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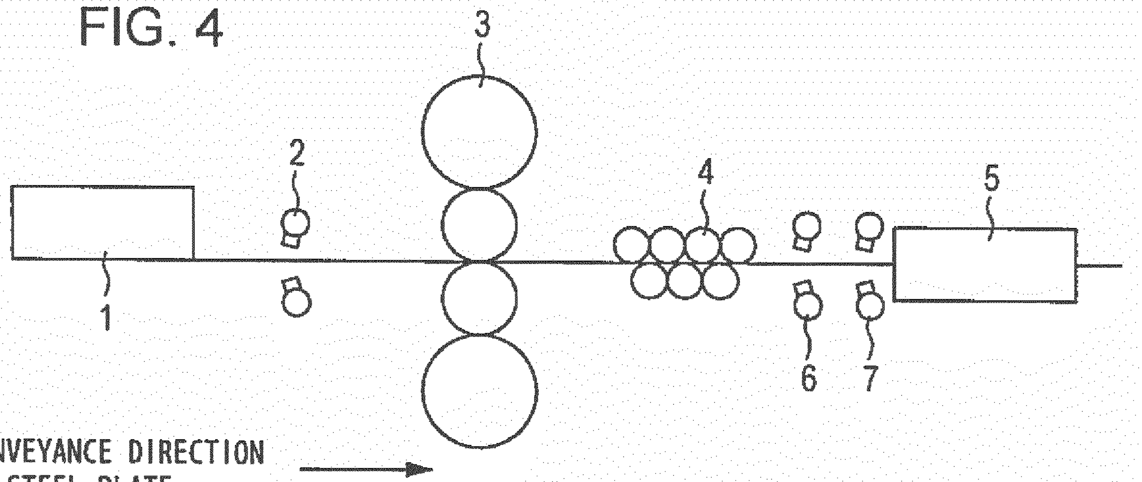
(54) **THICK STEEL PLATE MANUFACTURING METHOD**

(57) It is an object to provide a method for manufacturing a steel plate that provides a high-quality steel plate having less variation in quality.

A method for manufacturing a steel plate, which performs a hot rolling step, a hot correction step, and an accelerated cooling step in this order, the method further including a descaling step in which jetting of descaling water is performed two times between the hot correction step and the accelerated cooling step, wherein, in the descaling step, energy density of the descaling water that is jetted to a surface of the steel plate is greater than or equal to 0.07 J/mm^2 in total for the jetting performed two times, second-descaling water is jetted after 0.5 s or more after jetting first-descaling water, and a surface temperature of the steel plate just before the second-descaling water is jetted is lower than or equal to a Ar_3 transformation point.

FIG. 4



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Description

Technical Field

[0001] The present invention relates to a method for manufacturing a steel plate.

Background Art

[0002] In the process of manufacturing a steel plate by hot rolling, controlled cooling has been increasingly applied. For example, as shown in Fig. 1, after re-heating a steel plate (not shown) in a heating furnace 1, the steel plate is descaled at a descaling apparatus 2. Then, after rolling the steel plate by a rolling apparatus 3, the steel plate is subjected to correction by a shape correcting apparatus 4. Thereafter, an accelerated cooling apparatus 5 performs controlled cooling by water cooling or air cooling. The direction of an arrow indicates a conveyance direction of a steel plate.

[0003] It is known that, as shown in Fig. 2, when a steel plate is cooled by water cooling at the accelerated cooling apparatus, as scales on surfaces of the steel plate become thicker, the cooling speed is increased and the cooling time is reduced. However, if there are variations in scale thickness, the cooling speed becomes non-uniform, to cause variation in material quality such as strength and hardness.

[0004] When the scale thickness is non-uniform, the cooling speed becomes non-uniform as mentioned above. In such a case, the surface temperature of the steel plate when accelerated cooling is stopped in a steel plate width direction (hereunder, referred to as "cooling stop temperature") is known to have a distribution that varies, for example, as shown in Fig. 3. Accordingly, since there are variations in the cooling stop temperature of the steel plate, uniform material quality cannot be obtained. In a specific example thereof, when there is a portion where the scale thickness is 40 μm and a portion where the scale thickness is 20 μm in the width direction of the steel plate, the cooling stop temperature when the steel plate having a plate thickness of 25 mm is cooled from 800°C to a target temperature of 500°C is 460°C at the portion where the scale thickness is 40 μm, and is 500°C at the portion where the scale thickness is 20 μm. The cooling stop temperature of the portion where the scale thickness is 40 μm is lower than the target temperature by 40°C. As a result, uniform material quality cannot be obtained.

[0005] Accordingly, Patent Literature 1 discloses a method of realizing a uniform cooling stop temperature by making the cooling speed uniform by controlling the scale thickness. In Patent Literature 1, by using descaling apparatuses that are provided in front of and behind a rolling apparatus during rolling, the jetting water amount for descaling at a tail end side of a steel plate is controlled to be greater than the jetting water amount for descaling at a leading end side of the steel plate when the cooling stop temperature of the tail end of the steel plate becomes lower than the cooling stop temperature of the leading end of the steel plate. By controlling residual thickness and scale removal percentage in a longitudinal direction of a steel plate, the heat transfer coefficient of surfaces of the steel plate during controlled cooling is changed to make uniform the cooling stop temperature in the longitudinal direction of the steel plate.

Citation List

Patent Literature

[0006] PTL 1: Japanese Unexamined Patent Application Publication No. 6-330155

Summary of Invention

Technical Problem

[0007] In the prior art, the cooling stop temperature is made uniform by adjusting the cooling water amount and the conveyance velocity. However, in this method, the cooling speed is non-uniform when there are variations in the scale thickness. Therefore, it is difficult not only to make the cooling speed uniform, but also to make the cooling stop temperature uniform.

[0008] In addition, in the method in Patent Literature 1, since the heat transfer coefficient also cannot be controlled if the scale removal percentage and residual thickness cannot be controlled on-line, the cooling speed cannot be made uniform with high precision. When the scale removal percentage is changed, the cooling stop temperature at the portion where the scale remains and the cooling stop temperature at the portion where the scale is peeled off differ from each other, causing variations in material quality.

[0009] An object of the present invention to solve the above-described problems and to provide a method for manufacturing a steel plate, which can ensure a high-quality steel plate having less variation in quality.

Solution to Problem

[0010] The present invention is made in order to solve the above-described existing problems. The gist of the present invention is as follows:

[1] A method for manufacturing a steel plate by performing a hot rolling step, a hot correction step, and an accelerated cooling step in that order, the method further including a descaling step in which jetting of descaling water is performed two times between the hot correction step and the accelerated cooling step, wherein, in the descaling step, energy density of the descaling water that is jetted to a surface of the steel plate is greater than or equal to 0.07 J/mm^2 in total for the jetting performed two times, second-descaling water is jetted after 0.5 s or more after jetting first-descaling water, and a steel-sheet surface temperature just before the second-descaling water is jetted is lower than or equal to a Ar_3 transformation point.

[2] A method for manufacturing a steel plate by performing a hot rolling step, a hot correction step, and an accelerated cooling step in that order, the method further including a descaling step in which jetting of descaling water is performed two or more times between the hot correction step and the accelerated cooling step, wherein, in the descaling step, energy density of the descaling water that is jetted to a surface of the steel plate is greater than or equal to 0.07 J/mm^2 in total for the jetting performed two or more times, final-descaling water is jetted after 0.5 s or more after jetting just-before-final-descaling water, and a steel-sheet surface temperature just before the final-descaling water is jetted is lower than or equal to a Ar_3 transformation point.

[3] In the method for manufacturing a steel plate according to either [1] or [2], wherein a time t [s] from after completion of the descaling step to start of the accelerated cooling step satisfies the expression $t \leq 5 \times 10^{-9} \times \exp(25000/T)$, where a temperature of the steel plate before cooling is T [K].

Advantageous Effects of Invention

[0011] According to the present invention, it is possible to make the cooling speed and the cooling stop temperature uniform. As a result, it is possible to manufacture a high-quality steel plate having less variation in quality. Brief Description of Drawings

[0012]

[Fig. 1] Fig. 1 is a schematic view of a conventional facility for manufacturing a steel plate.

[Fig. 2] Fig. 2 shows the relationship between scale thickness, cooling time, and surface temperature of the steel plate when performing accelerated cooling.

[Fig. 3] Fig. 3 shows the relationship between the position in the width direction of the steel plate and cooling stop temperature after accelerated cooling.

[Fig. 4] Fig. 4 is a schematic view of a facility for manufacturing a steel plate according to an embodiment of the present invention.

[Fig. 5] Fig. 5 is a schematic view showing the arrangement relationship of jetting nozzles of descaling apparatus, with Fig. 5(a) being a schematic view showing the relationship between the positions of jetting nozzles and Fig. 5(b) being a schematic view of a spray pattern.

[Fig. 6] Fig. 6 shows the relationship between energy density of descaling water and scale peeling percentage.

[Fig. 7] Fig. 7 shows temperature history of the steel plate in each descaling in a descaling step.

[Fig. 8] Fig. 8 is a transformation diagram of steel plate from a first descaling to a second descaling.

[Fig. 9] Fig. 9 is a side view of an accelerated cooling apparatus according to the embodiment of the present invention.

[Fig. 10] Fig. 10 is a side view of another accelerated cooling apparatus according to the embodiment of the present invention.

[Fig. 11] Fig. 11 illustrates an exemplary nozzle arrangement at a partition wall according to the embodiment of the present invention.

[Fig. 12] Fig. 12 illustrates flow of drain cooling water along an upper side of the partition wall.

[Fig. 13] Fig. 13 illustrates another flow of drain cooling water along the upper side of the partition wall.

[Fig. 14] Fig. 14 illustrates temperature distribution of a steel plate in a width direction thereof in a related art.

[Fig. 15] Fig. 15 illustrates flow of cooling water in the accelerated cooling apparatus.

[Fig. 16] Fig. 16 illustrates non-interference with respect to drain cooling water along the upper side of the partition wall in the accelerated cooling apparatus. Description of Embodiment

[0013] An embodiment according to the present invention is described below with reference to the drawings.

[0014] Fig. 4 is a schematic view of a facility for manufacturing a steel plate according to an embodiment of the present invention. In Fig. 4, the direction of an arrow corresponds to a conveyance direction of a steel plate. From an upstream side in the t conveyance direction of the steel plate, a heating furnace 1, a descaling apparatus 2, a rolling apparatus 3, a shape correcting apparatus 4, a descaling apparatus 6, a descaling apparatus 7, and an accelerated cooling apparatus 5 are set in this order. In Fig. 4, after re-heating the steel plate (not shown) in the heating furnace 1, the steel plate is descaled for primary scale removal in the descaling apparatus 2. Then, after the rolling apparatus 3 has performed hot rolling on the steel plate, and the shape correcting apparatus 4 has subjected the steel plate to correction, the descaling apparatus 6 and the descaling apparatus 7 perform descaling for completely removing scale. Thereafter, the accelerated cooling apparatus 5 performs controlled cooling by water cooling or air cooling.

[0015] In the present embodiment, two descaling apparatuses, that is, the descaling apparatus 6 and the descaling apparatus 7 are set between the shape correcting apparatus 4 and the accelerated cooling apparatus 5. The descaling apparatus shown in Fig. 4 is configured in only two rows. Descaling apparatus may be configured in three or more rows. When the descaling apparatus shown in Fig. 4 is configured in two rows, energy density of descaling water that is jetted to surfaces of the steel plate from the descaling apparatus 6 and the descaling apparatus 7 is greater than or equal to 0.07 J/mm^2 in total for the two rows of jetting nozzles, and the descaling water is jetted from the descaling apparatus 7 after 0.5 s or more after jetting the descaling water from the descaling apparatus 6, and the surface temperature of the steel plate just before the descaling water is jetted from the descaling apparatus 7 is made lower than or equal to a Ar_3 transformation point. When descaling apparatus is configured in three or more rows, energy density is greater than or equal to 0.07 J/mm^2 in total for all rows of jetting nozzles of the descaling apparatus, and final-descaling water is jetted after 0.5 s or more after jetting just-before-final-descaling water from the descaling apparatus, and the surface temperature of the steel plate just before the final-descaling water is jetted is made lower than or equal to the Ar_3 transformation point. This allows the scale to be completely removed, so that uniform cooling can be realized.

[0016] In the present invention, for example, as shown in Fig. 5(a), a descaling header 6-1 of the descaling apparatus 6 and a descaling header 7-1 of the descaling apparatus 7 are set in two rows in a longitudinal direction of the steel plate. Descaling water is jetted from a plurality of jetting nozzles 6-2 and 7-2 of the descaling headers to a steel plate 1, to form a spray pattern 22 as shown in Fig. 6(b). In order to prevent splashed descaling water from the descaling apparatus 7 in the second row from interfering with the descaling water from the descaling apparatus 6 in the first row, it is desirable that the jetting nozzles 6-2 and the jetting nozzles 7-2 be separated from each other by 500 mm or more in the longitudinal direction of the thick steel plate, that is, the conveyance direction of the steel plate. It is desirable that jetting patterns in the width direction be in a staggered arrangement in which the jetting nozzles 6-2 and the jetting nozzles 7-2 are shifted from each other in the width direction. The descaling apparatus shown in Fig. 5(a) is configured in two rows. The same effects are obtained even if the number of rows is three or more. As in the case where the descaling apparatus is configured in two rows, even when descaling apparatus is configured in three or more rows, it is desirable that the nozzle rows be separated by 500 mm or more in the longitudinal direction and be in a staggered arrangement. Here, since the above-described effect is no longer increased when the number of rows exceeds three, it is desirable that the upper limit be three rows.

[0017] At the time of descaling, by cooling the scale surface with descaling water, thermal stress is generated in the scale, and impact force acts due to the descaling water. As a result, the scale is removed by peeling or destruction. The inventors carried out assiduous studies and found out that, by performing descaling two or more times between a hot shape correction step and an accelerated cooling step, the effects of thermal stress that is generated at the time of descaling can be provided two or more times. The relationship between energy density and scale peeling percentage (proportion of the area in which the scale has been peeled off to the area of the steel plate) is specifically "no transformation occurs" in Fig. 6.

[0018] Further, when, as indicated by "transformation occurs" in Fig. 6, the energy density of the descaling water that is jetted to the surfaces of the steel plate is greater than or equal to 0.07 J/mm^2 in total for the two jettings, and the descaling water is jetted to the surfaces of the steel plate from the descaling apparatus 7 after 0.5 s or more after jetting the descaling water from the descaling apparatus 6 to the surfaces of the steel plate, and the surface temperature of the steel plate just before starting the jetting of the descaling water from the descaling apparatus is made lower than or equal to the Ar_3 transformation point, the scale can be more efficiently removed. The effect of making it possible to more efficiently remove scale when the surface temperature of the steel plate at the time of starting jetting of descaling water is made lower than or equal to the Ar_3 transformation point was confirmed for the case in which the number of jettings of descaling water was three or more. Here, the energy density in total for the two descalings can be calculated by totaling up the energy density of each descaling calculated by an expression described later. The Ar_3 transformation point can be calculated by the following Expression (*) :

$$Ar_3\ (^\circ C) = 910 - 310C - 80Mn - 20Cu - 15Cr - 55Ni - 80Mo \quad \cdots (*)$$

where the chemical symbol indicates the content of the element in steel (mass%), with the content being zero when the element is absent.

[0019] The inventors carried out studies and found out that, when the energy density of the descaling water that is jetted to the surfaces of the steel plate is greater than or equal to 0.07 J/mm^2 in total for two or more jettings, and when the surface temperature of the steel plate just before the final-descaling water is jetted is made lower than or equal to the Ar_3 transformation point, it is possible to transform the surfaces of the, and, due to the transformation of base iron, cause an interface between the scale and the base iron to be shifted and reduce scale adhesion. Therefore, the scale is easily removed by the descaling, and the scale can be peeled off by the descaling water having a smaller energy density.

[0020] Temperature history when the descaling water is jetted from the descaling apparatus 6 and 7 is as shown in Fig. 7. Since an outermost surface layer portion of the base iron is excessively cooled and the transformation is accelerated, even when a holding time at the Ar_3 transformation point or lower is very short at less than or equal to 1 s, a ferrite transformation of only a few tens of μm occurs in the outermost surface layer of the base iron. The inventors carried out studies on the occurrence and non-occurrence of ferrite transformation in the outermost surface layer portion of the base iron by variously changing the descaling water jetting time of a first descaling and a second descaling, and found out that the results are as shown in Fig. 8. When the surface temperature of the steel plate at the time of starting the jetting of descaling water in the second descaling is lower than or equal to the Ar_3 transformation point, and the time up to when the second descaling is performed from the first descaling is greater than or equal to 0.5 s, ferrite transformation occurs in the outermost surface layer of the base iron. Since the transformation occurs for only a few tens of μm in the outermost layer portion of the base iron, scale is easily peeled off by the descaling almost without affecting the material quality such as strength.

[0021] Therefore, when the time to the jetting of second-descaling water after jetting the first-descaling water is greater than or equal to 0.5 s, and the surface temperature of the steel plate just before the jetting of the descaling water in the second descaling is lower than or equal to the Ar_3 transformation point, the scale peeling effect in the second descaling is increased, and energy of the descaling water used during the descaling and required for peeling off the scale is reduced.

[0022] Similarly, even in the case where the number of jettings of descaling water is three or more, when the time to the jetting of the final-descaling water after jetting the just-before-final-descaling water is greater than or equal to 0.5 s and the surface temperature of the steel plate just before the final-descaling water is jetted is lower than or equal to the Ar_3 transformation point, the scale peeling effect of the final descaling is increased, and energy of the descaling water used during the descaling and required for peeling off the scale is reduced.

[0023] The inventors also carried out studies on the energy density at the time of the first descaling by the descaling apparatus 6 and the energy density at the time of the second descaling by the descaling apparatus 7. As described above, when the first descaling causes the base iron surface layer to undergo ferrite transformation before jetting the second-descaling water, the scale peeling effect by the second descaling is increased. Therefore, by applying the required energy for transforming the base iron surface layer in the first descaling and performing the second descaling with a large energy density, the scale can be effectively peeled off. More specifically, it is desirable that the energy density at the time of the first descaling be greater than or equal to 0.02 J/mm^2. When the energy density is less than this value, in order to transform the base iron surface layer by cooling the steel plate with the first-descaling water, it becomes necessary to cool the steel plate before the descaling, such as lowering the temperature of the steel plate in advance before starting the descaling. The energy density of the descaling water has no upper limit as descaling capability. However, when the energy density is greater than or equal to 0.7 J/mm^2 in total for the two descalings, for example, the pump discharge pressure becomes extraordinarily high. Therefore, it is desirable that the energy density be less than or equal to 0.7 J/mm^2.

[0024] When the surface temperature of the steel plate at the time of the second descaling is higher than the Ar_3 transformation point, or when the time up to when the second descaling is performed from the first descaling is less than 0.5 s, ferrite transformation does not occur before the second descaling, and, thus, an increase in scale peelability by the transformation cannot be expected.

[0025] Due to this relationship, even when descaling is performed two or more times and the energy density in total therefor is greater than or equal to 0.07 J/mm^2, if transformation has not occurred by the time the second-descaling water is jetted, scale remains on part of the steel plate, and, thus, there are variations in the cooling stop temperature and the material quality becomes non-uniform.

[0026] Even in the case where the number of descalings is greater than or equal to three, as in the case where the number of descalings is two, it is desirable that the energy density for the just-before-final descaling be greater than or equal to 0.02 J/mm^2, and the total energy density of the descaling water for all the number of the descalings be less than or equal to 0.7 J/mm^2.

[0027] Here, the energy density E (J/mm^2) of the descaling water that is jetted to the steel plate indicates the capability of removing scale by descaling, and is defined by the following Expression (1):

$$E = Q\rho v^2 t \div (2dW) \quad \ldots (1)$$

where Q: jetting flow rate [m^3/s] of descaling water,
d: spray jet thickness [mm] of flat nozzle,
W: spray jet width [mm] of flat nozzle,

fluid density is denoted by ρ [kg/m^3],
fluid velocity at the time of collision with steel plate is denoted by v [m/s],
collision time is denoted by t [s] (t = d/1000 V; conveyance velocity is denoted by V [m/s].

[0028] However, it is not necessarily easy to measure the fluid velocity v at the time of collision with the steel plate. Therefore, strictly determining the energy density E defined by Expression (1) is very troublesome.

[0029] Accordingly, the inventors carried out further studies and found out that, as a simple definition of energy density E (J/mm^2) of descaling water that is jetted to the steel plate, the expression "water amount density × jetting pressure × collision time" may be used. Here, the water amount density (m^3/(mm^2 · min)) is a value that is calculated by using "jetting flow rate of descaling water ÷ collision area of descaling water". The jetting pressure (N/m^2 = Pa)) is defined by discharge pressure of descaling water. The collision time (s) is a value that is calculated by using "collision thickness of descaling water ÷ conveyance velocity of steel plate". The relationship between the energy density of high-pressure water, which is calculated based on this simple definition, and the scale peeling percentage is also as shown in Fig. 6.

[0030] The scale on the surfaces of the steel plate that affects the stability of cooling of the steel plate by the accelerated cooling apparatus 5 is such that, in general, the growth of the scale on the steel plate can be determined by diffusion control, and is known to be represented by the next Expression (2):

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

where ξ: scale thickness, a: constant, Q: activation energy, R: constant, T: temperature [K] of steel plate before cooling, and t: time.

[0031] Therefore, considering the growth of the scale after removing the scale by the descaling apparatus 6 and the descaling apparatus 7, a simulation experiment for the scale growth was conducted for various temperatures and times, the constant in Expression (2) above was experimentally derived, and, further, assiduous tests were carried out regarding the scale thickness and cooling stability. The result is that the cooling becomes stable when the scale thickness is less than or equal to 15 μm, becomes more stable when the scale thickness is less than or equal to 10 μm, and becomes very stable when the scale thickness is less than or equal to 5 μm.

[0032] When the scale thickness is less than or equal to 15 μm, the following Expression (3) can be derived based on Expression (2) above. That is, when the time t [s] from after the completion of the removal of the scale on the steel plate by the descaling apparatuses 6 and 7 to the start of the cooling of the steel plate by the accelerated cooling apparatus 5 satisfies the following Expression (3), the cooling by the accelerated cooling apparatus 5 becomes stable:

$$t \leq 5 \times 10^{-9} \times \exp(25000/T) \quad \ldots (3)$$

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

[0033] When the scale thickness is less than or equal to 10 μm, the following Expression (4) can be derived based on Expression (2) above. That is, when the time t [s] from after the completion of the removal of the scale on the steel plate by the descaling apparatuses 6 and 7 to the start of the cooling of the steel plate by the accelerated cooling apparatus 5 satisfies the following Expression (4), the cooling by the accelerated cooling apparatus 5 becomes more stable:

$$t \leq 2.2 \times 10^{-9} \times \exp(25000/T) \quad \ldots (4)$$

[0034] Further, when the scale thickness is less than or equal to 5 μm, the following Expression (5) can be derived based on Expression (2) above. That is, when the time t [s] from after the completion of the removal of the scale on the steel plate by the descaling apparatuses 6 and 7 to the start of the cooling of the steel plate by the accelerated cooling apparatus 5 satisfies the following Expression (5), the cooling by the accelerated cooling apparatus 5 becomes very stable:

$$t \leq 5.6 \times 10^{-10} \times \exp(25000/T) \quad \dots(5)$$

[0035] The accelerated cooling apparatus 5 according to the present invention is described. As shown in Fig. 9, the upper surface cooling facility of the accelerated cooling apparatus 5 according the present invention includes an upper header 11 that supplies cooling water to an upper surface of a steel plate 10, cooling water injection nozzles 13 that are suspended from the upper header 11 and that are used for jetting rod-shaped cooling water, and a partition wall 15 that is set between the steel plate 10 and the upper header 11. It is desirable that the partition wall 15 have a plurality of water supply ports 16 in which lower end portions of the cooling water injection nozzles 13 are inserted, and a plurality of water drainage ports 17 for draining away the cooling water, supplied to the upper surface of the steel plate 10, to an upper side of the partition wall 15.

[0036] More specifically, the upper surface cooling facility includes the upper header 11 that supplies cooling water to the upper surface of the steel plate 10, the cooling water injection nozzles 13 that are suspended from the upper header 11, and the partition wall 15 that is set horizontally along the width direction of the steel plate and between the upper header 11 and the steel plate 10, and that has a plurality of through holes (the water supply ports 16 and the water drainage ports 17). The cooling water injection nozzles 13 are circular tube nozzles for jetting rod-shaped cooling water. Ends of the cooling water injection nozzles 13 are inserted into the through holes (the water supply ports 16) in the partition wall 15, and are situated above a lower end portion of the partition wall 15. In order to prevent the cooling water injection nozzles 13 from being clogged by sucking in foreign matter at a bottom portion in the upper header 11, it is desirable that the cooling water injection nozzles 13 penetrate the upper header 11 such that upper ends of the cooling water injection nozzles 13 protrude into the upper header 11.

[0037] Here, the term "rod-shaped cooling water" according to the present invention refers to cooling water which is jetted in a state in which the cooling water is compressed to a certain extent from circular nozzle jetting ports (including elliptical and polygonal nozzle jetting ports), and which is a continuous and straight stream, the jetting velocity of the cooling water from the nozzle jetting ports being 6 m/s or higher and, desirably, 8 m/s or higher, and, the cross section of the stream jetted from the nozzle jetting ports being maintained in a substantially circular shape. That is, the cooling water differs from that which flows so as to fall freely from round tube laminar nozzles, and that which is jetted in liquid drops like a spray.

[0038] The ends of the cooling water injection nozzles 13 are inserted into the through holes so as to be set above the lower end portion of the partition wall 15, so that, even if a steel plate whose end is warped upward moves in, the cooling water jetting nozzles 13 are prevented from becoming damaged by the injection wall 15. This makes it possible to perform cooling for a long time with the cooling water injection nozzles 13 in a good state. Therefore, it is possible to prevent the occurrence of temperature unevenness in the steel plate without, for example, repairing the facility.

[0039] Since the ends of the circular tube nozzles 13 are inserted in the through holes, as shown in Fig. 16, the ends of the circular tube nozzles 13 do not interfere with the flow in the width direction of drainage water that flows along an upper surface of the partition wall 15 and that is indicated by a dotted arrow. Therefore, the cooling water jetted from the cooling water injection nozzles 13 can evenly reach the upper surface of the steel plate regardless of locations in the width direction, so that uniform cooling can be performed in the width direction.

[0040] In an example of the partition wall 15, as shown in Fig. 11, the partition wall 15 has a plurality of through holes, each having a diameter of 10 mm, in a grid pattern and at a pitch of 80 mm in the width direction of the steel plate and at a pitch of 80 mm in the conveyance direction. The cooling water injection nozzles 13, each having an outside diameter of 8 mm, an inside diameter of 3 mm, and a length of 140 mm, are inserted in the water supply ports 16. The cooling water injection nozzles 13 are arranged in a staggered manner. The through holes in which the cooling water injection nozzles 13 are not inserted correspond to the water drainage ports 17 for the cooling water. Accordingly, the plurality of through holes in the partition wall 15 of the accelerated cooling apparatus according to the present invention include the water supply ports 16 and the water drainage ports 17 that are substantially the same in number, with their roles and functions being divided among the water supply ports 16 and the water drainage ports 17.

[0041] At this time, the total sectional area of the water drainage ports 17 is sufficiently larger than the total sectional area at the inside diameters of the circular tube nozzles 13, which are the cooling water injection nozzles 13, and is approximately 11 times the total sectional area at the inside diameters of the circular tube nozzles 13. As shown in Fig. 9, the cooling water supplied to the upper surface of the steel plate fills a space between a surface of the steel plate and the partition wall 15, flows through the water drainage ports 17, is guided to a location above the partition wall 15, and is quickly discharged. Fig. 12 is a front view illustrating flow of drain cooling water near an end portion at the upper side of the partition wall in the width direction of the steel plate. A draining direction of the water drainage ports 17 is upward in a direction that is opposite to a cooling water injection direction. The drain cooling water that has flown out to a location above the partition wall 15 changes direction towards an outer side in the width direction of the steel plate, flows to a water drain flow path between the upper header 11 and the partition wall 15, and is drained off.

[0042] In an example shown in Fig. 13, the water drainage ports 17 are inclined in the width direction of the steel plate to cause the draining direction to be in an oblique direction towards the outer side in the width direction of the steel plate. This allows drainage water 19 at the upper side of the partition wall 15 to flow smoothly in the width direction of the steel plate, and the water drainage is accelerated. Therefore, this is desirable.

[0043] Here, when, as shown in Fig. 14, the water drainage ports and the corresponding water supply ports are provided in the same through holes, it becomes difficult for the cooling water that has collided with the steel plate to flow out to a location above the partition wall 15, as a result of which the cooling water flows between the steel plate 10 and the partition wall 15 and towards end portions in the width direction of the steel plate. This causes the flow rate of the drain cooling water between the steel plate 10 and the partition wall 15 to be larger towards the end portions in the width direction of the plate. Therefore, the force for causing jetted cooling water 18 to penetrate a stagnant water film and to reach the steel plate is interfered with to a greater extent towards the end portions in the width direction of the plate.

[0044] In the case of a thin steel sheet, since the sheet width is approximately 2 m at most, the effects thereof are limited. However, in the case of, in particular, a steel plate having a plate width of 3 m or greater, the effects thereof cannot be ignored. Therefore, cooling at the end portions in the width direction of the steel plate is weakened. The temperature distribution of the steel plate in the width direction thereof in this case is an uneven temperature distribution.

[0045] In contrast, as shown in Fig. 15, the accelerated cooling apparatus 5 according to the present invention includes the water supply ports 16 and the water drainage ports 17 that are separately provided. Since the roles of supplying water and draining off water are divided among the water supply ports 16 and the water drainage ports 17, the drain cooling water flows through the water drainage ports 17 in the partition wall 15 and smoothly flows to a location above the partition wall 15. Therefore, the drain water after the cooling is quickly drained off from the upper surface of the steel plate, so that cooling water that is subsequently supplied can easily penetrate the stagnant water film, and, thus, a sufficient cooling capacity can be provided. The temperature distribution of the steel plate in the width direction thereof in this case is a uniform temperature distribution, so that a uniform temperature distribution can be provided in the width direction.

[0046] Incidentally, when the total sectional area of the water drainage ports 17 is greater than or equal to 1.5 times the total sectional area at the inside diameters of the circular tube nozzles 13, the cooling water is quickly discharged. This can be realized, for example, when ports having a size that is greater than the outside diameter of the circular tube nozzles 13 are formed in the partition wall 15, and the number of water drainage ports is greater than or equal to the number of water supply ports.

[0047] When the total sectional area of the water drainage ports 17 is less than 1.5 times the total sectional area of inside diameter portions of the circular tube nozzles 13, the flow resistance at the water drainage ports is increased and, thus, it becomes difficult to drain off stagnant water. As a result, the amount of cooling water that can penetrate the stagnant water film and reach the surface of the steel plate is considerably reduced, thereby reducing the cooling capacity. Therefore, this is not desirable. It is more desirable that the total sectional area of the water drainage ports 17 be greater than or equal to 4 times the total sectional area of the inside diameter portions of the circular tube nozzles 13. On the other hand, when there are too many water drainage ports or the sectional diameter of the water drainage ports is too large, the rigidity of the partition wall 15 is reduced, as a result of which the partition wall 15 tends to be damaged when the steel plate collides with the partition wall 15. Therefore, it is desirable that the ratio between the total sectional area of the water drainage ports and the total sectional area at the inside diameters of the circular tube nozzles 13 be in the range of 1.5 to 20.

[0048] It is desirable that gaps between outer peripheral surfaces of the circular tube nozzles 13, which are inserted in the water supply ports 16 in the partition wall 15, and inner surfaces defining the water supply ports 16 be less than or equal to 3 mm in size. When the gaps are large, due to the effects of accompanied flow of the cooling water that is jetted from the circular tube nozzles 13, the drain cooling water discharged to the upper surface of the partition wall 15 is sucked into the gaps between the water supply ports 16 and the outer peripheral surfaces of the circular tube nozzles 13, and is re-supplied to the steel plate. Therefore, the cooling efficiency is reduced. In order to prevent this, it is more desirable that the outside diameter of the circular tube nozzles 13 be substantially the same as the size of the water supply ports 16. However, considering working accuracy and mounting errors, gaps of up to 3 mm, at which the effects are substantially small, are allowed. It is more desirable that the gaps be less than or equal to 2 mm in size.

[0049] Further, in order to allow the cooling water to penetrate the stagnant water film and to reach the steel plate, the inside diameter and length of the circular tube nozzles 13, the jetting velocity of the cooling water, and nozzle distance also need to be optimal values.

[0050] That is, it is desirable that the nozzle inside diameter be 3 to 8 mm. When the nozzle inside diameter is less than 3 mm, a flux of water that is jetted from the nozzles becomes thinner, and, thus, water strength is reduced. On the other hand, when the nozzle diameter exceeds 8 mm, the flow rate is reduced, as a result of which the force for causing the cooling water to penetrate the stagnant water film is reduced.

[0051] It is desirable that the length of each circular tube nozzle 13 be 120 to 240 mm. Here, the length of each circular tube nozzle 13 refers to the length from an inlet at the upper end of each nozzle that penetrates the header by a certain amount to a lower end of each nozzle inserted in the corresponding water supply port in the partition wall. When each circular tube nozzle 13 is shorter than 120 mm, the distance between a lower surface of the header and the upper surface of the partition wall becomes too small (for example, when the header thickness is 20 mm, a protruding amount of the upper end of each nozzle into the header is 20 mm, and an insertion amount of the lower end of each nozzle into the partition wall is 10 mm, the distance becomes less than 70 mm). Therefore, a drain space above the partition wall becomes small, as a result of which the drain cooling water cannot be smoothly discharged. On the other hand, when the length is greater than 240 mm, pressure loss at each circular tube nozzle 13 becomes large, and, thus, the force for causing the cooling water to penetrate the stagnant water film is reduced.

[0052] The jetting velocity of the cooling water from the nozzles needs to be greater than or equal to 6 m/s, and, desirably, greater than or equal to 8 m/s. This is because, when the jetting velocity is less than 6 m/s, the force for causing the cooling water to penetrate the stagnant water film becomes extremely weak. When the jetting velocity is greater than or equal to 8 m/s, a higher cooling capacity can be provided. Therefore, this is desirable. The distance from the lower end of each cooling water injection nozzle 13, used for cooling the upper surface of the steel plate, to the surface of the steel plate 10 may be 30 to 120 mm. When this distance is less than 30 mm, the frequency with which the steel plate 10 collides with the partition wall 15 is extremely high. Therefore, it becomes difficult to maintain the facility. When this distance exceeds 120 mm, the force for causing the cooling water to penetrate the stagnant water film becomes extremely weak.

[0053] In cooling the upper surface of the steel plate, draining rollers 20 may be set in front of and behind the upper header 11 so as to prevent the cooling water from spreading in the longitudinal direction of the steel plate. This causes a cooling zone length to be constant, and facilitates temperature control. Here, since the draining rollers 20 intercept the flow of the cooling water in the conveyance direction of the steel plate, the drain cooling water flows to the outer side in the width direction of the steel plate. However, the cooling water tends to stagnate near the draining rollers 20.

[0054] Accordingly, as shown in Fig. 10, it is desirable that, of the rows of circular tube nozzles 13 that are set side by side in the width direction of the steel plate, the cooling water injection nozzles in an uppermost-stream-side row in the conveyance direction of the steel plate be tilted towards an upstream side in the conveyance direction of the steel plate by 15 to 60 degrees, and the cooling water injection nozzles in a lowermost-stream-side row in the conveyance direction of the steel plate be tilted towards a downstream side in the conveyance direction of the steel plate by 15 to 60 degrees. This makes it possible to also supply the cooling water to locations close to the draining rollers 20, and, thus, increase the cooling efficiency without stagnation of the cooling water near the draining rollers 20.

[0055] It is desirable that the distance between the lower surface of the upper header 11 and the upper surface of the partition wall 15 be such that the sectional area of a flow path in the width direction of the steel plate in a space surrounded by the lower surface of the header and the upper surface of the partition wall be greater than or equal to 1.5 times the total sectional area at the inside diameters of the cooling water injection nozzles. This distance is, for example, desirably greater than or equal to approximately 100 mm. When the sectional area of the flow path in the width direction of the steel plate is not greater than or equal to 1.5 times the total sectional area at the inside diameters of the cooling water injection nozzles, the drain cooling water discharged to the upper surface of the partition wall 15 from the water drainage ports 17 in the partition wall may not be smoothly discharged in the width direction of the steel plate.

[0056] In the accelerated cooling apparatus according to the present invention, the range of the water amount density that is most effective is greater than or equal to 1.5 $m^3/(m^2 \cdot min)$. When the water amount density is lower than this value, the stagnant water film does not become so thick, and, even if a publicly known technology of cooling the steel plate by causing the rod-shaped cooling water to fall freely is applied, there are cases in which the degree of temperature unevenness in the width direction does not become so large. On the other hand, when the water amount density is greater than 4.0 $m^3/(m^2 \cdot min)$, the use of the technology according to the present invention is effective. However, since there are problems in terms of practical use, such as an increase in facility costs, the range of 1.5 to 4.0 $m^3/(m^2 \cdot min)$ is the most practical water amount density.

[0057] In applying the cooling technology according to the present invention, the case of disposing the draining rollers in front of and behind the cooling header is particularly effective. However, the cooling technology according to the present invention is applicable to the case in which the draining rollers are not provided. For example, it is possible to apply the cooling technology according to the present invention to a cooling facility that prevents water leakage to a non-water-cooling zone by spraying purging water in front of and behind a header that is relatively long in the longitudinal direction (approximately 2 to 4 m).

[0058] In the present invention, a cooling apparatus at a side of a lower surface of the steel plate is not particularly limited. In the embodiment shown in Figs. 9 and 10, an example in which a cooling lower header 12 provided with circular tube nozzles 14 as in the cooling apparatus at the side of the upper surface of the steel plate is given. In cooling the lower surface of the steel plate, since the jetted cooling water falls freely after colliding with the steel plate, a partition wall 15 for discharging drain cooling water in the width direction of the steel plate, like the one used in cooling the upper surface of the steel plate, need not be used. A publicly known technology of supplying, for example, membranous cooling water or cooling water in the form of a spray may be used.

[0059] The heating furnace 1 and the descaling apparatus 2 according to the present invention are not particularly limited, and conventional machines may be used for the heating furnace 1 and the descaling apparatus 2. The descaling apparatus 2 need not have the same structure as the descaling apparatuses 6 and 7 according to the present invention.

Example 1

[0060] Examples of the present invention are described below. In the description below, the temperatures of the steel plates are surface temperatures of the steel plates.

[0061] Each steel plate according to the present invention was manufactured by using a facility for manufacturing a steel plate such as that shown in Fig. 4. After re-heating a slab in the heating furnace 1, the slab was subjected to primary scale removal in the descaling apparatus 2, was subjected to hot rolling at the rolling apparatus 3, and was subjected to shape correction in the shape correcting apparatus 4. After the shape correction, descaling was performed. When the descaling was to be performed two times after hot correction, two descaling apparatuses, that is, the descaling apparatus 6 and the descaling apparatus 7, were set; and the descaling was performed two times on surfaces of the steel plates. When the descaling was to be performed three or more times, descaling apparatus was configured in three or more rows, and nozzle rows were separated by 500 mm or more in the longitudinal direction and arranged in a staggered arrangement. After completing the descaling, controlled cooling of each steel plate was performed by using the accelerated cooling apparatus 5.

[0062] The descaling apparatus 6 and the descaling apparatus 7 were such that the jetting distance (the distance from the jetting nozzles of the descaling apparatus to the surfaces of the steel plates) was 130 mm, the nozzle jetting angle was 66 degrees, and the attack angle was 15 degrees. After the descaling by the descaling apparatus 7, each steel plate was cooled to 500°C by the accelerated cooling apparatus 5. The nozzles of the descaling apparatus 6 and the nozzles of the descaling apparatus 7 were such that jetting areas of adjacent nozzles were arranged side by side in the width direction so as to overlap each other to a certain extent. The distance between the descaling apparatus 6 and the descaling 7 was such that the descaling apparatus 6 and the descaling 7 were separated 1.1 m from each other in the longitudinal direction. The nozzles were flat spray nozzles. Here, the jetting flow rate per nozzle and the nozzle jetting pressure at the time of the descaling after the hot rolling were the same for the descaling apparatus 6 and the descaling apparatus 7, and the conditions shown in Table 1 were used. The Ar_3 transformation point of each steel sheet used was 780°C. After finishing the rolling at the rolling apparatus 3, the plate thickness was 30 mm, and the temperature of each steel plate was 830°C or 840°C.

[0063] The conditions allowing the cooling to become stable and calculated on the basis of Expressions (3), (4), and (5) above were such that the time t from after the completion of the removal of scale on each steel plate by the descaling apparatus to the start of the cooling of each steel plate by the accelerated cooling apparatus was less than or equal to 42 s, desirably, less than or equal to 19 s, and even more desirably, less than or equal to 5 s.

[0064] Regarding the obtained steel plates, from the viewpoint of obtaining thick steel plates having little material quality variations, the result was rated as "pass", when the variation in the cooling stop temperature was within 25°C.

[0065] The manufacturing conditions and results are shown in Table 1. T in Table 1 denotes the temperature (K) of each steel plate before cooling.

[Table 1]

Table 1

	Jetting Pressure (MPa)	Number of Descalings	Water Amount per Nozzle (L/min) Value in ( ) is in (m^3/s)	Total Energy Density for Descaling (J/mm^2)	Finish Rolling Temperature (°C)	Conveyance Velocity (m/s)	Time from Just-Before-Final Descaling to Final Descaling (s)	Surface Temperature just before Final Descaling (°C)	Time from Completion of Descaling to Start of Controlled Cooling (s)	T (K)	Variation in Temperature (°C)
Inventive Example 1	17.7	2	45 (7.5 × 10^{-4})	0.19	830	0.7	1.57	756	8	1024	15
Inventive Example 2	17.7	2	45 (7.5 × 10^{-4})	0.07	830	1.9	0.58	778	3	1047	10
Inventive Example 3	15.0	3	40 (6.7 × 10^{-4})	0.08	830	1.9	0.58	775	3	1044	10
Inventive Example 4	15.0	2	40 (6.7 × 10^{-4})	0.34	840	0.3	3.7	750	19	1017	18
Comparative Example 1	17.7	2	45 (7.5 × 10^{-4})	0.06	830	2.1	0.52	779	3	1048	40
Comparative Example 2	17.7	2	45 (7.5 × 10^{-4})	0.07	840	1.9	0.58	785	3	1054	40
Comparative Example 3	20.0	2	48 (8.0 × 10^{-4})	0.07	830	2.3	0.48	780	2	1045	40

[0066] In Inventive Example 1, since the second descaling was performed after the transformation of austenite into ferrite at the surfaces of the steel plate, it was possible to completely remove the scale. The variation in the cooling stop temperature (hereunder simply referred to as "the temperature unevenness") in Inventive Example 1 were 15°C.

[0067] Also in Inventive Example 2, since the second descaling was performed after the transformation of austenite into ferrite at the surfaces of the steel plate, it was possible to completely remove the scale. In particular, in Inventive Example 2, since the time from the completion of the descaling to the controlled cooling was short at 3 s, the scale growing from after the completion of the scale removal to the start of the cooling became thin. As a result, the cooling was more stable, and temperature unevenness was 10°C

[0068] In Inventive Example 3, since the third descaling was performed after the transformation of austenite into ferrite at the surfaces of the steel plate, it was possible to completely remove the scale. Since the time from the completion of the descaling to the controlled cooling was short at 3 s, the scale growing from after the completion of the scale removal to the start of the cooling became thin. As a result, the cooling was more stable, and temperature unevenness was 10°C.

[0069] In Inventive Example 4, since the second descaling was performed after the transformation of austenite into ferrite at the surfaces of the steel plate, it was possible to completely remove the scale. The time from the completion of the descaling to the controlled cooling was 19 s, the scale grew from after the completion of the scale removal to the start of the cooling, and temperature unevenness was somewhat large at 18°C.

[0070] In Comparative Example 1, the time from the first descaling to the second descaling was 0.52 s, the surface temperature of the steel plate at the time of the second descaling was 779°C, and the second descaling was performed after the transformation of austenite into ferrite at the surfaces of the steel plate. However, the total energy density was small at 0.06 J/mm^2, the scale remained on part of the steel plate, and temperature unevenness was 40°C.

[0071] In Comparative Example 2, the energy density was 0.07 J/mm^2. However, the surface temperature of the steel plate at the time of the second descaling was 785°C. Since the second descaling was performed in a state in which austenite was not transformed into ferrite at the surfaces of the steel plate, the scale remained on part of the steel plate, and temperature unevenness was 40°C.

[0072] In Comparative Example 3, the energy density was 0.07 J/mm^2. However, the time from the first descaling to the second descaling was 0.48 s. Since the second descaling was performed in a state in which austenite was not transformed into ferrite at the surfaces of the steel plate, the scale remained on part of the steel plate, and temperature unevenness was 40°C.

Reference Signs List

[0073]

1 heating furnace
2 descaling apparatus
3 rolling apparatus
4 shape correcting apparatus
5 accelerated cooling apparatus
6 descaling apparatus
6-1 descaling header
6-2 jetting nozzle
7 descaling apparatus
7-1 descaling header
7-2 jetting nozzle
10 steel plate
11 upper header
12 lower header
13 upper cooling water injection nozzle (circular tube nozzle)
14 lower cooling water injection nozzle (circular tube nozzle)
15 partition wall
16 water supply port
17 water drainage port
18 jetting cooling water
19 drainage water
20 draining roller
21 draining roller
22 spray pattern

Claims

1. A method for manufacturing a steel plate by performing a hot rolling step, a hot correction step, and an accelerated cooling step in this order, the method further comprising:

   a descaling step in which jetting of descaling water is performed two times between the hot correction step and the accelerated cooling step,
   wherein, in the descaling step, energy density of the descaling water that is jetted to a surface of the steel plate is greater than or equal to 0.07 J/mm^2 in total for the jetting performed two times, second-descaling water is jetted after 0.5 s or more after jetting first-descaling water, and a surface temperature of the steel plate just before the second-descaling water is jetted is lower than or equal to a Ar_3 transformation point.

2. A method for manufacturing a steel plate by performing a hot rolling step, a hot correction step, and an accelerated cooling step in this order, the method further comprising:

   a descaling step in which jetting of descaling water is performed two or more times between the hot correction step and the accelerated cooling step,
   wherein, in the descaling step, energy density of the descaling water that is jetted to a surface of the steel plate is greater than or equal to 0.07 J/mm^2 in total for the jetting performed two or more times, final-descaling water is jetted after 0.5 s or more after jetting just-before-final-descaling water, and a surface temperature of the steel plate just before the final-descaling water is jetted is lower than or equal to a Ar_3 transformation point.

3. The method for manufacturing a steel plate according to either Claim 1 or Claim 2,
   wherein a time t [s] from after completion of the descaling step to start of the accelerated cooling step satisfies the expression $t \leq 5 \times 10^{-9} \times \exp(25000/T)$,
   where a temperature of the steel plate before cooling is T [K].

FIG. 1

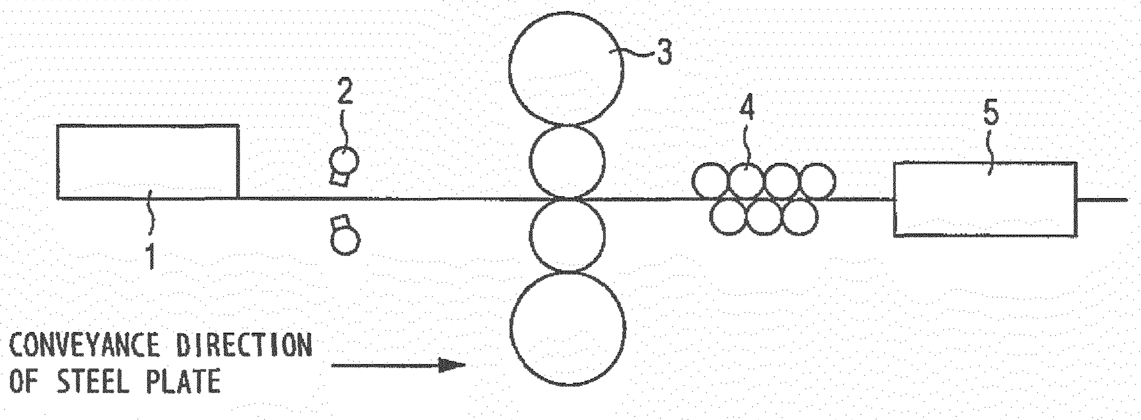


FIG. 2

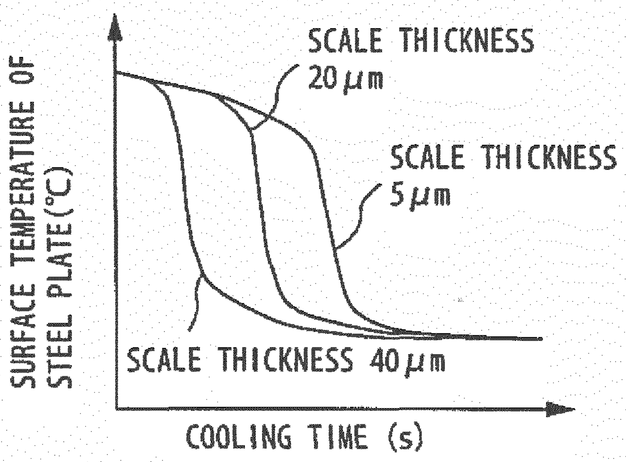


FIG. 3

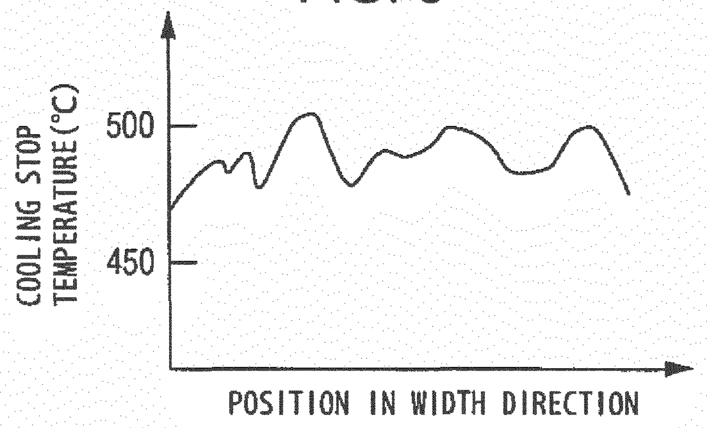


FIG. 4

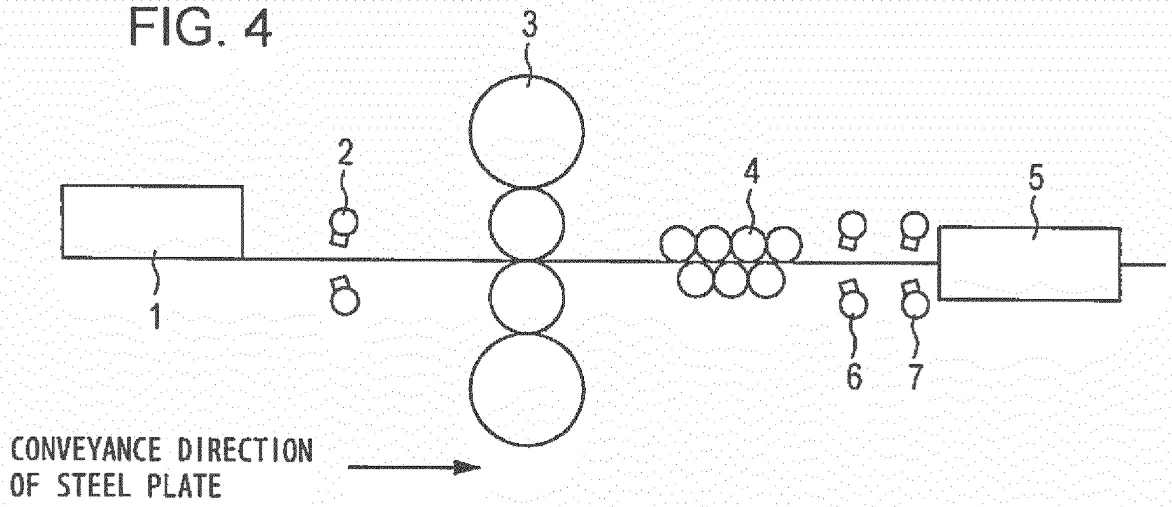


FIG. 5

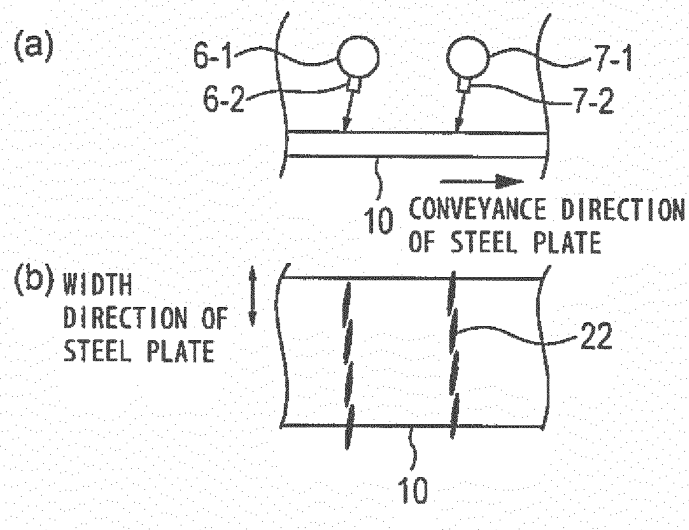


FIG. 6

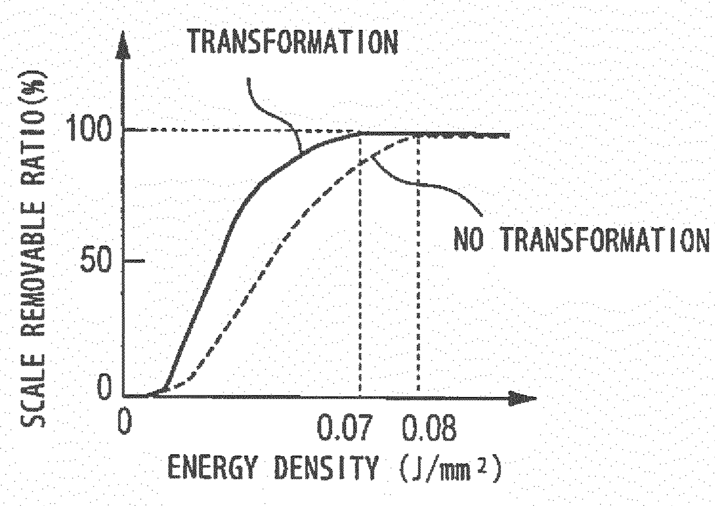


FIG. 7

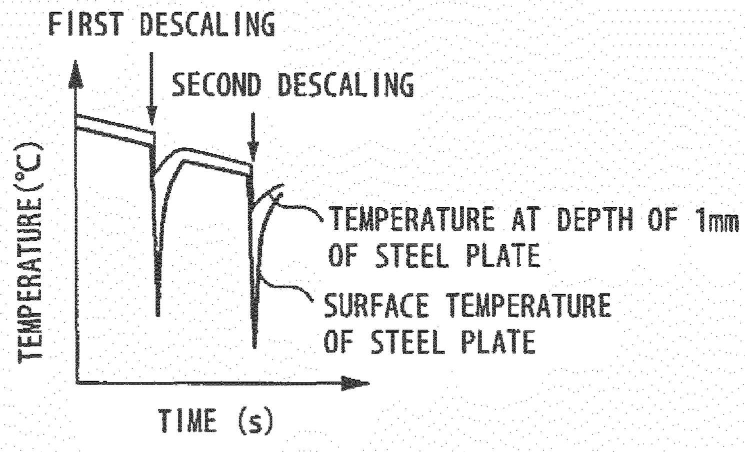

FIRST DESCALING
SECOND DESCALING
TEMPERATURE (°C)
TEMPERATURE AT DEPTH OF 1mm OF STEEL PLATE
SURFACE TEMPERATURE OF STEEL PLATE
TIME (s)

FIG. 8

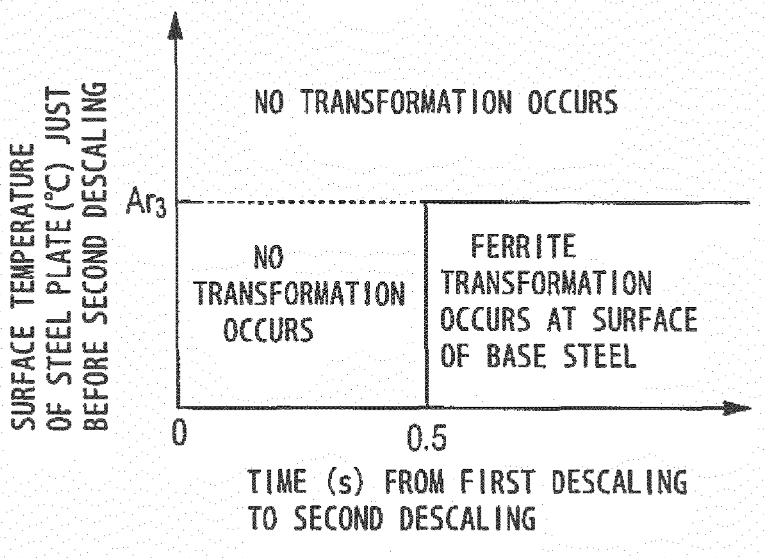

SURFACE TEMPERATURE OF STEEL PLATE (°C) JUST BEFORE SECOND DESCALING
NO TRANSFORMATION OCCURS
Ar3
NO TRANSFORMATION OCCURS
FERRITE TRANSFORMATION OCCURS AT SURFACE OF BASE STEEL
0
0.5
TIME (s) FROM FIRST DESCALING TO SECOND DESCALING

FIG. 9

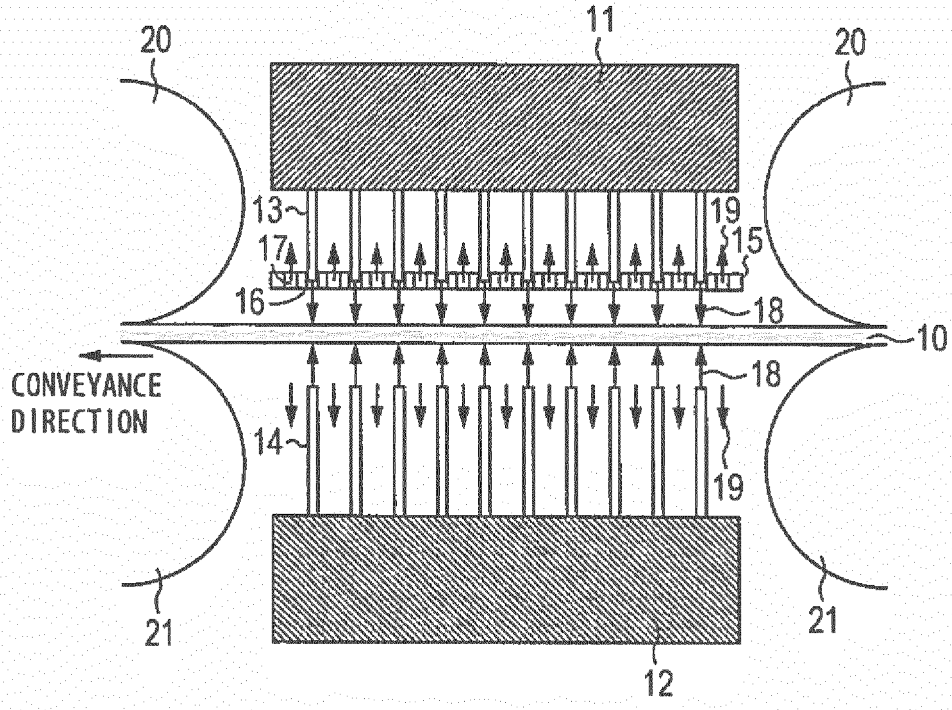

11
20
20
13
19
17
15
16
18
10
CONVEYANCE DIRECTION
18
14
19
21
21
12

FIG. 10

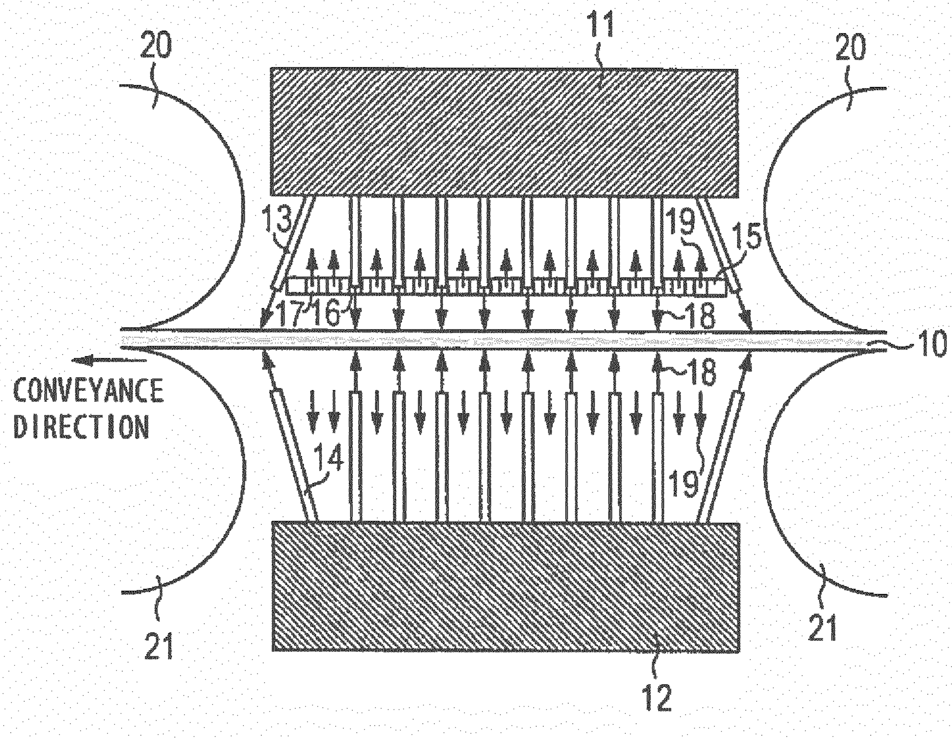

11
20
20
13
19
15
17
16
18
10
CONVEYANCE DIRECTION
18
14
19
21
21
12

FIG. 11

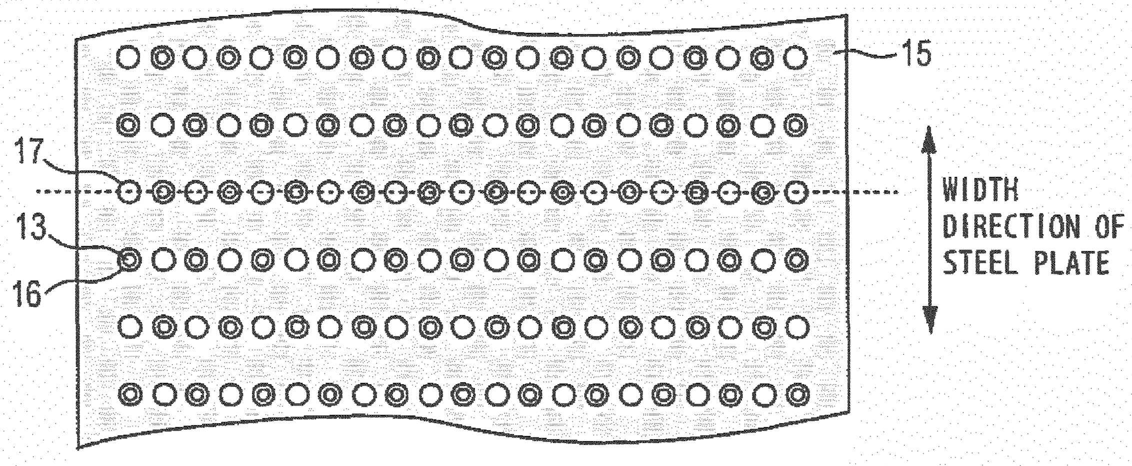

15
17
13
16
WIDTH
DIRECTION OF
STEEL PLATE

FIG. 12

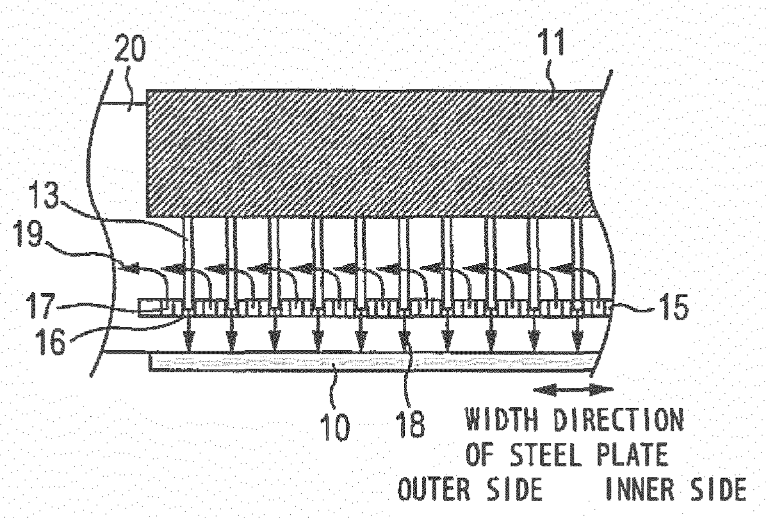

20
11
13
19
17
16
15
10
18
WIDTH DIRECTION
OF STEEL PLATE
OUTER SIDE
INNER SIDE

FIG. 13

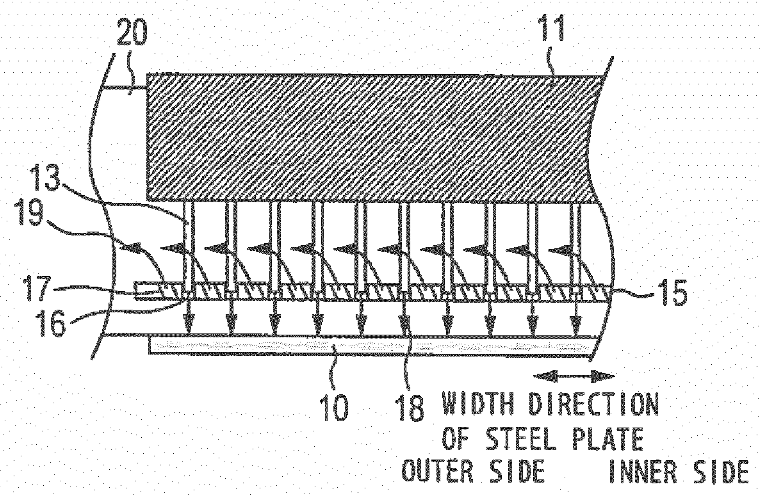

20
11
13
19
17
15
16
10
18
WIDTH DIRECTION
OF STEEL PLATE
OUTER SIDE
INNER SIDE

FIG. 14

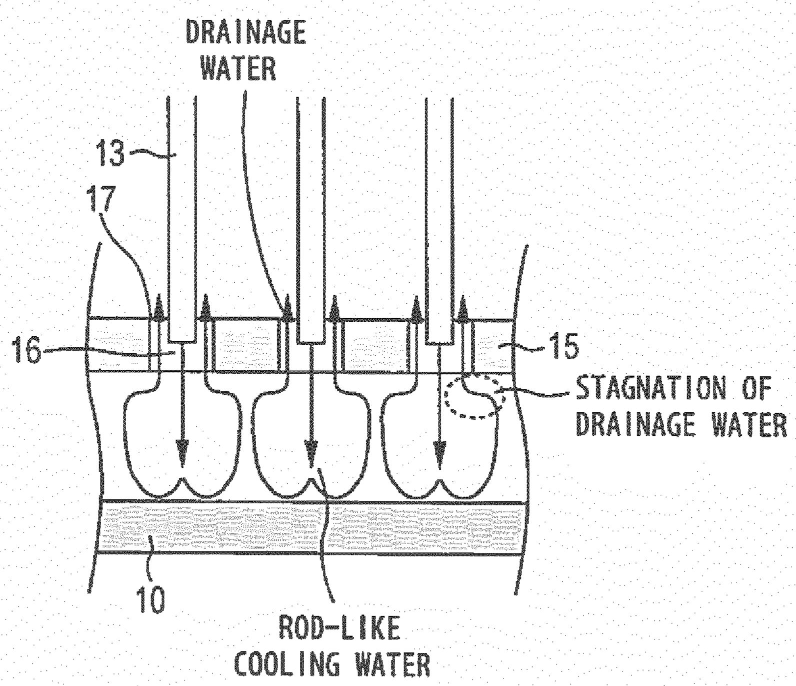

DRAINAGE
WATER
13
17
16
15
STAGNATION OF
DRAINAGE WATER
10
ROD-LIKE
COOLING WATER

FIG. 15

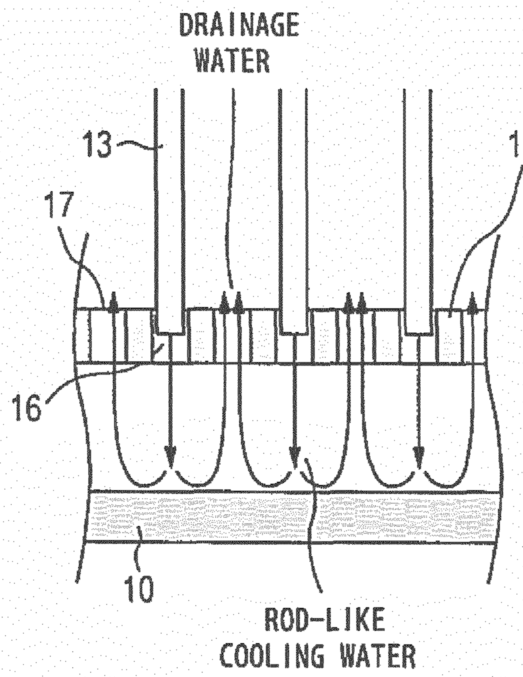
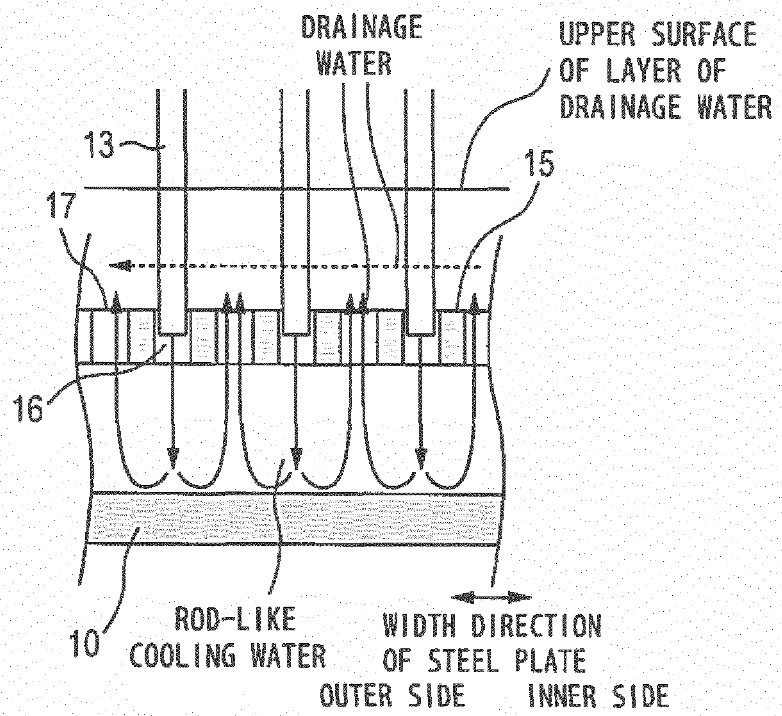

DRAINAGE
WATER
13
15
17
16
10
ROD-LIKE
COOLING WATER

FIG. 16


DRAINAGE
WATER
UPPER SURFACE
OF LAYER OF
DRAINAGE WATER
13
15
17
16
10
ROD-LIKE
COOLING WATER
WIDTH DIRECTION
OF STEEL PLATE
OUTER SIDE
INNER SIDE

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2015/004056

A. CLASSIFICATION OF SUBJECT MATTER
B21B45/08(2006.01)i, *B21B1/38*(2006.01)i, *B21B45/02*(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)
B21B45/08, B21B1/38, B21B45/02

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	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

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	WO 2010/110473 A1 (JFE Steel Corp.), 30 September 2010 (30.09.2010), claims; paragraphs [0005], [0017] to [0029], [0051] to [0058]; fig. 1 to 4 & JP 2010-247228 A & US 2012/0017660 A1 & EP 2412455 A1 claims; paragraphs [0005], [0017] to [0029], [0052] to [0059]; fig. 1 to 4 & CN 102361704 A & KR 10-2014-0004265 A & KR 10-2011-0115163 A	1-3
A	JP 2012-152761 A (JFE Steel Corp.), 16 August 2012 (16.08.2012), paragraphs [0011], [0015], [0052] to [0067]; fig. 1 to 3 (Family: none)	1-3

☒ 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	Date of mailing of the international search report
06 October 2015 (06.10.15)	13 October 2015 (13.10.15)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/004056

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 2012-77325 A (JFE Steel Corp.), 19 April 2012 (19.04.2012), claims (Family: none)	1-3

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 6330155 A **[0006]**