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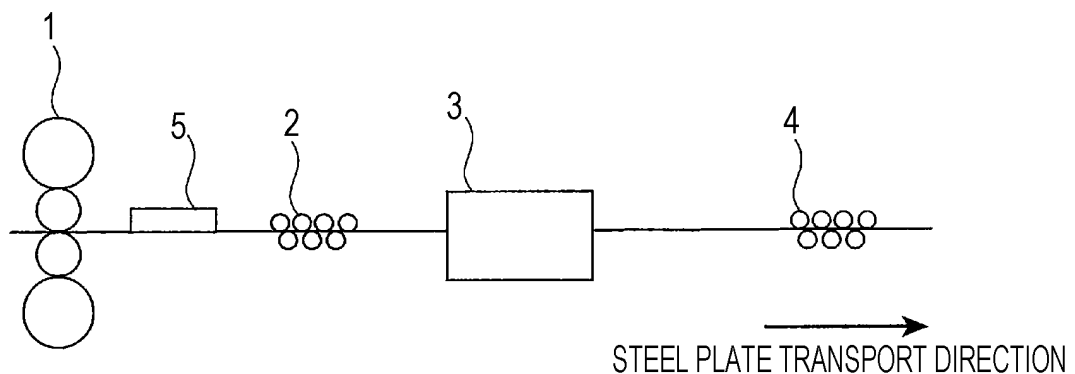
(54) **STEEL PLATE MANUFACTURING EQUIPMENT AND STEEL PLATE MANUFACTURING METHOD**

(57) Provided are a steel-plate manufacturing facility capable of uniformly cooling a hot steel plate through on-line cooling to manufacture a flat steel plate with a uniform quality, and a method for manufacturing a steel plate.

A hot rolling mill, a first shape correction device, and

an accelerated cooling device are arranged in this order. The accelerated cooling device includes dewatering rollers that restrict a steel plate from above and below, and a control system that controls a pressing load P to restrict the steel plate.

FIG. 1



Description

Technical Field

[0001] The present invention relates to a steel-plate manufacturing facility for cooling on-line a hot steel plate that has undergone hot rolling to obtain a high-quality product, and a method for manufacturing a steel plate, and particularly, to a steel-plate manufacturing facility for manufacturing a highly flat steel plate, and a method for manufacturing a steel plate.

Background Art

[0002] Controlled rolling to perform rolling, within a low temperature range or accelerated cooling to cool the rolled steel plates has been performed on-line, particularly for thick steel plates in these years. With improvements of the product quality, highly accurate temperature control, particularly, highly accurate cooling-stop temperature control has been increasingly important.

[0003] Generally, in a hot-rolled steel plate, cooling variation is likely to be caused while undergoing cooling due to the temperature distribution variation or the variation in shape or in surface state of the steel plate immediately after undergoing rolling. Particularly, cooling variation that occurs in a thick steel plate having a relatively large thickness is more likely to attribute to the performance of a cooling device. Cooling variation caused in a thick steel plate causes deformation, residual stress, variations in quality or the like in the thick steel plate. In view of the above, although various types of cooling device that can perform uniform cooling have been developed, the improvement of only the cooling device fails to completely flatten a steel plate, particularly, after cooling. Shape defect of a cooled steel plate causes operation troubles such as plate passage troubles in a manufacturing line, or requires correction in the subsequent process with a press or a correction device, and thus raises costs.

[0004] Causes of cooling variation of a steel plate include those attributable to the characteristics of a cooling nozzle, such as the temperature variation of the upper and lower surfaces or widthwise temperature uniformity, and those attributable to the shape of the steel plate before undergoing cooling.

[0005] To address the cooling variation attributable to the cooling nozzle, such as the temperature variation of the upper and lower surfaces or widthwise temperature uniformity, a large number of technologies have been disclosed thus far. On the other hand, not many but some technologies have been developed to address the cooling variation attributable to shape defect caused during rolling from the following viewpoints.

[0006] A first method is to perform shape correction in front of an accelerated cooling device to flatten the shape for uniform cooling during cooling. Patent Literature 1 describes correction of the shape of a steel plate with a first shape correction device to such an extent that dewatering rollers of the cooling device can fully drain the steel plate. Patent Literature 2 describes determination of the distance from the exit of a shape correction device to the entrance of a cooling device to prevent a flattening failure after cooling due to heat recuperation of a steel plate.

[0007] A second method is to restrict a steel plate with dewatering rollers. The dewatering rollers have two functions of 1) flattening a steel plate with pressure of the rollers and 2) preventing cooling water sprayed onto a cooling area from leaking to the outside.

[0008] Patent Literature 3 is a technology which includes dewatering rollers capable of individually rising and falling vertically and the rollers move upwards and downwards following the profile of a steel plate. Patent Literature 4 is a technology of pressing a steel plate with dewatering rollers with a predetermined load or higher to flatten the deformed steel plate to a predetermined level so as to effectively block the cooling water with reduction of gaps between the steel plate and the rollers.

Citation List

Patent Literature

[0009]

PTL 1: Japanese Unexamined Patent Application Publication No. 2002-11515

PTL 2: Japanese Unexamined Patent Application Publication No. 2005-74480

PTL 3: Japanese Unexamined Patent Application Publication No. 52-73111

PTL 4: Japanese Patent No. 3304816

Summary of Invention

Technical Problem

[0010] In these years, manufacturing lines that operate on-line with the technologies described in Patent Literatures 1 and 2 including a shape correction device in front of a cooling device have been increasing. However, when a cooling device not including dewatering rollers performs cooling, a cooling water that has leaked outside from the cooling water spray area stays on a steel plate, particularly, the upper surface of a steel plate for a long time, and the portion on the upper surface of the steel plate over which the accumulated water stays causes supercooling.

[0011] With the technologies of installing a cooling device on dewatering rollers, such as those described in Patent Literatures 3 and 4, a steel plate is more likely to have shape defect attributable to rolling particularly in a thin thickness area susceptible to shape defect, such as an area having a small thickness (for example, smaller than or equal to 30 mm) and a large width (for example, greater than or equal to 3000 mm). Thus, in a structure not including a shape correction device in front of the cooling device, the dewatering rollers are more likely to fail to appropriately come into contact with the steel plate to block the cooling water, thus allow the cooling water to leak out from the cooling water spray area on the upper surface of the steel plate, and cause supercooling and shape defect attributable to temperature variation.

[0012] The present invention has been made in view of the above circumstances, and aims to provide a steel-plate manufacturing facility capable of manufacturing a flat steel plate with a uniform quality by uniformly cooling a hot steel plate through on-line cooling, and a method for manufacturing a steel plate.

Solution to Problem

[0013] With the earnest study, the inventors of the present invention have found that highly flat steel plates can be manufactured by flattening the shape of the steel plates with a first shape correction device preferably to or below predetermined steepness, and then appropriately restraining the steel plates with dewatering rollers in an accelerated cooling device.

[0014] The gist of the present invention is as follows.

[1] A steel-plate manufacturing facility, including a hot rolling mill, a first shape correction device, and an accelerated cooling device arranged in this order, wherein the accelerated cooling device includes dewatering rollers that restrict a steel plate from above and below, and a control system that controls a pressing load P exerted to restrict the steel plate.

[2] The steel-plate manufacturing facility according to the paragraph [1], wherein the pressing load P satisfies formula (1), below:

$$P \leq 37 \times ((L-W) \times W^2 / (D^4 - d^4))^{-1.25} \dots (1),$$

, where

P denotes a pressing load (ton),

L denotes a roller body length (mm),

W denotes a plate width (mm),

D denotes a roller outer diameter (mm), and

d denotes a roller inner diameter (mm).

[3] The steel-plate manufacturing facility according to the paragraph [1] or [2], wherein a second shape correction device is arranged subsequent to the accelerated cooling device.

[4] The steel-plate manufacturing facility according to any one of the paragraphs [1] to [3], wherein the first shape correction device and/or the second shape correction device are/is roller levelers/a roller leveler.

[5] The steel-plate manufacturing method according to any one of the paragraphs [1] to [4], wherein the first shape correction device corrects a steepness of the steel plate to below 2.0%.

[6] A method for manufacturing a steel plate, including:

arranging a hot rolling mill, a first shape correction device, and an accelerated cooling device in this order; and rolling a steel plate with the hot rolling mill, then correcting a shape of the steel plate with the first shape correction

device, and then cooling the steel plate with the accelerated cooling device while restricting the steel plate from above and below with dewatering rollers at a predetermined pressing load P.

[7] The method for manufacturing a steel plate according to the paragraph [6], wherein the pressing load P satisfies formula (1), below:

$$P \leq 37 \times ((L-W) \times W^2 / (D^4 - d^4))^{-1.25} \dots (1),$$

, where

P denotes a pressing load (ton),
L denotes a roller body length (mm),
W denotes a plate width (mm),
D denotes a roller outer diameter (mm), and
d denotes a roller inner diameter (mm).

[8] The method for manufacturing a steel plate according to the paragraph [6] or [7], wherein a second shape correction device is arranged subsequent to the accelerated cooling device, and the second shape correction device further corrects the shape of the steel plate.

[9] The method for manufacturing a steel plate according to any one of the paragraphs [6] to [8], wherein the first shape correction device and/or the second shape correction device are/is roller levelers/a roller leveler.

[10] The method for manufacturing a steel plate according to any one of the paragraphs [6] to [9], wherein the first shape correction device corrects a steepness of the steel plate to below 2.0%.

Advantageous Effects of Invention

[0015] According to the present invention, flat steel plates with a uniform quality can be manufactured by uniformly cooling hot steel plates through on-line cooling. Brief Description of Drawings

[0016]

[Fig. 1] Fig. 1 is a schematic diagram of a structure of a steel-plate manufacturing facility according to the present invention.

[Fig. 2] Fig. 2 is a schematic diagram illustrating how a steel plate passes through a first shape correction device and an accelerated cooling device.

[Fig. 3] Fig. 3 is a schematic diagram illustrating a gap between a steel plate and dewatering rollers, where Fig. 3(a) illustrates the state where the pressing load of the dewatering rollers is insufficient, Fig. 3(b) illustrates the state where the pressing load of the dewatering rollers is excessive, and Fig. 3(c) illustrates the state where the pressing load of the dewatering rollers is appropriate.

[Fig. 4] Fig. 4 is a graph illustrating the relationship between the pressing load and deflection of the dewatering rollers.

[Fig. 5] Fig. 5 illustrates the definition of steepness λ .

[Fig. 6] Fig. 6 is a graph illustrating the relationship between the steepness and the pressing load with or without cooling water leakage where the roller diameter is 400Φ.

[Fig. 7] Fig. 7 illustrates a model of the pressing load of the dewatering rollers.

[Fig. 8] Fig. 8 is a graph illustrating the relationship between the deflection parameter and the pressing load of the dewatering rollers with or without cooling water leakage from the dewatering rollers. Description of Embodiments

[0017] As illustrated in Fig. 1, a manufacturing facility according to the present invention includes a hot rolling mill 1, a first shape correction device 2, an accelerated cooling device 3, and a second shape correction device 4, arranged in this order. A steel plate 5 undergoes rolling with the hot rolling mill 1, subsequent shape correction with the first shape correction device 2, control cooling with the accelerated cooling device 3, and, as appropriate, shape correction with the second shape correction device 4. The arrow in Fig. 1 indicates the transport direction of the steel plate.

[0018] Fig. 2 is a schematic diagram illustrating how the steel plate 5 passes through the first shape correction device 2 and the accelerated cooling device 3. The steel plate 5 that has undergone rolling with the hot rolling mill 1 is more likely to have shape defect such as edge wave. After being flattened by the first shape correction device 2, the steel plate 5 undergoes control cooling with the accelerated cooling device 3. The accelerated cooling device 3 includes dewatering rollers 31, which restrict the steel plate 5 from above and below, cooling nozzles 32, which allow cooling

water to be sprayed therethrough, and pressing-load control systems 33, which control the pressing load P of the dewatering rollers 31. The cooling nozzles 32 may be arranged between the dewatering rollers 31.

[0019] Fig. 3 is a schematic diagram of gaps between the steel plate 5 and the dewatering rollers 31. When the steel plate has a non-flat shape (for example, concave downward in the steel plate width direction), the steel plate 5 is pressed against the dewatering rollers 31 while being deformed. Thus, for example, with an insufficient pressing load, the dewatering rollers 31 fail to flatten the steel plate 5 that is concave downward as illustrated in Fig. 3(a), and leave gaps between the steel plate 5 and themselves. On the other hand, when the pressing load of the dewatering roller 31 is excessive, the dewatering rollers 31 bend and form gaps between the steel plate 5 and themselves (Fig. 3(b)). It is generally known that flattening a steel plate with a shape defect such as edge wave by pressing it with the dewatering rollers requires a pressing load of approximately several hundreds of tons. Fig. 4 is a graph illustrating the relationship between the pressing load from dewatering rollers with a roller diameter of 300 mm (solid roller) and a body length of 6 m exerted on a steel plate with a plate width of 4000 mm and deflection of the dewatering rollers. Deflection is measured by a clearance gauge. It is assumed that a gap of at least approximately 1 mm or smaller is required to appropriately block water with the dewatering rollers. When the pressing load exceeds several tens of tons, the dewatering rollers deflect more than 1 mm, and when loaded with approximately a hundred tons, each dewatering roller causes a gap of approximately 6 mm, and can no longer exert its function as a dewatering roller.

[0020] To make a gap between the steel plate 5 and each dewatering roller 31 appropriate as illustrated in Fig. 3(c), it is conceivable that the steel plate has a flat initial shape, the pressing load of the dewatering rollers 31 is restricted to a predetermined level or lower, and the pressing load of the predetermined level is required to be retained while the steel plate is passing between the dewatering rollers 31.

[0021] Subsequently, by changing the correction conditions (pressing amount) of the first shape correction device 2 with the manufacturing facility illustrated in Figs. 1 and 2, steel plates with various different shapes are caused to pass through the accelerated cooling device 3 to check the cooling water leakage state. The steel plates have a plate thickness of 30 mm, a plate width of 3500 mm, and a temperature of 850°C. The shape of each steel plate after passing through the first shape correction device 2 is quantified using steepness λ (%), expressed in Fig. 5 and with the definition of the following formula (2), and controlled as appropriate with the pressing amount of the first shape correction device 2. The value δ/p in formula (2) is the mean value of the entire edge wave shape in the longitudinal direction:

$$\lambda = (\delta/p) \times 100 \dots (2)$$

, where

λ denotes steepness (%),
 δ denotes a wave height (mm), and
 p denotes a wave pitch (mm).

[0022] For the dewatering rollers 31 in the accelerated cooling device 3, solid rollers of a body length of 6000 mm, and roller diameters of 300Φ and 400Φ, which fall within a typical roller diameter range for dewatering rollers of accelerated cooling devices, were used.

[0023] Fig. 6 is a graph illustrating the steepness and the pressing load with or without cooling water leakage where the roller diameter is 400Φ. In Fig. 6, circles denote the cases where water did not leak between the steel plate and the rollers, and crosses denote the cases where water leaked between the steel plate and the rollers. The cooling water leakage was visually confirmed.

[0024] The results in Fig. 6 reveal that an excessively large pressing load of the dewatering roller 31 causes cooling water leakage, and an excessively small pressing load also causes cooling water leakage. Thus, the pressing load needs to be adjusted as appropriate. The results also reveal that excessively large steepness of the steel plate 5 also fails to prevent cooling water leakage even with an adjustment of the pressing load. It is assumed that the excessively large pressing load causes the above described deflection of the dewatering rollers 31 to allow the steel plate to be in the state of Fig. 3(b), whereas the insufficient pressing load fails to prevent deformation of the steel plate 5 to allow the steel plate to be in the state of Fig. 3(a).

[0025] The results in Fig. 6 reveal that the steel plate 5 needs to be flattened to a certain level before being transported into the accelerated cooling device 3, and needs to receive a predetermined pressing load. Thus, which level of the pressing load is preferable is studied on the basis of the finding that an excessively large pressing load bends the rollers.

[0026] When deflection of the dewatering rollers 31 is simulated using a model in Fig. 7 from the viewpoint of material mechanics, a deflection amount δ at the center of the dewatering roller 31 in the body length direction can be calculated with the following formula:

[Math 1]

$$\delta = \frac{P(L-W)W^2}{32EI} \quad \dots (3)$$

, where

P denotes the pressing load (ton),

L denotes the body length (mm) of the dewatering roller,

W denotes the plate width (mm),

E denotes the Young's modulus of the dewatering roller (= 21 ton/mm²), and

I denotes the cross sectional secondary moment (mm⁴).

[0027] In the case of a hollow roller, the cross sectional secondary moment I can be described with the following formula:

[Math 2]

$$I = \frac{\pi(D^4 - d^4)}{64} \quad \dots (4)$$

, where

D denotes the outer diameter of the dewatering roller (mm),

d denotes the inner diameter of the dewatering roller (mm), and

π denotes the ratio of the circumference of a circle to its diameter.

[0028] In the case of a solid roller, in the formula (4) representing the cross sectional secondary moment I, the inner diameter d of the dewatering roller 31 may be defined as 0. It is conceived from the above formula that the deflection amount δ of the dewatering roller 31 attributable to the width of the steel plate 5 or the dimensions of the dewatering roller 31 is in proportional to the following parameters:

[Math 3]

$$\delta \propto \frac{(L-W)W^2}{(D^4 - d^4)} \quad \dots (5)$$

[0029] Hereinbelow, the right side of formula (5) is referred to as a deflection parameter.

[0030] Subsequently, to confirm the effect of deflection of rollers on the blocking capability of the dewatering rollers 31, several types of steel plate with a steepness of 0.75% were manufactured in advance, and the steel plates were transported to the accelerated cooling device 3 and were sprayed with cooling water by the accelerated cooling device 3 under various different pressing loads from the dewatering rollers 31 to confirm whether the cooling water leaks. Each of the steel plates had a plate thickness of 30 mm, and a plate width of 2500 mm, 3500 mm, or 5000 mm, and the dewatering rollers, regardless of solid rollers or hollow rollers, had a diameter of 400 mm (the inner diameter of hollow rollers is 32 mm with a thickness of 40 mm), and a roller body length of 6000 mm. Whether the cooling water leakage occurred or not was visually confirmed, and the case where water leakage between the steel plate and the rollers occurred was determined as cooling water leakage (cross, denoting poor) occurring.

[0031] Fig. 8 is a graph illustrating the effect of the pressing load of the dewatering rollers 31 and the deflection parameter, on whether cooling water leakage occurs passing by the dewatering rollers 31. The graph shows that a larger deflection parameter causes cooling water leakage with a lower pressing load. Fig. 8 reveals that the limit of cooling water leakage occurrence has the following relationship:

[Math 4]

$$P = 37 \left\{ \frac{(L-W)W^2}{D^4 - d^4} \right\}^{-1.25} \quad \dots (6)$$

[0032] Specifically, it is found that, when the outer diameter D, the inner diameter d, and the body length L of the dewatering roller 31 are determined, the pressing load P satisfies the formula (1), below, in accordance with the plate width of W, so that the dewatering rollers 31 are prevented from being deflected, and can secure preferable draining performance:

$$P \leq 37 \times ((L-W) \times W^2 / (D^4 - d^4))^{-1.25} \dots (1),$$

where

P denotes the pressing load (ton),
 L denotes the roller body length (mm),
 W denotes the plate width (mm),
 D denotes the roller outer diameter (mm), and
 d denotes the roller inner diameter (mm).

[0033] The lower limit of the pressing load P is preferably higher than or equal to 1.0 ton from the viewpoint of flattening distortion slightly left in the steel plate forced by the roller leveler to the minimum drainable level with the pressing force of the dewatering rollers.

[0034] The first shape correction device 2 may be either a press-down skin pass leveler or a roller leveler for repeated bending. In the present invention, when the leading end portion of the steel plate 5 causes warpage, the steel plate 5 may fail to be inserted between the dewatering rollers 31 of the accelerated cooling device 3. Thus, the leading end portion of the steel plate 5 preferably undergoes correction with the roller leveler capable of performing repeated bending and exerting a higher correction performance than the skin pass leveler that has a lower correction performance on the longitudinal warpage that occurs in the trailing end portion of the steel plate 5.

[0035] When the first shape correction device 2 is to correct the steel plate 5, the steepness of the steel plate 5 is preferably corrected to below 2.0%. More preferably, the steepness is corrected to below 1.0%.

[0036] The accelerated cooling device 3 is not suitable for regulating the flow rate in the steel plate width direction to make the flow rate completely uniform. The temperature variation during controlled cooling may thus cause slight warpage, so that, preferably, the second shape correction device 4 further corrects the steel plate 5 after the controlled cooling of the accelerated cooling device 3. A roller leveler capable of performing repeated bending is preferably used as the second shape correction device 4 for correction.

[0037] Each dewatering roller 31 may have either a hollow structure or a solid structure. In view of minimizing deflection of the dewatering roller 31, a solid structure (solid roller) is more preferable, since the roller preferably has higher rigidity. The solid structure can also reduce an additional pressing load, such as a hydraulic pressure, using the weight of the dewatering rollers.

[0038] The cooling nozzles 32 are not limited to particular nozzles. Usable examples include multiple cylindrical jet nozzles, slit nozzles, a spray nozzle that sprays water alone, such as a flat spray, a corner spray, a full cone spray, or an oval spray, or a mist spray nozzle that mixes water and air with the same shape.

[0039] The pressing-load control systems 33 may be any system that can apply a predetermined pressure such as a spring, a pneumatic pressure or a hydraulic pressure. In the present invention, it is important that the pressing-load control systems 33 retain such a pressing load that the dewatering rollers 31 are not bent. Thus, a control system that can retain a predetermined pressing force is preferable. However, in the case of a spring system, the pressing amount of the spring changes in accordance with the shape of the steel plate 5, and thus, the pressing load also changes to a large extent. Thus, in the case of a spring control system, the steel plate needs to have low steepness (preferably, lower than 1.0%) in the shape correction of the steel plate with the first shape correction device 2. Thus, a control system using a hydraulic pressure or a pneumatic pressure that promisingly has a predetermined pressing load is preferable.

[0040] Preferably, the present invention is applied to a steel plate having a plate thickness of smaller than or equal to 30 mm and/or a plate width of greater than or equal to 3000 mm, and is capable of reducing occurrence of shape defect attributable to rolling.

Example 1

[0041] Steel plates were manufactured by the manufacturing facility illustrated in Fig. 1. Steel plates 5 with a plate thickness of 25 mm and a plate width of 3500 mm were manufactured by the hot rolling mill 1, then had their shapes corrected by the first shape correction device 2 to have predetermined steepness, and transported to the accelerated cooling device 3. The steepness of the steel plates 5 was controlled by adjusting the press-down settings of the first

shape correction device 2. As needed, the steel plates 5 were corrected by the second shape correction device 4. When the steel plates 5 had distortion after being corrected by the second shape correction device 4, the steel plates 5 underwent re-correction by the cold-rolling correction device.

[0042] As illustrated in Fig. 2, an example used as the accelerated cooling device 3 includes ten units arranged in the travel direction of the steel plates 5, each unit including dewatering rollers 31, cooling nozzles 32 arranged between the dewatering rollers 31, and pressing-load control systems 33. The pressing-load control systems 33 were pneumatic pressure systems. The dewatering rollers 31 were hollow rollers with a body length of 6000 mm, a roller outer diameter of 400 mm, and a roller inner diameter of 320 mm.

[0043] Firstly, as a first embodiment, the relationship between the steepness of the steel plates 5, the pressing load P of the dewatering rollers 31, the temperature distribution of the cooled steel plates, and the subsequent shapes were examined (Examples 1 and 2 and comparative examples 2 to 4).

[0044] After controlled cooling, from the viewpoint of checking the temperature variation in the steel-plate width direction and obtaining a predetermined quality, the steel plates having a temperature variation within 25°C in the steel-plate width direction were determined as acceptable. The material having a temperature variation exceeding 25°C underwent re-correction with the cold-rolling correction device to such a level that satisfies predetermined production specifications.

[0045] Table 1 shows the results.

[Table 1]

	Steel plate Thickness (mm)	Steel plate Width (mm)	Steepness (%)	Pressing Load (ton) of Dewatering Rollers	Pressing Load P (ton) of Formula 1	Temperature Deviation after Cooling (°C)	Re-correction
Example 1	25	3500	0.75	10	15.3	12	Not Needed
Example 2	25	3500	1.5	10	15.3	22	Not Needed
Comparative Example 2	25	3500	0.75	30	15.3	72	Needed
Comparative Example 3	25	3500	1.5	30	15.3	69	Needed
Comparative Example 4	25	3500	2.5	30	15.3	58	Needed

$$P = 37 \times ((L-W) \times W^2 / (D^4 - d^4))^{-1.25} \dots (1)$$

[0046] Examples 1 to 2 are examples where the dewatering rollers 31 have a pressing load of 10 tons, which is smaller than or equal to the pressing load P (15.3 tons) expressed with Formula (1) in the present invention. Examples 1 and 2 respectively have a steepness of 0.75% and 1.5%, and a temperature variation in the width direction of 12°C and 22°C, which fall within the acceptable range. After being corrected by the second shape correction device 4, the steel plates remained flat without the need of re-correction. In the mechanical test, the tensile strength was satisfactory without variation. When Examples 1 and 2 are compared, the steel plate of Example 1 having smaller steepness has better temperature variation.

[0047] Comparative examples 2 to 4 are examples where the dewatering rollers 31 have a pressing load of 30 tons, which is larger than the pressing load P (15.3 tons) expressed by Formula (1) of the present invention. Here, regardless of the steepness of the steel plates 5, large temperature variation (58 to 72°C) occurred in the plate width direction. In observation during the examination, a large amount of accumulated water was observed on the steel plate, particularly, at the center in the width direction. This probably results from a failure of blocking the cooling water with the dewatering rollers 31. Accumulated water is left at the center in the width direction, which has probably caused large temperature variation. The steel plates of Comparative Examples 2 to 4 have large distortion after being corrected by the second shape correction device 4, and required re-correction with the cold-rolling correction device, which caused additional manufacturing costs. Moreover, mechanical tests conducted on the steel plates of comparative examples 2 to 4 revealed large variation in tensile strength.

[0048] Subsequently, as a second embodiment, the relationship between the plate width of steel plates, the pressing

load of the dewatering rollers 31, the temperature distribution of the cooled steel plates, and the subsequent shapes was examined for steel plates 5 before undergoing accelerated cooling, the steel plates 5 being flattened by the first shape correction device 2 to have a steepness of 0.75% and then undergoing controlled cooling with the accelerated cooling device 3 (Examples 3 and 4 and comparative examples 5 and 6).

[0049] The examination was conducted for steel plates with a plate thickness of 30 mm and a plate width of 2000 mm and 5000 mm. As in the first embodiment, steel plates having a widthwise temperature variation within 25°C in the plate width direction were regarded as acceptable. As in the first embodiment, the material having a temperature variation exceeding 25°C underwent re-correction by the cold-rolling correction device.

[0050] Table 2 shows the results.

[Table 2]

	Steel plate Thickness (mm)	Steel plate Width (mm)	Steepness (%)	Pressing Load (ton) of Dewatering rollers	Pressing Load P(ton) of Formula 1	Temperature Deviation after Cooling (°C)	Re-correction
Example 3	30	2000	0.75	30	34.5	18	Not Needed
Comparative Example 5	30	2000	0.75	50	34.5	100	Needed
Example 4	30	5000	0.75	15	19.7	10	Not Needed
Comparative Example 6	30	5000	0.75	30	19.7	40	Needed

$$P = 37 \times ((L-W) \times W^2 / (D^4 - d^4))^{-1.25} \dots (1)$$

[0051] Example 3 is the example where the dewatering roller 31 has a pressing load of 30 tons, which is smaller than the pressing load P (34.5 tons) expressed by Formula (1) of the present invention. Example 3 has a temperature variation in the width direction of 18°C, which is small to fall within the acceptable level, without the need of correction by the second shape correction device 4. In observation during the examination, Example 3 caused no accumulated water. On the other hand, Comparative Example 5 is an example where the dewatering rollers have the same width as Example 3 and a pressing load of 50 tons, which is greater than the pressing load P (34.5 tons) expressed by Formula (1) of the present invention. In Comparative Example 5, large temperature variation (100°C) occurred in the plate width direction. A large amount of accumulated water was observed on the steel plate, particularly, at the center in the width direction. This probably results from a failure of blocking the cooling water with the dewatering rollers 31. As in the above-described comparative examples, the steel plate of Comparative Example 5 had large distortion after being corrected by the second shape correction device 4, and required re-correction with the cold-rolling correction device, which caused additional manufacturing costs. Moreover, mechanical tests revealed large variation in tensile strength.

[0052] Example 4 is the example where the dewatering rollers 31 have a pressing load of 15 tons, which is smaller than the pressing load P (19.7 tons) expressed by Formula (1) of the present invention. Example 4 had a temperature variation in the width direction of 10°C, which is preferable, and retained the flat shape also after being corrected by the second shape correction device 4. On the other hand, in Comparative Example 6, temperature variation was 100°C and a large supercooling occurred. In Comparative Example 6, a large amount of accumulated water was observed on the steel plate, particularly, at the center in the width direction. This probably results from a failure of blocking the cooling water with the dewatering rollers 31. As in the above-described comparative examples, the steel plate of Comparative Example 6 had large distortion after being corrected by the second shape correction device 4, and required re-correction with the cold-rolling correction device, which caused additional manufacturing costs. Moreover, mechanical tests revealed large variation in tensile strength.

[0053] The above examination reveals that, restraining the steel plate with a predetermined pressing load with the dewatering rollers concurrently with flattening of the steel plate enables uniformization of the temperature distribution of the steel plate to obtain a highly flat steel plate, and that changing of the pressing load as appropriate in accordance with the plate width enables uniformization of the temperature distribution of the steel plate to manufacture a highly flat steel plate.

Reference Signs List

[0054]

- 5 1 hot rolling mill
 2 first shape correction device
 3 accelerated cooling device
 31 dewatering roller
 32 cooling nozzle
 10 33 pressing-load control system
 4 second shape correction device
 5 steel plate
 W plate width
 L roller body length
 15 P pressing load
 δ wave height
 p wave pitch

20 **Claims**

1. A steel-plate manufacturing facility, comprising
 a hot rolling mill, a first shape correction device, and an accelerated cooling device arranged in this order,
 wherein the accelerated cooling device includes dewatering rollers that restrict a steel plate from above and below,
 and a control system that controls a pressing load P exerted to restrict the steel plate.
2. The steel-plate manufacturing facility according to Claim 1, wherein the pressing load P satisfies formula (1), below:

$$P \leq 37 \times ((L-W) \times W^2 / (D^4 - d^4))^{-1.25} \dots (1)$$

, where

- P denotes a pressing load (ton),
 L denotes a roller body length (mm),
 W denotes a plate width (mm),
 D denotes a roller outer diameter (mm), and
 d denotes a roller inner diameter (mm).

3. The steel-plate manufacturing facility according to Claim 1 or 2, wherein a second shape correction device is arranged subsequent to the accelerated cooling device.
4. The steel-plate manufacturing facility according to any one of Claims 1 to 3, wherein the first shape correction device and/or the second shape correction device are/is roller levelers/a roller leveler.
5. The steel-plate manufacturing facility according to any one of Claims 1 to 4, wherein the first shape correction device corrects a steepness of the steel plate to below 2.0%.
6. A method for manufacturing a steel plate, comprising:
 arranging a hot rolling mill, a first shape correction device, and an accelerated cooling device in this order; and
 rolling a steel plate with the hot rolling mill, then correcting a shape of the steel plate with the first shape correction device, and then cooling the steel plate with the accelerated cooling device while restricting the steel plate from above and below with dewatering rollers at a predetermined pressing load P.
7. The method for manufacturing a steel plate according to Claim 6, wherein the pressing load P satisfies formula (1), below:

$$P \leq 37 \times ((L-W) \times W^2 / (D^4 - d^4))^{-1.25} \dots (1)$$

, where

P denotes a pressing load (ton),
 L denotes a roller body length (mm),
 W denotes a plate width (mm),
 D denotes a roller outer diameter (mm), and
 d denotes a roller inner diameter (mm).

8. The method for manufacturing a steel plate according to Claim 6 or 7, wherein a second shape correction device is arranged subsequent to the accelerated cooling device, and the shape of the steel plate is further corrected by the second shape correction device.
9. The method for manufacturing a steel plate according to any one of Claims 6 to 8, wherein the first shape correction device and/or the second shape correction device are/is roller levelers/a roller leveler.
10. The method for manufacturing a steel plate according to any one of Claims 6 to 9, wherein the first shape correction device corrects a steepness of the steel plate to below 2.0%.

FIG. 1

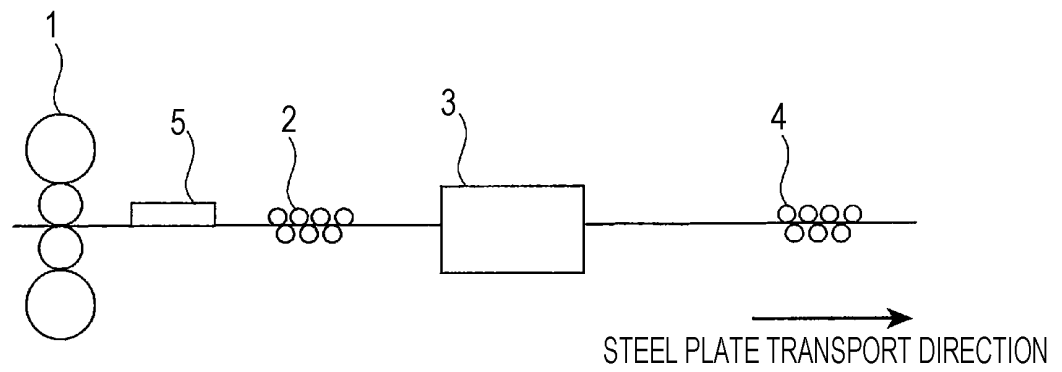


FIG. 2

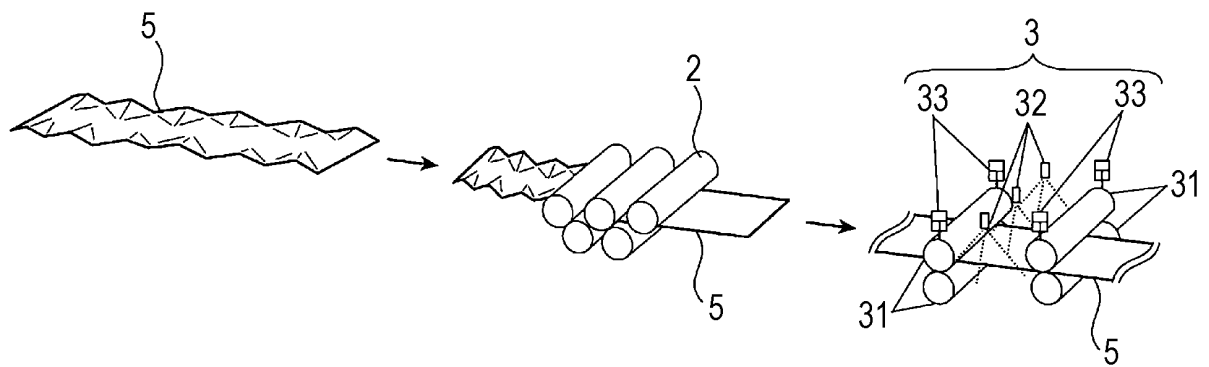


FIG. 3

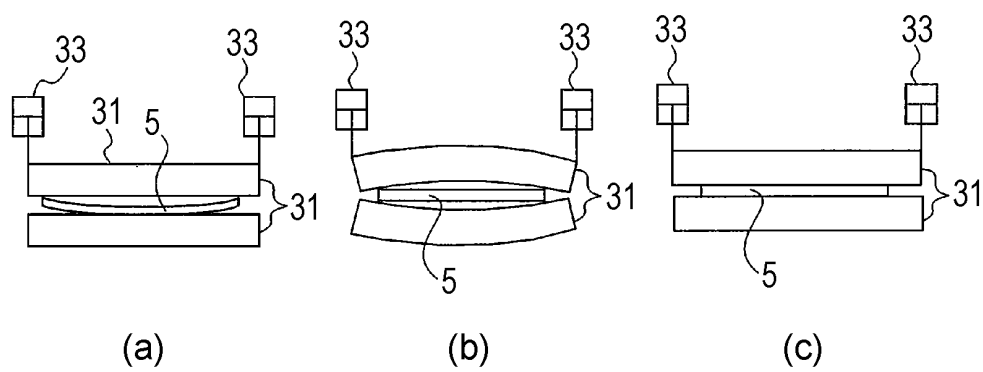


FIG. 4

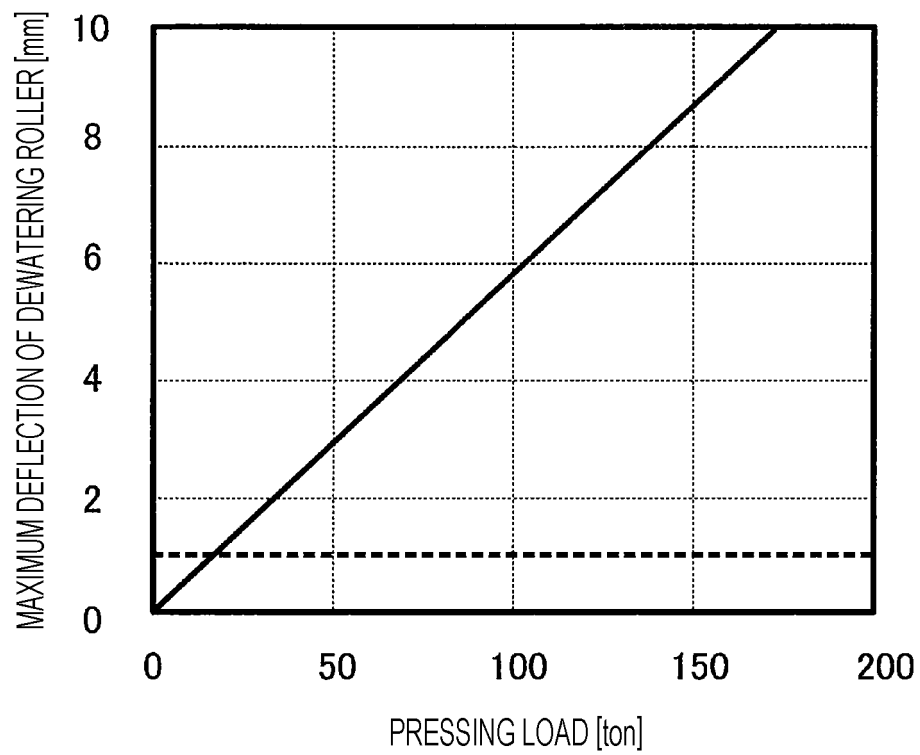


FIG. 5

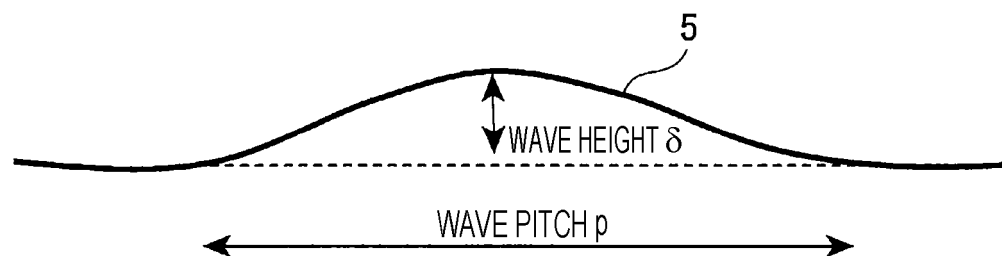


FIG. 6

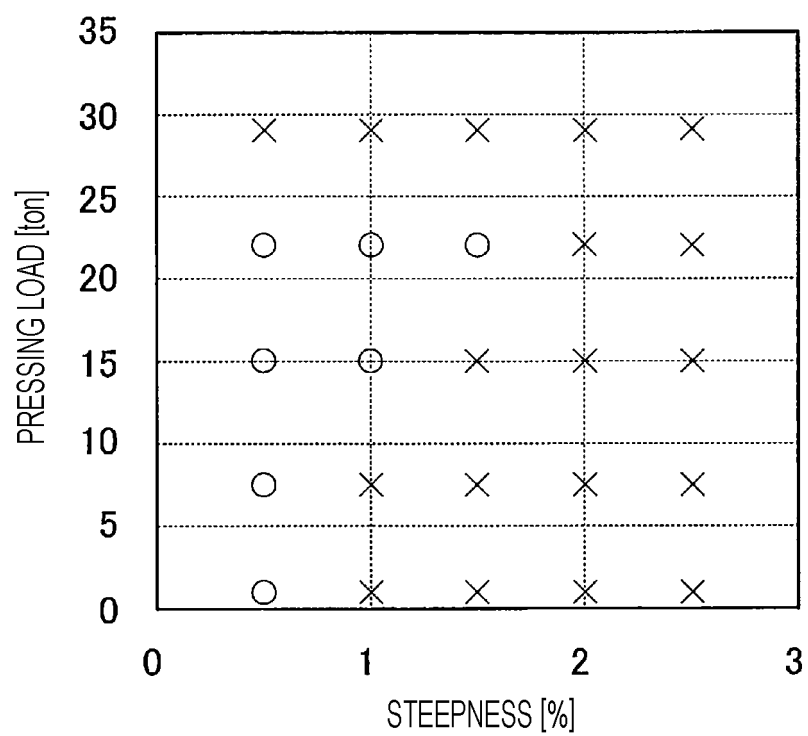


FIG. 7

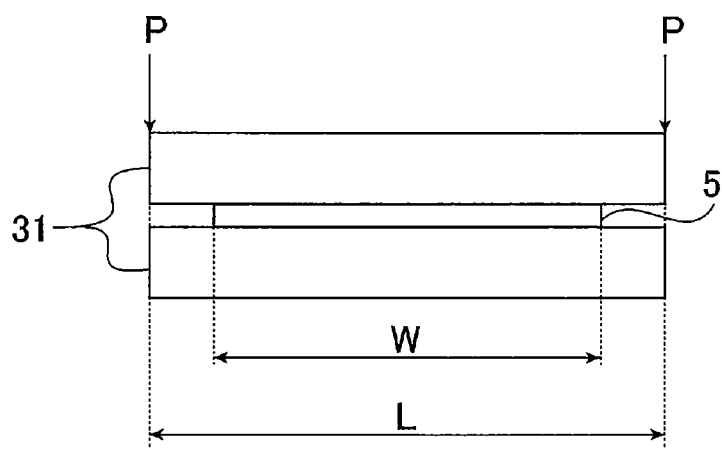
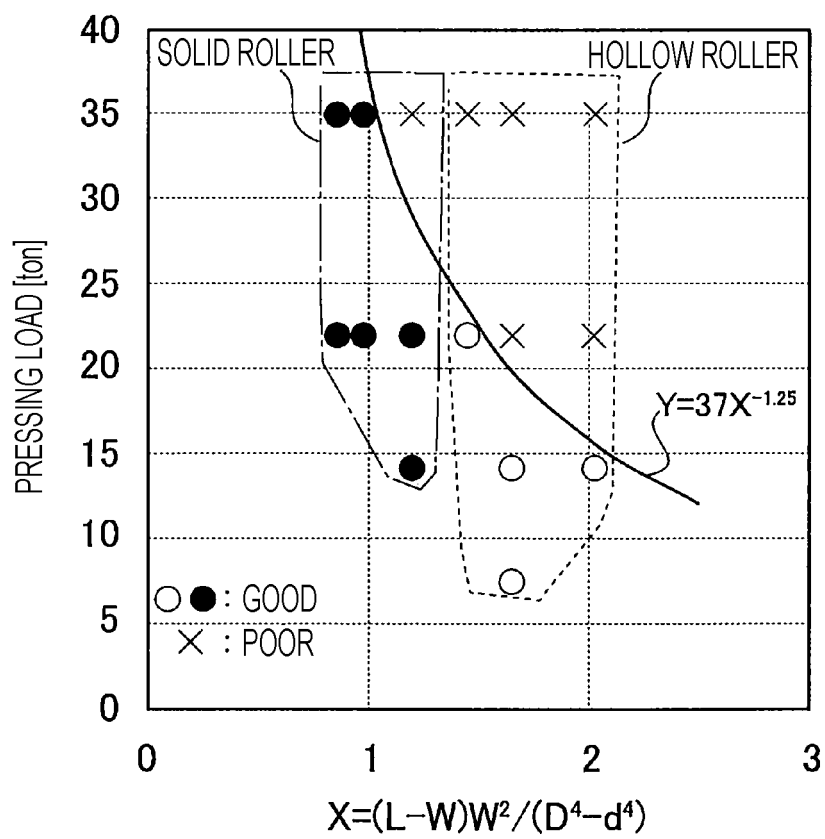


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/034420

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. B21B45/02 (2006.01) i, B21B1/38 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl. B21B45/02, B21B1/38

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

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2007-7676 A (JFE STEEL CORP.) 18 January 2007 (Family: none)	1-10
A	JP 2002-11515 A (NKK CORP.) 15 January 2002 (Family: none)	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search
03.10.2018Date of mailing of the international search report
16.10.2018Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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