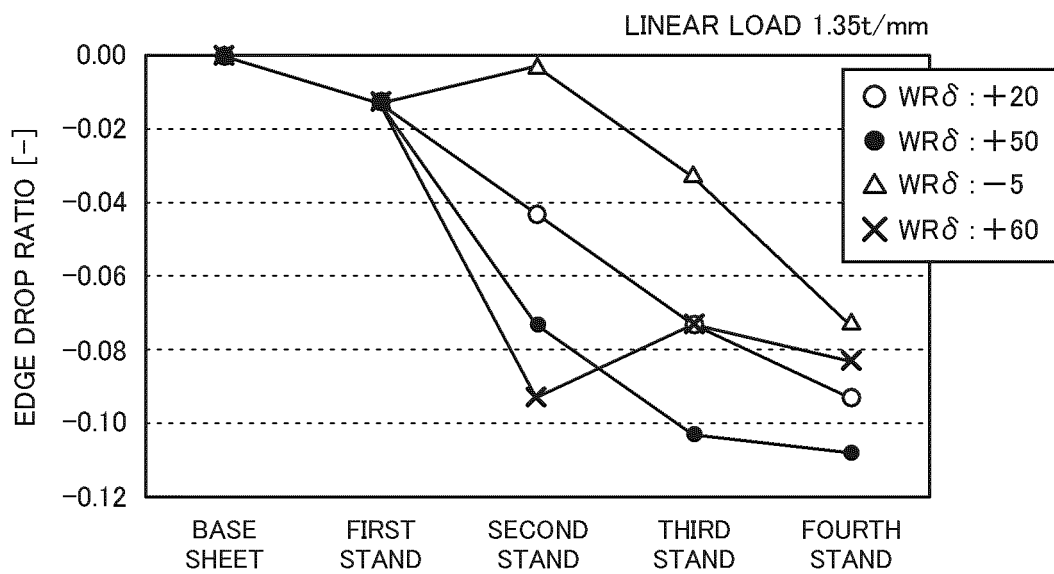


FIG. 13

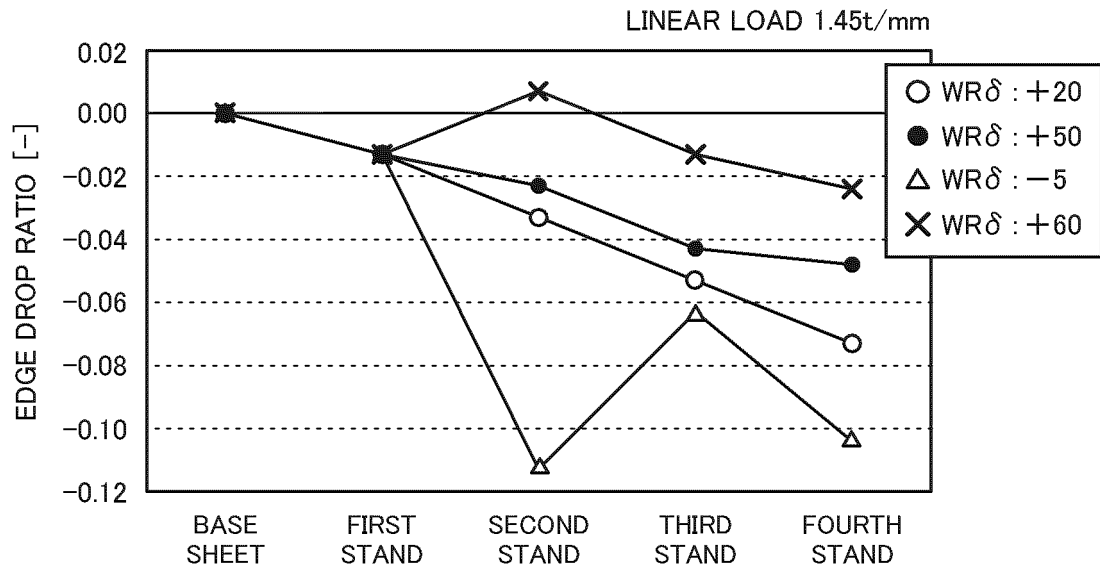


FIG. 14

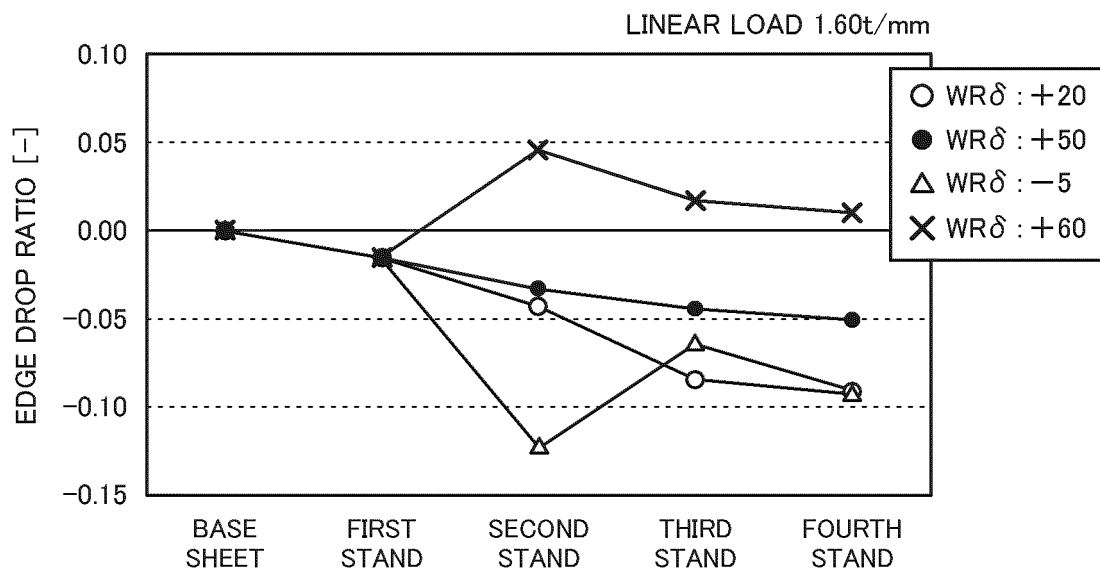


FIG. 15

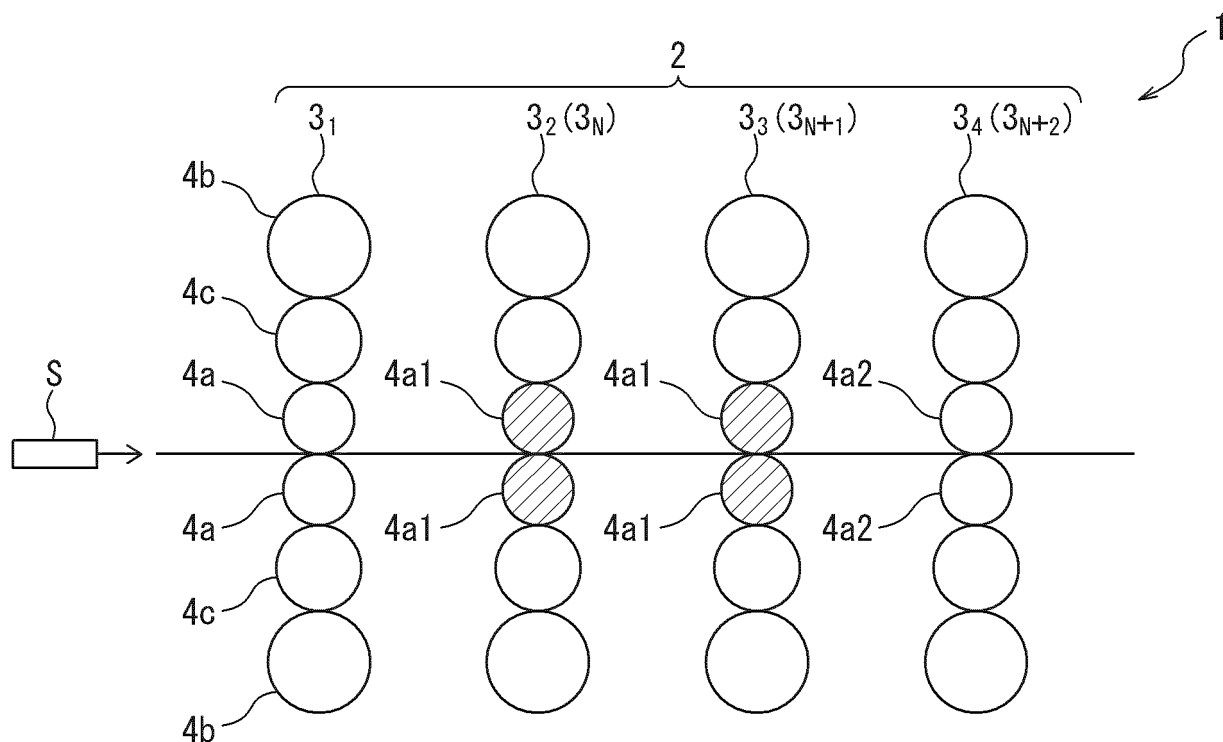
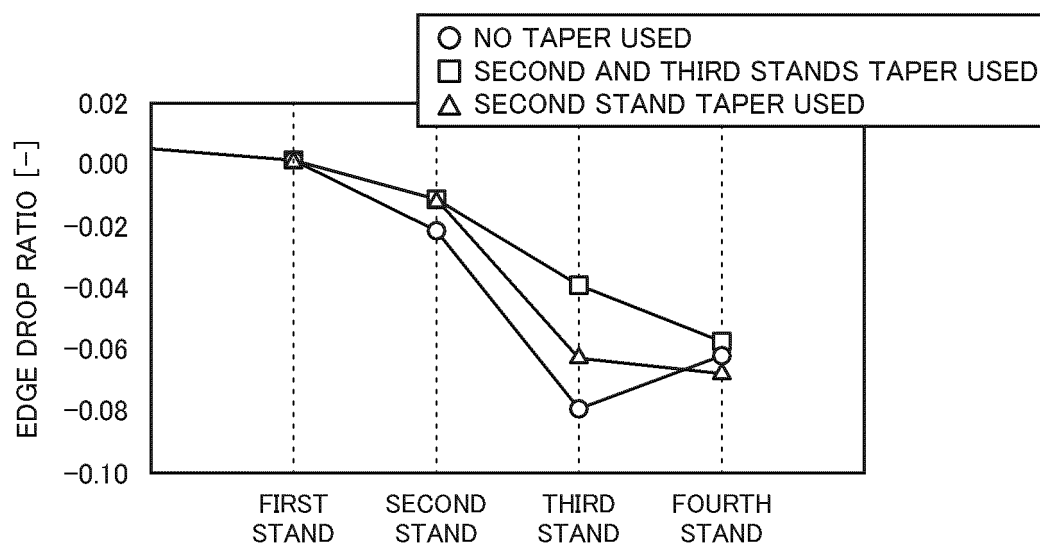


FIG. 16



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/032889

A. CLASSIFICATION OF SUBJECT MATTER

B21B 37/28(2006.01)i; **B21B 37/40**(2006.01)i
FI: B21B37/28 120; B21B37/40 110

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B21B37/28; B21B37/40

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2021
Registered utility model specifications of Japan 1996-2021
Published registered utility model applications of Japan 1994-2021

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 6-91309 A (NIPPON STEEL CORP.) 05 April 1994 (1994-04-05) claims, paragraphs [0006]-[0008], [0021]-[0023], [0025], [0026], fig. 4, 5	1, 4, 8, 11, 15
A		2, 3, 5-7, 9, 10, 12-14
A	JP 8-252618 A (KAWASAKI STEEL CORP.) 01 October 1996 (1996-10-01) claims	1-15
A	JP 5-177213 A (NKK CORP.) 20 July 1993 (1993-07-20) claims	1-15

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

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Date of the actual completion of the international search

07 October 2021

Date of mailing of the international search report

19 October 2021

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)
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Authorized officer

Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2021/032889

5

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP	6-91309	A	05 April 1994	(Family: none)	
JP	8-252618	A	01 October 1996	(Family: none)	
JP	5-177213	A	20 July 1993	(Family: none)	

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP H1029010 A [0006]