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(54) METHOD FOR COOLING STEEL SHEET AND METHOD OF MANUFACTURING STEEL SHEET

VERFAHREN ZUM KÜHLEN VON STAHLBLECH UND VERFAHREN ZUR HERSTELLUNG VON STAHLBLECH

PROCEDE DE REFROIDISSEMENT D'UNE FEUILLE D'ACIER, ET PROCEDE DE FABRICATION D'UNE FEUILLE D'ACIER

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Description

TECHNICAL FIELD

[0001] The present invention relates to a method for cooling a hot-rolled steel plate, particularly, method and apparatus for cooling the steel plate uniformly without generation of camber or buckling of the steel plate during cooling, and a fabrication method of the steel plate using the cooling method.

BACKGROUND ART

[0002] Generally, a hot-rolled steel plate is transferred in such a way that the steel plate surface is held horizontally, and then cooled by water sprayed from upside and downside of the steel plate surface. At that time, inhomogeneous cooling is apt to occur in the steel plate, which causes not only heterogeneous residual stress and characteristics of the steel plate, but also camber generation of the steel plate leading to trouble in operation. Moreover, the steel plate having camber is required to pass a finishing process for rectifying the camber using a press machine or like, causing an increase in cost.

[0003] Recently, when fabricating a steel plate by controlled-rolling and controlled-cooling process (TMCP) combining rolling with cooling, a demand for fabricating a strain-free or flat steel plate continuously by performing highly accurate temperature control without inhomogeneous cooling is increasing. Particularly, when fabricating a steel plate having a large thickness, in some cases where the width of the steel plate is as large as 5 m, it is important to konow how the cooling water discharged from cooling apparatus is prevented from flowing out to a part of the steel plate not to be cooled, or how the homogeneous cooling is designed by so-called "draining".

[0004] As an example of draining at a stage of cooling, JP-UM-A-53-39508 discloses a technique, in which air nozzles are disposed on an upper surface of steel plate in a vertically movable manner, and the draining is performed by air spray. Moreover, JP-UM-A-58-125611 discloses a method of draining by holding and pressing a steel plate using gum rollers. Furthermore, JP-A-60-206516 discloses a technique of draining by arranging draining rollers and water spray nozzles located downstream of the rollers along the width direction of steel plate, and spraying water from center to edge of steel plate.

[0005] However, the draining can not be performed perfectly in either of these methods, and when a steel plate is cooled rapidly, the upper and lower surfaces of the steel plate are not necessarily cooled equally, causing a generation of camber in the width and longitudinal directions of the steel plate.

[0006] The camber in the width direction, of which the degree or the direction is determined by the width, the thickness, and the difference in temperature or thermal history between the upper and lower surfaces, produces a gap between the steel plate and the draining rollers, thereby a large amount of cooling water is flown out, resultantly the draining becomes difficult to be conducted and the inhomogeneous cooling is accelerated.

[0007] The camber in the longitudinal direction, of which the degree or the direction is determined by the transfer speed of the steel plate in addition to the width, the thickness, and the difference in temperature or thermal history between the upper and lower surfaces, causes an unstable transfer of the steel plate, resulting in trouble in operation. In some cases, the generation of camber may occur largely after the steel plate passes through a cooling apparatus.

[0008] JP-A-10-263670 discloses a technique of cooling in which the steel plate surface is constrained during cooling to prevent the generation of camber in the width direction. In this method, since the steel plate is constrained by a certain force and cooled, the steel plate can be flat.

[0009] However, in the method according to JP-A-10-263670, when the steel plate is constrained by a certain force , in some cases, the steel plate itself buckles and the large camber generates while the steel plate is in the cooling apparatus or after the steel plate passes through the apparatus, resulting in an impossible transfer of the steel plate.

DISCLOSURE OF THE INVENTION

[0010] The present invention aims to provide a method and an apparatus for cooling a hot-rolled steel plate uniformly without generation of camber due to inhomogeneous cooling and buckling due to constraint force, and a fabrication method of the steel plate using the method.

The object is achieved by a cooling method of steel plate comprising the features of claim 1.

[0011] The cooling method of steel plate is realized using a cooling apparatus for a steel plate as described below. Preferred embodiments of the invention are defined in the respective dependent claims.

BRIEF DESCRIPTION OF THE DRAWING

[0012]

Fig. 1 is an example of a cooling apparatus of steel plate for performing a method according to the present invention.

EMBODIMENTS OF THE INVENTION

[0013] Fig. 1 shows an example of a cooling apparatus of steel plate for performing a method according to the present invention.

[0014] In a cooling apparatus, a steel plate 1 immediately after rolling is transferred with being constrained between twenty sets of upper and lower rollers, which, comprising upper rollers 2 and lower rollers 3, are disposed at an interval of 1 m. At that time, the upper surface of the steel plate is cooled by water through slit nozzles 4 and the lower surface is cooled by water through cylindrical nozzles 5. In Fig. 1, three sets of upper and lower rollers and two sets of cooling zones are shown.

[0015] To the upper surface of the steel plate 1 inserted between upper and lower rollers, water of 2 m^3/min per unit area of the steel plate flows through the slit nozzles 4 from upstream to downstream along the forward direction of the steel plate 1. On the other hand, to the lower surface of the steel plate 1, water flows through the cylindrical nozzles 5.

[0016] In twenty sets of upper and lower rollers, the lower rollers 3 also serve as transfer rollers and are fixed. The upper rollers 2 having a diameter of 250 mm are movable up and down at a pitch of 0.5 mm. A gap between the upper rollers 2 and the lower rollers 3 is set to be equal to the thickness of the steel plate 1 or smaller, and, when the steel plate 1 passes through the gap, the steel plate 1 receives a force due to reaction force of the upper rollers 2 against pressing force by hydraulic cylinders 6, thereby the steel plate 1 is constrained. When a constraint force, which is measured by pressure sensors, exceeds a value described later, the pressure by hydraulic cylinders 6 is adjusted. When the pressure by hydraulic cylinders 6 is adjusted, the constraint force corresponding to the pressure acts on the steel plate 1, and the upper rollers 2 can move up and down in accordance with the steel plate 1 in response to the reaction force of the steel plate 1. There is provided a mechanism for promptly evacuating the upper rollers 2 upward when the position of the upper rollers 2 exceeds a certain value. Furthermore, there is provided a draining spray nozzle 7 for removing the cooling water, which leaks from the gap between the upper rollers 2 and the steel plate 1, from the steel plate edge.

[0017] When the constraint force on the steel plate by a set of upper and lower rollers is not lower than P1 [t] and lower than P2 [t], and the upper and lower surfaces of the steel plate are cooled in water amount of 2 m^3/min or more per unit area with the steel plate being constrained, temperature is diffused and temperature deviation is dissolved, therefore no camber generation occurs, and the draining can be performed securely and thus the homogeneous cooling is achieved. Accordingly, even if the steel plate is free of constraint force after cooling, the flatness is attained.

[0018] When the constraint force is lower than P1 [t], the camber in the width direction lifts the upper and lower rollers, thereby the cooling water leaks, causing an inhomogeneous cooling.

[0019] When the constraint force is P2 [t] or more, the steel plate buckles, and the steel plate is being kept flat at the time, however, if the water cooling is subsequently stopped, the steel plate is curved, and can not be transferred through the cooling apparatus, or may damage the apparatus, or may have large residual strain therein after passing through the cooling apparatus.

[0020] When the constraint force becomes P2 [t] or more, if plural sets of upper and lower rollers move up and down in accordance with the steel plate pressing the steel plate by a force lower than P2 [t], the steel plate can be transferred through the cooling apparatus and does not damage the apparatus. Furthermore, large residual strain does not remain in the steel plate at a step of cooling, for example, on a cooling floor after passing through the cooling apparatus. On the other hand, if the steel plate is pressed by a large constraint force when the cooling is inhomogeneous and the camber of the steel plate is beginning to generate, inverse camber may generate in the cooling apparatus, or unexpectedly large camber may generate when the steel plate comes out of the cooling apparatus. Actually, when the constraint force becomes P2 [t] or more, the reaction force against the constraint force is detected by the pressure sensor, and firstly the pressure applied to the hydraulic cylinder 6 is reduced until the constraint force is lower than P2 [t], as a result the upper roller is lifted. Here, when the steel plate is transferred without problem, the steel plate passes as it is. However, when the reaction force of the steel plate (constraint force) is still P2 [t] or more even if the cylinder pressure is reduced and the upper roller is lifted to a certain height, for example, 300 mm, the upper roller is promptly opened to release the constraint force, and then evacuated upward. In such an operation, for example, when the cooling water for the lower or upper surface does not flow, or flows in a non-predetermined flow rate because of some reason, and the steel plate is cooled in a vertically unsymmetrical manner and thus large temperature difference is produced between the upper and lower surfaces of the steel plate, since the temperature difference causes a large camber of the steel plate, the reaction force of the steel plate to lift the upper roller significantly exceeds P2 [t] and acts to thrust the upper roller 2 upward, however, if the upper roller is promptly evacuated as above, the trouble in equipment or the damage to the equipment can be prevented.

[0021] Although the above description relates to the constraint force by one set of upper and lower rollers, when the constraint force becomes P2 [t] or more in another set of upper and lower rollers, the same means as above may be taken.

[0022] When a steel slab is rolled into a steel plate, then the steel plate is rectified and then cooled using the cooling method of steel plate according to the present invention, and further the cooled steel plate is rectified, a flat and homogenous steel plate can be fabricated without generating camber or buckling of the steel plate during cooling.

Example

[0023] Some steel plates were cooled using the cooling apparatus of steel plate shown in Fig. 1 under the various conditions of thickness S [mm] of the steel plates, distance L [mm] between the upper and lower roller sets, and constraint force P [t] as shown in Table 1, and the generation of camber was investigated. Table 1 also shows P1 and P2 derived from the above formulas (1) and (2), where the examples of the present invention satisfy the relation of P1 ⟨P ⟨ P2.

[0024] Each of the steel plates cooled using the method of the present invention passed through the cooling apparatus without problem, and showed good profile after being cooled to room temperature on a cooling floor.

[0025] For the examples 4 and 6 of the present invention, although the constraint force exceeded P2 during transfer, the rollers were lifted at the same time, and thus the constraint force not lower than P2 was not applied. The steel plates were able to pass through the cooling apparatus, and, although the steel plates initially had camber on the cooling floor, after the steel plates were cooled to room temperature, the camber disappeared and the steel plates became flat.

[0026] On the other hand, for the comparative examples 1, 2, 5, 7, 9, and 11, in which the steel plates were cooled with being constrained by the constraint force lower than P1, the steel plates were lifted due to camber in the width direction generated in the cooling apparatus, thereby a gap was produced between the steel plates and the rollers, and the cooling water leaked from the gap and thus the homogeneity of temperature locally deteriorated, therefore a large camber generated on the cooling floor.

[0027] For comparative examples 4, 6, 8, 10 and 12 where the steel plates were cooled with being constrained by the constraint force of P2 or more, although no strain generated in the cooling apparatus, a large longitudinal camber generated on the cooling floor. It is considered that, after yielding in the cooling apparatus, the steel plates were flat at a stage of coming out of the cooling apparatus, however, the strain corresponding to the yielding generated after the temperature became more uniform when approaching the room temperature.

Table 1

	Thickness S [mm]	Distance L between rollers [mm]	P1 in formula (1) [t]	P2 in formula (2) [t]	Actually applied P [t]	Homogeneity of temperature immediately after cooling	Strain after cooling	Evaluation
Example 1	12	1000	0.1	0.2	0.15	O	O	O
Example 2	12	2000	0.2	0.3	0.2	O	O	O
Example 3	25	1000	1.0	1.7	1.5	O	O	O
Example 4	25	2000	1.5	2.6	2	O	O	O
Example 5	40	1000	3.9	6.8	4	O	O	O
Example 6	40	2000	6.1	10.7	8	O	O	O
Comp. Ex. 1	12	1000	0.1	0.2	0.07	x	x	x
Comp. Ex. 2	12	1000	0.1	0.2	0.2	O	x	x
Comp. Ex. 3	12	2000	0.2	0.3	0.13	x	x	x
Comp. Ex. 4	12	2000	0.2	0.3	0.4	O	x	x

(continued)

	Thickness S [mm]	Distance L between rollers [mm]	P1 in formula (1) [t]	P2 in formula (2) [t]	Actually applied P [t]	Homogeneity of temperature immediately after cooling	Strain after cooling	Evaluation
Comp. Ex. 5	25	1000	1.0	1.7	0.6	x	x	x
Comp. Ex. 6	25	1000	1.0	1.7	2	O	x	x
Comp. Ex. 7	25	2000	1.5	2.6	1.1	x	x	x
Comp. Ex. 8	25	2000	1.5	2.6	3	O	x	x
Comp. Ex. 9	40	1000	3.9	6.8	3	x	x	x
Comp. Ex. 10	40	1000	3.9	6.8	8	O	x	x
Comp. Ex. 11	40	2000	6.1	10.7	5	x	x	x
Comp. Ex. 12	40	2000	6.1	10.7	12	O	x	x

Claims

1. A cooling method of steel plate (1) comprising the steps of;
transferring a steel plate (1) horizontally with the steel plate surface being constrained by plural sets of upper (2) and lower (3) rollers;
water-cooling the steel plate (1) being transferred from upside and downside of the steel plate surface;
moving plural sets of upper (2) and lower (3) rollers up and down in accordance with camber of the steel plate (1) with the rollers (2, 3) being pressed by a force lower than an upper limit force P2 [t] when a constraint force on the steel plate (1) reaches or exceeds this upper limit force P2 [t]; and
opening upper (2) and lower (3) rollers and thus releasing a constraint force on the steel plate (1) when the moving distance of plural sets of upper (2) and lower (3) rollers exceeds a predetermined threshold value,
characterized in that a constraint force on the steel plate (1) per one set of upper (2) and lower (3) rollers is not lower than P1 [t] and lower then P2 [t], shown in the following formulas (1) and (2),

$$P1=6.85x10^{-7}S^{3}L^{0.65}\ldots \qquad (1)$$

$$P2=1.2x10^{-6}S^{3}L^{0.65}\ldots \qquad (2)$$

here, L is the dimension less value in mm of the distance between the sets of upper (2) and lower (3) rollers adjacent with each other, and S is the dimension less value in mm of the thickness of the steel plate (1).

2. A fabrication method of steel plate (1) comprising the steps of;
rolling a steel slab into a steel plate (1);
rectifying the steel plate (1);
cooling the rectified steel plate (1) using any one of cooling methods of steel plate (1) according to claim 1; and rectifying the cooled steel plate (1).

3. The fabrication method of steel plate (1) according to claim 2, wherein the upper surface and the lower surface of the steel plate (1) are cooled in a water amount of 2 m^3/min or more per unit area respectively.

Patentansprüche

1. Abkühlverfahren für ein Stahlblech (1), umfassend die Schritte:

des horizontalen Transferierens eines Stahlblechs (1) mit der von einer Vielzahl von Reihen oberer (2) und unterer (3) Walzen beaufschlagter Stahlblech-Oberfläche;
der Wasserabkühlung des Stahlblechs (1), das transferiert wird, von oberhalb und unterhalb der Stahlblech-Oberfläche;
des Bewegens der Vielzahl von Reihen von oberer (2) und unterer (3) Walzen nach oben und unten in Übereinstimmung mit der Biegung des Stahlblechs (1), wobei die Walzen (2, 3) mit einer Kraft niedergedrückt werden, die geringer als eine obere Grenzkraft P2 (in Tonnen) ist, wenn eine Beaufschlagungskraft auf das Stahlblech (1) diese obere Grenzkraft P2 (in Tonnen) erreicht oder übersteigt; und
des Öffnens der oberen (2) und unteren (3) Walzen und somit die Freigabe einer Niederhaltekraft auf das Stahlblech (1) dann, wenn die Bewegungsdistanz der Vielzahl von Reihen von oberen (2) und unteren (3) Walzen einen vorab festgelegten Grenzwert übersteigt, **dadurch gekennzeichnet, dass** eine Niederhaltekraft auf das Stahlblech (1) pro Satz oberer (2) und unterer (3) Walzen nicht kleiner als P1 (in Tonnen) und kleiner als P2 (in Tonnen), gezeigt in den nachfolgend angegebenen Formeln (1) und (2) ist,

$$P1=6.85x10^{-7}S^3L^{0.65}\ldots$$

$$P2=1.2x10^{-6}S^3L^{0.65}\ldots$$

wobei L der dimensionslose Wert in mm der Distanz zwischen den Sätzen oberer (2) und unterer (3) zueinander benachbarter Walzen und S der dimensionslose Wert in mm der Dicke des Stahlblechs (1) ist.

2. Herstellungsverfahren für ein Stahlblech (1), umfassend die Schritte:

Walzen einer Stahlbramme in ein Stahlblech (1);
Richten des Stahlblechs (1);
Abkühlen des gerichteten Stahlblechs (1) unter Verwendung eines der Abkühlverfahren für ein Stahlblech (1) gemäß Anspruch 1; und
Richten des gekühlten Stahlblechs (1).

3. Herstellungsverfahren für ein Stahlblech (1) gemäß Anspruch 2, wobei die obere Oberfläche und die untere Oberfläche des Stahlblechs (1) mit einer Wassermenge von 2 m^3/min oder mehr pro jeweiliger Bereichseinheit gekühlt werden.

Revendications

1. Procédé de refroidissement d’une plaque d’acier (1) comprenant les étapes consistant à:

transférer une plaque d’acier (1) de manière horizontale, la surface de la plaque d’acier étant contrainte par plusieurs ensembles de rouleaux supérieurs (2) et inférieurs (3);
refroidir à l’eau la plaque d’acier (1) en cours de transfert, depuis la face supérieure et la face inférieure de la surface de la plaque d’acier;
déplacer la pluralité d’ensembles des rouleaux supérieurs (2) et inférieurs (3) vers le haut et vers le bas conformément à une cambrure de la plaque d’acier (1) avec les rouleaux (2, 3) qui sont pressés par une force inférieure à une force limite supérieure P2 [t] lorsqu’une force de contrainte sur la plaque d’acier (1) atteint ou dépasse cette force limite supérieure P2 [t]; et

ouvrir des rouleaux supérieurs (2) et inférieurs (3) et libérer ainsi une force de contrainte sur la plaque d'acier (1) lorsque la distance de déplacement de la pluralité d'ensembles des rouleaux supérieurs (2) et inférieurs (3) dépasse une valeur seuil prédéterminée,

caractérisé en ce qu'une force de contrainte sur la plaque d'acier (1) par ensemble de rouleaux supérieurs (2) et inférieurs (3) n'est pas inférieure à P1 [t] et inférieure à P2 [t], montrées dans les formules suivantes (1) et (2),

$$P1 = 6,85 \times 10^{-7} S^3 L^{0,65} \ldots \quad (1)$$

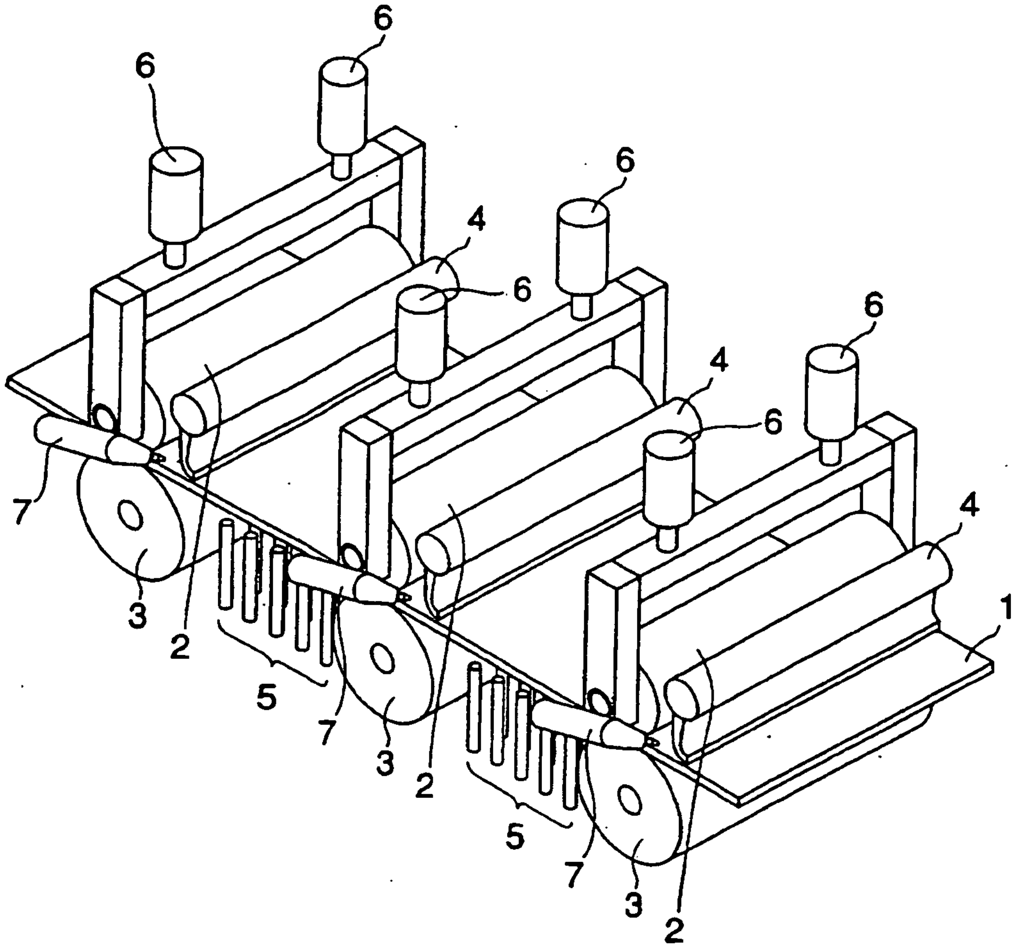
$$P2 = 1,2 \times 10^{-6} S^3 L^{0,65} \ldots \quad (2)$$

ici, L est la valeur non dimensionnelle en mm de la distance entre les ensembles de rouleaux supérieurs (2) et inférieurs (3) les uns adjacents aux autres, et S est la valeur non dimensionnelle en mm de l'épaisseur de la plaque d'acier (1).

2. Procédé de fabrication d'une plaque d'acier (1) comprenant les étapes consistant à;
laminer une brame d'acier en une plaque d'acier (1);
rectifier la plaque d'acier (1);
refroidir la plaque d'acier (1) rectifiée en utilisant l'un quelconque des procédés de refroidissement de la plaque d'acier (1) selon la revendication 1; et
rectifier la plaque d'acier refroidie (1).

3. Procédé de fabrication d'une plaque d'acier (1) selon la revendication 2, dans lequel la surface supérieure et la surface inférieure de la plaque d'acier (1) sont refroidies avec une quantité d'eau de 2 m^3/min ou plus par aire unitaire, respectivement.

Fig.1



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