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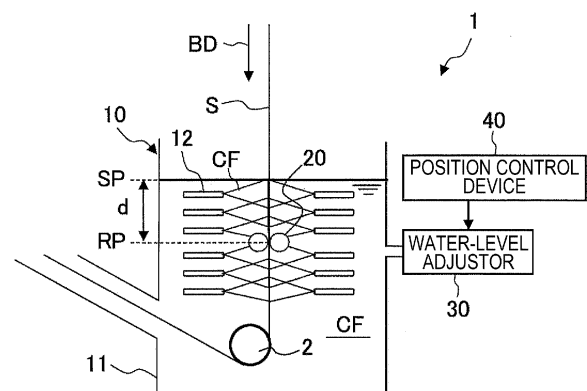
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(54) **QUENCH-HARDENING APPARATUS, QUENCH-HARDENING METHOD, AND METAL SHEET MANUFACTURING METHOD**

(57) Variations in the shape of a metal sheet generated during quenching is suppressed.

A metal-sheet quenching apparatus 1 cools a metal sheet S while conveying the metal sheet S and includes a cooling tank 11 in which a cooling fluid CF is to be stored and the metal sheet S is immersed in the cooling fluid CF to be cooled; restraining rolls 20 that are installed inside the cooling tank 11 and convey the metal sheet S that has been cooled in the cooling tank 11 while restraining the metal sheet S in the thickness direction; a water-level adjuster 30 that adjusts the height of a fluid surface of the cooling fluid CF inside the cooling tank 11; and a position control device 40 that adjusts the height of the fluid surface of the cooling fluid CF inside the cooling tank 11 by controlling the operation of the water-level adjuster 30.

FIG. 1



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 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 a high tensile strength steel sheet, a technique of rapidly cooling the 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 by a cooling liquid. 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, which 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 capacity 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 suppressing generation of variations in the shape of a metal sheet at the time of quenching, a quenching method, and a method of manufacturing a metal-sheet product.

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 tank in which a cooling fluid is to be stored and the metal sheet is cooled by being immersed in the cooling fluid; a restraining roll that is installed inside the cooling tank and that conveys the metal sheet cooled in the cooling tank while restraining the metal sheet in a thickness direction; a water-level adjustor that adjusts a height of a fluid surface of the cooling fluid inside the cooling tank, the fluid surface being a cooling start position of the metal sheet; and a position control device that controls the height of the fluid surface of the cooling fluid inside the cooling tank by controlling an operation of the water-level adjustor.

[2] The metal-sheet quenching apparatus described in [1], further including a plurality of nozzles through which the cooling fluid is jetted to the metal sheet to cool the metal sheet, the plurality of nozzles being installed inside the cooling tank.

[3] The metal-sheet quenching apparatus described in [1] or [2], in which the water-level adjustor includes an adjustment tank that stores the cooling fluid and that is connected to the cooling tank, a supply source at the adjustment tank, and a weir that controls discharge of the cooling fluid from the adjustment tank, and the height of the fluid surface of the cooling fluid inside the cooling tank is adjusted by adjusting a stored amount of the cooling fluid inside the adjustment tank.

[4] The metal-sheet quenching apparatus described in any one of [1] to [3], in which the position control device adjusts the height of the fluid surface of the cooling fluid inside the cooling tank 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 position control device sets a distance from the 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 in the cooling tank is started, the target temperature, and a cooling rate of cooling of the metal sheet and adjusts the height of the fluid surface of the cooling fluid inside the cooling tank such that the set distance is achieved.

[7] The metal-sheet quenching apparatus described in [6], in which the position 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 in the cooling tank.

[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 position control device.

[9] The metal-sheet quenching apparatus described in [2], in which a distance between a liquid surface of the cooling fluid inside the cooling tank and a hitting position on the metal sheet at which a liquid jet stream from each of the nozzles hits the metal sheet is more than or equal to 30 mm and less than or equal to 2000 mm.

[10] A metal-sheet quenching method in which a metal sheet is cooled while being conveyed, the method including: immersing the metal sheet in a cooling fluid that is stored in a cooling tank and cooling the metal sheet with a cooling start position set at a height of a fluid surface of the cooling fluid inside the cooling tank, in which the height of the fluid surface of the cooling fluid inside the cooling tank is adjusted such that the metal sheet is restrained at a position at which the metal sheet has a target temperature by a restraining roll.

[11] The metal-sheet quenching method described in [10], 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.

[12] The metal-sheet quenching method described in [10] or [11], in which, in adjustment of the height of the fluid surface of the cooling fluid, a distance from the cooling start position to the restraining roll is set 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 in which the height of the fluid surface of the cooling fluid inside the cooling tank is adjusted such that the set distance is achieved.

[13] The metal-sheet quenching method described in [12], in which, as the distance from the cooling start position in the cooling tank 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.

[14] The metal-sheet quenching method described in [13], 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 $CV = \alpha/t$.

[15] A method of manufacturing a high strength cold rolled steel sheet, the method using the metal-sheet quenching method described in any one of claims 10 to 14.

[16] 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 [15].

[17] The metal-sheet quenching method described in [10], in which the cooling fluid is jetted from a nozzle that is installed inside the cooling tank to the metal sheet to cool the metal sheet, and a distance between a liquid surface of the cooling fluid inside the cooling tank and a hitting position on the metal sheet at which a liquid jet stream from the nozzle hits the metal sheet is more than or equal to 30 mm and less than or equal to 2000 mm. Advantageous Effects of Invention

[0011] According to the present invention, by controlling the operation of a water-level adjustor at the time of quenching of a metal sheet to adjust the height of a fluid surface of a cooling fluid inside a cooling tank, the fluid surface being a cooling start position, it is possible to control the distance from the cooling start position to a restraining roll. Consequently, it is possible to suppress variations in the shape of the metal sheet generated during 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 a water-level adjustor in Fig. 1 is illustrated.

[Fig. 3] Fig. 3 is a schematic diagram in which one example of the definition of a warp amount of a metal sheet is illustrated.

[Fig. 4] Fig. 4 is a graph showing a relationship between a line speed and a target temperature in a present invention example.

[Fig. 5] Fig. 5 is a graph showing a relationship between a line speed and a warp amount of a metal sheet in a present invention example.

[Fig. 6] Fig. 6 is a graph showing a relationship between a line speed and a target temperature in Comparative example 1.

[Fig. 7] Fig. 7 is a graph showing a relationship between a line speed and a warp amount of a metal sheet in Comparative example 1.

[Fig. 8] Fig. 8 is a graph showing a relationship between a line speed and a target temperature in Comparative example 2.

[Fig. 9] Fig. 9 is a graph showing a relationship between a line speed and a warp amount of a metal sheet in Comparative example 2.

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 a metal sheet 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, slit 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, cooling that uses an oil or an ionic liquid 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 preset temperature range. For example, the metal sheet S may be cooled by only the cooling tank 11 without the use of the nozzles 12.

[0017] 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, the restraining rolls 20 are not limited to being provided as a pair. A plurality of pairs 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.

[0018] Here, quenching of the metal sheet S is performed by immersing the metal sheet S in the cooling fluid CF stored in the cooling tank 11. Therefore, a cooling start position SP of the metal sheet S varies depending on the water level in the cooling tank 11. The metal quenching apparatus 1 thus has a function of varying the cooling start position SP by varying the height of the fluid surface in the cooling tank 11.

[0019] The metal quenching apparatus 1 includes a water-level adjustor 30 that adjusts the height of the fluid surface of the cooling fluid CF contained in the cooling tank 11, and a position control device 40 that controls the operation of the water-level adjustor 30. Fig. 2 is a schematic diagram in which one example of the water-level adjustor 30 in Fig. 1 is illustrated. The water-level adjustor 30 in Fig. 2 includes an adjustment tank 31 in which the cooling fluid CF is stored, a supply source 32 that supplies the cooling fluid CF to the adjustment tank 31, and a weir 33 that controls discharge of the cooling fluid CF inside the adjustment tank 31. The adjustment tank 31 and the cooling tank 11 are connected to each other by a discharge pipe 34 through which the cooling fluid CF is discharged from the cooling tank 11 and a supply pipe 35 through which the cooling fluid CF is supplied to the cooling tank 11. Preferably, the discharge pipe 34 and the supply pipe 35 are provided below a liquid surface so as not to impede a boiling phenomenon and jetting through the nozzles 12. Further, the discharge pipe 34 and the supply pipe 35 may be integrated together.

[0020] As a result of the fluid flowing through the discharge pipe 34 and the supply pipe 35, the heights of the fluid surfaces in the adjustment tank 31 and the cooling tank 11 are adjusted to be the same due to the atmospheric pressure. Consequently, it is possible to adjust the height of the fluid surface in the cooling tank 11 by, for example, adjusting the stored amount in the adjustment tank 31 while monitoring the height of the fluid surface in the adjustment tank 31. Consequently, it is also possible to adjust the cooling start position SP. Specifically, when the cooling start position SP is to be raised, the cooling fluid CP is supplied from the supply source 32 into the adjustment tank 31 to increase the stored amount. Consequently, the height of the liquid surface in the cooling tank 11, in other words, the cooling start position SP is raised. When the cooling start position SP is to be lowered, the weir 33 is moved, in other words, the weir 33 is lowered and the cooling fluid CP inside the adjustment tank 31 overflows the weir 33, and the cooling fluid CP is thereby discharged from the adjustment tank 31. Consequently, the height of the liquid surface in the cooling tank 11, in other words, the cooling start position SP is lowered.

[0021] Note that the water-level adjustor 30 is not limited to having the configuration in Fig. 2 and may include a pump or the like that supplies and discharges the cooling medium CF to/from the cooling tank 11 and may adjust the height of the liquid surface by immersing or removing an object of a volume that is determined at the time of design in/from the adjustment tank 31. Considering management of the temperature, dirt, or the like of the cooling fluid CF and accuracy and reactivity of adjustment of the height of the liquid surface, it is preferable to, in addition to performing above-described drainage by the pump, adjust the liquid surface in the cooling tank 11 by connecting the adjustment tank 31 to the cooling tank 11 and adjusting the stored amount in the adjustment tank 31.

[0022] The position control device 40 is formed by a hardware resource such as a computer and controls the height of the fluid surface of the cooling fluid CF inside the cooling tank 11 by controlling the water-level adjustor 30. In particular,

the position control device 40 controls the operation of the water-level adjuster 30 to adjust the height of the fluid surface of the cooling fluid CF inside the cooling tank 11 such that the metal sheet S is restrained at a position RP at which the metal sheet S has a target temperature. Here, the target temperature is preferably set in the 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 S starts and $TMf(^{\circ}C)$ 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.

[0023] The position control device 40 calculates a distance d from the target 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 adjusts the height of the fluid surface of the cooling fluid CF inside the cooling tank 11 on the basis of the calculated distance d . At this time, the position control device 40 calculates the distance d by using a line speed v (mm/s), a cooling start temperature $T1(^{\circ}C)$, and a target temperature $T2(^{\circ}C)$ of the metal sheet S, and a cooling rate $CV(^{\circ}C/s)$ of cooling of the metal sheet S by the cooling device 10. 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. The cooling start temperature $T1(^{\circ}C)$ denotes the temperature of the metal sheet S at the time when cooling of the metal sheet S is started, specifically, the temperature of the metal sheet S just before the cooling start position SP. For example, the temperature of the metal sheet S 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. The target temperature $T2$ denotes a target value of the temperature of the metal sheet S at the position RP at which the metal sheet S is restrained by the restraining rolls 20.

[0024] Specifically, the relationship between the distance d and the cooling rate $CV(^{\circ}C/s)$ is expressed by Formula (1) below.

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

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

[0025] The cooling rate $CV(^{\circ}C/s)$ can be expressed using a sheet thickness t of the metal sheet S and a coefficient $\alpha(^{\circ}C \cdot mm/s)$, 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 (2) below.

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

[0026] By substituting Formula (2) for Formula (1), the distance d can be expressed by Formula (3) below.

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

[0027] In the position control device 40, the cooling rate $CV(^{\circ}C/s)$ or $\alpha(^{\circ}C \cdot mm/s)$ that is previously obtained through an experiment, a numerical analysis, and the like is stored. Then, the position control device 40 obtains the distance d by using Formula (1) or Formula (3) and adjusts the height of the fluid surface of the cooling fluid CF inside the cooling tank 11 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 $2000(^{\circ}C/s)$, and $\alpha = 500$ to $2000(^{\circ}C \cdot mm/s)$. Thus, in the position control device 40, the cooling rate CV may be set to $1500(^{\circ}C/s)$, which is an intermediate value in the aforementioned range. In this case, α may be treated as $1250(^{\circ}C \cdot mm/s)$, 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.

[0028] If changing of the height of the liquid surface is possible, it is possible to change the cooling rate CV of the metal sheet S at the initial stage by a combination use of slow cooling by simply immersing the metal sheet S in the liquid and rapid cooling by the nozzles 12. In a section of cooling by the nozzles 12 through which the liquid is jetted, a

vapor film that is generated on the surfaces of the metal sheet S due to boiling is broken by liquid jet streams, and the cooling rate CV that is high can be thereby obtained. Meanwhile, in a section of cooling by simply immersing the metal sheet S in the liquid, the surfaces of the metal sheet S are in a film boiling state covered by the vapor film, and heat transfer between the liquid and the metal sheet S is impeded by the vapor film. The cooling rate CV is thus decreases.

By using slow cooling by this film boiling, it is possible not only to suppress a stress generated by a sudden temperature variation but also to more uniformly cool the metal sheet S at an initial stage of cooling and reduce variations in temperature. It is thus possible to suppress a shape deformation of the metal sheet S and obtain the metal sheet S having a more flattened shape.

[0029] For such a reason, when simply immersing the metal sheet S in the liquid and cooling by the nozzles 12 are used in combination, the height of the liquid surface is preferably higher than a position at which the liquid jet stream from each of the nozzles 12 hits the metal sheet S. The range of the height of the liquid surface from the nozzles 12, in other words, the distance between the liquid surface and the nozzles 12 is preferably, for example, more than or equal to 30 mm and less than or equal to 2000 mm.

[0030] When the liquid surface is close to the hitting position of each of the liquid jet streams such that the distance therebetween is less than 30 mm, which is the lower limit value of the aforementioned distance, the liquid surface fluctuates due to an influence of the liquid jet streams from the nozzles 12. Specifically, a periodical vertical movement of the liquid surface is generated, which makes the cooling capacity with respect to the metal sheet S unstable. As a result, the temperature (restrain temperature) at a portion at which the metal sheet S is restrained by the restraining rolls 20 fluctuates, and there is a possibility of generation of a periodical shape variation in the metal sheet S.

[0031] The upper limit value of the aforementioned distance is preferably determined, as appropriate, on the basis of metallurgical characteristics of the metal sheet S, the line speed v, the cooling rate CV, and the like. In general, rapid cooling in a transformation temperature range is required in order to obtain desired metal characteristics by liquid quenching. Therefore, in consideration that the range of the line speed in a step of general quenching of a metal sheet is 10 m/min to 600 m/min, it is not preferable that the upper limit value be more than 2000 mm. This is because, when the upper limit value is more than 2000 mm, there is a high possibility that a sufficient cooling capacity with respect to the metal sheet S in the transformation temperature range is not obtained. It is thus preferable that the distance between the liquid surface and the nozzles 12 be more than or equal to 30 mm and less than or equal to 2000 mm. Further, it is more preferable that the distance be more than or equal to 50 mm and less than or equal to 1000 mm in order to further stabilize the liquid surface and obtain an effective cooling rate.

[0032] With reference to Fig. 1, a quenching method and a method of manufacturing a metal sheet in the present invention will be described. First, the metal sheet S is cooled by the cooling device 10 while the metal sheet S is conveyed, and quenching of the metal sheet S is performed. At this time, the height of the fluid surface of the cooling fluid CF inside the cooling tank 11 is adjusted such that the metal sheet S is restrained from two sides in the thickness direction of the metal sheet S at the position RP at which the metal sheet S has the target temperature T2. Specifically, the position control device 40 calculates the distance d by using Formula (1) or Formula (3) mentioned above and adjusts the height of the fluid surface of the cooling fluid CF inside the cooling tank 11 such that the metal sheet S is restrained at a position corresponding to the calculated distance d. Note that adjustment of the height of the fluid surface can be successively performed also during quenching of the metal sheet S. For example, the position control device 40 may calculate the distance d and adjust the height of the fluid surface at a timing when the line speed v is changed.

[0033] 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 at portions such as a leading end and a tail end of the metal sheet S where the speed decreases can be improved, that the height of the fluid surface be movable with the metal sheet S being restrained by the restraining rolls 20. Alternatively, the position control device 40 may calculate the distance d and adjust the height of the fluid surface for every set period.

[0034] According to the aforementioned embodiment, the operation of the water-level adjustor 30 is controlled to adjust the height of the fluid surface, which is the cooling start position, of the cooling fluid CF inside the cooling tank 11. Consequently, it is possible 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 is 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.

[0035] 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 S, 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.

[0036] It has been found that adjusting the height of the fluid surface of the cooling fluid CF inside the cooling tank 11 is effective to solve this problem, in other words, to accurately control the shape of the metal sheet S at an optimal temperature position that varies depending on conditions of manufacture. It is possible by adjusting the height of the

fluid surface of the cooling fluid CF inside the cooling tank 11 to restrain the metal sheet S in an intended temperature range even when conditions of manufacture vary.

[0037] 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.

[0038] 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 is not limited to a steel sheet and may be a metal sheet other than a steel sheet.

Example 1

[0039] An example of the present invention will be described. As a present invention example, quenching of a high tensile strength cold rolled steel sheet (hereinafter, referred to as the 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 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 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 of the steel sheet at a time of passing the restraining rolls 20 may be simply set in the range of 450°C to 100°C. In the present example, the target temperature T_2 was set to 400°C. In addition, the cooling start temperature T_1 was set to 800°C. The temperature of the cooling fluid CF was substantially 30°C, and the cooling rate CV was set to 1500(°C/s).

[0040] The line speed v was varied in the range of 1000 mm/s 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 $d = 267$ mm to 800 mm on the basis of Formula (1). Ten steel sheets after being cooled were collected at every 100 m 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. 3 is a schematic diagram in which one example of the definition of the warp amount is illustrated. As illustrated in Fig. 3, 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.

[0041] Fig. 4 is a graph showing the relationship between the line speed v and the target temperature in the present invention example, and Fig. 5 is a graph showing the relationship between the line speed v and the warp amount of a metal sheet in the present invention example. As illustrated in Fig. 4, the temperature (°C) of each of the steel sheets at the time of passing the restraining rolls 20 was $400 \pm 25^\circ\text{C}$, even when the line speed v was varied, as a result of adjusting the height of the fluid surface of the cooling fluid CF in accordance with the line speed v and varying the distance d . In other words, even when the line speed v was varied, it was possible to control the temperature (°C) of each of the steel sheets at the time of passing the restraining rolls 20 to be in the range (450°C to 100°C) of the target temperature T_2 . 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. 5. Consequently, a variation, which is a difference between a maximum value and a minimum value of the warp amount, was suppressed to be 4.2 mm.

[0042] Fig. 6 is a graph showing the relationship between the line speed v and the target temperature in Comparative example 1, and Fig. 7 is a graph showing the relationship between the line speed v and the warp amount of a metal sheet in Comparative example 1. In Comparative example 1, the distance d (mm) from the cooling start position to the restraining rolls 20 was fixed as $d = 400$ mm, and other conditions were the same as those in the aforementioned present invention example.

[0043] In Comparative example 1, as illustrated in Fig. 6, the temperature (°C) of the steel sheet at the time of passing the restraining rolls 20 greatly varied depending on the line speed v (mm/s) and was uncontrollable. Therefore, under

conditions other than $v = 1000 \text{ mm/s}$ and $v = 1500 \text{ mm/s}$, the temperature ($^{\circ}\text{C}$) of each of the steel sheets at the time of passing the restraining rolls 20 was out of the range of 450°C to 100°C , which is the target temperature T2. As a result, under conditions other than $v = 1000 \text{ mm/s}$ and $v = 1500 \text{ mm/s}$, all of the warp amounts of the steel sheets were more than or equal to 10 mm, as illustrated in Fig. 7, and the effect of suppressing a deformation of the steel sheets 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.

[0044] Fig. 8 is a graph showing the relationship between the line speed v and the target temperature in Comparative example 2, and Fig. 9 is a graph showing the relationship between the line speed v and the warp amount of the metal sheet S in Comparative example 2. In Comparative example 2, as indicated in Patent Literature 2, the distance d was controlled by moving the movable masking member with the restraining rolls 20 being fixed and controlling the cooling start position. Other conditions were set to be the same as those in the present invention example, and the aforementioned steel sheet was manufactured.

[0045] As illustrated in Fig. 8, the temperature ($^{\circ}\text{C}$) of the steel sheet at the time of passing the restraining rolls 20 greatly varied in Comparative example 2 regardless of the line speed v (mm/s) and was uncontrollable. Therefore, under all of conditions, there was a case in which the temperature ($^{\circ}\text{C}$) of the steel sheet at the time of passing the restraining rolls 20 was out of the range of 450°C to 100°C , which is the target temperature T2. Then, as illustrated in Fig. 9, under all of conditions, there was the steel sheet in which the warp amount of the steel sheet was more than 10 mm, and the effect of suppressing a deformation of the steel sheet was insufficient. As a result, a variation, which is a difference between the maximum value and a minimum value of the warp amount, was increased to 9.2 mm.

[0046] 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 T2 is $(\text{TM}_s + 150)^{\circ}\text{C}$ to $(\text{TM}_f - 150)^{\circ}\text{C}$ in the example presented in the aforementioned embodiment, the target temperature T2 is not limited thereto. The target temperature T2 may be not limited to $(\text{TM}_s + 150)^{\circ}\text{C}$ to $(\text{TM}_f - 150)^{\circ}\text{C}$ 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.

[0047] In this case, the target temperature T2 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. In addition, by positional adjustment of the restraining rolls 20, the distance d from the cooling start position to the restraining rolls 20 is controlled. Thus, the temperature of the metal sheet S at the time of passing the restraining rolls 20 is caused to be the previously determined temperature T2 so that variations in the shape of the metal sheet S, in other words, the warp amount of the metal sheet S defined in Fig. 3 is 4 mm or less.

[0048] Further, while the position of the restraining rolls 20 is fixed in the presented example, the restraining rolls 20 may be configured to move in the longitudinal direction of the metal sheet S, in other words, the conveyance direction of the metal sheet S. In other words, the quenching apparatus 1 for the metal sheet S may include a roll moving device that is constituted by, for example, a motor or the like and that moves the restraining rolls 20. In this case, the distance d is controlled by both the height of the fluid surface of the cooling fluid CF and the position of the restraining rolls 20. Consequently, for example, when the distance d is intended to be increased, the distance d can be quickly adjusted by moving the restraining rolls 20 in the conveyance direction of the metal sheet S while the height of the fluid surface is raised. Alternatively, the distance d can be minutely controlled by, for example, roughly adjusting the distance d by the water-level adjuster 30 and finely adjusting the distance d by the positional adjustment of the restraining rolls 20.

Example 2

[0049] Quenching of a steel sheet was performed under the same conditions of manufacture as those in Example 1 except that the line speed v was varied in the range of 1000 mm/s to 2500 mm/s and the distance between the liquid surface and a hitting position (hereinafter, referred to as the hitting position) on the steel sheet at which the liquid jet stream from each of the nozzles 12 hits the steel sheet was varied in the range of 0 mm to 400 mm in the perpendicular direction. Table 1 shows results of verification on the relationship between the liquid surface height and the hitting position in Example 2. Note that the aforementioned hitting position is a position at which a straight line extending from the center of each nozzle 12 in a liquid jetting direction intersects the surface of the steel sheet. In addition, presence/absence of a shape variation in each steel sheet in the longitudinal direction (in other words, the same direction as the conveyance direction of each steel sheet) was visually inspected under a sufficiently bright fluorescent lamp in an exit side inspection.

[Table 1]

	Distance between liquid surface and jet-stream hitting position on steel sheet [mm]	Line Speed v [m/sec]	Presence of shape fluctuation of steel sheet in longitudinal direction	Maximum warp amount [mm]
Reference Example 1	0	1000	Yes	8.0
Reference Example 2	10	1037	Yes	8.0
Reference Example 3	20	1075	Yes	8.0
Present Invention Example 1	30	1113	No	7.6
Present Invention Example 2	50	1188	No	7.5
Present Invention Example 3	100	1375	No	7.5
Present Invention Example 4	200	1750	No	7.1
Present Invention Example 5	400	2500	No	6.2

[0050] As shown in Table 1, a fluctuation in which the warp shape of the steel sheet fluctuated between an upward warp and a downward warp periodically in the conveyance direction of the steel sheet was seen in each of Reference examples 1 to 3 in each of which the distance between the liquid surface and the hitting position is 0 mm to 20 mm. The upward warp denotes a deformation in which a central portion in the width direction of the steel sheet protrudes upward more than two end portions thereof. The downward warp denotes a deformation in which, contrary to the upward warp, the two end portions in the width direction of the steel sheet protrude upward more than the central portion thereof.

[0051] In each of Reference examples 1 to 3, a tendency in which the maximum warp amount in the width direction of the steel sheet collected at every 100 m was slightly higher than that in Present invention examples 1 to 5 was seen.

[0052] In Present invention examples 1 to 5 in each of which the distance between the liquid surface and the hitting position was more than or equal to 30 mm, a periodical warp fluctuation in the longitudinal direction of the steel sheet was not seen. In addition, a tendency in which the maximum warp amount in the width direction of the steel sheet collected at every 100 m decreased with increases in the aforementioned distance and the line speed v was seen. In other words, it was possible in Present invention examples 1 to 5 to cause the cooling of the steel sheet in the initial stage to be slow cooling by setting the liquid surface height to be higher than the hitting position of the liquid jet stream from each of the nozzles by more than or equal to 30 mm. Consequently, it was possible to reduce a stress generated by sudden thermal contraction, possible to suppress the deformation of the shape of the steel sheet, and possible to reduce the warp amount of the steel sheet.

Reference Signs List

Reference Signs List

[0053]

- 1 metal-sheet quenching apparatus
- 10 cooling device
- 11 cooling tank

12 nozzle
 20 restraining roll
 30 water-level adjustor
 40 position control device
 5 BD conveyance direction
 CF cooling fluid
 S metal sheet

10 Claims

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

15 a cooling tank in which a cooling fluid is to be stored and the metal sheet is cooled by being immersed in the cooling fluid;
 a restraining roll that is installed inside the cooling tank and that conveys the metal sheet cooled in the cooling tank while restraining the metal sheet in a thickness direction;
 a water-level adjustor that adjusts a height of a fluid surface of the cooling fluid inside the cooling tank, the fluid
 20 surface being a cooling start position of the metal sheet; and
 a position control device that controls the height of the fluid surface of the cooling fluid inside the cooling tank by controlling an operation of the water-level adjustor.

25 2. The metal-sheet quenching apparatus according to claim 1, further comprising a plurality of nozzles through which the cooling fluid is jetted to the metal sheet to cool the metal sheet, the plurality of nozzles being installed inside the cooling tank.

30 3. The metal-sheet quenching apparatus according to claim 1 or claim 2, wherein the water-level adjustor includes an adjustment tank that stores the cooling fluid and that is connected to the cooling tank, a supply source at the adjustment tank, and a weir that controls discharge of the cooling fluid from the adjustment tank, and the height of the fluid surface of the cooling fluid inside the cooling tank is adjusted by adjusting a stored amount of the cooling fluid inside the adjustment tank.

35 4. The metal-sheet quenching apparatus according to any one of claims 1 to 3, wherein the position control device adjusts the cooling start position of the metal sheet by adjusting the height of the fluid surface of the cooling fluid inside the cooling tank such that the restraining roll restrains the metal sheet at a position at which the metal sheet has a target temperature.

40 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 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.

45 6. The metal-sheet quenching apparatus according to claim 4 or 5, wherein the position control device sets a distance from the 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 in the cooling tank is started, the target temperature, and a cooling rate of cooling of the metal sheet and adjusts the height of the fluid surface of the cooling fluid inside the cooling tank such that the set distance is achieved.

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

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

55 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 in the cooling tank.

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 position control device.

9. The metal-sheet quenching apparatus according to claim 2, wherein a distance between a liquid surface of the cooling fluid inside the cooling tank and a hitting position on the metal sheet at which a liquid jet stream from each of the nozzles hits the metal sheet is more than or equal to 30 mm and less than or equal to 2000 mm.

10. A metal-sheet quenching method in which a metal sheet is cooled while being conveyed, the method comprising:

immersing the metal sheet in a cooling fluid that is stored in a cooling tank and cooling the metal sheet with a cooling start position set at a height of a fluid surface of the cooling fluid inside the cooling tank, wherein the height of the fluid surface of the cooling fluid inside the cooling tank is adjusted such that the metal sheet is restrained at a position at which the metal sheet has a target temperature by a restraining roll.

11. The metal-sheet quenching method according to claim 10, 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.

12. The metal-sheet quenching method according to claim 10 or 11,

wherein, in adjustment of the height of the fluid surface of the cooling fluid, a distance from the cooling start position to the restraining roll is set 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

wherein the height of the fluid surface of the cooling fluid inside the cooling tank is adjusted such that the set distance is achieved.

13. The metal-sheet quenching method according to claim 12, wherein, as the distance from the cooling start position in the cooling tank 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.

14. The metal-sheet quenching method according to claim 13, 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 $CV = \alpha/t$.

15. 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 10 to 14.

16. 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 15.

17. The metal-sheet quenching method according to claim 10, wherein the cooling fluid is jetted from a nozzle that is installed inside the cooling tank to the metal sheet to cool the metal sheet, and a distance between a liquid surface of the cooling fluid inside the cooling tank and a hitting position on the metal sheet at which a liquid jet stream from each of the nozzle hits the metal sheet is more than or equal to 30 mm and less than or equal to 2000 mm.

FIG. 1

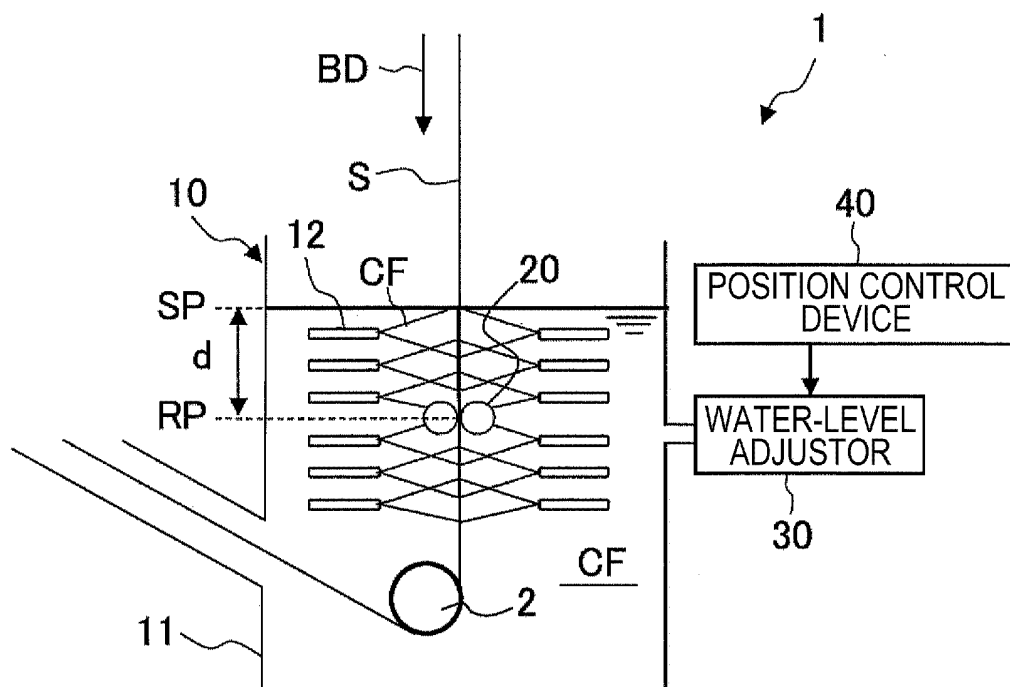


FIG. 2

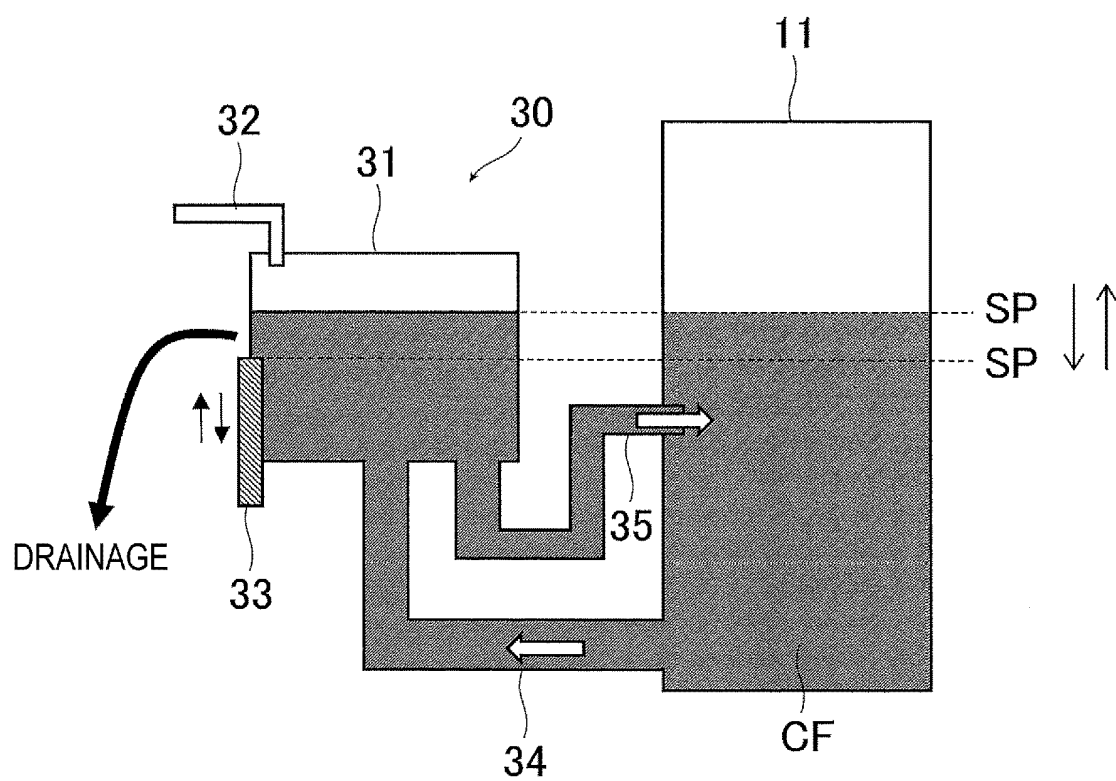


FIG. 3

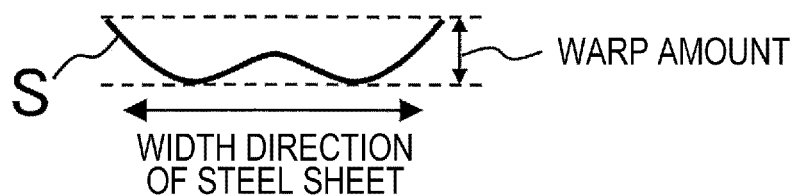


FIG. 4

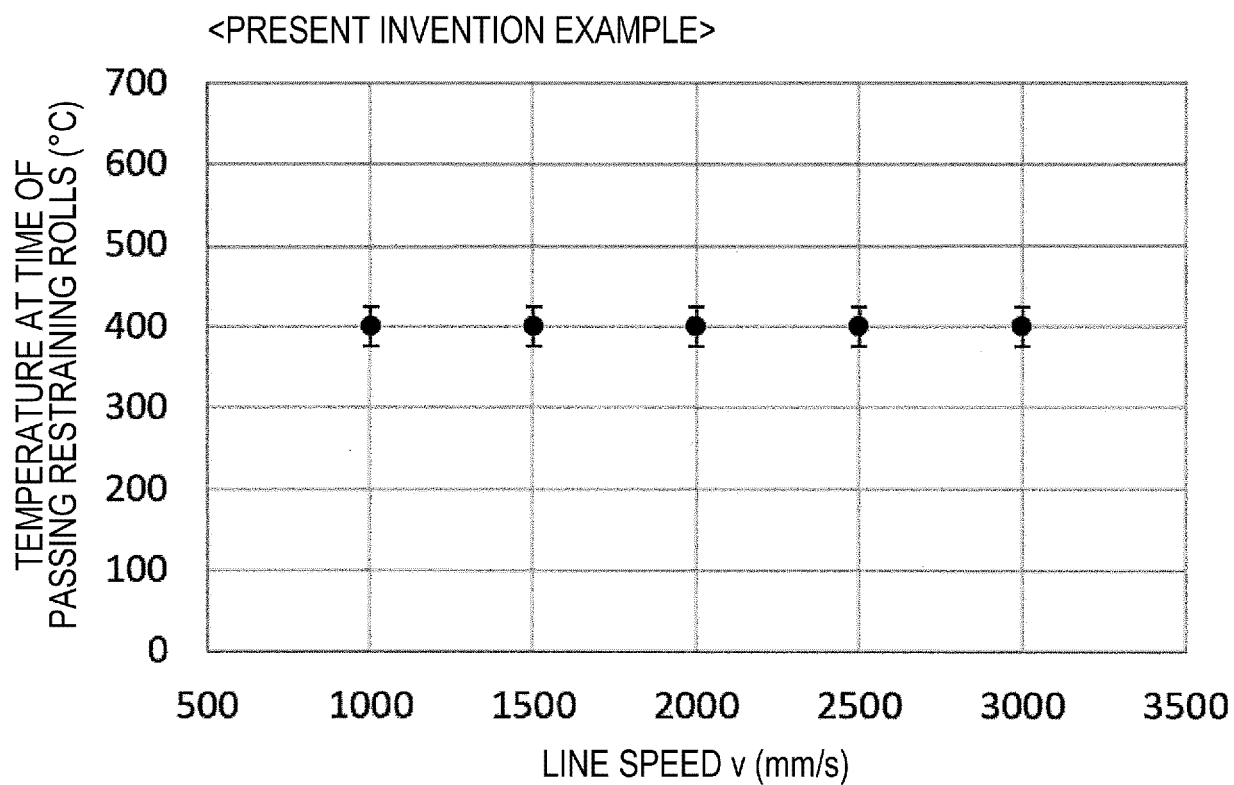


FIG. 5

<PRESENT INVENTION EXAMPLE>

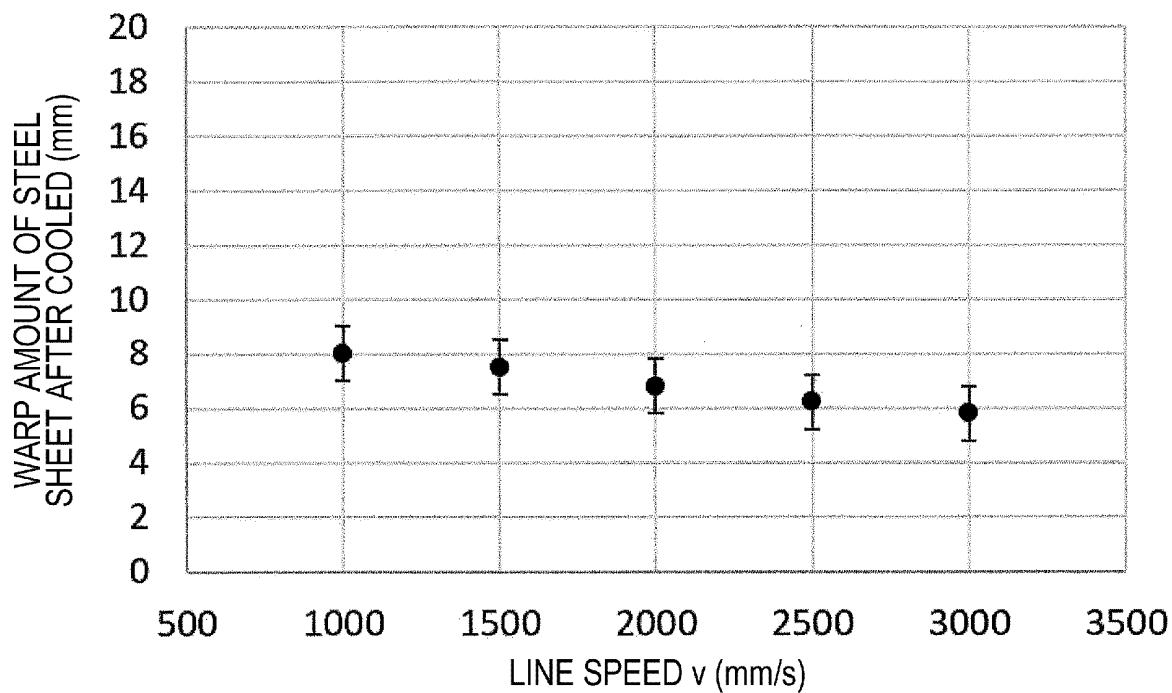


FIG. 6

<COMPARATIVE EXAMPLE 1>

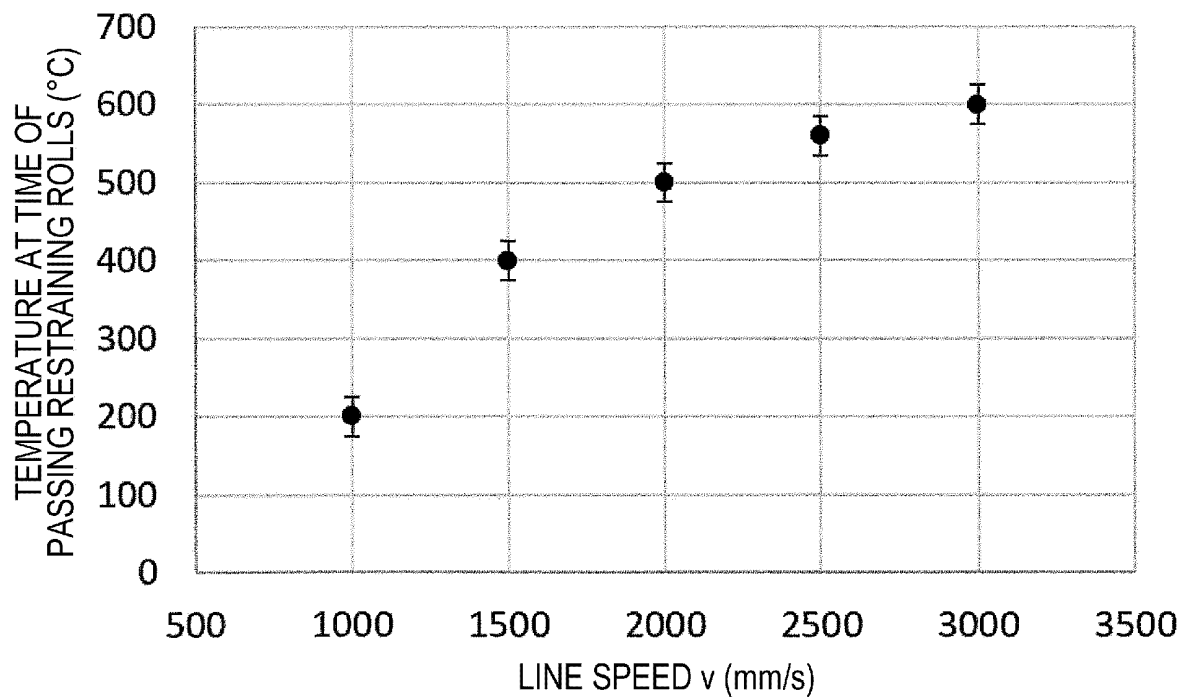


FIG. 7

<COMPARATIVE EXAMPLE 1>

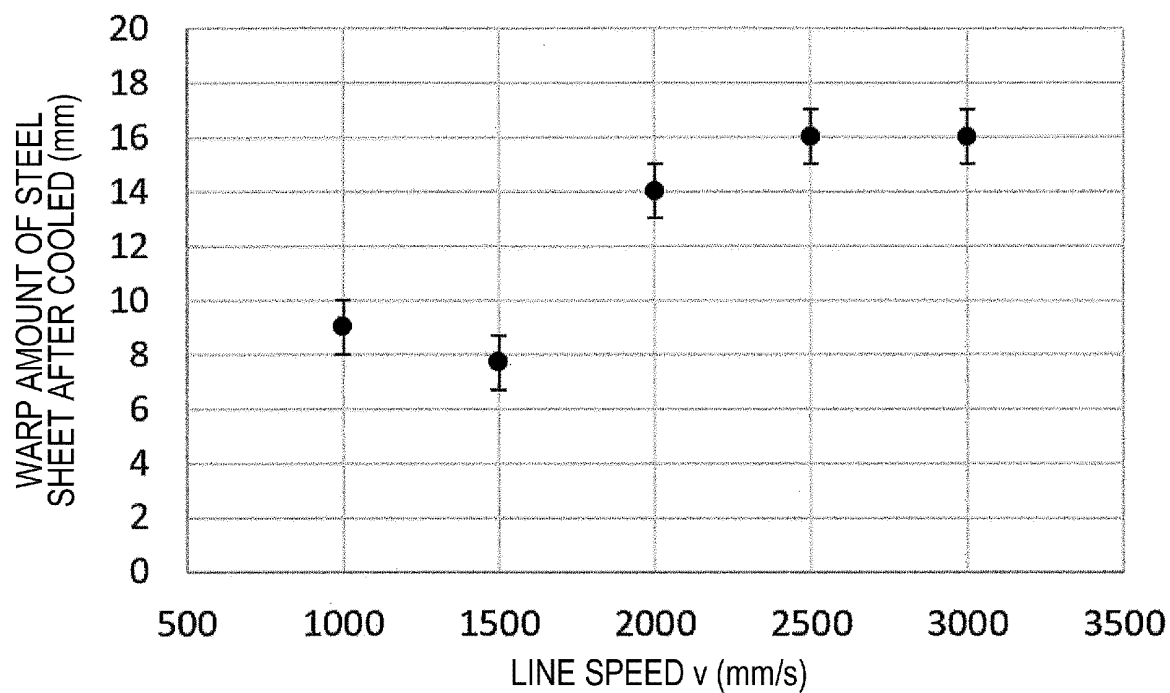


FIG. 8

<COMPARATIVE EXAMPLE 2>

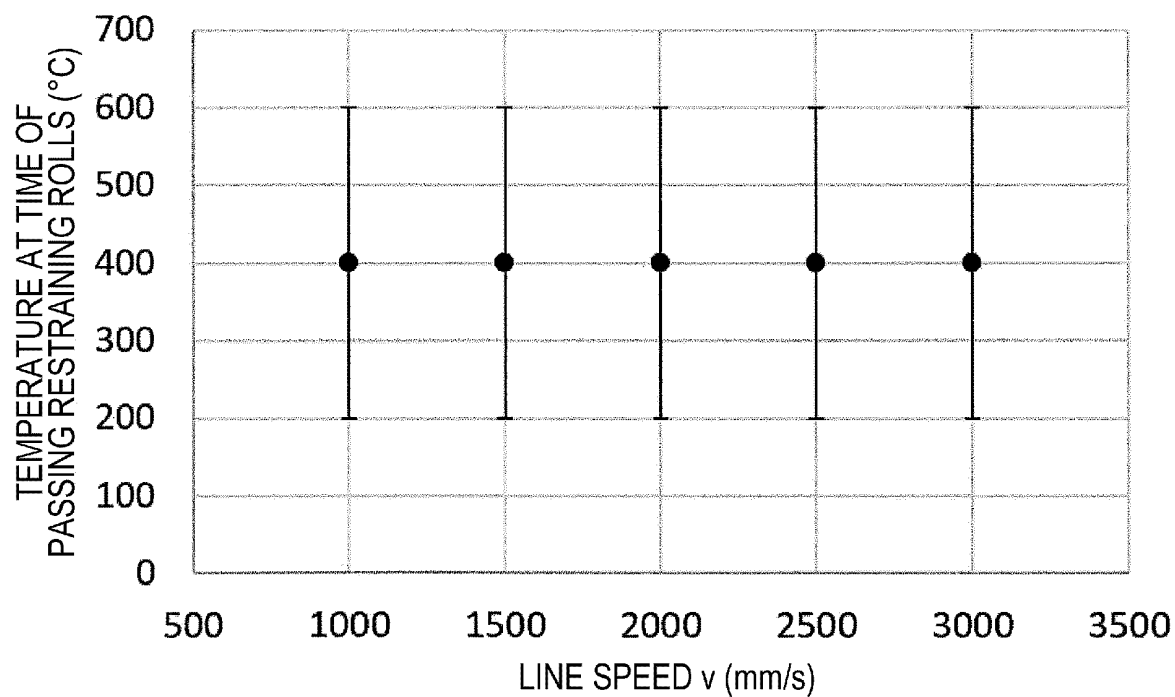
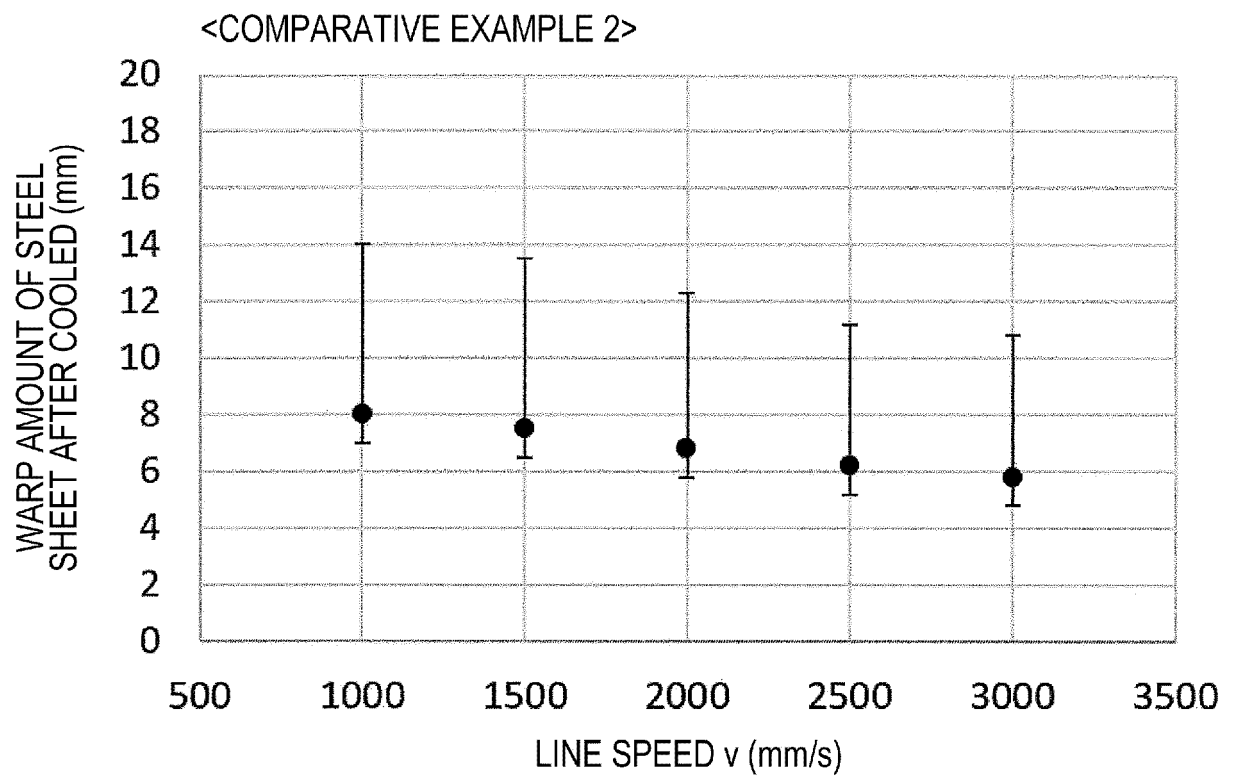


FIG. 9



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/029365

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	JP 46-002733 B1 (TOYO KOHAN CO., LTD.) 23 January 1971 (1971-01-23) claims, column 2, line 19 to column 4, line 22, fig. 1-2	1-2, 4, 9-10, 15-17
Y		3, 5-8, 11-14
X	JP 48-055811 A (SHIN NIPPON SEITETSU KK) 06 August 1973 (1973-08-06) claims, p. 2, lower left column, line 16 to p. 4, upper right column, line 16, fig. 1-2, 5-6	1
A		2-17
Y	JP 56-005932 A (NIPPON KOKAN KK) 22 January 1981 (1981-01-22) p. 3, upper right column, lines 7-18, fig. 4	3
Y	JP 2019-090106 A (JFE STEEL CORP) 13 June 2019 (2019-06-13) claims, paragraphs [0010], [0028]-[0059]	5-8, 11-14
A	JP 51-073911 A (NIPPON KOKAN KK) 26 June 1976 (1976-06-26)	1-17

☐ 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

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.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/029365

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Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP	46-002733	B1	23 January 1971	(Family: none)	
JP	48-055811	A	06 August 1973	(Family: none)	
JP	56-005932	A	22 January 1981	GB 2054661 A	p. 3, left column, lines 1-7, fig. 7
				DE 3023571 A1	
				FR 2460333 A1	
JP	2019-090106	A	13 June 2019	(Family: none)	
JP	51-073911	A	26 June 1976	US 4052235 A	
				FR 2296015 A1	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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