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(71) Applicant: **JFE Steel Corporation**
Tokyo, 100-0011 (JP)

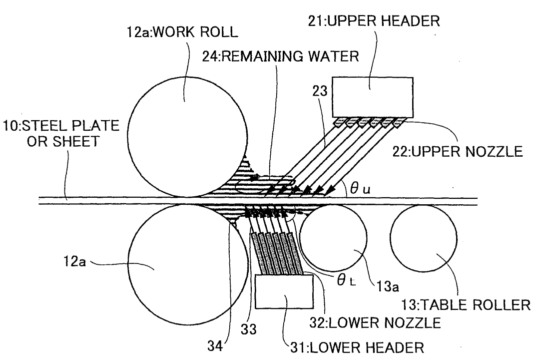
(72) Inventors:
- **NAKATA, Naoki,**
  JFE STEEL CORPORATION
  Tokyo 100-0011 (JP)
- **KUROKI, Takashi,**
  JFE STEEL CORPORATION
  Tokyo 100-0011 (JP)
- **FUJIBAYASHI, Akio,**
  JFE STEEL CORPORATION
  Tokyo 100-0011 (JP)
- **TOMITA, Shogo,**
  JFE STEEL CORPORATION
  Tokyo 100-0011 (JP)

(74) Representative: **HOFFMANN EITLE**
Patent- und Rechtsanwälte
Arabellastrasse 4
81925 München (DE)

(54) HOT ROLLING FACILITY OF STEEL PLATE AND HOT ROLLING METHOD

(57) A hot rolling mill for a steel plate or sheet, which is superior in terms of equipment cost, equipment maintainability, and cooling performance and is capable of efficiently manufacturing a steel plate or sheet having good characteristics by appropriately controlling the temperature of a rolling material; and a method for hot rolling a steel plates or sheet are provided. Specifically, cooling equipment 20 for supplying cooling water onto a top surface and a bottom surface of a steel plate or sheet 10 that is being conveyed is provided at a position near an entrance side and an exit side of a hot rolling mill 12. The cooling equipment 20 includes an upper header 21 having upper nozzles 22 for jetting rod-like water flows 23 onto the top surface of the steel plate or sheet 10 at an angle of depression θ_U in the range of 30° to 60°, which is positioned such that remaining cooling water 24 supplied to the steel plate or sheet is retained by work rolls 12a. The cooling equipment 20 further includes a lower header 31 having lower nozzles 32 for jetting rod-like water flows 33 onto the bottom surface of the steel plate or sheet 10 at an angle of elevation in the range of 45° to 90°, which is positioned between the work rolls 12a and a table roller adjacent thereto.

FIG.3



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Description

Technical Field

[0001] The present invention relates to a hot rolling mill and a method for hot rolling a steel plate or sheet.

Background Art

[0002] In recent years, in the process of manufacturing a steel plate or sheet by hot rolling, a variety of temperature control of a material to can realize production of a steel plate or sheet having excellent characteristics has been conducted.

[0003] For example, a high-performance steel plate or sheet is produced by application of controlled rolling (CR), in which finish rolling in the non-recrystallization temperature range.

[0004] Manufacture of a thin-scale steel sheet by supplying cooling water onto a steel plate or sheet that has just left the roll bite in a hot rolling mill to cool the surfaces thereof to minimize scale formation has been studied.

[0005] Examples of techniques used to control the temperature of a rolling material include the following:

[0006] For example, Japanese Unexamined Patent Application Publication No. 2002-361315 discloses a technique for cooling a steel sheet by supplying cooling water during hot finish rolling of the steel sheet. In this technique, a laminar water flow is supplied from a slit-shaped nozzle of a header provided between finishing stands to realize high cooling rate. It is said that this technique can be used for manufacturing a fine-grain steel plate or sheet.

[0007] Japanese Unexamined Patent Application Publication No. 62-260022 discloses a technique for cooling a hot steel plate or sheet by supplying cooling water. This technique uses opposing nozzle units that jet cooling water and that is liftable. It is said that a wide range of cooling rate can be ensured by using the nozzle units in combination with an additional laminar nozzle or a spray nozzle.

[0008] However, the techniques disclosed in the above-mentioned Japanese Unexamined Patent Application Publication Nos. 2002-361315 and 62-260022 have problems in terms of equipment cost, equipment maintainability, cooling performance, and the like.

[0009] First, in the technique disclosed in Japanese Unexamined Patent Application Publication No. 2002-361315, the cooling water supplied onto the top surface of a steel plate or sheet remains there for a while. When the state of remaining water changes, however, a cooling area of the steel plate or sheet changes, whereby precise temperature control cannot be performed. Further, a header containing a flow adjuster contributes to an increase in size of the equipment, which limits how close the equipment and the rolling mill can be arranged to each other. Thus, this technique is not suitable for manufacturing a thin-scale steel sheet.

[0010] Second, in the technique disclosed in Japanese Unexamined Patent Application Publication No. 62-260022, the slit-shaped nozzle units need to be brought close to a steel plate or sheet. In the case of the slit-shaped nozzle units cooling a steel plate or sheet whose leading end or trailing end is warped, the steel plate or sheet may collide with the slit-shaped nozzle units and damage them, or may become immovable, thereby stopping the manufacturing line or lowering the yield rate. The slit-shaped nozzle units may be moved upward by actuating a lifting equipment when the leading end or the trailing end passes. In that case, however, the leading end or the trailing end is not sufficiently cooled, whereby the desired quality cannot be realized. The cost for installing the lifting equipment is also problematic. Further, the presence of the lifting equipment makes it difficult to install the nozzle units close to the rolling mill. Thus, this technique is not suitable for manufacturing a thin-scale steel sheet.

[0011] Moreover, the techniques disclosed in the above-mentioned Japanese Unexamined Patent Application Publication Nos. 2002-361315 and 62-260022 require the use of the slit-shaped nozzle. The nozzle opening needs to be maintained clean, otherwise a laminar cooling water flow cannot be obtained. For example, as shown in FIG. 6, if foreign matter 60 adheres to and clogs a nozzle opening of a slit-shaped nozzle 52, a laminar water flow 53 is split. Further, the cooling water needs to be jetted at a high pressure to retain the cooling water within a jet area (cooling area). However, if the laminar water flow 53 is jetted at a high pressure, the jet pressure becomes unbalanced, which tends to cause a split of the laminar water flow 53. If the laminar water flow 53 is not properly produced, the cooling water flows toward the upstream or the downstream of the jet area and remains on the steel plate or sheet. This partially cools the steel plate or sheet 10 and leads to a temperature deviation. Although there is a technique for removing the cooling water remaining on the top surface of the steel plate or sheet 10 by using a side spray or the like, the cooling water cannot be completely removed if there is a large amount thereof. Therefore, the temperature deviation occurs.

[0012] The present invention has been made in view of the above-described situations. It is an object of the invention to provide a hot rolling mill for a steel plate or sheet, which is superior in terms of equipment cost, equipment maintainability, and cooling performance and is capable of efficiently manufacturing a steel plate or sheet having good characteristics by appropriately controlling the temperature of a rolling material when performing hot rolling of the steel plate or sheet; and a method for hot rolling a steel plates or sheet.

Disclosure of Invention

[0013] To solve the above-described problems, the present invention has the following features:

[1] A hot rolling mill for a steel plate or sheet, characterized in that it includes cooling equipment for supplying cooling water onto a top surface of the steel plate or sheet that is being conveyed, the cooling equipment being provided at a position near the rolling mill, on an entrance side and/or an exit side thereof, the cooling equipment including a header having nozzles for jetting rod-like water flows onto the top surface of the steel plate or sheet at an angle of depression in the range of 30˚ to 60˚ toward the rolling mill, the header being positioned such that the cooling water supplied to the steel plate or sheet is retained by work rolls of the rolling mill.
A rod-like water flow (also referred to as a "plume cooling water flow") of the present invention refers to a cooling water flow jetted from a circular (including ellipsoidal and polygonal) nozzle opening. The rod-like water flow of the present invention is not a spray-like flow but a continuous and straight cooling water flow whose cross-section keeps substantially circular shape since it is jetted from a nozzle opening until it hits a steel plate or sheet.
[2] The hot rolling mill for a steel plate or sheet according to the above-described [1], characterized in that the cooling equipment further includes a header having nozzles for jetting rod-like water flows onto a bottom surface of the steel plate or sheet at an angle of elevation in the range of 45˚ to 90˚ toward the rolling mill, the header being positioned between the work rolls of the rolling mill and a table roller adjacent thereto.
[3] A method for hot rolling a steel plate or sheet using the hot rolling mill for a steel plate or sheet according to the above-described [1] or [2], characterized in that it includes conducting rolling while jetting the cooling water such that the cooling water supplied onto the steel plate or sheet reaches the work rolls of the rolling mill.
[4] A method for hot rolling a steel plate or sheet using the hot rolling mill for a steel plate or sheet according to the above-described [1] or [2], characterized in that it includes jetting the cooling water while setting a roll gap of the work rolls to 2 mm or smaller in rolling interval.

[0014] The present invention provides superiority in terms of equipment cost, equipment maintainability, and cooling performance, and is capable of efficiently manufacturing a steel plate or sheet having good characteristics by appropriately controlling the temperature of a rolling material in conducting hot rolling of a steel plate or sheet.

Brief Description of the Drawings

[0015]

FIG. 1 is an arrangement drawing of a hot rolling mill for a steel plate or sheet according to an embodiment of the present invention;
FIG. 2 is an arrangement drawing of another hot rolling mill for a steel plate or sheet according to an embodiment of the present invention;
FIG. 3 is a detail drawing of cooling equipment according to an embodiment of the present invention;
FIG. 4 is a detail drawing of cooling equipment according to an embodiment of the present invention;
FIG. 5 shows an exemplary arrangement of nozzles of a header according to an embodiment of the present invention; and
FIG. 6 shows a related art.

(Description of Reference Numerals)

[0016] 10: steel plate or sheet, 11: reheating furnace, 12: hot rolling mill, 12a: work roll, 13: table roller, 20: cooling equipment, 21: upper header, 22: upper nozzle, 23: rod-like water flow, 24: remaining water, 25: cooling water, 31: lower header, 32: lower nozzle, 33: rod-like water flow, and 34: supplied cooling water

Best Mode for Carrying Out the Invention

[0017] Embodiments of the present invention will now be described with reference to the drawings.
[0018] FIGS. 1 and 2 shows hot rolling mills according to embodiments of the present invention. FIG. 1 shows a hot rolling mill for a steel plate or a hot roughing mill for a steel sheet, and FIG. 2 shows a hot finishing mill for a steel sheet.
[0019] FIG. 1 shows a reheating furnace 11 for heating a slab to a predetermined temperature, a rolling mill (herein, a reverse rolling mill) 12 for rolling the slab 10 extracted from the reheating furnace 11 into a steel plate or sheet 10 having a predetermined thickness, and cooling equipment 20 for supplying cooling water onto the top and bottom surfaces of the slab (steel plate or sheet) 10 that is being conveyed. The cooling equipment 20 is provided close to the entrance

side (upstream side) and the exit side (downstream side) of the rolling mill 12. In FIG. 1, a table roller is denoted by reference numeral 13.

[0020] FIG. 2 shows a reheating furnace 11 for heating a slab to a predetermined temperature, a roughing mill (not shown) for rough rolling the slab 10 extracted from the reheating furnace 11 into a steel plate or sheet 10 having a predetermined thickness, a finishing mill (herein, a tandem mill) 12 for rolling the rough rolled steel plate or sheet 10 to a predetermined finished thickness, and a cooling equipment 20 for supplying cooling water onto the top and bottom surfaces of the steel plate or sheet 10 that is being conveyed. The cooling equipment 20 is provided close to the exit side (downstream side) of the rolling mill 12. In FIG. 2, a table roller is denoted by reference numeral 13.

[0021] As shown in FIG. 3, the cooling equipment 20 has an upper header 21 including upper nozzles (circular tube nozzles) 22 for jetting rod-like water flows 23 against the top surface of the steel plate or sheet 10 at an angle of depression θ_U in the range of 30° to 60° toward work rolls 12a of the rolling mill 12. The upper header 21 is positioned such that the water supplied onto the top surface of the steel plate or sheet 10, i.e., remaining water 24, is retained by the work rolls 12a of the rolling mill 12. The cooling equipment 20 further has a lower header 31 including lower nozzles (circular tube nozzles) 32 for jetting rod-like water flows 33 against the bottom surface of the steel plate or sheet 10 at an angle of elevation θ_L in the range of 45° to 90° toward the work rolls 12a of the rolling mill 12. The lower header 31 is positioned between work rolls 12a of the rolling mill 12 and a table roller 13a adjacent thereto.

[0022] FIG. 5 shows an exemplary arrangement of the circular tube nozzles 22 mounted on the upper header 21. The circular tube nozzles 22 are arranged in a plurality of rows (herein, six rows) in the transfering direction of the steel plate or sheet 10, and are arranged in the plate or sheet width direction such that they can supply the cooling water onto the overall width of the steel plate or sheet 10 that is being conveyed. The circular tube nozzles 32 mounted on the lower header 31 are arranged in a similar manner.

[0023] The circular tube nozzles are arranged in the plurality of rows in the transfering direction because it is difficult to retain the remaining water from the cooling water jetted against the steel plate or sheet with a single row of nozzles. Accordingly, it is preferable that the circular tube nozzles be arranged in at least three rows, more preferably, at least five rows, in the transfering direction. The circular tube nozzles 22 and 32 are arranged in the plate or sheet width direction such that they can supply the cooling water onto the overall width of the steel plate or sheet 10 that is being conveyed. Although only one upper header is provided herein, two or more headers having the circular tube nozzles 22 may be provided.

[0024] In the present embodiment, the cooling water jetted from the upper nozzles 22 is composed of the rod-like water flows because the rod-like water flows can be produced more stably and have greater power to retain the remaining water than a laminar water flow or the like.

[0025] Another reason for using the rod-like water flows is that, in the case of obliquely jetting a laminar water flow, the laminar water flow becomes thin near the steel plate or sheet as the distance between the steel plate or sheet and the nozzles increases. This may result in higher probability of occurrence of a split.

[0026] The angle of depression θ_U of the rod-like water flows 23 jetted from the upper nozzles 22 is set in the range of 30° to 60° because, if the angle of depression θ_U is smaller than 30°, the rod-like water flows 23 have a small velocity component in the vertical direction, which weakens the jetting of the rod-like water flows 23 against the steel plate or sheet 10 and degrades cooling performance; and because, if the angle of depression θ_U is greater than 60°, the rod-like water flows 23 have an insufficient velocity component in the transfering direction, which makes it more difficult to retain the remaining water 24, allows the remaining water 24 to flow outside of the transfering direction, and makes the cooling area unstable. A more preferable angle of depression θ_U is 40 to 50°.

[0027] The angle of elevation θ_L of the rod-like water flows 33 jetted from the lower nozzles 32 is set in the range of 45 to 90° because, if the angle of elevation θ_L is smaller than 45°, the rod-like water flows have a small velocity component in the vertical direction, which weakens the jetting of the rod-like water flows against the steel plate or sheet 10 and degrades cooling performance, and the distance between the work rolls 12a and the table roller 13a must be increased; and because, if the angle of elevation θ_L is greater than 90°, the cooling water is splashed around the rolling mill 12, which is undesirable from the viewpoint of the operability and equipment maintainability.

[0028] The cooling equipment 20 supplies the cooling water from the upper header 21 onto the top surface of the steel plate or sheet 10 such that the water flow rate at the surface of the steel plate or sheet is at least 4 $m^3/m^2/min$, and supplies the cooling water from the lower header 31 onto the bottom surface of the steel plate or sheet 10 such that the water flow rate at the surface of the steel plate or sheet is at least 4 $m^3/m^2/min$.

[0029] The reason for setting the water flow rate to at least 4 $m^3/m^2/min$ is as follows. The remaining water 24 shown in FIG. 3 is produced by being retained by the rod-like water flows 23 supplied onto the top surface of the steel plate or sheet 10. At this time, if the water flow rate is low, the remaining water 24 cannot be retained. If the water flow rate is higher than a predetermined level, the amount of remaining water 24 that can be retained increases. This balances the amount of the cooling water that overflows from the ends of the steel plate or sheet in the width direction and the amount of the cooling water that is supplied onto the steel plate or sheet, whereby the amount of the remaining water 24 is maintained at a constant level.

[0030] A typical steel plate has a width of 2 to 5 m. If the steel plate is cooled at a water flow rate of 4 m^3/m^2/min or higher, the remaining water can stay at a water cooling area over the width. Accordingly, the steel plate or sheet 10 can be cooled to a desired temperature during the rolling path.

[0031] If the water flow rate is set at 4 m^3/m^2/min or higher, waiting time for desired temperature drop can be reduced with various controlled rolling materials. For example, if the water flow rate is low, a reduction in waiting time can only be achieved with thin rolling materials. If the water flow rate is increased, a reduction in waiting time can be achieved with rolling materials having certain thicknesses. However, the effect of waiting time reduction achieved by increasing the amount of water becomes small as the water flow rate increases. Accordingly, it is preferable that the water flow rate be determined while taking into consideration the effect of waiting time reduction, the equipment cost, and the like. A more preferable water flow rate is 4 to 10 m^3/m^2/min.

[0032] Preferably, the upper nozzles 22 jet the rod-like water flows 23 at a jet velocity of at least 8 m/s. The maximum number of the rows may be appropriately determined on the basis of the size, speed of travel, target temperature, etc., of the steel plate or sheet to be cooled. A jet velocity exceeding 30 m/s may result in large pressure loss and increased wear of the inner surfaces of the nozzles. Further, the capacity of a pump and the outside diameter of a pipe may be increased, which leads to excessive equipment cost. Accordingly, it is preferable that the jet velocity be 30 m/s or lower.

[0033] The inside diameter of the nozzles may be in the range of 3 to 8 mm to avoid clogging of the nozzles and to ensure a certain jet velocity of the cooling water. The distance between adjacent nozzles aligned along an imaginary line in the plate or sheet width direction may be set within a range ten times the inside diameter of the nozzles to prevent the cooling water from flowing between the rod-like water flows.

[0034] Further, in the case of supplying a laminar water flow, which is not stable, onto the steel plate or sheet 10, the header needs to be brought close to the steel plate or sheet 10. In contrast, in the case of supplying the rod-like water flows 23 onto the steel plate or sheet, the upper header 21 may be provided at a position upwardly away from a pass line. Therefore, it is preferable that tips of the upper nozzles 22 be positioned away from the pass line to prevent upper nozzles 22a and 22b from being damaged by the warped steel plate or sheet 10 or the like. However, if the distance is too large, the cooling water becomes diffused and loses its rod-like shape, whereby the effect of retaining the cooling water is deteriorated. Therefore, it is preferable that the distance between the pass line and the tips of the upper nozzles 22 be set in the range of 500 mm to 1800 mm.

[0035] When performing hot rolling of a steel plate or sheet using the hot rolling mill of the above-described structure, the hot rolling is performed while jetting the rod-like water flows 23 and 33 so that the remaining water 24 supplied onto the top surface of the steel plate or sheet 10 and the cooling water 34 supplied onto the bottom surface of the steel plate or sheet 10 reach the work rolls 12a of the rolling mill 12.

[0036] As described above, in the present embodiment, the rod-like water flows 23 are jetted against the top surface of the steel plate or sheet 10 at an angle of depression θ_U in the range of 30° to 60° toward the work rolls 12a so that the remaining water 24 supplied onto the top surface of the steel plate or sheet 10 reaches the work rolls 12a. Therefore, the remaining water 24 is retained between the work rolls 12a and the rod-like water flows 23, and a stable cooling area is formed. Accordingly, the problem that the remaining water 24 randomly moves over the steel plate or sheet 10 to nonuniformly cool the steel plate or sheet 10, thereby causing a temperature deviation can be eliminated, and the steel plate or sheet 10 can be uniformly cooled.

[0037] Herein, the cooling area refers to a area of the steel plate or sheet 10 between a position sandwiched between the work rolls and a position at which the rod-like water flows jetted from the circular tube nozzles of the upper header, which are positioned at the furthermost row (outermost row) from the work rolls, hit.

[0038] By producing the cooling area in this manner, the distance between the roll bite of the work rolls 12a and a cooling-start position (a position from where cooling by the cooling water starts) becomes zero.

[0039] Because the tips of the upper nozzles 22 may be provided a certain distance away from the pass line, even when a steel plate or sheet whose leading end or trailing end is warped is cooled, the steel plate or sheet 10 does not collide with and damage the upper header 21 nor become immovable. Thus, a stoppage of the manufacturing line or a lowering of the yield rate can be avoided. Because a lifting system for preventing the steel plate or sheet 10 from colliding with the upper header 21 is not necessary, the equipment cost can be reduced.

[0040] Further, because a lifting system or the like is not provided, the upper header 21 can be provided close to the rolling mill 12. By supplying cooling water onto the steel plate or sheet 10 that has just left the roll bite of the rolling mill 12 to reduce the temperature of the surface of the steel plate or sheet 10, scale formation can be suppressed. Accordingly, the hot rolling mill suitable for manufacturing a thin-scale steel sheet can be provided.

[0041] Further, because the cooling water 24 and the cooling water 34 supplied onto the steel plate or sheet 10 contact the surfaces of the work rolls 12a and cool the work rolls 12a, an additional cooling system for cooling rolls is not necessary. Accordingly, the equipment cost can be reduced.

[0042] Further, by jetting the cooling water 23 and the cooling water 33 when the work rolls 12a do not roll the steel plate or sheet 10, such as an interval between passes, or an interval between a passing of a preceding rolling material and a passing of a following rolling material, the cooling water 25 jetted thereon flows as shown in FIG. 4. Thus, it becomes possible to supply a large amount of cooling water to the upper and lower work rolls 12a. This suppresses a thermal crown from developing, whereby highly accurate size control becomes possible. At that time, if the roll gap is set to have a certain allowance, and if an interval between a passing of a preceding rolling material and a passing of a following rolling material is 45 seconds or more, for example, the cooling water 23 and the cooling water 33 may be jetted while temporarily narrowing the roll gap between the work rolls 12a to about 2 mm. This prevents the cooling water 25 from passing through the roll gap and being splashed around. Further, this enables the cooling water 25 to be supplied onto a wider area in the peripheral direction of the work rolls 12a. Needless to say, if such a cooling of the rolls in an interval between passes or the like is not necessary, the jetting of the cooling water 23 and the cooling water 33 may be stopped.

[0043] As described above, the present embodiment provides superiority in terms of equipment cost, equipment maintainability, and cooling performance, and is capable of efficiently manufacturing a steel plate or sheet having good characteristics by appropriately controlling the temperature of a rolling material in conducting hot rolling of a steel plate or sheet.

[0044] In the present embodiment, the upper headers 21 and the lower headers 31 are provided at the entrance side and the exit side, respectively, of the rolling mill 12 in FIG. 1, and the upper headers 21 and the lower headers 31 are provided at the exit side of the rolling mill 12 in FIG. 2. However, the present invention is not limited thereto. In the case where the installation space is limited, or the available effect may be limited, for example, the upper headers 21 and the lower headers 31 may be provided at one of the entrance side and the exit side of the rolling mill 12. Alternatively, only the upper headers 21, without lower headers 31, may be provided. However, in order to prevent the rolling material from being warped while being rolled by the rolling mill 12, it is preferable that both the upper header 21 and the lower header 31 be provided so as to equalize cooling performance at both of the upper and lower sides.

Example 1

[0045] As Example 1 of the present invention, controlled rolling of a steel plate in a hot rolling line was conducted. After a steel plate was rolled down to a thickness of 28 mm, controlled rolling was conducted in the last three passes at a predetermined rolling temperature.

[0046] At that time, using a hot rolling mill shown in the above-described embodiment (FIG. 1) as Example 1 of the present invention, the steel plate or sheet 10 was rolled through four passes while being cooled by jetting the rod-like water flows from the cooling equipment 20 provided on the entrance side and the exit side of the hot rolling mill 12 so that the temperature of the steel plate or sheet 10 became a predetermined temperature when the processing through the four passes was finished, before conducting the controlled rolling. The controlled rolling is then conducted in the subsequent last three passes.

[0047] The angle of depression θ_U of the upper nozzles 22 was set at 45°, and the angle of elevation θ_L of the lower nozzles 32 was set at 60°.

[0048] The inside diameters of the upper nozzles 22 and the lower nozzles 32 were set to 6 mm, and the jet velocity of the rod-like water flows was set to 8 m/s.

[0049] On the other hand, as Comparative Example 1, using a hot rolling mill having no cooling equipment for cooling a steel plate or sheet during rolling, controlled rolling was conducted. A steel plate or sheet having been rolled down to a thickness of 28 mm at a relatively high temperature was cooled to a predetermined temperature by performing air-cooling for 30 seconds before conducting controlled rolling. Then, controlled rolling was conducted in the last three passes.

[0050] Further, as Comparative Example 2, using a hot rolling mill having cooling equipment disclosed in the above-described Japanese Unexamined Patent Application Publication No. 62-260022 instead of the cooling equipment 20 of Example 1 of the present invention, controlled rolling was conducted in the same manner as Example 1 of the present invention. That is, a steel plate or sheet was rolled while being cooled by a laminar water flow jetted from the slit-shaped nozzle during processing through the four passes before conducting controlled rolling so that the steel plate or sheet had a predetermined temperature when the processing through the four passes was finished. Then, controlled rolling was conducted in the last three passes. The header was installed such that the distance between the roll bite of the work rolls and the cooling-start position (a position from where cooling by the cooling water starts) was 4 m. Cooling was performed on the steel plate or sheet that is being conveyed.

[0051] The result is shown in Table 1. In Table 1, × denotes a case where a decline in productivity or quality occurred, and O denotes a case where a decline in productivity or quality did not occur.

Table 1

	Distance to the Cooling-start Position (*)	Method of supplying Cooling Water	Equipment Cost	Damage to Equipment	Effect of Cooling Rolls	Rolling Pitch	Yield Rate
Comparative Example 1	no cooling equipment	-	-	-	× no	210 s	reference
Comparative Example 2	4 m	laminar water flow	× high	× frequently occurred	× no	186 s	10% decline
Example 1 of the Present Invention	0 m	rod-like water flow	○ low	○ no	○ yes	180 s	equal to Comparative Example 1
*Distance from the roll bite of the work rolls to the cooling-start position							

[0052] As shown in Table 1, in Comparative Example 1, because 30-second air-cooling was performed before conducting controlled rolling, a rolling pitch was 210 seconds. This shows a decline in the rolling efficiency.

[0053] In Comparative Example 2, because the lifting equipment had to be installed, the equipment cost was high. Further, steel plates or sheets having a warped leading end often collided with the nozzle units and damaged the equipment. The steel plates or sheets that had damaged the equipment were deformed and unable to become finished products. Thus, the yield rate declined as much as by 10%. Although the controlled rolling could be performed without 30-second air-cooling, an increase in transportation distance of a steel plate or sheet in four passes before conducting controlled rolling increased the transportation time. Thus, in total, a rolling pitch was 186 seconds, which is 24 seconds shorter than in Comparative Example 1.

[0054] In both Comparative Examples 1 and 2, an additional cooling system for cooling the work rolls was required, and the equipment cost therefor was needed.

[0055] In contrast, in Example 1 of the present invention, the remaining water 24 was retained between the work rolls 12a and the rod-like water flows 23, whereby a stabilized cooling area was formed. This eliminated the problem that the remaining water 24 randomly moves over the steel plate or sheet 10 to nonuniformly cool the steel plate or sheet 10, thereby causing a temperature deviation. Thus, the steel plate or sheet 10 could be uniformly cooled.

[0056] In addition, even in the case where a steel plate or sheet having a warped leading end or trailing end was cooled, the problem that the steel plate or sheet 10 collides with the upper header 21 and damages the upper header 21, or that the steel plate or sheet 10 becomes immobilized, thereby causing a stoppage of the manufacture line or a decline in the yield rate did not occur. Accordingly, a lifting system for preventing the steel plate or sheet 10 from colliding with the upper header 21 was not necessary, whereby the equipment cost could be reduced.

[0057] Further, because controlled rolling could be performed without 30-second air-cooling, and because the transportation distance of a steel plate or sheet in four passes before conducting controlled rolling was almost the same as in Comparative Example 1, a rolling pitch was 180 seconds, which is 6 seconds shorter than in Comparative Example 2.

[0058] Further, because the cooling water 24 and the cooling water 34 having been supplied onto the steel plate or sheet 10 contacted the surfaces of the work rolls 12a and cooled the work rolls 12a, an additional cooling system for cooling the rolls was not necessary. Accordingly, the equipment cost could be reduced.

Example 2

[0059] As Example 2 of the present invention, rough rolling of a steel sheet in a hot rolling line was conducted. A slab was rolled down to a thickness of 42 mm by a roughing mill.

[0060] At that time, using a hot rolling mill shown in the above-described embodiment (FIG. 1) as Example 2 of the present invention, the steel plate or sheet 10 was rolled through three passes in the rough rolling while being cooled by jetting the rod-like water flows from the cooling equipment 20 provided on the entrance side and the exit side of the rolling mill 12. The angle of depression θ_U of the upper nozzles 22 was set at 45˚, and the angle of elevation θ_L of the lower nozzles 32 was set at 60˚.

[0061] The inside diameters of the upper nozzles 22 and the lower nozzles 32 were set to 6 mm, and the jet velocity of the rod-like water flows was set to 8 m/s.

[0062] On the other hand, as Comparative Example 3, using a hot rolling mill having no cooling equipment for cooling a steel plate or sheet during rolling, rough rolling was conducted. When the slab was heated at a relatively high temperature, the temperature thereof after the rough rolling was high. Therefore, 15-second air-cooling was performed at the entrance side of the finishing mill to suppress formation of scale defects.

[0063] Further, as Comparative Example 4, using a hot rolling mill having cooling equipment disclosed in the above-described Japanese Unexamined Patent Application Publication No. 62-260022 instead of the cooling equipment 20 of Example 2 of the present invention, rough rolling was conducted in the same manner as Example 2 of the present invention. That is, a steel plate or sheet was rolled through three passes in the rough rolling while being cooled by a laminar water flow jetted from the slit-shaped nozzle. The header was installed such that the distance between the roll bite of the work rolls and the cooling-start position (a position from where cooling by the cooling water starts) was 4 m. Cooling was performed on the steel plate or sheet that is being conveyed. The result is shown in Table 2. In Table 2, × denotes a case where a decline in productivity or quality occurred, and ○ denotes a case where a decline in productivity or quality did not occur.

Table 2

	Distance to the Cooling-start Position(*)	Method of Supplying Cooling Water	Equipment Cost	Damage to Equipment	Effect of Cooling Rolls	Rolling pitch	Yield Rate
Comparative Example 3	no cooling equipment	-	-	-	× no	105 s	reference
Comparative Example 4	4 m	laminar water flow	× high	× frequently occurred	× no	93 s	10% decline
Example 2 of the Present Invention	0 m	rod-like water flow	○ low	○ no	○ yes	90 s	equal to Comparative Example 3
*Distance from the roll bite of the work rolls to the cooling-start position							

[0064] As shown in Table 2, in Comparative Example 3, because 15-second air-cooling was performed at the entrance side of the finishing mill when the slab was heated at a relatively high temperature, a rolling pitch was 105 seconds. This shows a decline in the rolling efficiency.

[0065] In Comparative Example 4, because the lifting equipment had to be installed, the equipment cost was high. Further, steel plates or sheets having a warped leading end often collided with the nozzle units and damaged the equipment. The steel plates or sheets that had damaged the equipment were deformed and unable to become finished products. Thus, the yield rate declined as much as by 10%. Although 15-second air-cooling at the entrance side of the finishing mill was not necessary, an increase in transportation distance of a steel plate or sheet increased the transportation time. Thus, in total, a rolling pitch was 93 seconds, which is 12 seconds shorter than in Comparative Example 3.

[0066] In both Comparative Examples 3 and 4, an additional cooling system for cooling the work rolls was required, and the equipment cost therefor was needed.

[0067] In contrast, in Example 2 of the present invention, the remaining water 24 was retained between the work rolls 12a and the rod-like water flows 23, whereby a stabilized cooling area was formed. This eliminated the problem that the remaining water 24 randomly moves over the steel plate or sheet 10 to nonuniformly cool the steel plate or sheet 10, thereby causing a temperature deviation. Thus, the steel plate or sheet 10 could be uniformly cooled. This could properly suppress formation of scale defects.

[0068] In addition, in the case where a steel plate or sheet having a warped leading end or trailing end was cooled, the problem that the steel plate or sheet 10 collides with the upper header 21 and damages the upper header 21, or that the steel plate or sheet 10 becomes immobilized, thereby causing a stoppage of the manufacture line or a decline in the yield rate did not occur. Accordingly, the lifting system for preventing the steel plate or sheet 10 from colliding with the upper header 21 was not necessary, whereby the equipment cost could be reduced.

[0069] Further, because rough rolling could be performed without 15-second air-cooling at the entrance side of the finishing mill, and because the transportation distance of a steel plate or sheet when cooled by the cooling equipment 20 was almost the same as in Comparative Example 3, a rolling pitch was 90 seconds, which is 3 seconds shorter than in Comparative Example 4.

[0070] Further, because the cooling water 24 and the cooling water 34 having been supplied onto the steel plate or sheet 10 contacted the surfaces of the work rolls 12a and cooled the work rolls 12a, an additional cooling system for cooling the rolls was not necessary. Accordingly, the equipment cost could be reduced.

Example 3

[0071] As Example 3 of the present invention, finish rolling of a steel sheet in a hot rolling line was conducted. Using a finishing mill including seven stands, namely, F1 to F7, a steel sheet was rolled down to a finished thickness of 3 mm.

[0072] At that time, using a hot finishing mill shown in the above-described embodiment (FIG. 2) as Example 3 of the present invention, the steel plate or sheet 10 was rolled through four stands, namely, F4 to F7, while being cooled by jetting the rod-like water flows from the cooling equipment 20 provided on the exit side of the rolling mill 12. The angle of depression θ_U of the upper nozzles 22 was set at 45°, and the angle of elevation θ_L of the lower nozzles 32 was set at 60°.

[0073] The inside diameters of the upper nozzles 22 and the lower nozzles 32 were set to 6 mm, and the jet velocity of the rod-like water flows was set to 8 m/s.

[0074] On the other hand, as Comparative Example 5, using a hot rolling mill having cooling equipment as disclosed in the above-described Japanese Unexamined Patent Application Publication No. 2002-361315 instead of the cooling equipment 20 of Example 3 of the present invention, finish rolling was conducted in the same manner as Example 3 of the present invention. That is, a steel plate or sheet was rolled through four stands, namely, F4 to F7, while being cooled by a laminar water flow jetted from the slit-shaped nozzle. The header was installed such that the distance between the roll bite of the work rolls and the cooling-start position (a position from where cooling by the cooling water starts) was 2 m.

[0075] Further, as Comparative Example 6, using a hot rolling mill having cooling equipment as disclosed in the above-described Japanese Unexamined Patent Application Publication No. 62-260022 instead of the cooling equipment 20 of Example 3 of the present invention, finish rolling was conducted in the same manner as Example 3 of the present invention. That is, a steel plate or sheet was rolled through four stands, namely, F4 to F7, while being cooled by a laminar water flow jetted from the slit-shaped nozzle. The header was installed such that the distance between the roll bite of the work rolls and the cooling-start position (a position from where cooling by the cooling water starts) was 2 m.

[0076] The result is shown in Table 3. In Table 3, × denotes a case where a decline in productivity or quality occurred, and ○ denotes a case where a decline in productivity or quality did not occur.

Table 3

	Distance to the Cooling-start Position (*)	Method of Supplying Cooling Water	Equipment Cost	Occurrence of Temperature Deviation due to Remaining Water	Variation in Quality of Products	Damage to Equipment	Manufacture of Thin-scale Steel Sheet	Effect of Cooling Rolls	Yield Rate
Comparative Example 5	2 m	laminar water flow	× high	× yes	× yes	○ no	× impossible	× no	reference
Comparative Example 6	2 m	laminar water flow	× high	○ no	○ no	× frequently occurred	× impossible	× no	10% decline
Example 3 of the Present Invention	0 m	rod-like water flow	○ low	○ no	○ no	○ no	○ possible	○ yes	equal to Comparative Example 5

*Distance from the roll bite of the work rolls to the cooling-start position

[0077] As shown in Table 3, in Comparative Example 5, a change in state of the cooling water remained on the top surface of the steel plate or sheet caused a change in the cooling area of the steel plate or sheet, whereby a temperature deviation increased. This increased variations in quality (strength), such as tensile strength, of products (the difference between the maximum strength and the minimum strength: 3 kg/mm^2 or larger), resulting in a failure to manufacture a high quality steel plate or sheet.

[0078] In Comparative Example 6, because the lifting equipment had to be installed, the equipment cost was high. Further, steel plates or sheets having a warped leading end often collided with the nozzle units and damaged the equipment. The steel plates or sheets that had damaged the equipment were deformed and unable to become finished products. Thus, the yield rate declined as much as by 10%.

[0079] In both Comparative Examples 5 and 6, because the header was installed at a position 2 m away from the work rolls, scale formation on a steel plate or sheet that has just left the roll bite could not be suppressed. Accordingly, a thin-scale steel sheet could not be manufactured.

[0080] In both Comparative Examples 5 and 6, an additional cooling system for cooling the work rolls was required, and the equipment cost therefor was needed.

[0081] In contrast, in Example 3 of the present invention, the remaining water 24 was retained between the work rolls 12a and the rod-like water flows 23, whereby a stabilized cooling area was formed. This eliminated the problem that the remaining water 24 randomly moves over the steel plate or sheet 10 to nonuniformly cool the steel plate or sheet 10, thereby causing a temperature deviation. Thus, the steel plate or sheet 10 could be uniformly cooled. This enabled to manufacture a high quality steel plate or sheet having little variations in quality, such as tensile strength, (the difference between the maximum strength and the minimum strength: 1 kg/mm^2 or smaller).

[0082] Even when a steel plate or sheet whose leading end or trailing end is warped is cooled, the steel plate or sheet 10 did not collide with and damage the upper header 21 nor become immovable. Thus, a stoppage of the manufacturing line or a lowering of the yield rate could be avoided. This eliminated the necessity to provide a lifting system for preventing the steel plate or sheet 10 from colliding with the upper header 21, whereby the equipment cost could be reduced.

[0083] Further, because the temperature of the surfaces of the steel plate or sheet 10 that has just left the roll bite of the rolling mill 12 could be reduced by supplying cooling water onto the steel plate or sheet 10, scale formation could be suppressed. Accordingly, a thin-scale steel sheet could be manufactured.

[0084] Further, because the cooling water 24 and the cooling water 34 having been supplied onto the steel plate or sheet 10 contacted the surfaces of the work rolls 12a and cooled the work rolls 12a, an additional cooling system for cooling the rolls was not necessary. Accordingly, the equipment cost could be reduced.

Claims

1. A hot rolling mill for a steel plate or sheet, comprising: cooling equipment for supplying cooling water onto a top surface of the steel plate or sheet that is being conveyed, the cooling equipment being provided at a position near the rolling mill, on an entrance side and/or an exit side thereof, the cooling equipment including a header having nozzles for jetting rod-like water flows onto the top surface of the steel plate or sheet at an angle of depression in the range of 30˚ to 60˚ toward the rolling mill, the header being positioned such that the cooling water supplied to the steel plate or sheet is retained by work rolls of the rolling mill.

2. The hot rolling mill for a steel plate or sheet according to claim 1, wherein the cooling equipment further includes a header having nozzles for jetting rod-like water flows onto a bottom surface of the steel plate or sheet at an angle of elevation in the range of 45˚ to 90˚ toward the rolling mill, the header being positioned between the work rolls of the rolling mill and a table roller adjacent thereto.

3. A method for hot rolling a steel plate or sheet using the hot rolling mill for a steel plate or sheet according to claim 1 or 2, comprising: conducting rolling while jetting the cooling water such that the cooling water supplied onto the steel plate or sheet reaches the work rolls of the rolling mill.

4. A method for hot rolling a steel plate or sheet using the hot rolling mill for a steel plate or sheet according to claim 1 or 2, comprising: jetting the cooling water while setting a roll gap of the work rolls to 2 mm or smaller in rolling interval.

FIG.1

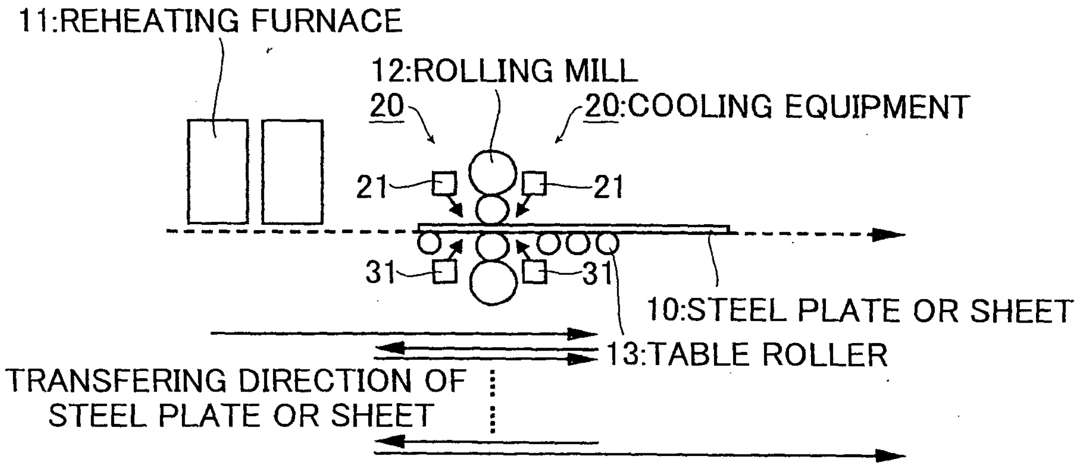

11:REHEATING FURNACE
12:ROLLING MILL
20
20:COOLING EQUIPMENT
21
21
31
31
10:STEEL PLATE OR SHEET
13:TABLE ROLLER
TRANSFERING DIRECTION OF
STEEL PLATE OR SHEET

FIG.2

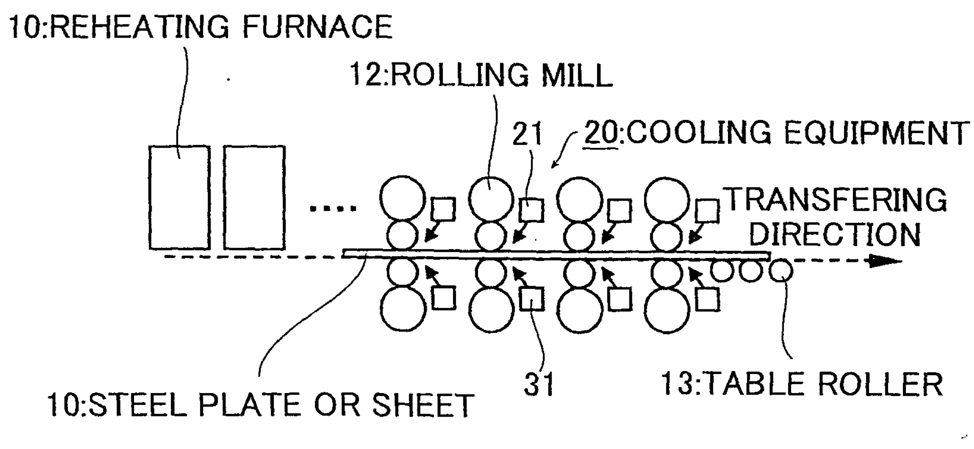

10:REHEATING FURNACE
12:ROLLING MILL
21
20:COOLING EQUIPMENT
TRANSFERING
DIRECTION
10:STEEL PLATE OR SHEET
31
13:TABLE ROLLER

FIG.3

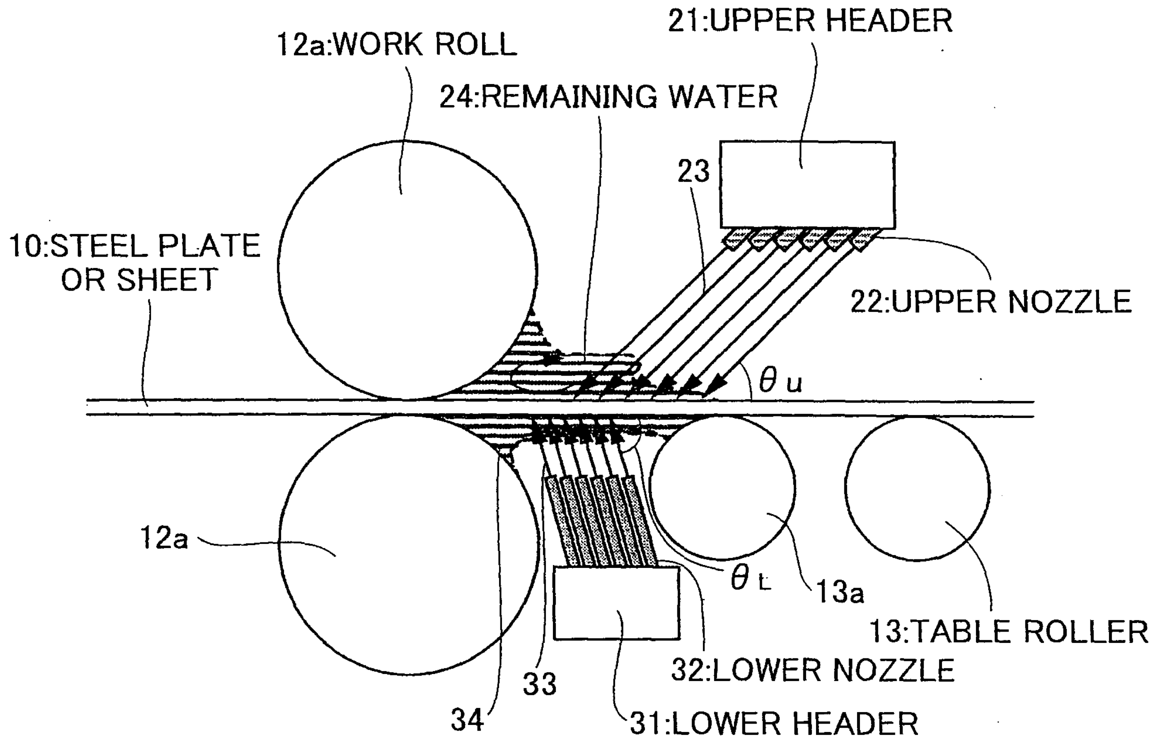

21:UPPER HEADER
12a:WORK ROLL
24:REMAINING WATER
23
10:STEEL PLATE
OR SHEET
22:UPPER NOZZLE
θu
12a
θL
13a
13:TABLE ROLLER
32:LOWER NOZZLE
33
34
31:LOWER HEADER

FIG.4

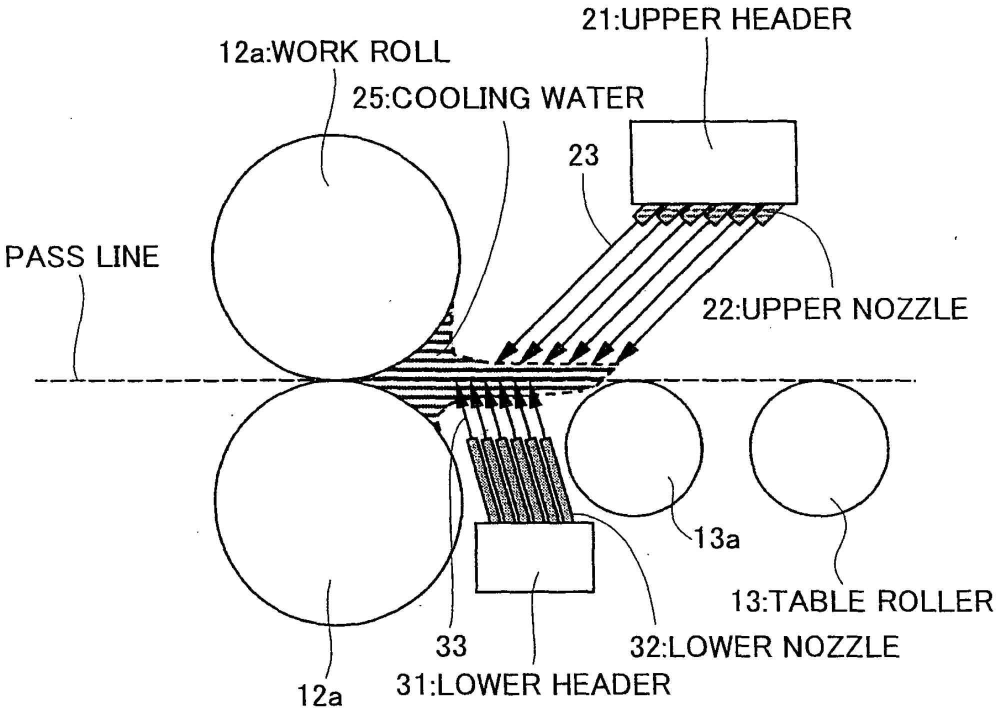

21:UPPER HEADER
12a:WORK ROLL
25:COOLING WATER
23
PASS LINE
22:UPPER NOZZLE
13a
13:TABLE ROLLER
33
32:LOWER NOZZLE
31:LOWER HEADER
12a

FIG.5

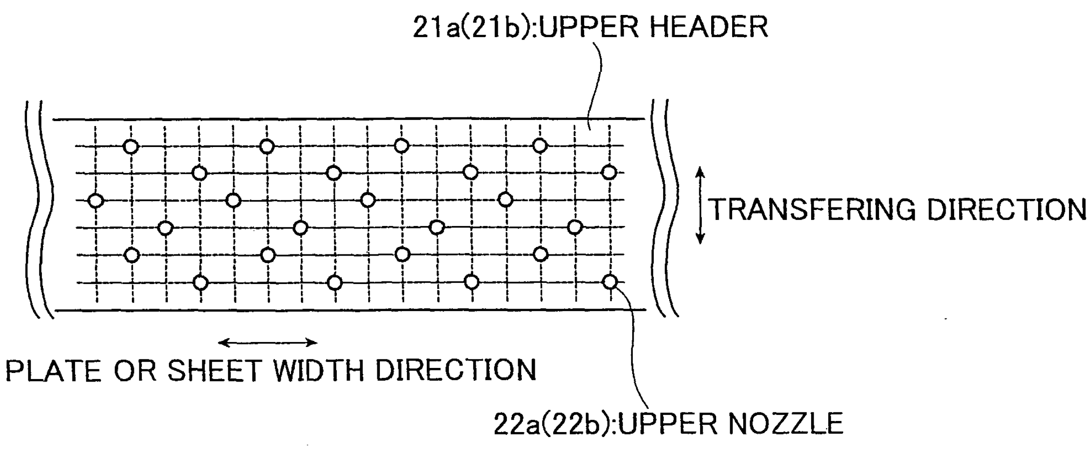
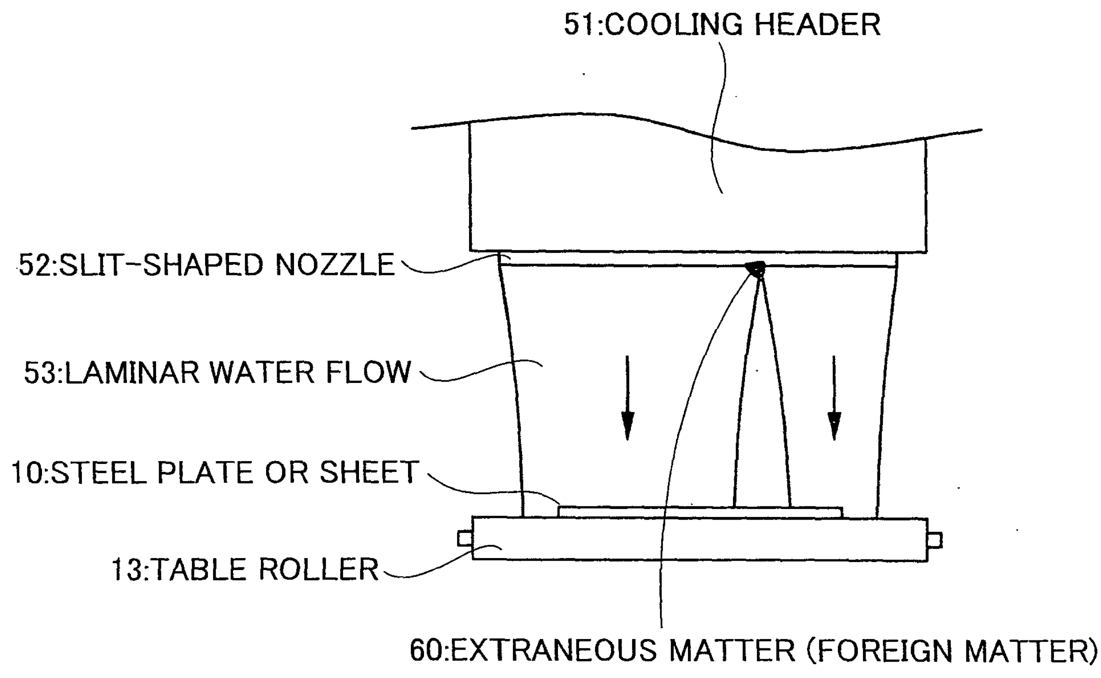

21a(21b):UPPER HEADER
TRANSFERING DIRECTION
PLATE OR SHEET WIDTH DIRECTION
22a(22b):UPPER NOZZLE

FIG.6


51:COOLING HEADER
52:SLIT-SHAPED NOZZLE
53:LAMINAR WATER FLOW
10:STEEL PLATE OR SHEET
13:TABLE ROLLER
60:EXTRANEOUS MATTER (FOREIGN MATTER)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2006/317394

A. CLASSIFICATION OF SUBJECT MATTER
B21B45/02(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B21B1/26, B21B1/38, B21B45/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2006
Kokai Jitsuyo Shinan Koho	1971-2006	Toroku Jitsuyo Shinan Koho	1994-2006

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2005-193258 A (Kawasaki Heavy Industries, Ltd.), 21 July, 2005 (21.07.05), Par. No. [0038]; Fig. 1 (Family: none)	1-4
A	JP 2002-361315 A (Kawasaki Heavy Industries, Ltd.), 17 December, 2002 (17.12.02), Claims; Fig. 5 (Family: none)	1-4
A	JP 62-260022 A (Ishikawajima-Harima Heavy Industries Co., Ltd.), 12 November, 1987 (12.11.87), Claims; Fig. 2 (Family: none)	1-4

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

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- "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
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 November, 2006 (16.11.06)	28 November, 2006 (28.11.06)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2006/317394

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2003-211205 A (JFE Steel Corp.), 29 July, 2003 (29.07.03), Par. Nos. [0032] to [0033] (Family: none)	1-4

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2002361315 A **[0006] [0008] [0009] [0011] [0074]**
- JP 62260022 A **[0007] [0008] [0010] [0011] [0050] [0063] [0075]**