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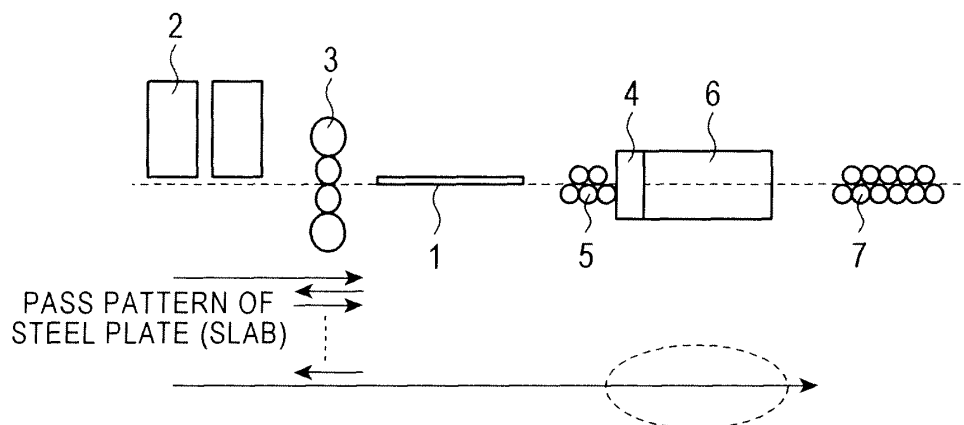
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(54) **STEEL PLATE MANUFACTURING EQUIPMENT AND METHOD OF MANUFACTURING**

(57) A facility is provided for manufacturing a steel plate excellent in steel plate shape and mechanical property while setting low cooling-water spraying performance in a descaling step and achieving uniform cooling in a cooling step. Specifically, a hot rolling mill 3, a first

hot leveler 5, a descaler 4, and cooling equipment 6 are arranged in that order from the upstream side in a conveying direction. A pressure P [MPa] at the point of impact of cooling water sprayed from the descaler to each surface of a steel plate 1 is greater than or equal to 1.5 MPa.

FIG. 1



Description

Technical Field

5 **[0001]** The present invention relates to a steel plate manufacturing facility and manufacturing method of hot rolling, hot leveling, and cooling a steel plate.

Background Art

10 **[0002]** The application of cooling control as a process of manufacturing a steel plate has recently been widening. Since a typical hot rolled steel plate is not necessarily uniform in, for example, shape and surface condition, however, strip temperature deviation tends to occur in the steel plate during cooling. The occurrence of deformation, residual stress, material nonuniformity, and the like in the steel plate subjected to cooling causes poor quality and operational trouble.

15 Patent Literature 1 discloses a method of performing descaling at least one of just before and just after a final pass of finish rolling, subsequently performing hot leveling, then performing descaling, and starting accelerated cooling. Patent Literature 2 discloses a method of performing finish rolling and hot leveling, performing descaling just before controlled cooling, and performing controlled cooling.

20 Citation List

Patent Literature

[0003]

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PTL 1: Japanese Unexamined Patent Application Publication No. 9-57327

PTL 2: Japanese Patent No. 3796133

Summary of Invention

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Technical Problem

[0004] In actually manufacturing a steel plate using the methods disclosed in Patent Literature 1 and Patent Literature 2 mentioned above, in some cases, scale is not completely removed during descaling, but descaling causes scale nonuniformity, resulting in poor surface condition. Although Patent Literature 1 and Patent Literature 2 do not mention a pressure at the point of impact of cooling water on each surface of a steel plate during descaling, pressures at the point of impact derived on the basis of spraying pressures and spraying distances of nozzles described in Patent Literature 1 and Patent Literature 2 and a typical kind of nozzle are estimated to be 0.08 to 1.00 MPa in Patent Literature 1 (when Everloy Descaling Nozzles DNX or DNH are used under conditions described in paragraph Nos. (0045) and (0046) in Patent Literature 1, a pressure at the point of impact is 0.08 to 1.00 MPa on the basis of a spray angle of 23° and Expressions (1) and (2) which will be described in paragraph Nos. (0030) and (0031) in this specification) and to be approximately 0.06 to 0.08 MPa in Patent Literature 2 (when Everloy Descaling Nozzles DNX are used under conditions described in paragraph No. (0024) in Patent Literature 2, a pressure at the point of impact is 0.06 to 0.08 MPa on the basis of a spray angle of 37° and Expressions (1) and (2) which will be described in paragraph Nos. (0030) and (0031) in the specification). The pressures at the point of impact of cooling water are low and the disclosed methods do not offer the performance of achieving uniform descaling. Accordingly, the surface condition of a scale removed portion differs from that of a portion where scale is not removed. Disadvantageously, uniform cooling is not achieved during controlled cooling.

[0005] In recent years in particular, a level of material uniformity required for a steel plate has been tightened. The harmful effect of cooling rate nonuniformity caused by the above-described scale nonuniformity during controlled cooling on material uniformity, especially in the width direction of the steel plate, is becoming unignorable. The present invention focused on the above-described unsolved problems of related art. An object of the present invention is to provide a facility and method for manufacturing a steel plate excellent in steel plate shape and mechanical property by performing uniform descaling in a descaling step and achieving uniform cooling in a cooling step.

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Solution to Problem

[0006] To accomplish the above-described object, a steel plate manufacturing facility according to the present invention

includes a hot rolling mill, a hot leveler, a descaler, and cooling equipment arranged in that order from the upstream side in a conveying direction, wherein a pressure P [MPa] at the point of impact of cooling water sprayed from the descaler to each surface of a steel plate is greater than or equal to 1.5 MPa.

After diligent study of a force causing the removal of scale using high-pressure water, the present inventors revealed that when descaling was performed after hot leveling, so long as a pressure at the point of impact of cooling water sprayed from the descaler to the steel plate was 1.5 MPa or higher, the scale thickness of a product decreased and was made uniform. The reason is that scale was temporarily and uniformly removed completely by descaling at a high pressure at the point of impact and, after that, scale was thinly and uniformly reproduced. According to the invention, therefore, since the scale thickness of the steel plate is thinned and made uniform before passing through the cooling equipment, the steel plate can be uniformly cooled with little surface temperature deviation among positions in the width direction of the steel plate while passing through the cooling equipment. Thus, the steel plate is excellent in steel plate shape and mechanical property.

[0007] Furthermore, since the descaler removes scale produced on each surface of the steel plate after hot leveling of the steel plate by the hot leveler, spraying nozzles of the descaler can be moved closer to the surfaces of the hot-leveled steel plate, thereby improving the descaling performance. Alternatively, the cooling water spraying performance of the descaler for providing a predetermined pressure at the point of impact can be set to low.

[0008] In the steel plate manufacturing facility according to the present invention, preferably, when V [m/s] denotes the conveying velocity from the descaler to the cooling equipment and T [K] denotes the temperature of the steel plate before cooling, the distance L [m] between the descaler and the cooling equipment satisfies the expression $L \leq V \times 5 \times 10^{-9} \times \exp(25000/T)$. According to the invention, cooling of the steel plate by the cooling equipment can be stabilized.

[0009] In the steel plate manufacturing facility according to the present invention, preferably, the components are arranged such that the distance L between the descaler and the cooling equipment is less than or equal to 12 m. According to the invention, cooling of the steel plate by the cooling equipment is very stable.

In the steel plate manufacturing facility according to the present invention, preferably, the distance H between each spraying nozzle of the descaler and the surface of the steel plate is greater than or equal to 40 mm and less than or equal to 140 mm. According to the invention, the spraying pressure and spray flow rate of the descaler for providing a predetermined pressure at the point of impact are low, thus reducing the pump capacity of the descaler.

[0010] In the steel plate manufacturing facility according to the present invention, preferably, the cooling equipment includes a header supplying cooling water to the upper surface of the steel plate, cooling water spraying nozzles extending from the header and spraying rod-like cooling water, and a dividing plate disposed between the steel plate and the header, and the dividing plate includes a plurality of water supply inlets receiving the lower ends of the cooling water spraying nozzles and a plurality of drain outlets draining the cooling water supplied to the upper surface of the steel plate onto the dividing plate.

According to the invention, cooling water supplied from the cooling water spraying nozzles through the water supply inlets cools the upper surface of the steel plate to turn to high-temperature drainage water and the drainage water flows from the drain outlets onto the dividing plate so that the drainage water after cooling is immediately eliminated from the steel plate. Advantageously, the cooling equipment offers adequate cooling performance that is uniform in the width direction.

[0011] According to the present invention, a steel plate manufacturing method including a hot rolling step, a hot leveling step, and a cooling step performed in that order to manufacture a steel plate includes a descaling step of spraying cooling water to each surface of the steel plate at a pressure at the point of impact of 1.5 MPa or higher, the descaling step being performed between the hot leveling step and the cooling step.

According to the invention, since the scale thickness of the steel plate is thinned and made uniform before the cooling step, the steel plate can be uniformly cooled with little surface temperature deviation among positions in the width direction of the steel plate in the cooling step. Thus, the steel plate excellent in steel plate shape and mechanical property can be manufactured.

In the steel plate manufacturing method according to the present invention, preferably, when T [K] denotes the temperature of the steel plate before cooling, the period of time t [s] between the completion of the descaling step and the start of the cooling step satisfies the expression $t \leq 5 \times 10^{-9} \times \exp(25000/T)$. According to the invention, cooling of the steel plate in the cooling step can be stabilized. Advantageous Effects of Invention

[0012] According to the steel plate manufacturing facility and manufacturing method of the present invention, uniform descaling can be performed in the descaling step and uniform cooling can be achieved in the cooling step, so that the steel plate excellent in steel plate shape and mechanical property can be manufactured.

Brief Description of Drawings

[0013]

[Fig. 1] Fig. 1 is a diagram illustrating the outline of a hot rolling facility according to the present invention.

[Fig. 2] Fig. 2 is a diagram illustrating cooling equipment constituting the hot rolling facility according to the present invention.

[Fig. 3] Fig. 3 is a diagram illustrating a dividing plate constituting the cooling equipment.

[Fig. 4] Fig. 4 is a diagram illustrating the flow of cooling water and that of drainage water in the cooling equipment.

[Fig. 5] Fig. 5 is a graph illustrating the relationship between the pressure at the point of impact of cooling water from a descaler and the thickness of scale produced on each surface of a steel plate product.

[Fig. 6] Fig. 6 is a graph illustrating the relationship between the position from the center of a steel plate in the width direction thereof and the temperature in a cooling step in the present invention.

[Fig. 7] Fig. 7 is a graph illustrating the relationship between the position from the center of a steel plate in the width direction thereof and the temperature in the cooling step in a related-art facility which does not include a descaling step before the cooling step.

[Fig. 8] Fig. 8 is a graph illustrating the relationship between the spraying pressure and the spraying distance for providing a pressure at the point of impact of 1.5 MPa while setting a spray flow rate, a spray angle of nozzle, and an angle between the spray direction and the vertical line in the descaler to predetermined values. Description of Embodiments

[0014] One embodiment (hereinafter, referred to as "embodiment") of practicing the present invention will be described in detail below with reference to the drawings.

Referring to Fig. 1, a hot rolling facility according to the present embodiment includes a heating furnace 2, a hot rolling mill 3, a first hot leveler 5, a descaler 4, cooling equipment 6, and a second hot leveler 7 arranged in that order from the upstream side in a conveying direction of a steel plate 1.

[0015] A slab discharged from the heating furnace 2 is passed through the hot rolling mill 3 multiple times, thus resulting in a rolled steel plate 1 having a predetermined thickness. The hot-rolled steel plate 1 is conveyed on a table roller (not illustrated) from the upstream side to the first hot leveler 5 on the downstream side. Although only one hot rolling mill 3 is illustrated, the hot rolling mill 3 may include a rough rolling mill and a finish rolling mill.

The first hot leveler 5 is configured to remove strain caused in the steel plate 1 during hot rolling. The illustrated hot leveler is of the roller leveler type in which the steel plate 1 is nipped between leveling rolls arranged one above the other in a staggered layout. The hot leveler is not limited to this type, but a skin-pass mill or a press machine may be used. When the hot rolling mill 3 includes a rough rolling mill and a finish rolling mill, the finish rolling mill may perform skin-pass rolling.

[0016] The second hot leveler 7 is configured to remove strain caused in the steel plate 1 during cooling by the cooling equipment 6. This hot leveler does not have to be used in the present invention. The second hot leveler 7 used is of the roller leveler type. The hot leveler is not limited to this type, but a skin-pass mill or a press machine may be used.

The cooling equipment 6 is configured to perform controlled cooling on a high-temperature steel plate 1 subjected to hot rolling under predetermined temperature conditions to control the structure of the steel plate 1 in order to obtain desired material properties. Any cooling equipment may be used so long as desired cooling conditions are provided. It is preferred to use cooling equipment capable of uniformly cooling the upper and lower surfaces of the steel plate 1 in the length and width directions. The present embodiment therefore uses the cooling equipment 6, illustrated in Fig. 2, which has high cooling performance and is excellent in cooling uniformity, especially in the width direction.

[0017] Referring to Fig. 2, the cooling equipment 6 in the present embodiment includes an upper header 10 which supplies cooling water to the upper surface of the steel plate 1, upper cooling water spraying nozzles 11 which downwardly extend from the upper header 10 toward the steel plate 1, a dividing plate 12 which is horizontally disposed between the upper header 10 and the steel plate 1 so as to extend in the width direction of the steel plate and has many holes, a lower header 13 which supplies cooling water to the lower surface of the steel plate 1, lower cooling water spraying nozzles 15 which upwardly extend from the lower header 13 toward the steel plate 1, and squeezing rolls 16 and 17 arranged on the upstream and downstream sides of the steel plate 1 in the conveying direction.

[0018] As illustrated in a plan view of the dividing plate 12 of Fig. 3, the dividing plate 12 has the many (multiple) holes 18 arranged in a grid pattern. The upper cooling water spraying nozzles 11 are inserted in predetermined holes 18 in a staggered layout. Lower openings of the holes 18, receiving the upper cooling water spraying nozzles 11, each serve as a water supply inlet 19. Lower openings of the holes 18, which do not receive the upper cooling water spraying nozzles 11, each serve as a drain outlet 20. The tips of the upper cooling water spraying nozzles 11 are received in the holes 18 (the water supply inlets 19) such that the level of each tip is higher than the lower end of the dividing plate 12. The reason is that the dividing plate 12 prevents the upper cooling water spraying nozzles 11 from being damaged even if a steel plate having an upwardly warped end enters. A broken line in Fig. 3 is parallel to the conveying direction of the steel plate and both ends of the dividing plate 12 in the width direction of the steel plate are not illustrated.

[0019] Fig. 4 is a side elevational view of one end of the steel plate when viewed from the conveying direction of the steel plate. As illustrated in Fig. 4, cooling water supplied from the upper cooling water spraying nozzles 11 through the

water supply inlets 19 cools the upper surface of the steel plate 1 to turn to high-temperature drainage water and then flows onto the dividing plate 12 through the drain outlets 20. Cooling water supplied from the lower cooling water spraying nozzles 15 cools the lower surface of the steel plate 1 and flows downward.

If the dividing plate 12 is not provided, cooling water supplied to the upper surface of the steel plate 1 is drained while flowing on the upper surface of the steel plate 1 in the width direction. The flow of this drainage water prevents cooling water supplied from the upper cooling water spraying nozzles 11 from reaching the upper surface of the steel plate 1, particularly in the vicinity of each end of the plate in the width direction, so that the cooling performance degrades in the vicinity of the end of the plate in the width direction and uniform cooling cannot be performed in the width direction. Accordingly, a temperature distribution in the width direction of the steel plate 1 is U-shaped such that the temperature of the center of the plate is low and the temperature of each end thereof is high. In contrast, the cooling equipment 6 in the present embodiment is configured such that drainage water after cooling is immediately drained from the upper surface of the steel plate 1 onto the dividing plate 12. Cooling water sprayed from the upper cooling water spraying nozzles 11 sequentially comes into contact with the steel plate 1, thus providing adequate cooling performance.

[0020] If the water supply inlets 19 and the drain outlets 20 are the same holes 18, cooling water supplied to the upper surface of the steel plate 1 does not tend to upwardly pass through the dividing plate 12, so that the water flows toward the ends of the steel plate 1 in the width direction between the upper surface of the steel plate 1 and the dividing plate 12. The flow of drainage water prevents cooling water supplied from the upper cooling water spraying nozzles 11 from reaching the upper surface of the steel plate 1. Disadvantageously, the cooling performance degrades in the vicinity of the ends of the plate in the width direction and uniform cooling cannot be performed in the width direction. In contrast, since the cooling equipment 6, illustrated in Fig. 2, in the present embodiment is provided with the holes 18 which serve as the water supply inlets 19 and the drain outlets 20 to share their functions, cooling water and drainage water after cooling smoothly flow. Furthermore, since the tips of the upper cooling water spraying nozzles 11 are received in the holes 18 of the dividing plate 12, drainage water flowing over the dividing plate 12 in the width direction does not interfere with cooling water sprayed from the upper cooling water spraying nozzles 11 and uniform cooling is achieved in the width direction, thus providing a uniform temperature distribution in the width direction, as illustrated in Fig. 6.

[0021] It is preferred that the total area of openings (hereinafter, referred to as "total cross-sectional area") of the drain outlets 20 be equal to or more than 1.5 times as large as the total area of openings (hereinafter, referred to as "total inner-diameter cross-sectional area") of the upper cooling water spraying nozzles 11, because cooling water is immediately drained through the drain outlets 20. If this value is less than 1.5 times, the flow resistance of each drain outlet increases, so that remaining water does not tend to be drained onto the dividing plate. Disadvantageously, the remaining water flows between the upper surface of the steel plate and the dividing plate toward the ends of the steel plate in the width direction, thereby degrading the cooling performance, particularly, in the vicinity of the ends of the steel plate in the width direction. On the other hand, if too many drain outlets are arranged or the area of opening (hereinafter, referred to as "cross-sectional diameter") of each drain outlet is too large, the stiffness of the dividing plate 12 is lowered. Disadvantageously, the dividing plate 12 tends to be damaged when hitting against a steel plate. It is therefore preferred that the ratio of the total cross-sectional area of the drain outlets 20 to the total inner-diameter cross-sectional area of the upper cooling water spraying nozzles 11 be in the range of 1.5 to 20.

[0022] In order to allow cooling water to pass through remaining water, reach a steel plate, and achieve uniform cooling in the width direction, it is preferred to optimize the inner diameter and length of each upper cooling water spraying nozzle 11, the spraying velocity of cooling water, and the distance between nozzles.

Specifically, the inner diameter of each nozzle is preferably 3 to 8 mm. If the inner diameter is less than 3 mm, the flux of water sprayed from the nozzle diminishes and the force of water becomes weak. Whereas, if the nozzle diameter is greater than 8 mm, the flow rate decreases and the force to pass through the remaining water becomes weak.

[0023] The length of each upper cooling water spraying nozzle 11 is preferably 120 to 240 mm. If the upper cooling water spraying nozzle 11 is shorter than 120 mm, the distance between the lower surface of the upper header 10 and the upper surface of the dividing plate 12 is too short, so that a drain space above the dividing plate 12 is reduced and drainage water after cooling cannot be smoothly drained. Whereas, if the upper cooling water spraying nozzle 11 is longer than 240 mm, the pressure loss of the upper cooling water spraying nozzle 11 increases, so that the force to pass through remaining water becomes weak.

[0024] The spraying velocity of cooling water from the nozzles is preferably 6 m/s or higher. If the spraying velocity is less than 6 m/s, the force of cooling water passing through the remaining water is extremely weakened. It is preferred that the spraying velocity be 8 m/s or higher, because higher cooling performance is ensured. The distance between the lower end of each upper cooling water spraying nozzle 11 and the upper surface of the steel plate 1 is preferably 30 to 120 mm. If the distance is less than 30 mm, the frequency of collision of the steel plate 1 with the dividing plate 12 extremely increases. It is therefore difficult to maintain the facility. If the distance is greater than 120 mm, the force of cooling water passing through the remaining water is extremely weakened.

[0025] The water flow rate at which the cooling equipment 6 in the present embodiment achieves maximum effect is $1.5 \text{ m}^3/\text{m}^2\cdot\text{min}$ or higher. If the water flow rate is lower than this value, the thickness of layer of the remaining water does

not become so thick. Even in the application of known technology to cool a steel plate while allowing free fall of rod-like cooling water, in some cases, strip temperature deviation in the width direction is not so large. Whereas, if the water flow rate is higher than $4.0 \text{ m}^3/\text{m}^2\cdot\text{min}$, the cooling equipment 6 in the present embodiment is effectively used but has practical use problems, for example, high facility cost. The most practical water flow rate is therefore 1.5 to $4.0 \text{ m}^3/\text{m}^2\cdot\text{min}$.

[0026] The cooling equipment 6 illustrated in Fig. 2 includes the lower header 13 which is the same as the cooling equipment above the upper surface and includes the lower cooling water spraying nozzles 15. During cooling of the lower surface of the steel plate, sprayed cooling water hits against the steel plate and then freely falls. The strip temperature deviation in the width direction is not so a big problem, like the problem on the upper surface of the steel plate. Therefore, cooling equipment below the lower surface of the steel plate is not particularly limited.

[0027] The descaler 4 is configured to remove scale, produced on each surface of the steel plate 1 after hot rolling while spraying high-pressure water from a plurality of spraying nozzles directed toward the surface of the steel plate 1 subjected to removal of strain, caused in the steel plate 1, through the first hot leveler 5.

According to the present embodiment, the pressure P [MPa] at the point of impact of high-pressure water sprayed from the spraying nozzles of the descaler 4 to each surface of the steel plate 1 is set to 1.5 MPa or higher, the descaler 4 removes scale produced on the surface of the steel plate 1, and after that, the cooling equipment 6 cools the steel plate 1, thus improving the steel plate shape and mechanical property of the steel plate 1.

[0028] The reason is as follows. In a related-art hot rolling facility, if surface treatment by a descaler is omitted after a steel plate is passed through a leveler, scale may be partially removed, thus causing a variation in scale thickness distribution of approximately 10 to $50 \text{ }\mu\text{m}$ depending on the presence or absence of scale removal. In such a case, it is difficult to uniformly cool the steel plate during cooling by cooling equipment. Specifically, when the steel plate having a variation in scale thickness distribution is cooled in the related-art hot rolling facility, portions with the remaining scale are cooled well and the temperatures of the portions fall as illustrated in Fig. 7, which illustrates a temperature distribution from the center of the steel plate in the width direction thereof. Accordingly, surface temperature deviation among positions in the width direction is large and the steel plate cannot be uniformly cooled, thus affecting the shape and mechanical property of the steel plate.

[0029] In contrast, the inventors found that scale was not completely removed depending on descaling conditions, rather scale nonuniformity was accelerated depending on the descaling conditions. After diligent study of force to cause complete scale removal, the inventors revealed that when descaling was performed after hot leveling, scale was uniformly removed completely so long as the pressure P [MPa] at the point of impact of cooling water sprayed from the spraying nozzles of the descaler 4 to each surface of the steel plate 1 was 1.5 MPa or higher, and the thickness of scale reproduced thereafter was $5 \text{ }\mu\text{m}$ or less and was uniform. Particularly, when the pressure P [MPa] at the point of impact is set to 2.0 MPa or higher, thin uniform scaling can be achieved.

[0030] As regards the pressure P at the point of impact, for example, the following expression (1) obtained experimentally is known and a pressure P_c at the point of impact calculated in this expression (1) is converted into a value in units of MPa that is an SI unit:

$$P_c = 0.05757 \times (Q/A)^{1.08} \times P_s^{0.473} \dots\dots (1)$$

where P_c : pressure at the point of impact [kgf/cm^2], Q: spray flow rate [L/min], A: spray area [cm^2], and P_s : spraying pressure [kgf/cm^2].

[0031] The spray area A is obtained using the following expression (2) by spray experiment:

$$A = B \times T = (2H \tan(\theta/2) \times (0.051H^{0.78} \times Q^{0.09} \times P_s^{-0.045}) \dots\dots (2)$$

where B: spraying width [cm] of spray, T: spraying thickness [cm] of spray, H: spraying distance (the distance between each spraying nozzle of the descaler 4 and each surface of the steel plate 1) [cm], and θ : spray angle [$^\circ$] of nozzle (the angle of spread of descaling water sprayed from the nozzles).

[0032] When Expression (2) is substituted into Expression (1), the following expression is obtained as an approximate expression.

$$P_c = 0.6775 \times Q \times H^{-2} (\tan(\theta/2))^{-1.08} \times P_s^{0.5} \dots\dots (3)$$

The form of expression to obtain the pressure P_c at the point of impact is not limited to this expression. Spray experiment may actually be performed and an expression expressing the regression of a pressure at a direct cooling point or impact point measured by a pressure sensor may be used.

[0033] The spraying distance H [cm] to provide a predetermined pressure at the point of impact is obtained by the following expression (4) as a deformation of Expression (3):

$$H = ((0.6775 \times Q \times (\tan(\theta/2))^{-1.08} \times P_s^{0.5}) / P_c)^{0.5} \dots (4)$$

where P_c : pressure [kgf/cm²] at the point of impact, Q : spray flow rate [L/min], P_s : spraying pressure [kgf/cm²], and θ : spray angle [°] of nozzle.

To set the pressure P [MPa] at the point of impact of spray to the surface of the steel plate 1 to 1.5 MPa or higher, the spraying distance H may be at or below a value of H obtained by substituting $P_c = 1.5/9.8 \times 100 = 15.3$ [kgf/cm²] into Expression (4).

[0034] Fig. 8 is a graph illustrating the relationship between the spraying pressure P_s and the spraying distance H for achieving a pressure P at the point of impact of 1.5 MPa when the spray flow rate Q is 64 L/min, the spray angle θ of nozzle (the angle of spread water sprayed) is 32°, and the angle between the spray direction and the vertical line (the angle by which the center axis of sprayed water is deviated from the vertical direction relative to the steel plate to the upstream side of the traveling direction of the steel plate) is 15°. It is found that when the spraying pressure P is 50 MPa, the spraying distance H may be less than or equal to 175 mm, when the spraying pressure P is 30 MPa, the spraying distance H may be less than or equal to 150 mm, when the spraying pressure P_s is 17.7 MPa, the spraying distance H may be less than or equal to 130 mm, and when the spraying pressure P_s is 14.7 MPa, the spraying distance may be less than or equal to 125 mm.

[0035] As the spraying distance H is shorter, the spraying pressure P_s and the spray flow rate Q for providing the predetermined pressure P at the point of impact are smaller. Thus, the pumping performance of the descender 4 can be reduced. It is therefore preferred that the spraying distance H be less than or equal to 140 mm. More preferably, the spraying distance H is less than or equal to 100 mm. In the present embodiment, since the steel plate 1 subjected to leveling through the first hot leveler 5 is moved into the descender 4, the spraying nozzles of the descender 4 can be moved closer to each surface of the steel plate 1. Preferably, the spraying distance H is greater than or equal to 40 mm and is less than or equal to 140 mm in consideration of contact between the nozzles and the steel plate 1.

[0036] The spraying pressure of a pump used in the normal descender 4 is less than or equal to 14.7 MPa (150 kgf/cm²). Accordingly, a spraying pressure at the tip of each nozzle is further lower than 14.7 MPa by pressure loss in a path. It is therefore preferred to use a pump having a spraying pressure that allows a higher spraying pressure P_s than normal. The upper limit of the spraying pressure P_s is not especially determined. If the spraying pressure P_s is set to high, energy required electric power becomes enormous. It is therefore preferred that the spraying pressure P_s be less than or equal to 50 MPa. A pump providing a spraying pressure P_s of 50 MPa exhibits a maximum spraying pressure among existing commercially available pumps.

[0037] As described above, according to the present embodiment, the descender 4, in which the pressure P at the point of impact of high-pressure water is set to 1.5 MPa or higher, removes scale produced on the surfaces of the steel plate 1, thereby eliminating a variation in scale thickness distribution. During cooling of the steel plate 1 by the cooling equipment 6, therefore, the steel plate 1 can be uniformly cooled with little surface temperature deviation among positions in the width direction as illustrated in Fig. 6. Consequently, the steel plate 1 excellent in steel plate shape and mechanical property can be manufactured.

[0038] Although strip temperature deviation in the width direction of a steel plate passed through the cooling equipment without being subjected to surface treatment by the descender is approximately 40 °C, strip temperature deviation in the width direction of a steel plate subjected to the above-described descaling according to the present invention and then cooled by general cooling equipment is reduced to approximately 10 °C. Moreover, strip temperature deviation in the width direction of the steel plate 1 passed through the descender 4, subjected to descaling according to the present invention, and then subjected to uniform cooling in the width direction by the cooling equipment 6, illustrated in Fig. 2, in the present embodiment is reduced to approximately 4 °C.

[0039] As regards scale on the surfaces of the steel plate 1 affecting stability during cooling of the steel plate 1 by the cooling equipment 6, it is known that the growth of scale on the steel plate 1 can be generally expressed as a diffusion controlled process and is expressed by the following expression (5):

$$\xi^2 = a \times \exp(-Q/RT) \times t \dots\dots\dots (5)$$

where ξ : scale thickness, a: constant number, Q: activation energy, R: constant number, and t: period of time.

[0040] The scale growth was simulated at various temperatures for various periods of time in consideration of scale growth after scale removal by the descaler 4, thereby obtaining the constant numbers in the above-described expression. Furthermore, after diligent study of scale thickness and cooling stability, it was found that cooling is stable at a scale thickness of 15 μm or less, cooling is more stable at a scale thickness of 10 μm or less, and cooling is very stable at a scale thickness of 5 μm or less.

[0041] In other words, it became clear that cooling by the cooling equipment 6 is stable when the period of time t [s] between the completion of removal of scale on the steel plate 1 by the descaler 4 and the start of cooling of the steel plate 1 by the cooling equipment 6 satisfies the following expression (6):

$$t \leq 5 \times 10^{-9} \times \exp(25000/T) \dots\dots (6)$$

where T: temperature [K] of the steel plate before cooling.

[0042] In addition, it became clear that cooling by the cooling equipment 6 is more stable when the period of time t [s] between the completion of removal of scale on the steel plate 1 by the descaler 4 and the start of cooling of the steel plate 1 by the cooling equipment 6 satisfies the following expression (7):

$$t \leq 2.2 \times 10^{-9} \times \exp(25000/T) \dots\dots (7)$$

[0043] Furthermore, it became clear that cooling by the cooling equipment 6 is very stable when the period of time t [s] between the completion of removal of scale on the steel plate 1 by the descaler 4 and the start of cooling of the steel plate 1 by the cooling equipment 6 satisfies the following expression (8):

$$t \leq 5.6 \times 10^{-10} \times \exp(25000/T) \dots\dots (8)$$

On the other hand, the distance L between the descaler 4 and the cooling equipment 6 is set so as to satisfy the following expression (9) with respect to conveying velocity V of the steel plate 1 and the period of time t (the period of time between the completion of processing by the descaler 4 and the start of processing by the cooling equipment 6).

$$L \leq V \times t \dots\dots (9)$$

[0044] It is more preferable that the above-described expression (9) should satisfy the following expression (10) on the basis of the above-described expression (6).

$$L \leq V \times 5 \times 10^{-9} \times \exp(25000/T) \dots\dots (10)$$

It is more preferable that the above-described expression (9) should satisfy the following expression (11) on the basis of the above-described expression (7).

$$L \leq V \times 2.2 \times 10^{-9} \times \exp(25000/T) \dots\dots (11)$$

[0045] Furthermore, it is preferable that the above-described expression (9) should satisfy the following expression (12) on the basis of the above-described expression (8).

$$L \leq V \times 5.6 \times 10^{-10} \times \exp(25000/T) \dots\dots (12)$$

5 For example, assuming that the temperature of the steel plate 1 before cooling by the cooling equipment 6 is 820 °C and the conveying velocity of the steel plate 1 is 0.28 to 2.50 m/s, cooling is stable when the distance L between the descender 4 and the cooling equipment 6 is in the range of 12 to 107 m or less, cooling is more stable when the distance L is in the range of 5 to 47 m or less, and cooling is very stable when the distance L is in the range of 1.3 to 12 m or less on the basis of the above-described expressions (10) to (12).

10 **[0046]** Accordingly, when it is assumed that the distance L between the descender 4 and the cooling equipment 6 is 12 m or less, even if the conveying velocity V of the steel plate 1 is low (for example, V = 0.28 m/s), cooling is stable. In contrast, when the conveying velocity V of the steel plate 1 is high (for example, V = 2.50 m/s), cooling is very stable. It is therefore preferable. It is more preferable that the distance L between the descender 4 and the cooling equipment 6 be less than or equal to 5 m.

15 **[0047]** Considering that most of steel plates 1 of kinds requiring controlled cooling are conveyed at a conveying velocity V of 0.5 m/s or higher, it is more preferable that the distance L as a condition required for very stable cooling at this conveying velocity V should be less than or equal to 2.5 m.

As described above, in the hot rolling facility in the present embodiment, the pressure P [MPa] at the point of impact of spray from the spraying nozzles of the descender 4 to each surface of the steel plate 1 is set to 1.5 or higher to make scale produced on the steel plate 1 uniform, and uniform cooling is achieved by the cooling equipment 6, so that the steel plate 1 excellent in shape and mechanical property can be manufactured.

20 **[0048]** In addition, since the steel plate 1 is subjected to hot leveling by the first hot leveler 5 and scale produced on each surface of the steel plate 1 is then removed by the descender 4, the spraying nozzles of the descender 4 can be moved closer to each surface of the steel plate 1. When the spraying distance H (the distance between each spraying nozzle of the descender 4 and the surface of the steel plate 1) is greater than or equal to 40 mm and less than or equal to 140 mm, the descaling performance is improved. Alternatively, the spraying pressure Ps, the spray flow rate Q, and the like for achieving a predetermined pressure P at the point of impact can be set to low, thus reducing the pumping performance of the descender 4.

25 **[0049]** When the distance L between the descender 4 and the cooling equipment 6 is set so as to satisfy $L \leq V \times 5 \times 10^{-9} \times \exp(25000/T)$, cooling of the steel plate 1 by the cooling equipment 6 can be stabilized.

When the period of time t [s] between the completion of removal of scale on the steel plate 1 by the descender 4 and the start of cooling of the steel plate 1 by the cooling equipment 6 is set so as to satisfy $t \leq V \times 5 \times 10^{-9} \times \exp(25000/T)$, cooling of the steel plate 1 by the cooling equipment 6 can be stabilized.

30 **[0050]** The cooling equipment 6 in the present embodiment is configured such that, as illustrated in Fig. 4, cooling water supplied from the upper cooling water spraying nozzles 11 through the water supply inlets 19 cools the upper surface of the steel plate 1 to turn to high-temperature drainage water and the drainage water flows through the holes 18, which do not receive the upper cooling water spraying nozzles 11, as drain flow paths onto the dividing plate 12 in the width direction of the steel plate 1 so that the drainage water after cooling is immediately removed from the steel plate 1. Cooling water flowing from the upper cooling water spraying nozzles 11 through the water supply inlets 19 sequentially comes into contact with the steel plate 1, thereby providing adequate cooling performance that is uniform in the width direction.

35 **[0051]** As in the present embodiment, strain caused during rolling is leveled by the first hot leveler 5 and surface treatment is performed on the steel plate 1 by the descender 4 to stabilize the controllability of cooling. Accordingly, the steel plate 1 to be processed by the second hot leveler 7 originally has high flatness and the temperature of the steel plate 1 is uniform. The second hot leveler 7 therefore does not need so high leveling reaction force. The distance between the cooling equipment 6 and the second hot leveler 7 may be longer than a maximum length of the steel plate 1 to be manufactured on lines. Since the second hot leveler 7 often performs reverse leveling or the like, the effect of preventing a trouble caused when the reversed steel plate 1 bounces on a conveying roll and hits against the cooling equipment 7 and the effect of making slight temperature deviation, caused during cooling, uniform to prevent the occurrence of a warp caused by temperature deviation after leveling can be expected.

EXAMPLES

40 **[0052]** The steel plate 1, rolled by the hot rolling mill 3, having a thickness of 30 mm and a width of 3500 mm was passed through the first hot leveler 5 and the descender 4 and was then controlled such that the steel plate was cooled from 820 °C to 420 °C. As regards a condition for stable cooling calculated from the above-described expressions (6), (7), and (8), the period of time t between the completion of removal of scale on the steel plate 1 by the descender 4 and the start of cooling of the steel plate 1 by the cooling equipment 6 is less than or equal to 42 s, preferably, less than or

equal to 19 s, and more preferably, less than or equal to 5 s.

[0053] As regards the descaler 4, the spraying pressure of nozzles was 17.7 MPa, the spray flow rate per nozzle was 64 L/min/nozzle, the spraying distance (the distance between each spraying nozzle of the descaler 4 and each surface of the steel plate 1) was 130 mm, the spray angle of nozzle was 32°, the angle between the spray direction and the vertical line was 15°, the nozzles were aligned in the width direction such that the spraying areas of the neighboring nozzles overlap to some extent, and the pressure at the point of impact in each position in the width direction was 1.5 MPa.

[0054] The cooling facility 6 was a facility provided with flow paths configured such that cooling water supplied to the upper surface of the steel plate flowed over the dividing plate as illustrated in Fig. 2 and the water was drained on one side in the width direction of the steel plate as illustrated in Fig. 4. The dividing plate was provided with 12 mm diameter holes arranged in a grid pattern such that the water supply inlets arranged in a staggered layout received the upper cooling water spraying nozzles and the other holes were used as drain outlets. The distance between the lower surface of the upper header and the upper surface of the dividing plate was 100 mm.

[0055] The upper cooling water spraying nozzles each had an inner diameter of 5 mm, an outer diameter of 9 mm, and a length of 170 mm. The tips of the nozzles projected into the header. The spraying velocity of rod-like cooling water was 8.9 m/s. Ten rows of nozzles were arranged in a zone, serving as a 1-m distance between table rollers, with a 50-mm nozzle pitch in the width direction of the steel plate. The water flow rate on the upper surface was 2.1 m³/m²·min. The lower end of each nozzle for upper surface cooling was placed in the middle between the upper and lower surfaces of the dividing plate having a thickness of 25 mm such that the distance between the lower end of the nozzle and the surface of the steel plate was 80 mm.

As regards the lower surface cooling facility, as illustrated in Fig. 2, the same cooling facility as the upper surface cooling facility was used, except that the facility included no dividing plate. The spraying velocity and water flow rate of rod-like cooling water were 1.5 times as high as those for the upper surface.

[0056] As illustrated in Table 1, the distance L between the descaler 4 and the cooling equipment 6, the steel plate conveying velocity V, and the period of time between the descaler 4 and the cooling equipment 6 were variously changed. In Table 1, descaling is a process of removing scale on the steel plate 1 by the descaler 4 and controlled cooling is a process of cooling the steel plate 1 by the cooling equipment 6.

[0057]

Table 1

	Descaling before Controlled Cooling	Descaling pressure at Point of Impact MPa	Distance between Descaler and Cooling Equipment L [m]	Steel Plate between Conveying Velocity V[m/s]	Period of Time Descaling and Controlled Cooling t [s]	Releveling Rate %
Example 1 of Invention	Done	1.5	5	0.28	18	5
Example 2 of Invention	Done	1.5	5	0.6	8	4
Example 3 of Invention	Done	1.5	5	1.8	3	2
Example 4 of Invention	Done	1.5	13	0.28	46	12
Example 5 of Invention	Done	2.4	2.5	0.8	3	1
Comparative Example 1	Not done	-	-	-	-	40
Comparative Example 2	Done	0.09	5	0.6	8	70

[0058] In each of Examples 1 to 5 (steel plates 1) of the present invention in Table 1, when cooled by the cooling equipment 6, the steel plate was uniformly cooled with little surface temperature deviation among positions in the width direction as illustrated in Fig. 6, so that the flatness was excellent, the rate of releveling caused by poor shape was low, and the surface condition was good.

Particularly, in Examples 1 to 3 in each of which the distance between the descaler 4 and the cooling equipment 6 was 5 m, the period of time t between the completion of removal of scale on the steel plate 1 by the descaler 4 and the start of cooling of the steel plate 1 by the cooling equipment 6 was less than or equal to 19 S that was the condition for more stable cooling by the cooling equipment 6 based on the above-described expression (6), irrespective of the steel plate conveying velocity V. The releveling rate was less than or equal to 5%, namely, it was good.

[0059] In Example 5 of the present invention in which the distance between the descaler 4 and the cooling equipment 6 was 2.5 m, the spraying pressure of nozzles was 17.7 MPa, the spray flow rate per nozzle was 64 L/min/nozzle, the spraying distance (the distance between each spraying nozzle of the descaler 4 and each surface of the steel plate 1) was 90 mm, the spray angle of nozzle was 40°, the angle between the spray direction and the vertical line was 15°, and the pressure at the point of impact was thereby 2.4 MPa, the releveling rate was 1%, namely, it was very good.

[0060] On the other hand, in Comparative Example 1 in which scale removal by the descaler 4 was not done and cooling by the cooling equipment 6 was performed, the flatness was degraded, which may be caused by temperature distribution of the steel plate. The releveling rate was 40%.

In Comparative Example 2 in which water pressure was 10 MPa, the spray flow rate per nozzle was 10 L/min/nozzle, the spraying distance was 180 mm, the spray angle of nozzle was 25°, the angle between the spray direction and the vertical line was 15°, and the pressure at the point of impact was 0.09 MPa as setting conditions for the descaler 4, scale was partially removed, so that the temperature distribution in the width direction of the steel plate was degraded. The releveling rate was 70%.

Reference Signs List

[0061] 1 steel plate, 2 heating furnace, 3 hot rolling mill, 4 descaler, 5 first hot leveler (hot leveler), 6 cooling equipment, 7 second hot leveler, 10 upper header (header), 11 upper cooling water spraying nozzle (cooling water spraying nozzle, 12 dividing plate, 13 lower header, 15 lower cooling water spraying nozzle, 16 and 17 squeezing rolls, 18 hole, 19 water supply inlet, and 20 drain outlet.

Claims

1. A steel plate manufacturing facility comprising:

a hot rolling mill, a hot leveler, a descaler, and cooling equipment arranged in that order from the upstream side in a conveying direction, wherein a pressure P at the point of impact of cooling water sprayed from the descaler to each surface of a steel plate is greater than or equal to 1.5 MPa.

2. The steel plate manufacturing facility according to Claim 1, wherein when V [m/s] denotes the conveying velocity from the descaler to the cooling equipment and T [K] denotes the temperature of the steel plate before cooling, the distance L [m] between the descaler and the cooling equipment satisfies the expression $L \leq V \times 5 \times 10^{-9} \times \exp(25000/T)$.

3. The steel plate manufacturing facility according to Claim 1, wherein the components are arranged such that the distance L between the descaler and the cooling equipment is less than or equal to 12 m.

4. The steel plate manufacturing facility according to any one of Claims 1 to 3, wherein the distance H between each spraying nozzle of the descaler and each surface of the steel plate is greater than or equal to 40 mm and less than or equal to 140 mm.

5. The steel plate manufacturing facility according to any one of Claims 1 to 4, wherein the cooling equipment includes a header supplying cooling water to the upper surface of the steel plate, cooling water spraying nozzles extending from the header and spraying rod-like cooling water, and a dividing plate disposed between the steel plate and the header, and the dividing plate includes a plurality of water supply inlets receiving the lower ends of the cooling water spraying nozzles and a plurality of drain outlets draining the cooling water supplied to the upper surface of the steel plate onto the dividing plate.

6. A steel plate manufacturing method including a hot rolling step, a hot leveling step, and a cooling step performed in that order to manufacture a steel plate, the method comprising:

a descaling step of spraying cooling water to each surface of the steel plate at a pressure at the point of impact

of 1.5 MPa or higher, the descaling step being performed between the hot leveling step and the cooling step.

7. The steel plate manufacturing method according to Claim 6, wherein when T [K] denotes the temperature of the steel plate before cooling, the period of time t [s] between the completion of the descaling step and the start of the cooling step satisfies the expression $t \leq 5 \times 10^{-9} \times \exp(25000/T)$.

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FIG. 1

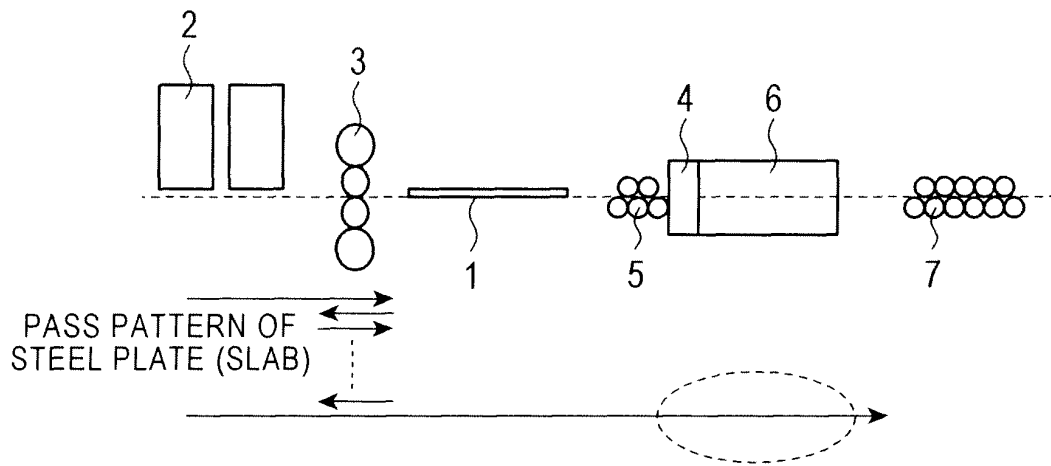


FIG. 2

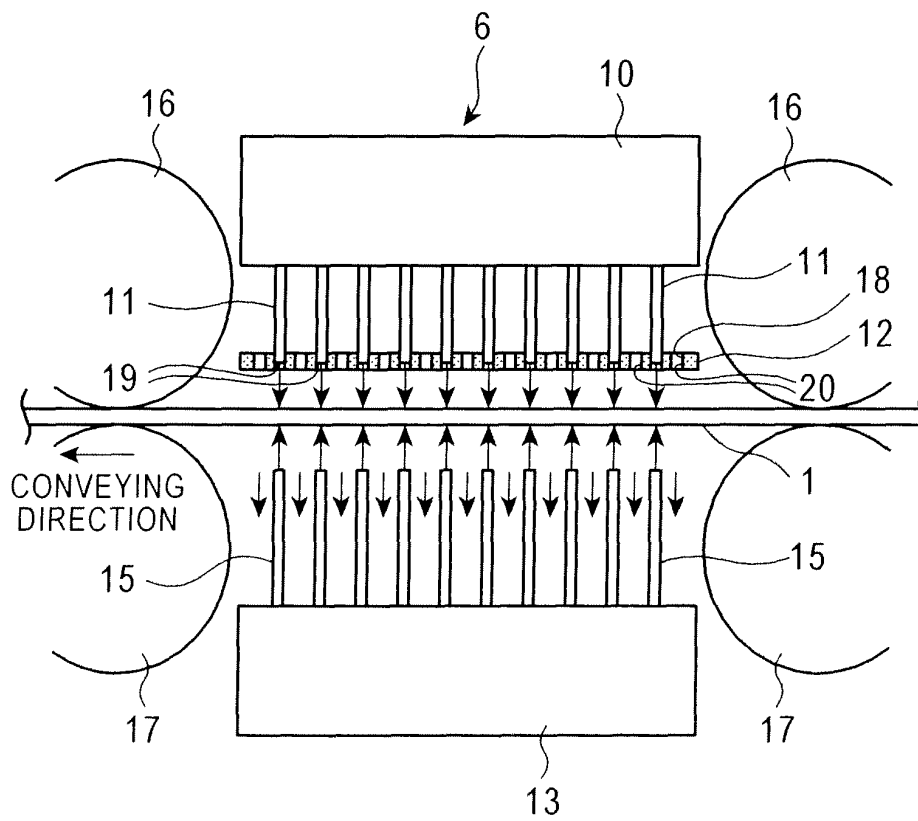


FIG. 3

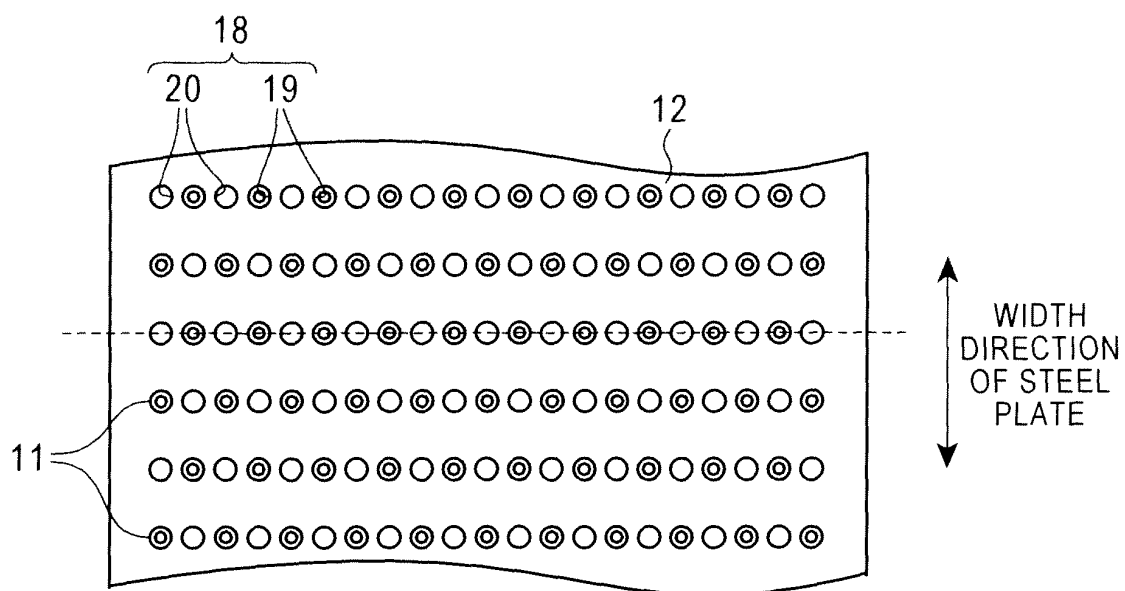


FIG. 4

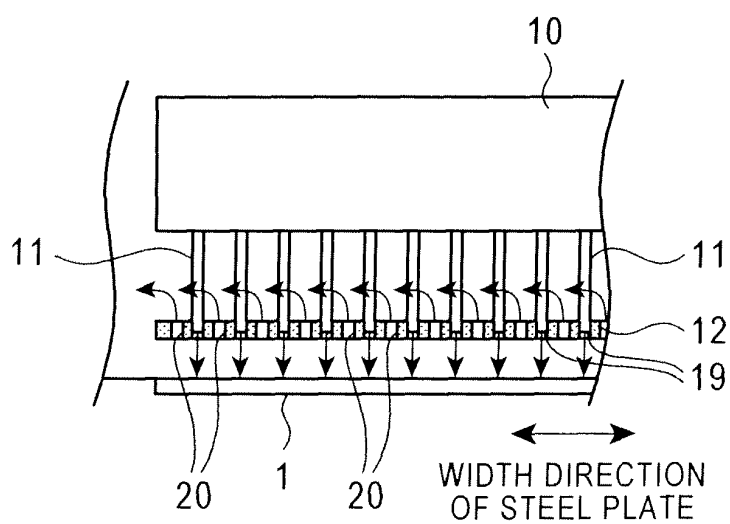


FIG. 5

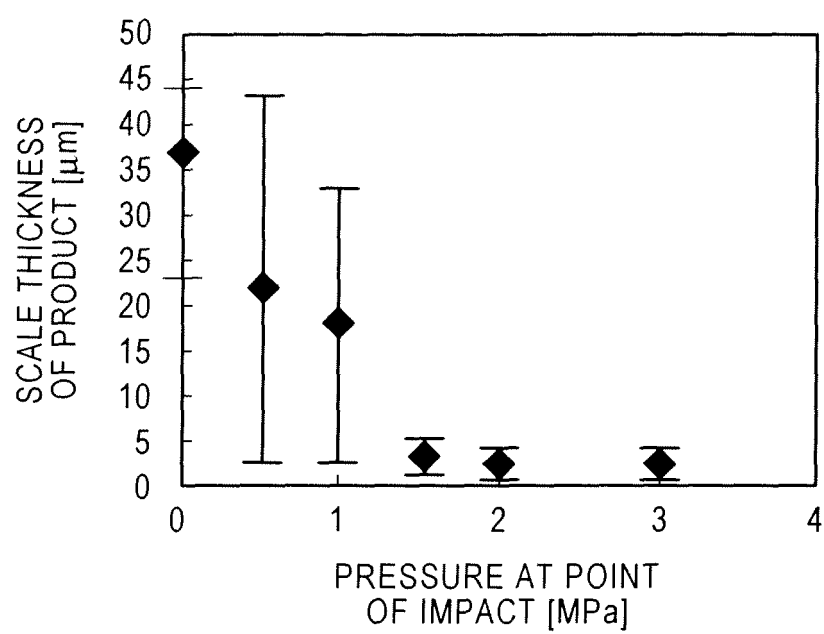


FIG. 6

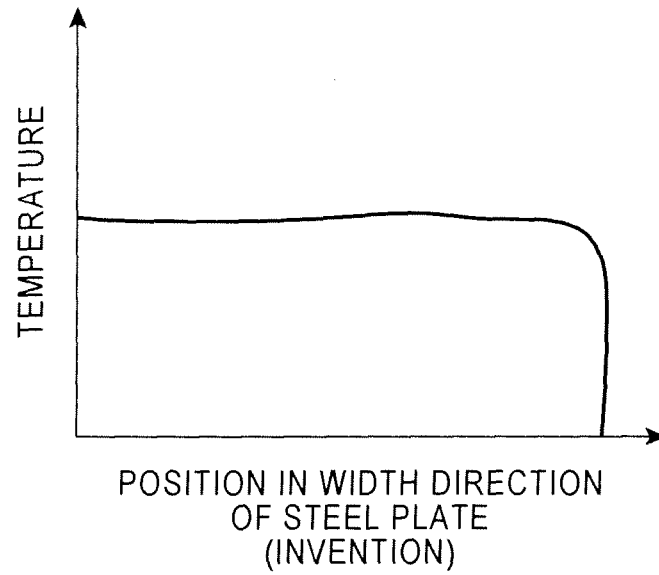


FIG. 7

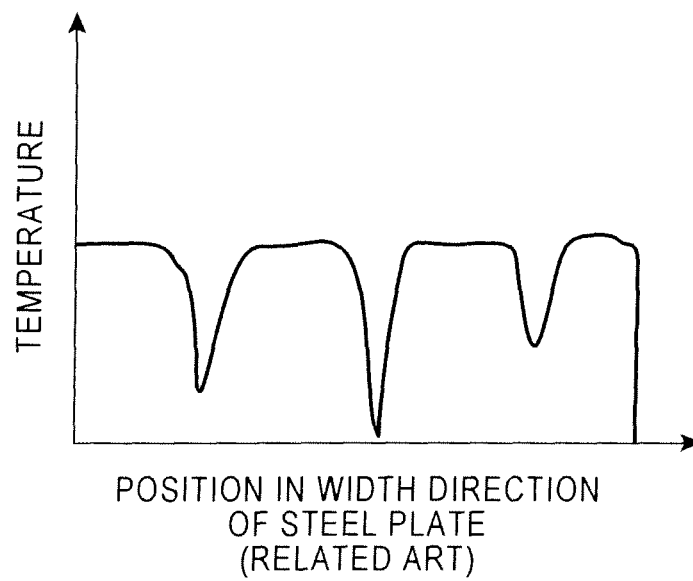
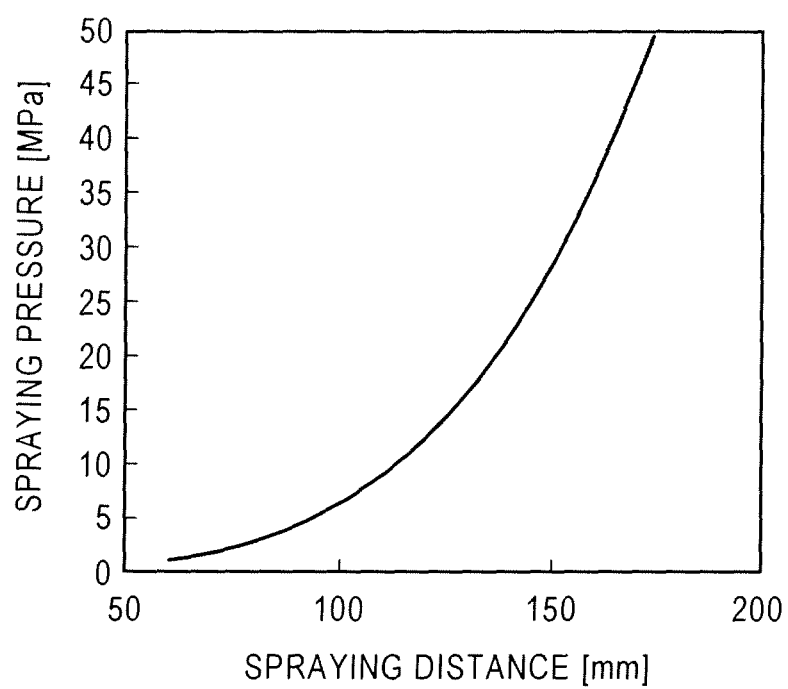


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/055497

A. CLASSIFICATION OF SUBJECT MATTER

B21B45/02(2006.01)i, B21B39/00(2006.01)i, B21B45/08(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)

B21B45/02, B21B39/00, B21B45/08

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2010

Kokai Jitsuyo Shinan Koho 1971-2010 Toroku Jitsuyo Shinan Koho 1994-2010

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.
Y A	JP 3796133 B2 (Nippon Steel Corp.), 12 July 2006 (12.07.2006), claims 1, 2, 5; paragraphs [0017] to [0025]; fig. 1 (Family: none)	1-4, 6, 7 5
Y A	JP 10-113713 A (Kobe Steel, Ltd.), 06 May 1998 (06.05.1998), paragraph [0015] (Family: none)	1-4, 6, 7 5
Y	JP 9-253734 A (Nisshin Steel Co., Ltd.), 30 September 1997 (30.09.1997), paragraph [0009] (Family: none)	4

☒ 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
15 April, 2010 (15.04.10)Date of mailing of the international search report
27 April, 2010 (27.04.10)Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2010/055497

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 59-144513 A (Mitsubishi Heavy Industries, Ltd.), 18 August 1984 (18.08.1984), fig. 4, 5 (Family: none)	5

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REFERENCES CITED IN THE DESCRIPTION

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