

Description

Technical Field

[0001] The present invention relates to a quenching apparatus that performs annealing while continuously conveying a metal sheet, a quenching method, and a method of manufacturing a metal sheet.

[0002] In continuous annealing facilities in which annealing is performed while continuously conveying a metal sheet, the metal sheet is cooled after heated and causes a phase transformation, and the microstructure of the metal sheet is thereby made. In particular, in the automotive industry, there is an increased demand for a thinned high tension steel sheet (high tensile strength steel sheet) to achieve both a weight reduction of a vehicle body and crash safety. In manufacture of the high tensile strength steel sheet, a technique of rapidly cooling a steel sheet is important. A water quenching method is known as one of the technique in which the cooling rate of cooling of a metal sheet is highest. In the water quenching method, at the same time when a heated metal sheet is immersed in water, cooling water is jetted through a quench nozzle provided in the water to the metal sheet, and the metal sheet is thereby quenched.

[0003] At the time of quenching of the metal sheet, shape defects such as warps, wavy deformations, and the like are generated in the metal sheet. This is caused by thermal contraction or the like of the metal sheet due to being rapidly cooled. In particular, when the temperature of the metal sheet changes from a temperature M_s at which a martensitic transformation starts to a temperature M_f at which the martensitic transformation ends, sudden thermal contraction and transformation expansion occur at the same time.

[0004] Thus, various methods for preventing shape defects of metal sheets at the time of quenching have been proposed (refer to, for example, Patent Literature 1 and Patent Literature 2). Patent Literature 1 proposes a method of restraining a metal sheet by a pair of restraining rolls that are provided in a cooling liquid when the temperature of the metal sheet is in the range of $(TMs + 150)(^{\circ}C)$ to $(TMf - 150)(^{\circ}C)$, where $TMs(^{\circ}C)$ is a M_s temperature at which a martensitic transformation of the metal sheet starts and $TMf(^{\circ}C)$ is a M_f temperature at which the martensitic transformation ends.

[0005] Patent Literature 2 discloses that, while a metal sheet is restrained by restraining rolls, a distance between a position at which cooling of the metal sheet by a cooling fluid is started and the restraining rolls is controlled by a movable masking member when a quenching method in which cooling is performed by jetting water through a plurality of water jetting nozzles to surfaces of the metal sheet is performed. Further, as in Patent Literature 1, there is proposed a method in which a metal sheet with a temperature from $(TMs + 150)(^{\circ}C)$ to $(TMf - 150)(^{\circ}C)$, where $TMs(^{\circ}C)$ is the M_s temperature at which a martensitic transformation of the metal sheet starts and $TMf(^{\circ}C)$ is the M_f temperature at which the martensitic transformation ends, is caused to pass the restraining rolls.

Citation List

Patent Literature

[0006]

PTL 1: Japanese Patent No. 6094722

PTL 2: Japanese Unexamined Patent Application Publication No. 2019-90106

Summary of Invention

Technical Problem

[0007] In the method described in Patent Literature 1, however, the position at which the temperature of the metal sheet is in the range of $(TMs + 150)(^{\circ}C)$ to $(TMf - 150)(^{\circ}C)$ varies depending on conditions of manufacture of the metal sheet. Therefore, it may be impossible for the restraining rolls to restrain the metal sheet at a position at which the temperature of the metal sheet is in the range of $(TMs + 150)(^{\circ}C)$ to $(TMf - 150)(^{\circ}C)$, and variations in the shape of the metal sheet may be generated.

[0008] In the method described in Patent Literature 2, water that hits the movable masking member falls by gravity and interferes with water that is jetted through the water jetting nozzles at a lower portion of the movable masking member, thereby causing a cooling performance of cooling of the metal sheet to be unstable. In addition, since masking is performed for each nozzle, the cooling performance varies in steps (discontinuously) and, as a result, causes the position at which the temperature of the metal sheet is in the range of $(TMs + 150)(^{\circ}C)$ to $(TMf - 150)(^{\circ}C)$ to be unstable, and variations in the shape of the metal sheet may be generated.

[0009] The present invention has been made to solve such problems, and an object of the present invention is to

provide a quenching apparatus capable of highly accurately controlling the temperature of a metal sheet at a position at which the metal sheet is restrained and suppressing generation of variations in the shape of the metal sheet at the time of quenching, a quenching method, and a method of manufacturing a metal-sheet product.

5 Solution to Problem

[0010]

[1] A metal-sheet quenching apparatus that cools a metal sheet while conveying the metal sheet, the metal-sheet quenching apparatus including: a cooling device that cools the metal sheet that is conveyed; a restraining roll that conveys the metal sheet cooled by the cooling device while restraining the metal sheet in a thickness direction; a roll moving device that moves the restraining roll in a conveyance direction of the metal sheet; and a movement control device that adjusts a position of the restraining roll by controlling an operation of the roll moving device.

[2] The metal-sheet quenching apparatus described in [1], in which the cooling device includes a plurality of nozzles through which a cooling fluid is jetted to the metal sheet to cool the metal sheet.

[3] The metal-sheet quenching apparatus described in [1] or [2], in which the cooling device includes a cooling tank in which the metal sheet is immersed and cooled.

[4] The metal-sheet quenching apparatus described in any one of [1] to [3], in which the movement control device controls the operation of the roll moving device to position the restraining roll such that the restraining roll restrains the metal sheet at a position at which the metal sheet has a target temperature.

[5] The metal-sheet quenching apparatus described in [4], in which the target temperature is set in a temperature range of $(TMs + 150)(^{\circ}C)$ to $(TMf - 150)(^{\circ}C)$, where $TMs(^{\circ}C)$ is a M_s temperature at which a martensitic transformation of the metal sheet starts and $TMf(^{\circ}C)$ is a M_f temperature at which the martensitic transformation ends.

[6] The metal-sheet quenching apparatus described in [4] or [5], in which the movement control device sets a distance from a cooling start position by the cooling device to the restraining roll based on a line speed of the metal sheet, a cooling start temperature of the metal sheet at a time when cooling by the cooling device is started, the target temperature, and a cooling rate of cooling of the metal sheet, and moves the position of the restraining roll such that the set distance is achieved.

[7] The metal-sheet quenching apparatus described in [6], in which the movement control device obtains a distance d (mm) from the cooling start position to the restraining roll by Formula (1) below:

$$d = (T1 - T2) \times v / CV \quad (1),$$

where v (mm/s) is the line speed of the metal sheet, $T1(^{\circ}C)$ is the cooling start temperature, $T2(^{\circ}C)$ is the target temperature, and $CV(^{\circ}C/s)$ is the cooling rate of cooling of the metal sheet by the cooling device.

[8] The metal-sheet quenching apparatus described in [7], in which, based on a sheet thickness t of the metal sheet and a coefficient α indicating a condition of cooling of the metal sheet, the cooling rate CV is set as $CV = \alpha/t$ in the movement control device.

[9] A metal-sheet quenching method in which a metal sheet is cooled while being conveyed, the method including: moving a restraining roll in a conveyance direction of the metal sheet such that, when the metal sheet that has been cooled is restrained by the restraining roll in a thickness direction, the metal sheet is restrained at a position at which the metal sheet has a target temperature.

[10] The metal-sheet quenching method described in [9], in which the target temperature is set in a temperature range of $(TMs + 150)(^{\circ}C)$ to $(TMf - 150)(^{\circ}C)$, where $TMs(^{\circ}C)$ is a M_s temperature at which a martensitic transformation of the metal sheet starts and $TMf(^{\circ}C)$ is a M_f temperature at which the martensitic transformation ends.

[11] The metal-sheet quenching method described in [9] or [10], in which moving of the restraining roll is performed by setting a distance from a cooling start position to the restraining roll based on a line speed of the metal sheet, a cooling start temperature of the metal sheet at a time when cooling is started, the target temperature, and a cooling rate of cooling of the metal sheet and moving the restraining roll such that the set distance is achieved.

[12] The metal-sheet quenching method described in [11], in which, as the distance from the cooling start position to the restraining roll, a distance d (mm) from the cooling start position to the restraining roll is obtained by Formula (1) below:

$$d = (T1 - T2) \times v / CV \quad (1),$$

where v (mm/s) is the line speed of the metal sheet, $T1(^{\circ}C)$ is the cooling start temperature, $T2(^{\circ}C)$ is the target

temperature, and $CV(^{\circ}C/s)$ is the cooling rate of cooling of the metal sheet.

[13] The metal-sheet quenching method described in [12], in which, based on a sheet thickness t of the metal sheet and a coefficient α indicating a condition of cooling of the metal sheet, the cooling rate CV is set as $CV = \alpha/t$.

[14] A method of manufacturing a high strength cold rolled steel sheet, the method using the metal-sheet quenching method described in any one of [9] to [13].

[15] A method of manufacturing a high strength steel sheet, the method comprising performing any of a hot-dip galvanizing treatment, an electro-galvanizing treatment, or a hot-dip galvannealing treatment on a high strength steel sheet obtained by the method described in [14]. Advantageous Effects of Invention

[0011] According to the present invention, by adjusting the position of restraining rolls in a conveyance direction of a metal sheet in accordance with the temperature of the metal sheet at the time of quenching of the metal sheet to control the distance from a cooling start position to the restraining rolls, it is possible to suppress variations in the shape of metal sheet generated at the time of quenching.

Brief Description of Drawings

[0012]

[Fig. 1] Fig. 1 is a schematic diagram in which a quenching apparatus according to an embodiment of the present invention is illustrated.

[Fig. 2] Fig. 2 is a schematic diagram in which one example of the definition of a warp amount of a metal sheet is illustrated.

[Fig. 3] Fig. 3 is a graph showing a relationship between a line speed and a target temperature in a present invention example.

[Fig. 4] Fig. 4 is a graph showing a relationship between a line speed and a warp amount of a metal sheet in a present invention example.

[Fig. 5] Fig. 5 is a graph showing a relationship between a line speed and a target temperature in Comparative example 1.

[Fig. 6] Fig. 6 is a graph showing a relationship between a line speed and a warp amount of a metal sheet in Comparative example 1.

[Fig. 7] Fig. 7 is a graph showing a relationship between a line speed and a target temperature in Comparative example 2.

[Fig. 8] Fig. 8 is a graph showing a relationship between a line speed and a warp amount of a metal sheet in Comparative example 2.

[Fig. 9] Fig. 9 describes movements of restraining rolls and nozzles in another example of the quenching apparatus according to an embodiment of the present invention.

Description of Embodiments

[0013] An embodiment of the present invention will be described on the basis of the drawings. Fig. 1 is a schematic diagram in which a quenching apparatus according to an embodiment of the present invention is illustrated. A quenching apparatus 1 in Fig. 1 performs quenching of a steel material as, for example, a metal sheet S and is employed in cooling facilities provided at the exit side of a soaking zone of a continuous annealing furnace. The quenching apparatus 1 for the metal sheet S in Fig. 1 includes a cooling device 10 that cools the metal sheet S and restraining rolls 20 that restrain the cooled metal sheet S in a thickness direction.

[0014] The cooling device 10 cools the metal sheet S by using a cooling fluid CF and includes a cooling tank 11 in which the cooling fluid CF is stored and a plurality of nozzles 12 installed inside the cooling tank 11 and through which the cooling fluid CF is jetted to the surfaces of the metal sheet S . Water is stored as the cooling fluid CF in the cooling tank 11, and, for example, the metal sheet S is immersed in the water from the upper surface of the cooling tank 11 toward a conveyance direction BD . A sink roll 2 that changes the conveyance direction of the metal sheet S is installed inside the cooling tank 11.

[0015] The plurality of nozzles 12 are formed by, for example, quench nozzles or the like and are installed on two surface sides of the metal sheet S to be arranged in the conveyance direction of the metal sheet S . Consequently, the metal sheet S is cooled by the cooling fluid CF inside the cooling tank 11 and the cooling fluid CF that is jetted through the plurality of nozzles 12. Cooling the metal sheet S by thus using both the cooling tank 11 and the plurality of nozzles 12 stabilizes the boiling state of the surfaces of the metal sheet S and enables uniform shape control.

[0016] While water quenching that uses water as the cooling fluid CF is employed in the example, oil cooling that uses an oil as the cooling fluid CF may be employed. In addition, while the plurality of nozzles 12 are installed inside the

cooling tank 11 in the example in Fig. 1, the method of cooling is not limited thereto as long as the method can cool the metal sheet S in a desired temperature range. For example, the metal sheet S may be cooled by only the cooling tank 11 and may be cooled by only the plurality of nozzles 12.

[0017] When the nozzles 12 are installed inside the cooling tank 11, the distance between the metal sheet S and the nozzles 12 is important in rapid cooling by liquid quenching. Since a vapor film generated by a boiling phenomenon is broken by liquid jet streams to perform rapid cooling, it is preferable that the nozzles 12 be installed close to the metal sheet S. The distance between the tip portion of each of the nozzles 12 and the metal sheet S is preferably more than or equal to 10 mm and less than or equal to 150 mm. When the distance is less than 10 mm, there is a possibility that the metal sheet S is deformed into a flapping state and comes into contact with the nozzles 12. In addition, when the distance is more than 150 mm, the effect of breaking the vapor film weakens and makes it difficult to ensure a sufficient cooling performance.

[0018] The restraining rolls 20 restrain the metal sheet S cooled by the cooling device 10 in the thickness direction and these rolls 20 are respectively installed on both surfaces of metal sheet S inside the cooling tank 11. A pair of the restraining rolls 20 are installed to face each other in Fig. 1 but may be installed at positions displaced from each other in the conveyance direction as long as the restraining rolls 20 are configured to perform restraining. In addition, while a pair of the restraining rolls 20 are installed in the example in Fig. 1, a plurality of pairs of restraining rolls 20 may be installed in the conveyance direction.

[0019] In consideration of the correlation between roll rigidity and a flexure due to a restraining stress, the roll diameter of each of the restraining rolls 20 is preferably more than or equal to 50 mm and less than or equal to 300 mm. The material of the restraining rolls 20 is not limited. When general steel rolls are used as the restraining rolls 20 and when the roll diameter of each of the rolls is less than 50 mm, roll rigidity is insufficient. Consequently, causing a uniform restraining force to act on the metal sheet S is made to be difficult due to a flexure, and the restraining rolls 20 may be broken. Meanwhile, when the roll diameter is more than 300 mm, a section in which a jet stream from each of the nozzles 12 does not reach the metal sheet S is lengthened, and there is a possibility that breakage of the vapor film becomes insufficient and the cooling performance decreases.

[0020] The restraining rolls 20 are installed to be movable in the conveyance direction of the metal sheet S. Here, the conveyance direction is a direction in which the metal sheet S is conveyed. Specifically, the quenching apparatus 1 for the metal sheet S includes a roll moving device 30 that moves the restraining rolls 20 and a movement control device 40 that controls the movement of the restraining rolls 20. The roll moving device 30 includes publicly known driving means, for example, a motor or the like and is configured to cause the restraining rolls 20 to move toward the conveyance direction BD of the metal sheet S or a direction opposite to the conveyance direction BD in the conveyance direction of the metal sheet S. Specifically, the roll moving device 30 can be suitably produced by combining mechanical components such as a power jack, a screw lifting device formed by a screw mechanism or a gear mechanism, and a less-resistance linear motion guide (LM guide) that uses rolling. In Fig. 1, an example in which the roll moving device 30 is constituted by a screw lifting device is illustrated. Each of the restraining rolls 20 is rotatably attached to one end portion of an L-shape arm 31. A screw portion 32, another screw portion (not illustrated) that engages with the screw portion 32, and driving mean (not illustrated) that drives the other screw portion are provided on the other end side of the arm 31. The driving means is fixed to a fixation portion (not illustrated). Consequently, when the other screw portion receives torque that is generated by the driving means and rotates, the arm 31 moves in a direction parallel to the conveyance direction BD along with the rotation.

[0021] When the above-described driving means is immersed in a liquid, maintenance of the driving means may be difficult. Therefore, it is preferable that the driving means be installed above a liquid surface in the cooling tank 11. In addition, it is preferable that the driving means be installed in a space that is shielded from the inside of a furnace in which the temperature is high.

[0022] The roll moving device 30 may have a function of causing the restraining rolls 20 to move in the thickness direction of the metal sheet S and restrain the metal sheet S or release restraining. While the method of moving is not particularly limited as long as moving is possible, an electric type is more preferable in consideration of responsivity.

[0023] The movement control device 40 is formed by a hardware resource such as a computer and controls the movement of the restraining rolls 20. In particular, the movement control device 40 controls the operation of the roll moving device 30 to position the restraining rolls 20 such that the metal sheet S is restrained at the position RP at which the metal sheet S has the target temperature. Here, the target temperature is preferably set in the temperature range of $(T_m + 150)(^{\circ}\text{C})$ to $(T_m - 150)(^{\circ}\text{C})$, where $T_m(^{\circ}\text{C})$ is a M_s temperature at which a martensitic transformation of the metal sheet S starts and $T_m(^{\circ}\text{C})$ is a M_f temperature at which the martensitic transformation ends. Consequently, the restraining rolls 20 can restrain a deformation of the metal sheet S at a position at which sudden thermal contraction and transformation expansion occur at the same time in the metal sheet S and can suppress the deformation of the metal sheet S at the time of quenching.

[0024] The movement control device 40 calculates a distance d from the cooling start position SP of cooling of the metal sheet S by the cooling fluid CF to the position RP at which the metal sheet S has the target temperature and is

restrained by the restraining rolls 20, and moves the restraining rolls 20 on the basis of the calculated distance d. To calculate the distance d, the movement control device 40 uses the line speed v (mm/s) of the metal sheet S, the cooling start temperature T1(°C), the target temperature T2(°C) at which restraining is performed by the restraining rolls 20, and the cooling rate CV(°C/s) of cooling of the metal sheet S by the cooling device 10. Here, the cooling start temperature T1 is the temperature of the metal sheet S just before the cooling start position SP at which cooling of the metal sheet S by the cooling fluid CF is started. For example, the temperature just before reaching the cooling start position SP can be calculated on the basis of a cooled state of the metal sheet S until reaching the cooling start position SP or the quenching apparatus 1. Specifically, the temperature of the metal sheet S is measured at the exit side of a soaking zone of a continuous annealing furnace by a contactless thermometer. Then, on the basis of the temperature and a temperature decrease of the metal sheet S due to being naturally cooled until reaching the quenching apparatus 1, the temperature of the metal sheet S just before or at the point of time of reaching the cooling start position SP can be calculated. The above-described temperature decrease of the metal sheet S due to being naturally cooled can be obtained previously through an experiment. Note that the aforementioned parameters may be successively obtained from set values or actual operation results of a process computer and may be measured by using a speed sensor, a temperature sensor, or the like.

[0025] Specifically, the relationship between the distance d and the cooling rate CV(°C/s) is expressed by Formula (1) below.

$$CV = (T1 - T2) / (d/v)$$

$$d = (T1 - T2) \times v / CV \cdots (1)$$

[0026] The cooling rate CV(°C/s) can be expressed using a sheet thickness t of the metal sheet S and a coefficient α (°C·mm/s), which indicates cooling conditions such as the shape of the nozzles or the type, the temperature, the jetting amount of the cooling fluid CF that is to be jetted, by Formula (3) below.

$$CV = \alpha / t \cdots (2)$$

[0027] By substituting Formula (2) for Formula (1), the distance d can be expressed by Formula (3) below.

$$d = (T1 - T2) \times v \times t / \alpha \cdots (3)$$

[0028] In the movement control device 40, the cooling rate CV(°C/s) or α (°C·mm/s) that is previously obtained through an experiment, a numerical analysis, and the like is stored. Then, the movement control device 40 obtains the distance d by using Formula (1) or Formula (3) and moves the restraining rolls 20 such that the metal sheet S is restrained at a position corresponding to the obtained distance d. Note that the cooling rate CV is a value that is determined in accordance with the sheet thickness and the like. When the sheet thickness is 1 to 2 mm, the cooling rate CV = 1000 to 2000(°C/s), and α = 500 to 2000(°C·mm/s). Thus, in the movement control device 40, the cooling rate CV may be set to 1500(°C/s), which is an intermediate value in the aforementioned range. In this case, α may be treated as 1250(°C·mm/s), which is an intermediate value. As described above, cooling conditions α obtained by the above-described cooling rate CV, the sheet thickness t, and Formula (2) may be set.

[0029] With reference to Fig. 1, a quenching method and a method of manufacturing the metal sheet S in the present invention will be described. First, the metal sheet S is cooled by the cooling device 10 while being conveyed, and quenching of the metal sheet S is performed. At this time, the restraining rolls 20 move in the conveyance direction such that the metal sheet S having the target temperature T2 at the position RP is restrained in the thickness direction. At this time, the movement control device 40 calculates the distance d by using Formula (1) or Formula (3) mentioned above, and the restraining rolls 20 move so as to restrain the metal sheet S at a position corresponding to the calculated distance d. Note that the movement of the restraining rolls 20 may be performed successively also during quenching of the metal sheet S. The movement control device 40 may calculate the distance d and move the restraining rolls 20, for example, at a timing when the line speed v is changed.

[0030] The line speed of the metal sheet S fluctuates even with respect to a single metal sheet S (in one coil). Therefore, it is more preferable, since a yield by shape defects of portions such as a leading end and a tail end of the metal sheet S where the speed decreases can be improved, that the metal sheet S be movable in the conveyance direction or a direction opposite to the conveyance direction while being restrained by the restraining rolls 20. Alternatively, the move-

ment control device 40 may calculate the distance d and move the restraining rolls 20 for every set period.

[0031] The movement distance of the restraining rolls 20 for adjusting the restraining rolls 20 to be at the position RP, at which the metal sheet S is restrained, based on the distance d can be estimated as substantially 10 mm to 150 mm actually. As illustrated in Fig. 1, when the nozzles 12 are installed inside the cooling tank 11, the restraining rolls 20 may be lifted and lowered between these nozzles 12 in a state in which an interval between the nozzles 12 are previously widened to about 10 mm to 150 mm. Rapid cooling by liquid jet streams has, for example, a cooling performance of about 1000°C/sec, and, when the traveling speed of the metal sheet S is 60 m/min (= 1000 mm/sec), the temperature varies by about 100°C with a distance of 100 mm. In other words, when the restraining rolls 20 can be lifted and lowered in the range of 10 mm to 150 mm, the temperature of the restrained metal sheet S can be adjusted by about 10°C to 150°C, and the above-described movement distance of the restraining rolls 20 is actually in a sufficient control adjustment range.

[0032] Here, a case in which the restraining rolls 20 are moved by a larger amount than in the above-described example will be described. When the composition, the sheet thickness, the line speed, and the like of the metal sheet S are greatly varied, it is required to move the restraining rolls 20 by 150 mm or more to position the restraining rolls 20 at the position RP at which the metal sheet S is restrained. A configuration that moves the restraining rolls 20 by 150 mm or more will be described. Fig. 9 is a diagram in which another example of the quenching apparatus according to an embodiment of the present invention is illustrated. A quenching apparatus 50 illustrated in Fig. 9 includes, in addition to the roll moving device 30 that moves the restraining rolls 20, a nozzle moving device 60 that moves the nozzles 12. As illustrated in Fig. 9(A), the nozzle moving device 60 is disposed on each of two sides of the metal sheet S. The nozzle moving device 60 is configured to move the nozzles 12 along the metal sheet S and cause the nozzles 12 to come close to and separate from the metal sheet S. In the example illustrated in Fig. 9, the restraining rolls 20 on the two sides of the metal sheet S are shifted from each other in the up-down direction.

[0033] As illustrated in Fig. 9, the nozzle moving device 60 includes a lifting device 62 that moves cooling pipes 61 in communication with a corresponding one of the nozzles 12 in the up-down direction of the cooling device 10, and a slider 63 that causes the lifting device 62 to come close to and separate from the metal sheet S. The lifting device 62 is configured to be able to lift and lower each of a plurality of the cooling pipes 61 independently. Note that the lifting device 62 and the slider 63 may be a lifting device and a slider that have been known. In addition, a control device, which is not illustrated, that controls driving of the lifting device 62 and the slider 63 is provided.

[0034] Next, an operation of the quenching apparatus 50 illustrated in Fig. 9 will be described. When the restraining rolls 20 are moved upward from the position thereof illustrated in Fig. 9(A), the restraining rolls 20 and the nozzles 12 that are positioned on the upper side of the restraining rolls 20 interfere with each other. Therefore, the nozzles 12 are first separated from the metal sheet S by the slider 63 in the width direction (the left-right direction in Fig. 9) of the cooling device 10. In other words, the nozzles 12 are moved to be retracted from the restraining rolls 20. The interval between the metal sheet S and the tip portion of each of the nozzles 12 after the nozzles 12 are separated from the metal sheet S is set to an interval with which the restraining rolls 20 and the tip portions of the nozzles 12 do not come into contact with each other. In this state, the restraining rolls 20 are moved to the upper side or the lower side. In Fig. 9, the restraining rolls 20 are moved to the upper side. In other words, the restraining rolls 20 are moved to the position RP suitable for the target temperature T2 of the metal sheet S. In Fig. 9(B), the state thereof is illustrated.

[0035] In the state illustrated in Fig. 9(B), the restraining rolls 20 and the nozzles 12 are adjacent to each other in the width direction of the cooling tank 11. Therefore, the nozzles 12 that are adjacent to the restraining rolls 20 in the width direction are moved by the lifting device 62 as illustrated in Fig. 9(B) to be retract to the lower side of the restraining rolls 20. Consequently, the restraining rolls 20 and the nozzles 12 do not interfere with each other in either of the up-down direction and the width direction. In Fig. 9(C), the state thereof is illustrated. Next, the nozzles 12 are caused by the slider 63 to come close to the metal sheet S, and the interval therebetween is set and maintained at a preset interval. The movement of the restraining rolls 20 is thus completed. In Fig. 9(D), the state thereof is illustrated.

[0036] Note that the interval between the nozzles 12 may be widened to about 10 mm to 150 mm, substantially similarly to the example illustrated in Fig. 1, after the state illustrated in Fig. 9(D) is obtained, and, in this state, the restraining rolls 20 may be moved by about 10 mm to 150 mm to be adjusted to the aforementioned position RP. If allowable in terms of the cooling performance, the state in which the interval between the metal sheet S and the nozzles 12 is widened may be maintained so that the restraining rolls 20 can move by 150 mm or more.

[0037] According to the aforementioned embodiment, it is possible by installing the restraining rolls 20 to be movable in the conveyance direction to control the distance from the cooling start position to the restraining rolls 20 and to restrain the metal sheet S having the target temperature T2 by the restraining rolls 20 regardless of conditions of manufacture of the metal sheet S. As a result, it becomes possible to suppress shape defects of the metal sheet S generated due to conditions of manufacture of the metal sheet S during quenching in continuous annealing facilities.

[0038] In other words, the temperature of the metal sheet S conveyed to the quenching apparatus 1 varies depending on conditions of manufacture of the metal sheet, for example, the line speed v , the cooling start temperature T1 of the metal sheet S, the sheet thickness t of the metal sheet S, and the like. Therefore, when the distance d is set to be

constant regardless of conditions of manufacture, the temperature of the metal sheet S when the metal sheet S reaches the restraining rolls 20 also varies.

[0039] It has been found that varying the positions of the restraining rolls 20 is effective to precisely perform shape control at an optimal temperature position, which is different depending on conditions of manufacture to solve this problem. Since the restraining rolls 20 themselves move, it is possible, without causing instability of the cooling form, to restrain the metal sheet S in the target temperature range even when conditions of manufacture vary.

[0040] In particular, it is possible to reduce a shape having intricate uneven irregularities, which are generated when a martensitic transformation occurs during rapid cooling of the metal sheet S and causes volume expansion of the microstructure. Therefore, the deformation suppressing effect is increased in particular when the metal sheet S is a high strength steel sheet (high tensile strength steel sheet). Specifically, application to manufacture of a steel sheet whose tensile strength is more than or equal to 580 MPa is preferable. While the upper limit of the tensile strength is not particularly limited, the tensile strength may be less than or equal to 2000 MPa in one example. As examples of the aforementioned high strength steel sheet (high tensile strength steel sheet), there are presented a high strength cold rolled steel sheet, and a hot-dip galvanized steel sheet, an electro-galvanized steel sheet, a hot-dip galvanized steel sheet, and the like that are obtained by performing a surface treatment on high strength cold rolled steel sheets.

[0041] As a specific example of the composition of the high strength steel sheet, there is presented an example in which, in mass%, C is contained by more than or equal to 0.04% and less than or equal to 0.35%, Si is contained by more than or equal to 0.01% and less than or equal to 2.50%, Mn is contained by more than or equal to 0.80% and less than or equal to 3.70%, P is contained by more than or equal to 0.001% and less than or equal to 0.090%, S is contained by more than or equal to 0.0001% and less than or equal to 0.0050%, sol.Al is contained by more than or equal to 0.005% and less than or equal to 0.065%, at least one or more of Cr, Mo, Nb, V, Ni, Cu, and Ti are each contained, as necessary, by less than or equal to 0.5%, B and Sb are each further contained, as necessary, by less than or equal to 0.01%, and the remainder is constituted by Fe and incidental impurities. Note that the metal sheet S is not limited to a steel sheet and may be a metal sheet other than a steel sheet.

Example 1

[0042] An example of the present invention will be described. As a present invention example, quenching of a high tensile strength cold rolled steel sheet that is in a tensile strength class of 1470 MPa and that has the sheet thickness t of 1.0 mm and a sheet width of 1000 mm was performed by using the quenching apparatus 1 according to the aforementioned embodiment of the present invention. As the composition of the high tensile strength cold rolled steel sheet in the tensile strength class of 1470 MPa, C is contained by 0.20%, Si is contained by 1.0%, Mn is contained by 2.3%, P is contained by 0.005%, and S is contained by 0.002% in mass%. A temperature T_M s, which is the M_s temperature of the high tensile strength cold rolled steel sheet, is 300°C, and a temperature T_M f, which is the M_f temperature thereof, is 250°C. Therefore, the target temperature T_2 at a time of passing the restraining rolls 20 may be simply set in the range of 450°C to 100°C, and the target temperature T_2 was set to 400°C. In addition, the cooling start temperature T_1 was set to 800°C with the target temperature T_2 set to 400°C. The temperature of the cooling fluid CF was 30°C, and the cooling rate CV was set to 1500 (°C/s).

[0043] The line speed v was varied in the range of 1000 to 3000 mm/s as a variation in conditions of manufacture, and in accordance with the variation in the line speed v , the distance d (mm) was controlled in the range in which $d = 267$ to 800 mm on the basis of Formula (1). Ten steel sheets after being cooled were collected at every 100 mm in the longitudinal direction (that is, the same direction as the conveyance direction of the steel sheets), and the warp amount of each of the steel sheets was checked. Fig. 2 is a schematic diagram in which one example of the definition of the warp amount is illustrated. As illustrated in Fig. 2, the warp amount was defined as a height from a ground contact surface to a highest position of a steel sheet when the steel sheet was placed on a horizontal surface.

[0044] Fig. 3 is a graph showing the relationship between the line speed v and the target temperature in the present invention example, and Fig. 4 is a graph showing the relationship between the line speed v and the warp amount of a steel sheet as the metal sheet S in the present invention example. As illustrated in Fig. 3, it was possible, even when the line speed v was varied, to control the temperature (°C) at the time of passing the restraining rolls 20 to be the target temperature $400 \pm 25^\circ\text{C}$ by moving the restraining rolls 20 in accordance with the line speed v and varying the distance d . As a result, all of the warp amounts of the steel sheets decreased to be less than or equal to 10 mm, as illustrated in Fig. 4. Consequently, a variation, in other words, a difference between a maximum value and a minimum value of the warp amount was suppressed to be 4.2 mm.

[0045] Fig. 5 is a graph showing the relationship between the line speed v and the target temperature in Comparative example 1, and Fig. 6 is a graph showing the relationship between the line speed v and the warp amount of a steel sheet as the metal sheet S in Comparative example 1. As Comparative example 1, a quenching apparatus in which the restraining rolls 20 such as those in Patent Literature 1 are fixed was used, and the other conditions were the same as those in the aforementioned present invention example. In Comparative example 1, the distance d (mm) from the cooling

start position to the restraining rolls 20 was fixed as $d = 400$ mm.

[0046] In Comparative example 1, as illustrated in Fig. 5, the temperature ($^{\circ}\text{C}$) at the time of passing the restraining rolls greatly varied depending on the line speed v (mm/s) and was uncontrollable. Therefore, under conditions other than $v = 1000$ mm/s and $v = 1500$ mm/s, the temperature ($^{\circ}\text{C}$) at the time of passing the restraining rolls 20 was out of the range of 450°C to 100°C . As a result, under conditions other than $v = 1000$ mm/s and $v = 1500$ mm/s, all of the warp amounts of the steel sheets were more than or equal to 10 mm, as illustrated in Fig. 6, and the effect of suppressing a deformation was insufficient. As a result, a variation, which is a difference between a maximum value and a minimum value of the warp amount, was increased to be 10.3 mm.

[0047] Fig. 7 is a graph showing the relationship between the line speed v and the target temperature in Comparative example 2, and Fig. 8 is a graph showing the relationship between the line speed v and the warp amount of a steel sheet as the metal sheet S in Comparative example 2. As Comparative example 2, as indicated in Patent Literature 2, the distance d was controlled by the cooling start position by moving the movable masking member with the restraining rolls 20 being fixed. Other conditions were set to be the same as those in the present invention example, and the aforementioned high tensile strength cold rolled steel sheet was manufactured.

[0048] As illustrated in Fig. 7, the temperature ($^{\circ}\text{C}$) at the time of passing the restraining rolls 20 greatly varied in Comparative example 2 regardless of the line speed v (mm/s), which is a condition of manufacture of the steel sheet, and was uncontrollable. Therefore, under all conditions, the temperature ($^{\circ}\text{C}$) at the time of passing the restraining rolls was out of the range of 450°C to 100°C . Then, as illustrated in Fig. 8, the warp amount of the steel sheet was more than or equal to 10 mm, and the effect of suppressing a deformation was insufficient. As a result, the variation (i.e., the difference between the maximum value and the minimum value) in the warp amount was increased to be 9.2 mm.

[0049] Note that the embodiment of the present invention is not limited to the aforementioned embodiment, and various changes can be added thereto. For example, while the target temperature T_2 is $(T_{Ms} + 150)^{\circ}\text{C}$ to $(T_{Mf} - 150)^{\circ}\text{C}$ in the example presented in the aforementioned embodiment, the target temperature T_2 is not limited thereto. The target temperature T_2 may be not limited to $(T_{Ms} + 150)^{\circ}\text{C}$ to $(T_{Mf} - 150)^{\circ}\text{C}$ when absence of variations in the shape of the metal sheet S in terms of, for example, the warp amount and the like is simply required from the point of view of ensuring flexibility in processing and operation in subsequent steps.

[0050] In this case, the target temperature T_2 is previously determined in consideration of a predicted shape (for example, the warp amount) while ensuring of flexibility in processing and operation in subsequent steps and the like are taken into consideration, and the distance d from the cooling start position to the restraining rolls 20 is controlled by positional adjustment of the restraining rolls 20. Then, the temperature of the metal sheet S at the time of passing the restraining rolls 20 is caused to be the previously determined temperature T_2 so that the shape (for example, the warp amount) of the metal sheet S is substantially the same, for example, a variation in the warp amount defined in Fig. 2 is 4 mm or less.

[0051] Further, the restraining rolls 20 are not limited to being provided as a pair. A plurality of pairs of the restraining rolls 20 or a plurality of the restraining rolls 20 may be provided. In such a case, positions of the restraining roll pairs as a whole may be collectively controlled, or a mechanism that controls the position and opening/closing of each of a plurality of the restraining rolls may be employed.

Reference Signs List

[0052]

1	metal-sheet quenching apparatus
10	cooling device
11	cooling tank
12	nozzle
20	restraining roll
30	roll moving device
40	movement control device
BD	conveyance direction
CF	cooling fluid
S	metal sheet

Claims

1. A metal-sheet quenching apparatus that cools a metal sheet while conveying the metal sheet, the metal-sheet quenching apparatus comprising:

a cooling device that cools the metal sheet that is conveyed;
 a restraining roll that conveys the metal sheet cooled by the cooling device while restraining the metal sheet in
 a thickness direction;
 a roll moving device that moves the restraining roll in a conveyance direction of the metal sheet; and
 a movement control device that adjusts a position of the restraining roll by controlling an operation of the roll
 moving device.

2. The metal-sheet quenching apparatus according to claim 1, wherein the cooling device includes a plurality of nozzles
 through which a cooling fluid is jetted to the metal sheet to cool the metal sheet.

3. The metal-sheet quenching apparatus according to claim 1 or 2, wherein the cooling device includes a cooling tank
 in which the metal sheet is immersed and cooled.

4. The metal-sheet quenching apparatus according to any one of claims 1 to 3, wherein the movement control device
 controls the operation of the roll moving device to position the restraining roll such that the restraining roll restrains
 the metal sheet at a position at which the metal sheet has a target temperature.

5. The metal-sheet quenching apparatus according to claim 4, wherein the target temperature is set in a temperature
 range of $(TMs + 150)(^{\circ}C)$ to $(TMf - 150)(^{\circ}C)$, where $TMs(^{\circ}C)$ is a Ms temperature at which a martensitic transformation
 of the metal sheet starts and $TMf(^{\circ}C)$ is a Mf temperature at which the martensitic transformation ends.

6. The metal-sheet quenching apparatus according to claim 4 or 5, wherein the movement control device sets a distance
 from a cooling start position by the cooling device to the restraining roll based on a line speed of the metal sheet,
 a cooling start temperature of the metal sheet at a time when cooling by the cooling device is started, the target
 temperature, and a cooling rate of cooling of the metal sheet, and moves the position of the restraining roll such
 that the set distance is achieved.

7. The metal-sheet quenching apparatus according to claim 6, wherein the movement control device obtains a distance
 d (mm) from the cooling start position to the restraining roll by Formula (1) below:

$$d = (T1 - T2) \times v / CV \quad (1),$$

where v (mm/s) is the line speed of the metal sheet, $T1(^{\circ}C)$ is the cooling start temperature, $T2(^{\circ}C)$ is the target
 temperature, and $CV(^{\circ}C/s)$ is the cooling rate of cooling of the metal sheet by the cooling device.

8. The metal-sheet quenching apparatus according to claim 7, wherein, based on a sheet thickness t of the metal
 sheet and a coefficient α indicating a condition of cooling of the metal sheet, the cooling rate CV is set as $CV = \alpha/t$
 in the movement control device.

9. A metal-sheet quenching method in which a metal sheet is cooled while being conveyed, the method comprising:
 moving a restraining roll in a conveyance direction of the metal sheet such that, when the metal sheet that has been
 cooled is restrained by the restraining roll in a thickness direction, the metal sheet is restrained at a position at which
 the metal sheet has a target temperature.

10. The metal-sheet quenching method according to claim 9, wherein the target temperature is set in a temperature
 range of $(TMs + 150)(^{\circ}C)$ to $(TMf - 150)(^{\circ}C)$, where $TMs(^{\circ}C)$ is a Ms temperature at which a martensitic transformation
 of the metal sheet starts and $TMf(^{\circ}C)$ is a Mf temperature at which the martensitic transformation ends.

11. The metal-sheet quenching method according to claim 9 or 10, wherein moving of the restraining roll is performed by
 setting a distance from a cooling start position to the restraining roll based on a line speed of the metal sheet,
 a cooling start temperature of the metal sheet at a time when cooling is started, the target temperature, and a
 cooling rate of cooling of the metal sheet, and
 moving the restraining roll such that the set distance is achieved.

12. The metal-sheet quenching method according to claim 11, wherein, as the distance from the cooling start position
 to the restraining roll, a distance d (mm) from the cooling start position to the restraining roll is obtained by Formula

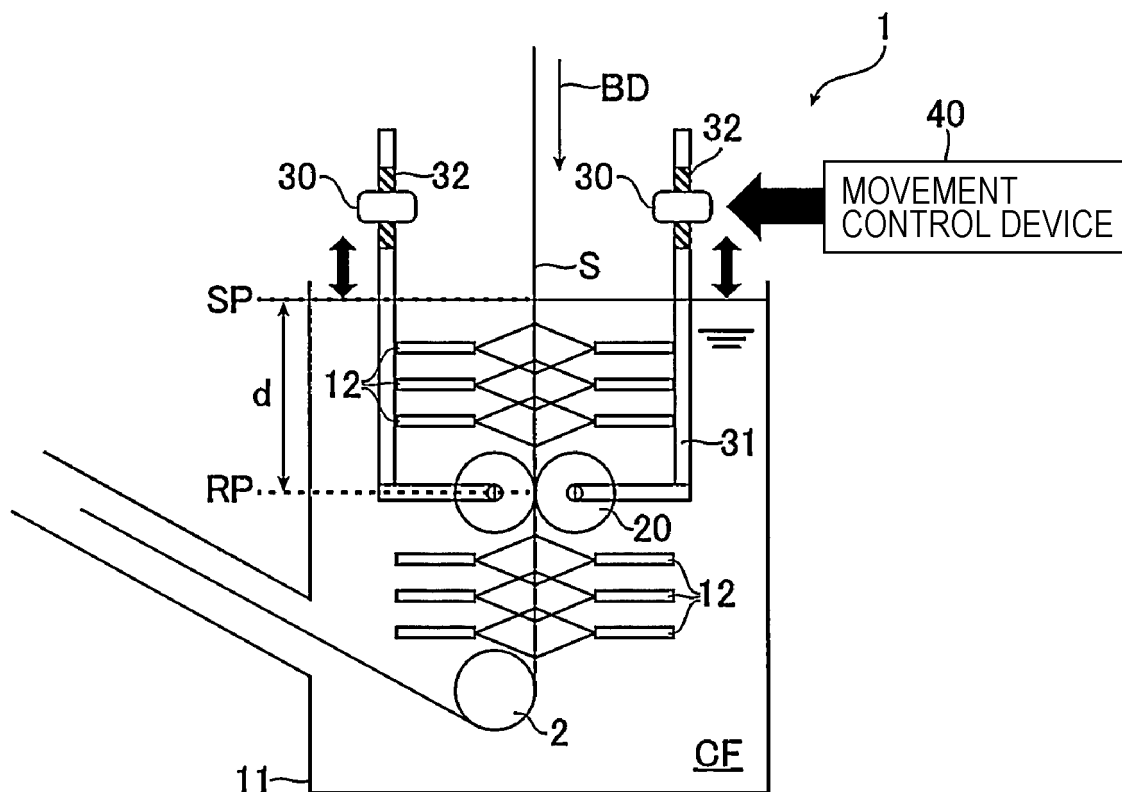
(1) below:

$$d = (T1 - T2) \times v / CV \quad (1),$$

where v (mm/s) is the line speed of the metal sheet, $T1(^{\circ}\text{C})$ is the cooling start temperature, $T2(^{\circ}\text{C})$ is the target temperature, and $CV(^{\circ}\text{C/s})$ is the cooling rate of cooling of the metal sheet.

13. The metal-sheet quenching method according to claim 12, wherein, based on a sheet thickness t of the metal sheet and a coefficient α indicating a condition of cooling of the metal sheet, the cooling rate CV is set as $CV = \alpha/t$.
14. A method of manufacturing a high strength cold rolled steel sheet, the method using the metal-sheet quenching method according to any one of claims 9 to 13.
15. A method of manufacturing a high strength steel sheet, the method comprising performing any of a hot-dip galvanizing treatment, an electro-galvanizing treatment, or a hot-dip galvannealing treatment on a high strength steel sheet obtained by the method according to claim 14.

FIG



FIG

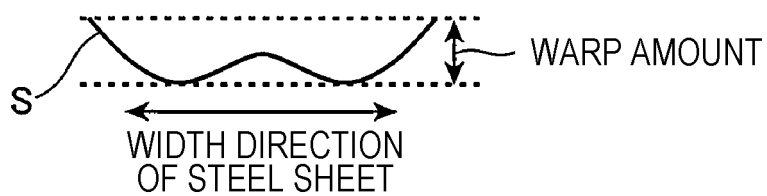


FIG. 3

<PRESENT INVENTION EXAMPLE>

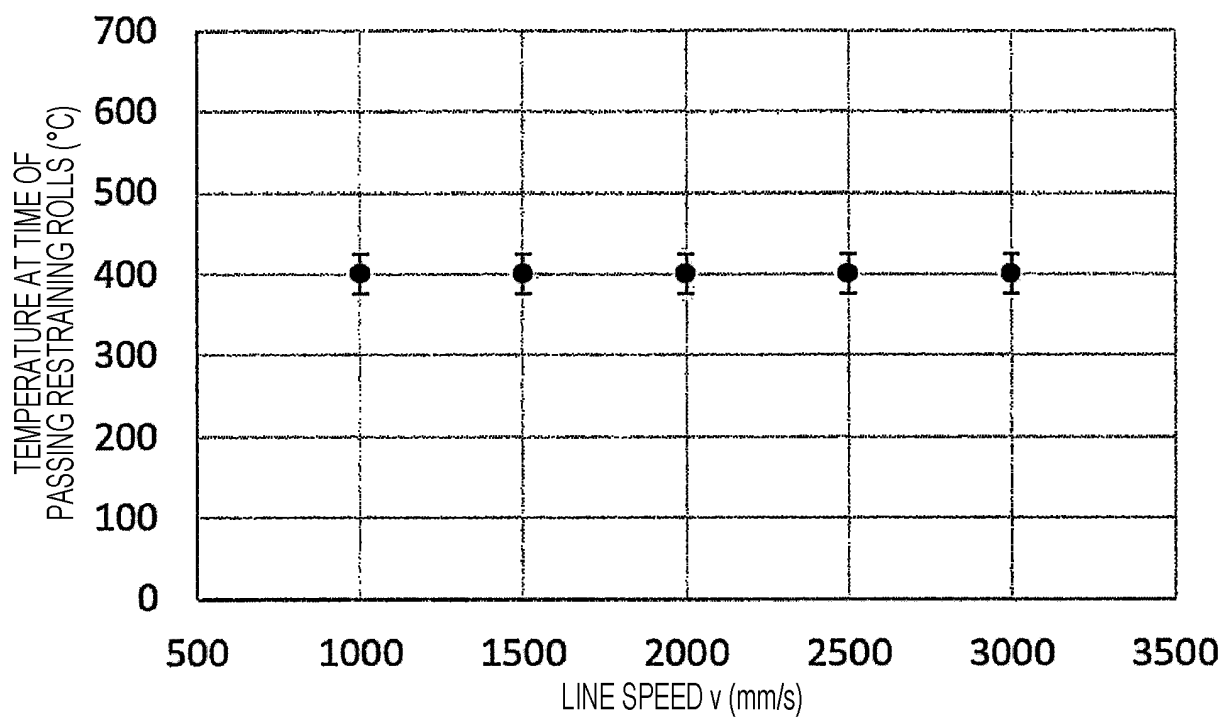


FIG. 4

<PRESENT INVENTION EXAMPLE>

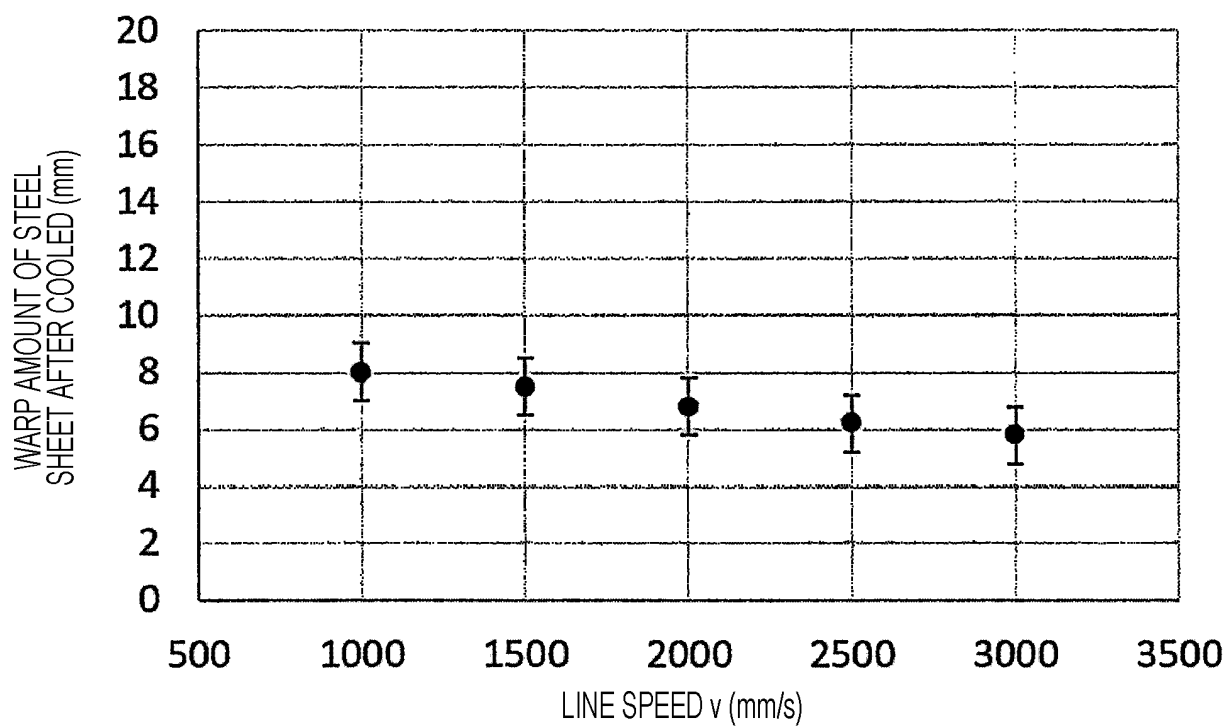


FIG. 5

<COMPARATIVE EXAMPLE 1>

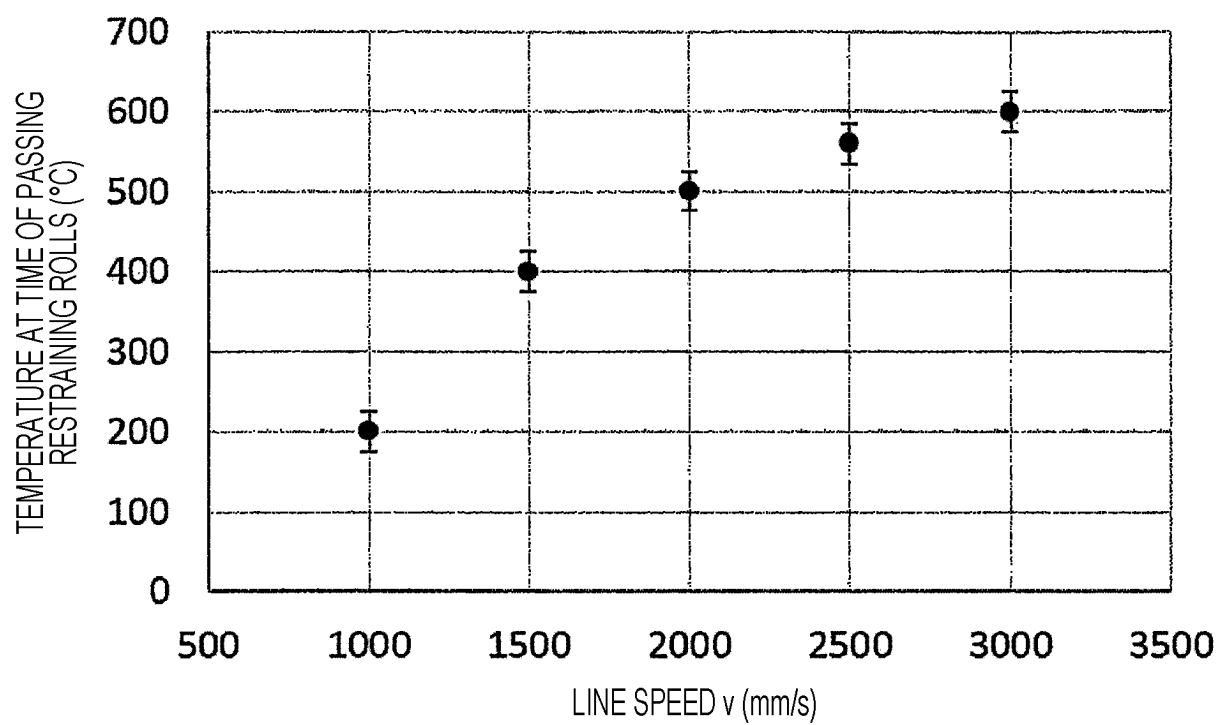


FIG. 6

<COMPARATIVE EXAMPLE 1>

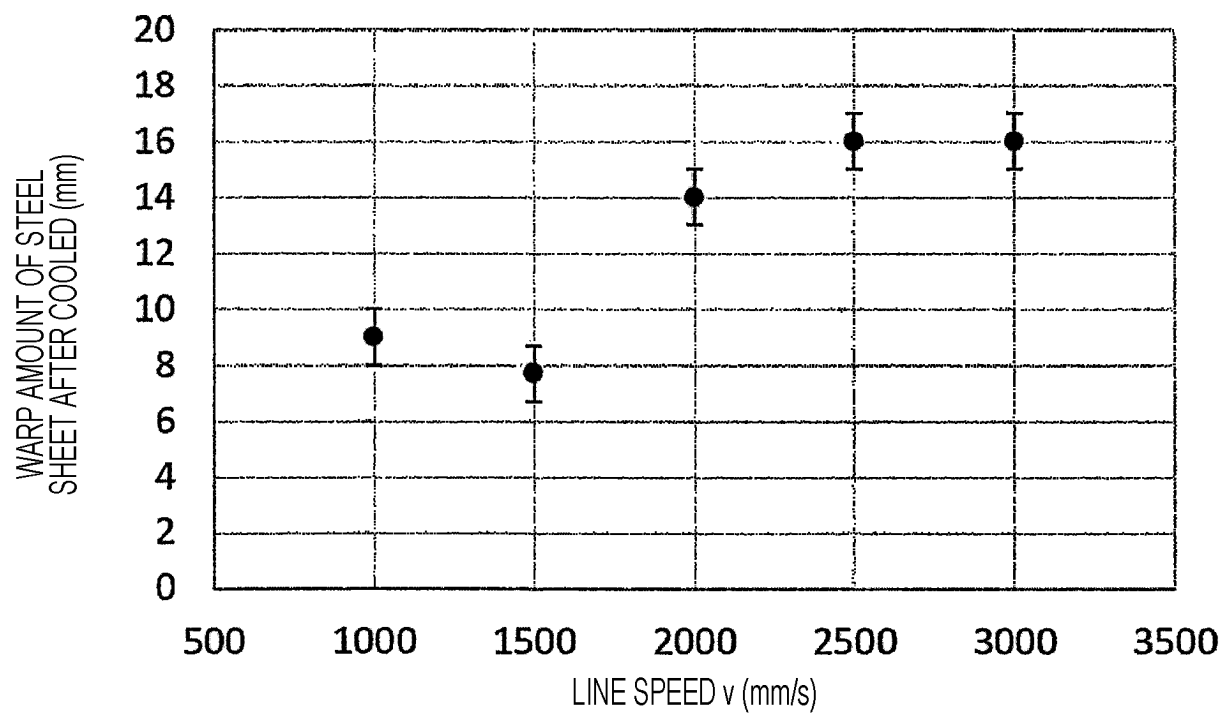


FIG. 7

<COMPARATIVE EXAMPLE 2>

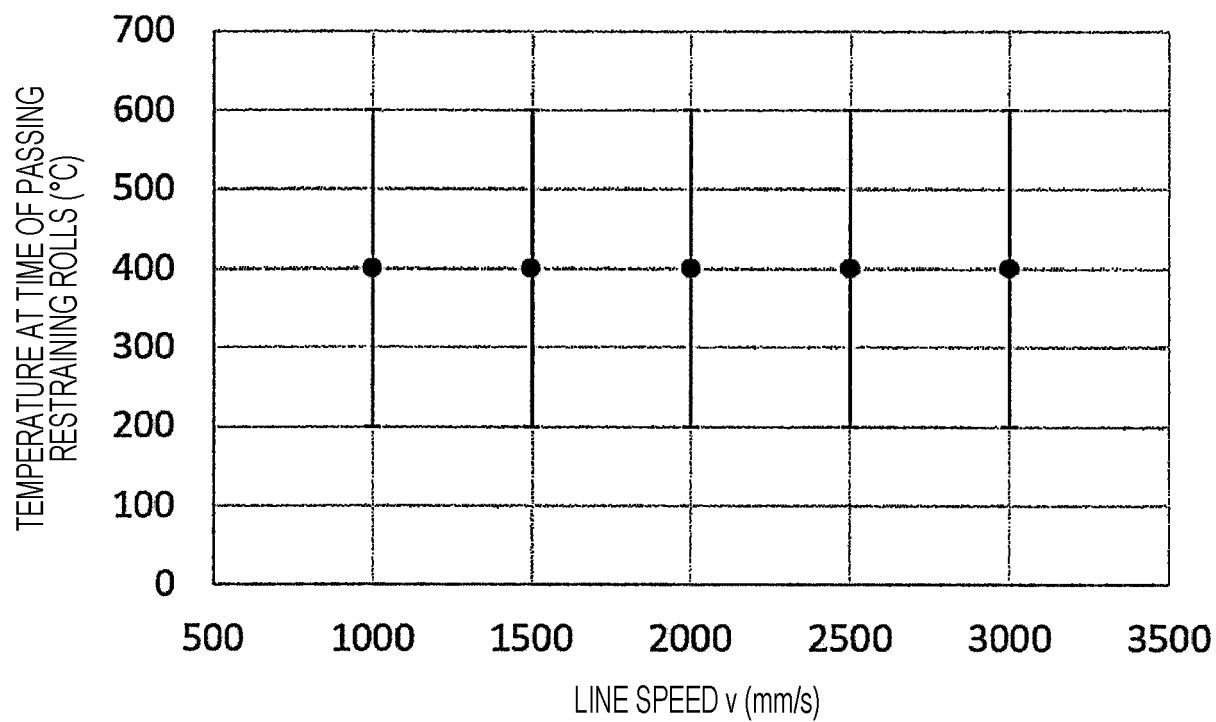
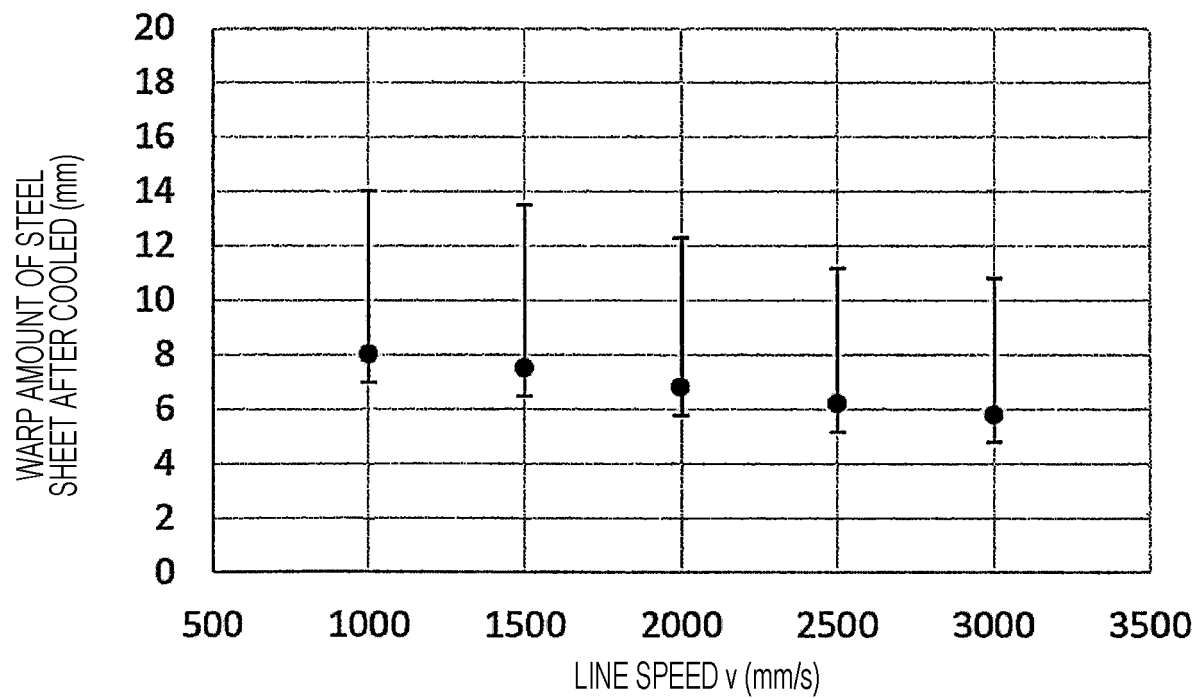


FIG. 8

<COMPARATIVE EXAMPLE 2>



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/029364

A. CLASSIFICATION OF SUBJECT MATTER

C21D 9/573(2006.01)i; *B21B 45/02*(2006.01)i; *C21D 1/18*(2006.01)i; *C21D 1/63*(2006.01)i; *C21D 1/667*(2006.01)i;
C22C 38/00(2006.01)n; *C22C 38/60*(2006.01)n
 FI: C21D9/573 101Z; B21B45/02 320S; B21B45/02 320U; C21D1/18 D; C21D1/63; C21D1/667; C22C38/00 301T;
 C22C38/00 301U; C22C38/60

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)

C21D9/52-9/66; B21B45/02; C21D1/00; C21D1/18; C21D1/63; C21D1/667; C22C38/00; C22C38/60

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

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2022
 Registered utility model specifications of Japan 1996-2022
 Published registered utility model applications of Japan 1994-2022

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 15607/1991 (Laid-open No. 114549/1992) (CHUGAI RO KOGYO KAISHA LTD) 08 October 1992 (1992-10-08), claims, paragraphs [0005]-[0010], fig. 1	1-4, 9
A		5-8, 10-15
Y	WO 2016/084283 A1 (JFE STEEL CORPORATION) 02 June 2016 (2016-06-02) claims, paragraphs [0015]-[0038], fig. 1, 2, 4	1-15
Y	JP 2011-184773 A (KOBE STEEL LTD) 22 September 2011 (2011-09-22) paragraph [0034], fig. 6	1-15
A	JP 2019-090106 A (JFE STEEL CORPORATION) 13 June 2019 (2019-06-13) paragraphs [0004]-[0008]	1-15

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

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier application or patent but published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 07 September 2022	Date of mailing of the international search report 20 September 2022
Name and mailing address of the ISA/JP Japan Patent Office (ISA/JP) 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915 Japan	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/029364

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 4-114549 U1	08 October 1992	(Family: none)	
WO 2016/084283 A1	02 June 2016	US 2017/0327926 A1 claims, paragraphs [0024]- [0044], fig. 1, 2, 4 EP 3225705 A1 KR 10-2017-0070217 A CN 107002164 A	
JP 2011-184773 A	22 September 2011	(Family: none)	
JP 2019-090106 A	13 June 2019	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 6094722 B [0006]
- JP 2019090106 A [0006]