

Description

Technical Field

5 **[0001]** The present invention relates to a secondary cooling method and apparatus for a continuously cast slab.

Background Art

10 **[0002]** A general method for manufacturing a continuously cast slab with vertical bending type continuous casting equipment, for example, will be described with reference to Figs. 3 and 4.

15 **[0003]** Molten steel poured into a mold 3 from a tundish (not illustrated) is subjected to first cooling by the mold 3 and formed into a flat plate-shaped cast slab 5 having a solidifying shell. The flat plate-shaped cast slab 5 moves downward through a vertical zone 9 and enters a curved zone 13. In a bending portion 11 provided at the entrance of the curved zone 13, the cast slab 5 is bent while being guided by a plurality of rollers (not illustrated) so that the curvature radius thereof is maintained constant.

20 **[0004]** After that, the cast slab 5 is unbent (straightened) in a straightening portion 15 such that the curvature radius thereof is gradually increased, and returns to the flat plate shape when the cast slab 5 moves out of the straightening portion 15 and into a horizontal zone 17. After being completely solidified in the horizontal zone 17, the cast slab 5 is cut to a predetermined length by a gas cutting machine 23 installed at the exit of a continuous casting machine.

25 **[0005]** The gas cutting machine 23 moves in a casting direction at a speed that matches a transport speed of the cast slab 5 while simultaneously moving a torch in a width direction. The gas cutting machine 23 discharges oxygen for cutting while heating the cast slab 5 with a preheating flame emitted from the torch, so that the cast slab 5 is melted and cut by oxidation heat of steel with oxygen.

30 **[0006]** When the casting speed is too high or when the cast slab temperature is too low, the cutting pitch of the gas cutting machine 23 cannot be synchronized with the casting speed. Therefore, a problem such as limitation to the casting speed or a cutting failure may occur. Accordingly, it is important to set a casting speed that matches the cutting performance and appropriately manage the temperature of the cast slab 5. The cast slab 5 cut by the gas cutting machine 23 is transported to a cast slab finishing plant or a rolling plant for the next process.

35 **[0007]** After leaving the mold 3, the cast slab 5 is subjected to secondary cooling for completely solidifying the cast slab 5 to a central portion thereof using water sprays (water-liquid sprays or water-air two-fluid mixture mist sprays) in a region from the vertical zone 9 to the horizontal zone 17.

40 **[0008]** In general, secondary cooling is performed by spraying water at a high flow rate in the vertical zone 9 that is directly below the mold 3, so that the cooling rate of the cast slab 5 is increased (in this specification, cooling of the cast slab at an increased cooling rate is referred to as "strong cooling") to ensure that the solidifying shell has a sufficient strength. In the curved zone 13 and the following zones, cooling of the cast slab 5 is reduced so that heat is conducted from a high-temperature region inside the cast slab 5 to increase the surface temperature of the cast slab 5 (heat recuperation). In the straightening portion 15, the surface temperature is adjusted to be above a brittle temperature range to avoid transversal cracking of the cast slab 5.

45 **[0009]** The cast slab 5 that has passed through the straightening portion 15 is completely solidified to the central portion thereof while being cooled in the horizontal zone 17. When the solidifying rate is low relative to the casting speed, there is a possibility that a solidification completion position will not be inside the continuous casting machine and that molten steel will flow out from the cut surface during gas cutting. This may cause severe damage, such as damage to the equipment or stoppage of the operation. When the solidification is completed too early, cooling water supplied after the completion of the solidification is wasted. In addition, the cast slab 5 is greatly reduced in temperature and cannot be easily cut, as described above. Thus, the productivity and production stability are greatly influenced by the settings of the cooling conditions in the horizontal zone 17.

50 **[0010]** Fig. 4 is a graph showing the result of numerical analysis for reproducing a temperature history of the cast slab 5 cast by a general continuous casting method according to the related art. The vertical axis represents the temperature, and the horizontal axis represents the distance from the meniscus (molten steel surface in the mold).

55 **[0011]** The reference signs of regions corresponding to the regions after the mold 3 illustrated in Fig. 3 are shown at the top of the graph.

60 **[0012]** In the graph, the solid line, the dashed line, and the one-dot chain line show the temperature histories at the center of the surface of the cast slab in the width direction, corner portions of the cast slab (corner portions), and the center of the cross section of the cast slab, respectively. In addition, in the graph, the thin dashed line shows the minimum temperature at which cutting can be performed. Cutting can be performed in a temperature region above this temperature (see the arrows). In addition, in the graph, the solidification completion position is denoted by A, and the end of the continuous casting machine is denoted by B.

65 **[0013]** As is clear from the temperature history at the center of the surface of the cast slab in the width direction, in

the vertical zone 9 directly below the mold 3, strong cooling at a high flow rate is performed by using water sprays to increase the shell thickness. Subsequently, in the bending portion 11 and the curved zone 13, the cooling rate is reduced so that heat is recuperated from the inside of the cast slab and that the surface temperature of the cast slab is controlled to be above a brittle temperature range 25 when the cast slab passes through the straightening portion 15. As a result, the cast slab 5 with satisfactory surface quality can be obtained.

[0014] The cast slab is also continuously cooled in the horizontal zone 17. When the central portion of the cast slab is completely solidified at point A, the temperature drop at the central portion of the cast slab increases. Then, the cast slab passes through the end of the continuous casting machine at point B, is cut to a predetermined length by the gas cutting machine 23, and is transported for the next process. In this example, the solidification completion position is sufficiently upstream of the end of the continuous casting machine, and the corner temperature of the cast slab is sufficiently higher than the temperature at which cutting can be performed. Therefore, the cast slab can be cut without any problem.

[0015] One problem that occurs during the above-described process of manufacturing the cast slab is a surface defect, such as longitudinal cracks and transverse cracks. The transverse cracks are characterized in being formed near the corner portions at the top surface of the cast slab in equipment such as a curved or vertical bending continuous casting machine in which straightening of the cast slab is performed. When the cast slab passes through the straightening portion while the temperature of the surface layer thereof is in the range of embrittlement of steel from the γ low temperature range to the γ/α transformation temperature range (region III embrittlement), transverse cracks are formed due to tensile stress on the surface of the cast slab during the straightening process. Non Patent Literature 1, for example, describes that the transverse cracks can be prevented by slowing the secondary cooling of the cast slab and shifting away from the embrittlement range toward the high-temperature side during the straightening process.

[0016] In addition, Patent Literature 1 discloses a technology for preventing surface cracks by reducing the amount of cooling water for secondary cooling or stopping the cooling water at the final straightening point in the straightening portion, that is, at a position near the entrance of the horizontal zone so that heat is recuperated in the surface layer of the cast slab.

[0017] However, according to the method of shifting away from the brittle temperature toward the high temperature side, the average temperature at the cross section of the slab is increased at the exit of the straightening portion. As a result, the completion of solidification of the central portion of the cast slab is delayed. Therefore, to complete the solidification at a location inside the continuous casting machine, the length of the continuous casting machine may need to be increased. Alternatively, there is a possibility that the casting speed will be limited and the productivity will be impaired.

[0018] Patent Literature 2 discloses a technology of performing cooling with an adjustment cooling device provided in the horizontal zone located downstream of the straightening portion so that the solidification completion position is located inside the caster.

[0019] However, Patent Literature 2 does not refer to specific cooling conditions. Therefore, the surface temperature may be significantly uneven in the width direction depending on the cooling conditions, and there is a risk that surface cracks (longitudinal cracks) will be formed in the slab surface due to thermal stress caused by the uneven temperature distribution. There is also a risk that the solidification completion position will not be uniform in the width direction and the internal quality will vary.

[0020] Patent Literature 3 discloses a technology for reducing uneven cooling in secondary cooling. According to this technology, the stability of the cooling process can be increased by controlling the boiling state of water in a striking area of a water spray such that film boiling is maintained in a front stage part of a cooling zone and nucleate boiling is maintained in a rear stage part of the cooling zone.

[0021] In general, when the cooling conditions are constant in the width direction, the cooling rate is higher at the corner portions of the cast slab than at the central portion of the cast slab in the width direction because heat is also dissipated from the sides. When cooling is started in a film boiling state, the film boiling state may be changed to a nucleate boiling state in response to a reduction in the temperature of the cooled surface. Therefore, when an attempt is made to maintain the film boiling state as in Patent Literature 3, the film boiling state is changed to the nucleate boiling state first at the corner portions of the cast slab at which the temperature is rapidly reduced, and the temperature is more rapidly reduced. Such a sudden change in temperature causes surface cracks in the cast slab due to thermal stress. In addition, the temperature drop at the corner portions of the cast slab may cause problems such as degradation of cutting properties or an increase in cutting time at the gas cutting machine provided at the exit of the continuous casting machine. These problems are not discussed in Patent Literature 3, and a method for controlling the temperature at the exit of the continuous casting machine is not clear.

[0022] Patent Literature 4 discloses a technology for cutting the cast slab after preliminarily heating the corner portions of the cast slab to ensure satisfactory cutting properties at the gas cutting machine. However, when strong cooling in a nucleate boiling state is performed as described above, the temperature of the cast slab is greatly reduced, and the required preheating time is longer than usual. In addition, when the casting speed is increased in accordance with the

thickness of the cast slab or the type of steel, there may be a case where the gas cutting speed is not sufficient and the casting speed needs to be limited or where a very large amount of energy is needed for preliminary heating.

Citation List

Patent Literature

[0023]

PTL 1: Japanese Patent No. 4690995
PTL 2: Japanese Unexamined Patent Application Publication No. 62-064462
PTL 3: Japanese Patent No. 6079387
PTL 4: Japanese Patent No. 2605329

Non Patent Literature

[0024] NPL 1: Ogibayashi et al., The Iron and Steel Institute-Joint Society on Iron and Steel Basic Research "Dynamic Behavior in Continuous Casting", 1985, p184

Summary of Invention

Technical Problem

[0025] As discussed above, secondary cooling conditions under which the surface quality is satisfactory, the productivity is not impaired, and no large additional energy cost is required are not clear.

[0026] In light of the above-described problems, an object of the present invention is to provide a secondary cooling method and apparatus for a continuously cast slab with which satisfactory surface quality of the cast slab can be ensured without impairing the productivity and without large additional energy cost.

Solution to Problem

[0027]

(1) A secondary cooling method for a continuously cast slab according to the present invention is a method in which the cast slab is cooled by spraying cooling water onto the cast slab in a secondary cooling zone of a continuous casting machine including a vertical zone, a bending portion, a curved zone, a straightening portion, and a horizontal zone arranged in that order from an upstream side in a casting direction, the cast slab being completely solidified in a section extending to an end of the horizontal zone. An upstream section of the horizontal zone in the casting direction is set to serve as a strong water cooling section in which the cast slab is cooled by spraying the cooling water under conditions such that the sprayed cooling water is in a nucleate boiling state at all positions in a width direction on a surface of the cast slab, and a section of the horizontal zone that is located downstream of the strong water cooling section in the casting direction and that extends to the end of the horizontal zone is set to serve as a non-water-cooled section in which spraying of the cooling water is stopped, so that a surface temperature of the cast slab is increased in the casting direction in a region from an end of the strong water cooling section to the end of the horizontal zone and that the surface temperature of the cast slab is within a predetermined range at the end of the horizontal zone.

(2) In the secondary cooling method for a continuously cast slab according to (1), the horizontal zone may be divided into n sections (n is an integer, $3 \leq n$) in the casting direction such that n -ith to n th sections (i is an integer, $0 \leq i < n-1$) each serve as the non-water-cooled section and that 1st to $n-i-1$ th sections each serve as the strong water cooling section. A flow density of the cooling water per unit time in 1st to j th sections (j is an integer, $1 \leq j < n-i-1$) among the 1st to $n-i-1$ th sections that each serve as the strong water cooling section may be greater than a flow density of the cooling water per unit time in $j+1$ th to $n-i-1$ th sections.

(3) In the secondary cooling method for a continuously cast slab according to (2), the flow density of the cooling water in the 1st to j th sections (j is an integer, $1 \leq j < n-i-1$) among the 1st to $n-i-1$ th sections that each serve as the strong water cooling section may be 500 L/(m²·min) or more and 2000 L/(m²·min) or less (min means minute as a unit of time), and the flow density of the cooling water in the $j+1$ th to $n-i-1$ th sections may be 50 L/(m²·min) or more and less than 500 L/(m²·min).

(4) In the secondary cooling method for a continuously cast slab according to any one of (1) to (3), the surface

temperature of the cast slab at the end of the horizontal zone may be 350°C or more at a position at which the surface temperature is minimum in the width direction of the cast slab.

(5) A secondary cooling apparatus for a continuously cast slab according to the present invention is an apparatus in which the cast slab is cooled by spraying cooling water onto the cast slab in a secondary cooling zone of a continuous casting machine including a vertical zone, a curved zone, and a horizontal zone arranged in that order from an upstream side in a casting direction, the cast slab being completely solidified in a section extending to an end of the horizontal zone. The horizontal zone is divided into n sections (n is an integer, $3 \leq n$) in the casting direction. The secondary cooling apparatus includes a plurality of spray nozzles, water supply means, and a water supply control device, the plurality of spray nozzles being disposed in respective ones of the sections of the horizontal zone, the water supply means and the water supply control device being capable of controlling spraying and stopping of the cooling water from the plurality of spray nozzles and a flow density of the cooling water per unit time for each of the sections. The water supply control device causes the spray nozzles to spray the cooling water in 1st to $n-i-1$ th sections (i is an integer, $0 \leq i < n-1$) from an upstream side in the casting direction so that the 1st to $n-i-1$ th sections each serve as a strong water cooling section in which the sprayed cooling water is in a nucleate boiling state at all positions in a width direction on a surface of the cast slab, and stops spraying of the cooling water from the spray nozzles in $n-i$ th to n th sections (i is an integer, $0 \leq i < n-1$) so that the $n-i$ th to n th sections each serve as a non-water-cooled section.

(6) In the secondary cooling apparatus for a continuously cast slab according to (5), the water supply control device may control the spraying of the cooling water from the spray nozzles such that a flow density of the cooling water per unit time in 1st to j th sections (j is an integer, $1 \leq j < n-i-1$) among the 1st to $n-i-1$ th sections that each serve as the strong water cooling section is greater than a flow density of the cooling water per unit time in $j+1$ th to $n-i-1$ th sections.

(7) In the secondary cooling apparatus for a continuously cast slab according to (6), the water supply control device may control the spraying of the cooling water from the spray nozzles such that the flow density of the cooling water in the 1st to j th sections (j is an integer, $1 \leq j < n-i-1$) among the 1st to $n-i-1$ th sections that each serve as the strong water cooling section is 500 L/(m²·min) or more and 2000 L/(m²·min) or less (min means minute as a unit of time), and that the flow density of the cooling water in the $j+1$ th to $n-i-1$ th sections is 50 L/(m²·min) or more and less than 500 L/(m²·min).

Advantageous Effects of Invention

[0028] According to the present invention, the upstream section of the horizontal zone in the casting direction is set to serve as the strong water cooling section in which the cast slab is cooled by spraying the cooling water under conditions such that the sprayed cooling water is in a nucleate boiling state at all positions in the width direction on the surface of the cast slab, and the section of the horizontal zone that is located downstream of the strong water cooling section in the casting direction and that extends to the end of the horizontal zone is set to serve as the non-water-cooled section in which spraying of the cooling water is stopped, so that the surface temperature of the cast slab is increased in the casting direction in a region from an end of the strong water cooling section to the end of the horizontal zone and that the surface temperature of the cast slab is within a predetermined range at the end of the horizontal zone. Therefore, satisfactory surface quality of the cast slab can be ensured without impairing the productivity and without large additional energy cost.

Brief Description of Drawings

[0029]

[Fig. 1] Fig. 1 illustrates the general structure of continuous casting equipment according to an embodiment of the present invention.

[Fig. 2] Fig. 2 is a graph showing the temperature history of a cast slab in a continuous casting method according to the embodiment of the present invention.

[Fig. 3] Fig. 3 illustrates the general structure of general continuous casting equipment according to the related art.

[Fig. 4] Fig. 4 is a graph showing the temperature history of a cast slab in a general continuous casting method according to the related art.

Description of Embodiments

[0030] A continuous casting machine to which a secondary cooling method for a continuously cast slab according to the present embodiment is applied will be described with reference to Fig. 1.

[0031] As illustrated in Fig. 1, a continuous casting machine 1 is an apparatus in which molten steel poured into a mold 3 from a tundish (not illustrated) is pulled out in the form of a cast slab 5 while being supported by rollers (not illustrated) and subjected to secondary cooling performed by cooling sprays (not illustrated) disposed between the rollers.

[0032] As illustrated in Fig. 1, the cast slab 5 is subjected to secondary cooling in a secondary cooling zone 7 that is divided into a vertical zone 9, a bending portion 11, a curved zone 13, a straightening portion 15, and a horizontal zone 17. The secondary cooling method according to the present invention is characterized mainly by a method for cooling the cast slab 5 in the horizontal zone 17.

[0033] In the secondary cooling zone 7 of the continuous casting machine 1, the horizontal zone 17 is divided into n sections (n is an integer, $3 \leq n$) and is provided with strong cooling equipment 21 including water supply means and a water supply control device 19 by which cooling water can be turned on and off and the amount thereof can be controlled for each section.

[0034] Although the number, n , of sections is determined in advance depending on the equipment, which of the n sections is to serve as a strong water cooling section or as a non-cooled section may be set as appropriate by the water supply control device 19.

[0035] Depending on the size of the equipment, the horizontal zone 17 may include nearly 100 rollers arranged at predetermined intervals in a casting direction. Spray nozzles that discharge cooling water are disposed between the rollers. Multiple spray nozzles are arranged in a width direction of the cast slab in each of the regions between the rollers.

[0036] In the strong cooling equipment 21 according to the present embodiment, the horizontal zone 17 is divided into n sections by dividing the spray nozzles into groups, each group including the spray nozzles disposed between a plurality of rollers (for example, ten rollers) arranged in the casting direction.

[0037] Therefore, in each section, the cooling water can be discharged from the group of spray nozzles at a high flow rate to quickly change the boiling state of the cooling water to a stable nucleate boiling state.

[0038] In each section, the nozzles and pipes that are used, for example, are changeable so that the cooling water may be discharged not only at a high flow rate but also at a low flow rate.

[0039] The spray nozzles used herein are not limited to water-liquid sprays and may instead be, for example, water-air two-fluid mixture mist spray nozzles as long as the flow density per unit time may be set as described below.

[0040] According to a secondary cooling method for a continuously cast slab of the present embodiment, the cast slab 5 that is cast by the above-described continuous casting machine 1 is cooled by spraying cooling water onto the cast slab 5 in the secondary cooling zone 7 including the vertical zone 9, the bending portion 11, the curved zone 13, the straightening portion 15, and the horizontal zone 17. The cast slab 5 is completely solidified within a section extending to an end of the horizontal zone. An upstream section of the horizontal zone 17 in the casting direction is set to serve as a strong water cooling section in which the cast slab 5 is cooled by spraying the cooling water under conditions such that the sprayed cooling water is in a nucleate boiling state on the surface of the cast slab. In addition, a section of the horizontal zone 17 that is located downstream of the strong water cooling section in the casting direction and that extends to the end of the horizontal zone is set to serve as a non-water-cooled section in which spraying of the cooling water is stopped.

[0041] The surface temperature of the cast slab is increased in the casting direction in a region from an end of the strong water cooling section to the end of the horizontal zone, and the surface temperature of the cast slab is within a predetermined range at the end of the horizontal zone.

[0042] Fig. 2 illustrates the result of numerical analysis for reproducing a temperature history of the surface of the cast slab manufactured by using the above-described continuous casting machine 1. In Fig. 2, the solid line, the dashed line, and the one-dot chain line show the temperature histories at the center of the surface of the cast slab in the width direction, corner portions of the cast slab (corner portions), and the center of the cross section of the cast slab, respectively. The thin dashed line shows the minimum temperature at which cutting can be performed. In addition, in Fig. 2, the solidification completion position is denoted by A', and the end of the continuous casting machine is denoted by B. Fig. 2 also shows the solidification completion position A according to the related art illustrated in Fig. 4.

[0043] The cast slab 5 is cooled in a manner similar to that in the technology of the related art until the cast slab 5 moving from the position directly below the mold 3 passes through the straightening portion 15, so that the surface temperature of the cast slab 5 in the straightening portion 15 is higher than the brittle temperature range 25.

[0044] When the cast slab enters the horizontal zone 17 and cooling by the strong cooling equipment 21 is started, the water sprays in the first one of the regions between the rollers in the horizontal zone 17 and water sprays downstream thereof in the casting direction in the horizontal zone 17 discharge water at a high flow rate so that a nucleate boiling state that is uniform in the width direction is achieved. As a result, the temperatures at the center of the cast slab in the width direction and at the corner portions of the cast slab are simultaneously reduced to a temperature close to the water temperature and stabilized.

[0045] After that, strong cooling is continued so that the nucleate boiling state is maintained. After the cast slab is completely solidified at point A', the internal temperature thereof starts to drop. It is not necessary to perform cooling after the interior is completely solidified or when the interior is not yet completely solidified but the temperature is

sufficiently low and it is certain that the solidification will be completed before the cast slab reaches the end of the caster. Therefore, spraying is stopped in a region including $i+1$ sections that are the $n-i^{\text{th}}$ to n^{th} sections (i is an integer, $0 \leq i < n-1$) so that heat is recuperated on the surface of the cast slab after point C. As a result, the temperature of the corner portions of the cast slab reaches or exceeds the temperature at which cutting can be performed at point B, and the cast slab can be cut without any problem.

[0046] In general, the temperature of the cast slab 5 is often controlled in response to a variation in the casting speed by changing the flow rate of the cooling water. However, when the temperature is reduced to a temperature close to a room temperature by performing strong cooling to ensure sufficient stability of the cooling process as in the present invention, the flow rate cannot be controlled because nucleate boiling is to be maintained. Accordingly, as described above, cooling needs to be stopped in some of the cooling sections to adjust the cooling time and control the temperature at which cooling is finished.

[0047] According to the present invention, strong cooling is performed in the horizontal zone 17. Therefore, when the casting speed is the same as that in the related art, the solidification completion position A' is located upstream of the position A according to the related art in the continuous casting machine 1. Accordingly, the casting speed can be increased from that in the related art. When the casting speed is increased, the time in which the cast slab passes through the cooling zone is reduced, and the cooling time is shortened. Accordingly, the number $i+1$ of non-water-cooled sections in which cooling is stopped may be reduced to increase the length of a portion of the cooling zone in which cooling is performed, so that the solidification is reliably completed in the continuous casting machine 1.

[0048] When casting is started or ended, the casting speed is reduced. In such a case, the number $i+1$ of non-water-cooled sections may be increased so that the temperature of the corner portions of the cast slab does not fall below the temperature at which cutting can be performed due to a drop in the overall temperature of the cast slab 5.

[0049] Regarding the spraying conditions of the cooling water (flow density per unit time) according to the present invention, conditions under which nucleate boiling is achieved over the entire area in the width direction in a short time irrespective of manufacturing conditions, such as a variation in the casting speed and the type of steel, or equipment conditions, such as arrangement intervals between the sprays, have been studied. As a result, it has been found that the flow density per unit time needs to be $500 \text{ L}/(\text{m}^2 \cdot \text{min})$ (min means minute as a unit of time) or more. The flow density per unit time is a value calculated by dividing the flow rate of the cooling water (L/min) in the cooling section by the area (m^2) of the cooling section.

[0050] When the flow density per unit time is less than or equal to the above-mentioned value, a stable nucleate boiling state cannot be achieved when the cast slab 5 at a high temperature is cooled, and the time at which nucleate boiling is achieved greatly differs between the positions at which the temperature drop is large (for example, the corner portions of the cast slab) and the positions at which the temperature drop is small (for example, the center of the cast slab in the width direction). As a result, the temperature significantly varies in the width direction.

[0051] Depending on the equipment arrangement or the type of steel, heat is greatly recuperated in regions toward which the cooling water is not directly discharged from the water sprays (for example, regions at and around the positions directly below the guide rollers), and there is a possibility that a stable nucleate boiling state cannot be achieved. This may cause a large temperature variation. Such a temperature variation may lead to deformation of the cast slab 5 and defects such as cracks.

[0052] When nucleate boiling is achieved, the cast slab is cooled mainly by boiling, and dependency of the cooling capacity on the flow density per unit time is reduced. Accordingly, when the flow density per unit time is increased beyond $2000 \text{ L}/(\text{m}^2 \cdot \text{min})$, the cooling capacity cannot be greatly increased. Also, the total amount of cooling water that is used becomes excessive, and the capital investment on the water treatment equipment is increased. Therefore, the flow density per unit time in the strong water cooling section is suitably in the range of $500 \text{ L}/(\text{m}^2 \cdot \text{min})$ or more and $2000 \text{ L}/(\text{m}^2 \cdot \text{min})$ or less.

[0053] When the cast slab 5 enters the above-described strong water cooling section and the surface temperature of the cast slab is reduced by nucleate boiling, the nucleate boiling state can be reliably maintained even when the flow rate is not as high as $500 \text{ L}/(\text{m}^2 \cdot \text{min})$ or more.

[0054] Therefore, when there is a limit to the total amount of cooling water that can be used in the continuous casting machine 1, the 1^{st} to j^{th} sections (j is an integer, $1 \leq j \leq n-i-1$) of the strong water cooling sections may be set to serve as a high-flow-rate region in which the flow density per unit time is greater than or equal to $500 \text{ L}/(\text{m}^2 \cdot \text{min})$, and the remaining $j+1^{\text{th}}$ to $n-i-1^{\text{th}}$ sections may be set to serve as a low-flow-rate region in which the flow density per unit time is as low as $50 \text{ L}/(\text{m}^2 \cdot \text{min})$ or more and less than $500 \text{ L}/(\text{m}^2 \cdot \text{min})$ because it is only necessary to maintain nucleate boiling. The number j of the sections set to serve as the high-flow-rate region may be any number in accordance with the manufacturing conditions, such as the type of steel and the thickness of the cast slab.

[0055] A temperature range in which satisfactory cutting properties can be ensured in the gas cutting machine at the exit of the continuous casting machine has also been studied. As a result, it has been found that the corner temperature of the cast slab needs to be controlled to be 350°C or more at a position immediately in front of the cutting machine. Therefore, the surface temperature of the cast slab at the end of the horizontal zone 17 is preferably 350°C or more at

the position at which the surface temperature is minimum in the width direction of the cast slab.

[0056] As described above, according to the present embodiment, the strong cooling equipment 21 divides the horizontal zone 17 of the secondary cooling zone 7 into a plurality of sections so that the strong water cooling section, in which cooling is performed while the nucleate boiling state is maintained, and the non-cooled section, which is located downstream of the strong water cooling section in the casting direction and in which spraying of the cooling water is stopped, are provided. The ranges of these sections are variable depending on the conditions such as the casting speed. Therefore, the temperature at the time when casting is ended can be controlled without causing a significantly uneven temperature distribution on the surface.

[0057] Accordingly, the cast slab 5 can be manufactured at a high speed while a high surface quality thereof is maintained, and can be cut without any problem even when the casting conditions are changed. Thus, stable production of a high quality cast slab 5 can be realized while the high productivity of the cast slab 5 is maintained.

[0058] The non-cooled section located downstream of the strong water cooling section in the casting direction is a section in which spraying of the cooling water is stopped to stop active cooling of the cast slab. Needless to say, the non-cooled section includes a section in which the cooling water is caused to fall onto the surface of the cast slab without an intention of cooling the cast slab as long as spraying of the cooling water for actively cooling the cast slab is stopped as described above. For example, the non-cooled section includes a section in which liquid remaining in the pipes falls onto the surface of the cast slab or in which a very small amount of water is supplied to prevent clogging of the spray nozzles.

[0059] In the non-cooled section, in addition to stopping the spraying of the cooling water, the temperature of the corner portions of the cast slab, at which the surface temperature of the cast slab is easily reduced, may be maintained or increased by using auxiliary means, such as a heat retaining cover or an edge heater.

[0060] When the predetermined flow density per unit time cannot be achieved for some reason, such as an abnormality in the equipment caused by leakage from the pipes, and when the nucleate boiling state cannot be quickly achieved after the cast slab enters the strong water cooling section, it is necessary to reliably achieve and maintain the nucleate boiling state by increasing the flow rate while monitoring the boiling state.

[0061] When the cooling water that is in contact with the surface of the cast slab is boiled, the cooling water is vaporized and turns into water vapor, which condenses into observable steam (water smoke) in air. In the nucleate boiling state, the cooling water that comes into contact with the cast slab surface violently forms bubbles and generates a large amount of water vapor and a large amount of water smoke. In contrast, in the film boiling state, the boiling cooling water forms less bubbles, and the amounts of water vapor and water smoke that are generated are reduced. Accordingly, a camera is installed in each section, and the amount of water smoke that is generated is monitored visually or by measurement with a transmissometer. A threshold of the amount of generated water smoke that delineates between nucleate boiling and film boiling is experimentally determined in advance, and whether the nucleate boiling state is achieved in a certain section can be determined by checking whether the amount of generated water smoke exceeds the threshold. When the nucleate boiling state is not achieved, the flow rate of the cooling water is increased. Thus, the nucleate boiling state can be reliably achieved and maintained.

Examples

[0062] The cast slab 5 was manufactured by using the continuous casting machine 1 (Fig. 1) according to the above-described embodiment, and effects of the present invention were verified. This will be further described below.

[0063] In these examples, the horizontal zone 17 was divided into twelve sections ($n=12$), and whether or not to perform spraying and the spraying flow rate were controlled for each section. The length of the continuous casting machine 1 was 45 m, and a thermometer for measuring the temperature distribution on the surface of the cast slab and the gas cutting machine 23 were provided at the end of the caster.

[0064] The cast slab 5 was manufactured under different manufacturing conditions, for example, different flow densities per unit time ($L/(m^2 \cdot min)$) in the horizontal zone, casting speeds, and slab thicknesses. The occurrence of an uneven temperature distribution during cooling, an estimated solidification completion position in the caster, the corner temperature of the cast slab in the cutting process, and the surface quality after the casting process were evaluated.

[0065] The manufacturing conditions and the results of the evaluation are shown in Table 1 given below. In Table 1, Examples 1 to 7 are within the scope of the present invention, and Comparative Examples 1 to 8 are outside the scope of the present invention.

[0066] The solidification completion position was estimated in advance by numerical analysis. In some of the comparative examples, no cast slab was actually manufactured because there was a risk that the solidification completion position will not be inside the continuous casting machine 1 according to the result of the preliminary estimation.

[Table 1]

	SLAB THICKNESS [mm]	CASTING SPEED [mpm]	FLOW DENSITY IN HORIZONTAL ZONE [J/(m ² ·min)]												UNEVEN TEMPERATURE DISTRIBUTION	ESTIMATED SOLIDIFICATION COMPLETION POSITION [m]	CORNER TEMPERATURE IN CUTTING PROCESS [°C]	SURFACE/INTERNAL QUALITY	NOTE
			1	2	3	4	5	6	7	8	9	10	11	12					
COMPARATIVE EXAMPLE 1	235	1.0	←						10					→	NO	36	580	GOOD	RELATED ART
COMPARATIVE EXAMPLE 2	235	2.5	←						10					→	-	OUTSIDE	-	-	ESTIMATION ONLY
COMPARATIVE EXAMPLE 3	235	2.5	←						500					→	NO	38	320	POOR	CUTTING FAILURE
COMPARATIVE EXAMPLE 4	235	2.2	←						400			→	←	0	LARGE	40	440	POOR	
COMPARATIVE EXAMPLE 5	235	2.5	500	←					40					0	LARGE	43	490	POOR	
COMPARATIVE EXAMPLE 6	235	2.5	400	←					50			→	←	0	LARGE	40	480	POOR	
COMPARATIVE EXAMPLE 7	260	0.8	←						10					→	NO	38	550	GOOD	
COMPARATIVE EXAMPLE 8	200	2.0	←						10					→	NO	39	600	GOOD	
EXAMPLE 1	235	2.5	←						500			→	←	0	NO	38	420	GOOD	
EXAMPLE 2	235	3.5	←						2000			→	←	0	NO	40	350	GOOD	
EXAMPLE 3	235	2.5	500	←					50			→	←	0	NO	43	430	GOOD	
EXAMPLE 4	235	3.5	2000	1000	500	←	100	→	←	50		→	←	0	NO	40	370	GOOD	
EXAMPLE 5	235	2.0	←						500			→	←	0	NO	35	460	GOOD	EXAMPLE 1 → DECELERATED
EXAMPLE 6	260	2.5	←						500					0	NO	42	440	GOOD	THICK
EXAMPLE 7	200	3.0	←						500			→	←	0	NO	37	430	GOOD	THIN

[0067] The results shown in Table 1 will now be discussed for each group of comparative examples and examples that relate to each other.

<Comparative Examples 1 and 2 and Examples 1 and 2>

[0068] In Comparative Examples 1 and 2 and Examples 1 and 2, the cast slab 5 having a thickness of 235 mm was manufactured by using the technology of the related art and the present invention.

[0069] In Comparative Example 1, the cast slab was manufactured under cooling conditions according to the related art (flow density per unit time was 10 L/(m²·min), and no cooling stop region was provided). In this example, stable film boiling was constantly maintained on the surface. Therefore, no uneven temperature distribution occurred, and no problems were found in the inspection of the surface of the cast slab after manufacture. The corner temperature of the cast slab in the cutting process was 580°C, and cutting was performed without any problem.

[0070] However, the casting speed was limited to 1.0 mpm at a maximum so that the solidification completion position (estimated to be at a position of 36 m) was inside the caster.

[0071] Accordingly, in Comparative Example 2, a case in which the casting speed was increased to 2.5 mpm to increase the productivity was studied. No cast slab was actually manufactured because the estimated solidification completion position was calculated to be outside the caster under these conditions. Thus, according to the related art, although the cast slab 5 with satisfactory surface quality can be manufactured, the casting speed is limited.

[0072] In contrast, in Example 1, the technology of the present invention was applied so that the flow density per unit time was set to 500 L/(m²·min) to perform strong cooling in the 1st to 9th sections and that the cooling water was stopped to adjust the surface temperature by heat recuperation in the 10th to 12th sections. Casting was performed at a casting speed increased to 2.5 mpm. As a result, a nucleate boiling state was achieved uniformly in the width direction by strong cooling, and no uneven temperature distribution occurred. The estimated solidification completion position was at 38 m and was sufficiently inside the caster, and therefore the cast slab was actually manufactured. As a result, the corner temperature of the cast slab in the cutting process was 420°C, which was lower than that in Comparative Example 1 but within the range in which cutting can be performed. Accordingly, cutting was performed without any problem. The surface of the cast slab was inspected after manufacture, and no cracks were found. Thus, it was possible to efficiently manufacture the cast slab 5 with satisfactory surface quality without any problem.

[0073] In Example 2, the technology of the present invention was applied so that the flow density per unit time was set to 2000 L/(m²·min) to perform strong cooling in a region of the 1st to 10th sections and that the cooling water was stopped in a region of the 11th and 12th sections. In this case, it was possible to further increase the casting speed to 3.5 mpm and efficiently manufacture the high quality cast slab 5 without any trouble in the cutting process or any problem in the surface quality.

<Comparative Examples 3 and 4>

[0074] In Comparative Examples 3 and 4, the cooling conditions in the strong water cooling sections were changed from those in Example 1. In Comparative Example 3, no cooling stop region was provided, and the flow density per unit time was set to 500 L/(m²·min) to perform strong cooling in all of the sections. In this case, no uneven temperature distribution occurred due to cooling, and the solidification completion position was inside the caster. However, since strong cooling was performed for a long time and heat recuperation was insufficient at the end of the caster, the corner temperature of the cast slab in the cutting process was reduced to 320°C. As a result, emergency reduction in the casting speed was necessary because it took a long time to cut the cast slab and there was a risk that cutting cannot be completed within the operation range of the gas cutting machine 23. In addition, the significant change in the casting speed caused degradation of the surface quality and internal quality of the cast slab 5 that was being manufactured.

[0075] In Comparative Example 4, the flow density per unit time was set to 400 L/(m²·min) in the 1st to 10th sections, and the cooling water was stopped in the 11th and 12th sections. As a result, in the strong water cooling sections, no stable nucleate boiling state not achieved on the cast slab at some positions in the width direction at the above-described flow rate. Nucleate boiling was achieved first at the corner portions of the cast slab, at which a large temperature drop occurs, and a significant temperature difference occurred in the width direction. Therefore, surface cracks and internal cracks were formed in the cast slab, and the quality of the cast slab 5 was degraded.

<Examples 3 and 4 and Comparative Examples 5 and 6>

[0076] In Examples 3 and 4 and Comparative Examples 5 and 6, the conditions were changed from those in Example 1 such that only the 1st section of the strong water cooling sections was set to serve as a high-flow-rate region, and the flow rate was reduced in the 2nd and the following sections.

[0077] In Example 3, the flow density per unit time was set to 500 L/(m²·min) in the 1st section serving as the high-

flow-rate section, and to 50 L/(m²·min) in the 2nd to 11th sections. In the 12th section, the cooling water was stopped. In this case, the nucleate boiling state was achieved by cooling in the 1st section of the strong water cooling sections, and was maintained without causing heat recuperation in the following sections. As a result, uneven cooling did not occur in the width direction. The solidification completion position was at 43 m, and was inside the caster. The corner temperature of the cast slab in the cutting process was 430°C, and cutting was performed without any problem. The surface of the cast slab was inspected after manufacture, and no cracks were found. Thus, it was possible to manufacture the cast slab 5 with satisfactory surface quality.

[0078] In Example 4, the flow density per unit time was reduced stepwise in the strong water cooling sections. Specifically, the flow density per unit time was set to 2000 L/(m²·min) in the 1st section, 1000 L/(m²·min) in the 2nd section, 500 L/(m²·min) in the 3rd section, 100 L/(m²·min) in the 4th and 5th sections, and 50 L/(m²·min) in the 6th to 10th sections. The cooling water was stopped in the 11th and 12th sections. In this case, the nucleate boiling state was achieved by cooling in the 1st section of the strong water cooling sections, and was maintained without causing heat recuperation in the following sections. As a result, uneven cooling did not occur in the width direction. The solidification completion position was at 40 m, and was inside the caster. The corner temperature of the cast slab in the cutting process was 370°C, and cutting was performed without any problem. The surface of the cast slab was inspected after manufacture, and no cracks were found. Thus, it was possible to manufacture the cast slab 5 with satisfactory surface quality.

[0079] In Comparative Example 5, the flow density per unit time was set to 40 L/(m²·min) in the latter ones of the strong water cooling sections serving as the low-flow-rate region. As a result, nucleate boiling was not maintained and the temperature was increased at the center of the cast slab in the width direction where large heat recuperation occurred, and a significantly uneven temperature distribution occurred in the width direction. Although the solidification completion position was inside the caster, the slab was deformed due to the uneven temperature distribution in the width direction, and cracks were formed in the surface.

[0080] In Comparative Example 6, the flow density per unit time was set to 400 L/(m²·min) in the first one of the strong water cooling sections serving as the high-flow-rate region. As a result, the nucleate boiling state was not quickly achieved when the cast slab 5 entered the strong water cooling section, and the nucleate boiling state and the film boiling state were both present in the width direction. Therefore, the surface temperature was significantly uneven, and surface cracks were formed. In addition, due to uneven cooling, the solidification completion position was also uneven, and the internal quality was degraded.

<Example 5>

[0081] Example 5 is an example in which the casting speed needed to be greatly reduced at, for example, the start and end of the casting process in Example 1. In this case, the casting speed was reduced to 2.0 mpm, and strong cooling was performed for a longer time. Accordingly, the non-water-cooled sections were increased to the 8th to 12th sections. As a result, uneven cooling did not occur, and the solidification completion position was at 35 m. The corner temperature of the cast slab in the cutting process was 460°C, and was within the range in which cutting can be performed. The surface of the cast slab was inspected after manufacture, and no cracks were found. Thus, it was possible to manufacture the cast slab 5 with satisfactory surface quality without any problem even when the casting speed was greatly changed.

<Comparative Examples 7 and 8 and Examples 6 and 7>

[0082] In Comparative Example 7 and Example 6 and in Comparative Example 8 and Example 7, the slab thickness was changed to 260 mm and 200 mm, respectively. In Comparative Examples 7 and 8, the slab thickness was changed to 260 mm and 200 mm, respectively, under the cooling conditions according to the related art similar to those in Comparative Example 1.

[0083] In Comparative Example 7, the slab thickness was 260 mm. Since the slab thickness was greater than that in Comparative Example 1 and the temperature drop was reduced accordingly, the casting speed was reduced to 0.8 mpm so that the solidification completion position was inside the caster. In Comparative Example 8, the slab thickness was 200 mm. To prevent an unnecessary temperature drop after the completion of solidification of the central portion due to the reduction in the slab thickness compared to that in Comparative Example 1, the casting speed was increased to 2.0 mpm.

[0084] In Example 6, the slab thickness was 260 mm. Since the slab thickness was greater than that in Example 1 and the temperature drop was reduced accordingly, the strong water cooling sections were increased to the 1st to 11th sections without changing the casting speed. The flow density per unit time in the strong water cooling sections was the same as that in Example 1. As a result, uneven cooling did not occur, and the solidification completion position was at 42 m. The corner temperature of the cast slab in the cutting process was 440°C, and was within the range in which cutting can be performed. The surface of the cast slab was inspected after manufacture, and no cracks were found. Thus, even when the casting thickness was increased, it was possible to manufacture the cast slab 5 with satisfactory

surface quality without any problem while the high casting speed was maintained.

[0085] In Example 7, the slab thickness was 200 mm. Since the slab thickness was less than that in Example 1 and the temperature drop was increased accordingly, the casting speed was increased to 3.0 mpm. The flow density per unit time in the strong water cooling sections was the same as that in Example 1, and the non-water-cooled sections were increased to the 9th to 12th sections. As a result, uneven cooling did not occur, and the solidification completion position was at 37 m. The corner temperature of the cast slab in the cutting process was 430°C, and was within the range in which cutting can be performed. The surface of the cast slab was inspected after manufacture, and no cracks were found. Thus, even when the casting thickness was reduced, it was possible to manufacture the cast slab 5 with satisfactory surface quality without any problem and without greatly reducing the casting speed.

[0086] Thus, according to the technology of the present invention, it is not necessary to greatly change the casting speed as in the related art even when the thickness of the cast slab is changed, and stable and efficient production of a high quality cast slab 5 can be realized.

[0087] As described above, an upstream section of the horizontal zone 17 in the casting direction is set to serve as a strong water cooling section in which the cast slab 5 is cooled by spraying the cooling water under conditions such that the sprayed cooling water is in a nucleate boiling state at all positions in the width direction on the surface of the cast slab. In addition, a section of the horizontal zone 17 that is located downstream of the strong water cooling section in the casting direction and that extends to the end of the horizontal zone is set to serve as a non-water-cooled section in which spraying of the cooling water is stopped. It has been verified that according to the above configuration, even when the casting conditions are changed, the cast slab 5 can be manufactured while the temperature thereof is maintained at a temperature that allows easy cutting without limitation to the casting speed or large additional energy cost for heating the cast slab 5. Reference Signs List

[0088]

- 1 continuous casting machine
- 3 mold
- 5 cast slab
- 7 secondary cooling zone
- 9 vertical zone
- 11 bending portion
- 13 curved zone
- 15 straightening portion
- 17 horizontal zone
- 19 water supply control device
- 21 strong cooling equipment
- 23 gas cutting machine
- 25 brittle temperature range

Claims

1. A secondary cooling method for a continuously cast slab in which the cast slab is cooled by spraying cooling water onto the cast slab in a secondary cooling zone of a continuous casting machine including a vertical zone, a bending portion, a curved zone, a straightening portion, and a horizontal zone arranged in that order from an upstream side in a casting direction, the cast slab being completely solidified in a section extending to an end of the horizontal zone, wherein an upstream section of the horizontal zone in the casting direction is set to serve as a strong water cooling section in which the cast slab is cooled by spraying the cooling water under conditions such that the sprayed cooling water is in a nucleate boiling state at all positions in a width direction on a surface of the cast slab, and a section of the horizontal zone that is located downstream of the strong water cooling section in the casting direction and that extends to the end of the horizontal zone is set to serve as a non-water-cooled section in which spraying of the cooling water is stopped, so that a surface temperature of the cast slab is increased in the casting direction in a region from an end of the strong water cooling section to the end of the horizontal zone and that the surface temperature of the cast slab is within a predetermined range at the end of the horizontal zone.
2. The secondary cooling method for a continuously cast slab according to Claim 1, wherein the horizontal zone is divided into n sections (n is an integer, $3 \leq n$) in the casting direction such that n-ith to nth sections (i is an integer, $0 \leq i < n-1$) each serve as the non-water-cooled section and that 1st to n-i-1th sections each serve as the strong water cooling section, and wherein a flow density of the cooling water per unit time in 1st to jth sections (j is an integer, $1 \leq j < n-i-1$) among the

1st to n-i-1th sections that each serve as the strong water cooling section is greater than a flow density of the cooling water per unit time in j+1th to n-i-1th sections.

- 5 3. The secondary cooling method for a continuously cast slab according to Claim 2, wherein the flow density of the cooling water in the 1st to jth sections (j is an integer, $1 \leq j < n-i-1$) among the 1st to n-i-1th sections that each serve as the strong water cooling section is 500 L/(m²·min) or more and 2000 L/(m²·min) or less (min means minute as a unit of time), and the flow density of the cooling water in the j+1th to n-i-1th sections is 50 L/(m²·min) or more and less than 500 L/(m²·min).

- 10 4. The secondary cooling method for a continuously cast slab according to any one of Claims 1 to 3, wherein the surface temperature of the cast slab at the end of the horizontal zone is 350°C or more at a position at which the surface temperature is minimum in the width direction of the cast slab.

- 15 5. A secondary cooling apparatus for a continuously cast slab in which the cast slab is cooled by spraying cooling water onto the cast slab in a secondary cooling zone of a continuous casting machine including a vertical zone, a curved zone, and a horizontal zone arranged in that order from an upstream side in a casting direction, the cast slab being completely solidified in a section extending to an end of the horizontal zone,

20 wherein the horizontal zone is divided into n sections (n is an integer, $3 \leq n$) in the casting direction, wherein the secondary cooling apparatus comprises a plurality of spray nozzles, water supply means, and a water supply control device, the plurality of spray nozzles being disposed in respective ones of the sections of the horizontal zone, the water supply means and the water supply control device being capable of controlling spraying and stopping of the cooling water from the plurality of spray nozzles and a flow density of the cooling water per unit time for each of the sections, and

25 wherein the water supply control device causes the spray nozzles to spray the cooling water in 1st to n-i-1th sections (i is an integer, $0 \leq i < n-1$) from an upstream side in the casting direction so that the 1st to n-i-1th sections each serve as a strong water cooling section in which the sprayed cooling water is in a nucleate boiling state at all positions in a width direction on a surface of the cast slab, and stops spraying of the cooling water from the spray nozzles in n-ith to nth sections (i is an integer, $0 \leq i < n-1$) so that the n-ith to nth sections each serve as a non-water-cooled section.

- 30 6. The secondary cooling apparatus for a continuously cast slab according to Claim 5, wherein the water supply control device controls the spraying of the cooling water from the spray nozzles such that a flow density of the cooling water per unit time in 1st to jth sections (j is an integer, $1 \leq j < n-i-1$) among the 1st to n-i-1th sections that each serve as the strong water cooling section is greater than a flow density of the cooling water per unit time in j+1th to n-i-1th sections.

- 35 7. The secondary cooling apparatus for a continuously cast slab according to Claim 6, wherein the water supply control device controls the spraying of the cooling water from the spray nozzles such that the flow density of the cooling water in the 1st to jth sections (j is an integer, $1 \leq j < n-i-1$) among the 1st to n-i-1th sections that each serve as the strong water cooling section is 500 L/(m²·min) or more and 2000 L/(m²·min) or less (min means minute as a unit of time), and that the flow density of the cooling water in the j+1th to n-i-1th sections is 50 L/(m²·min) or more and less than 500 L/(m²·min).

FIG. 1

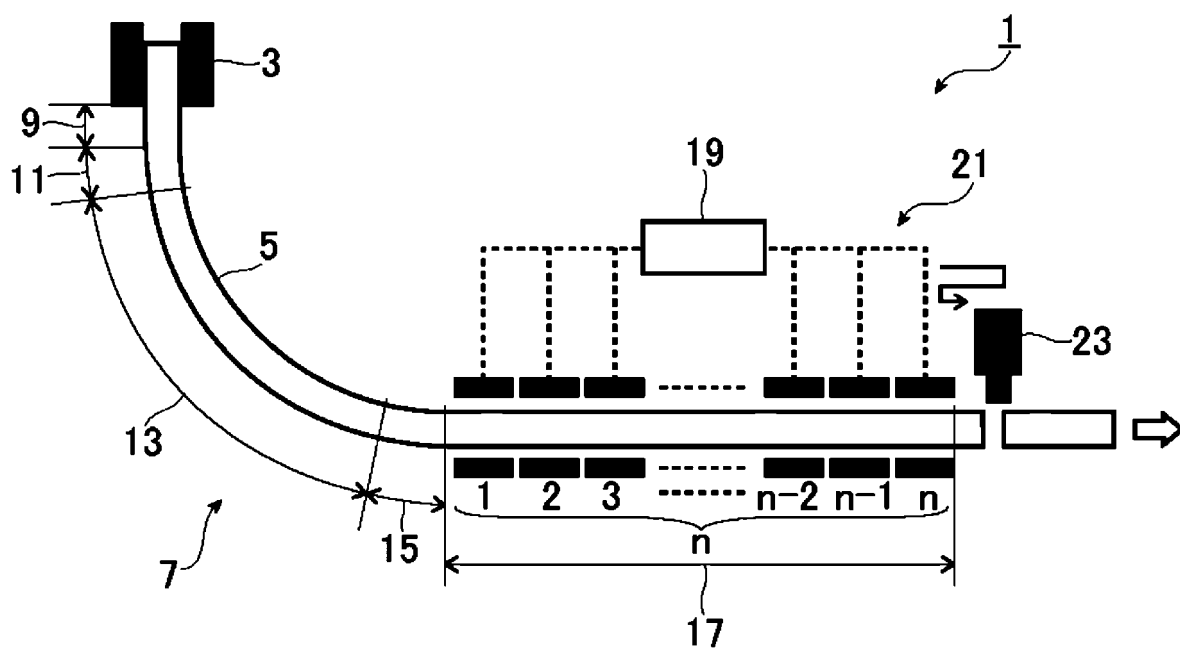


FIG. 2

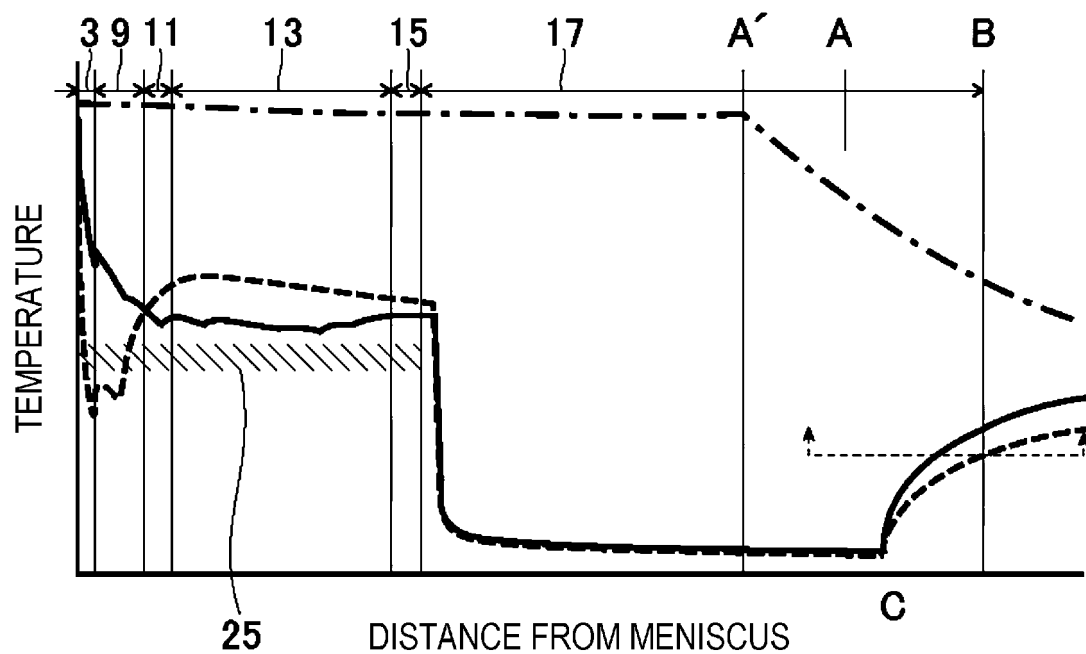


FIG. 3

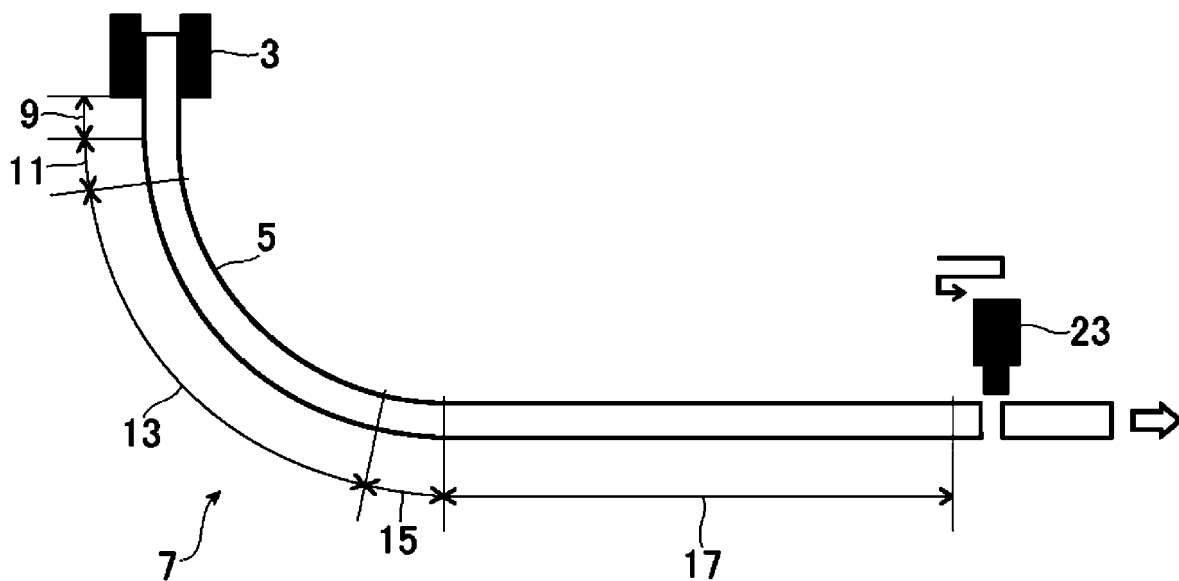
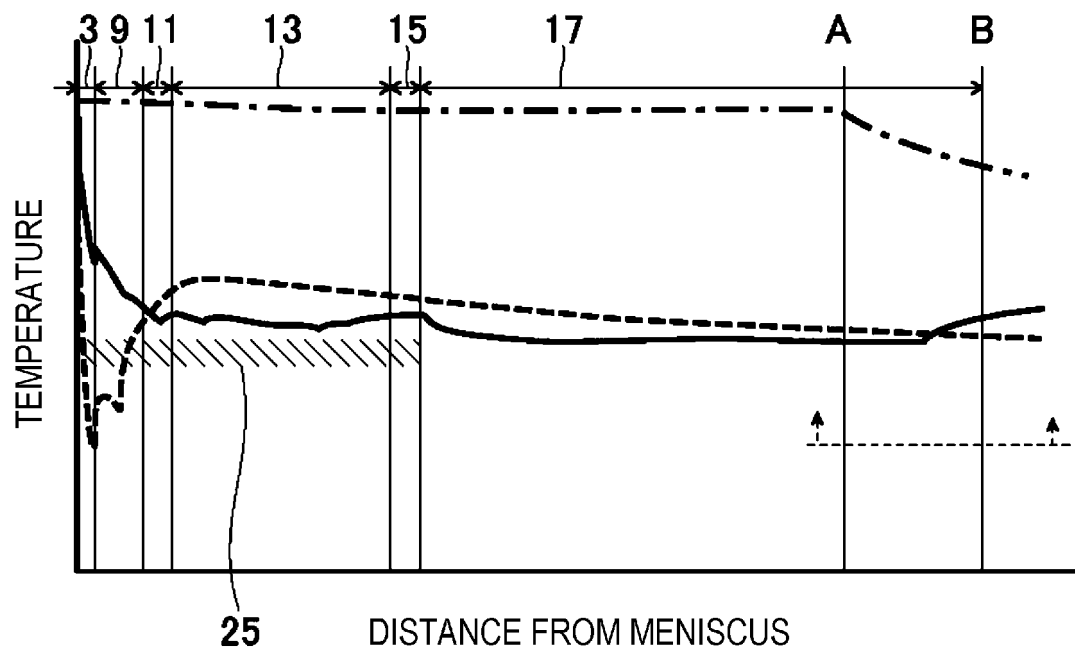


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/026488

A. CLASSIFICATION OF SUBJECT MATTER

B22D 11/124 (2006.01) i; B22D 11/22 (2006.01) i
 FI: B22D11/22 B; B22D11/124 N; B22D11/124 L

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)
 B22D11/00-B22D11/22

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	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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 2018-15781 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 01.02.2018 (2018-02-01) entire text, fig. 1-11	1-7
A	JP 2014-200803 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 27.10.2014 (2014-10-27) entire text, fig. 1-7	1-7



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

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Name and mailing address of the ISA/
 Japan Patent Office
 3-4-3, Kasumigaseki, Chiyoda-ku,
 Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/026488

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2018-15781 A	01 Feb. 2018	(Family: none)	
JP 2014-200803 A	27 Oct. 2014	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 4690995 B [0023]
- JP 62064462 A [0023]
- JP 6079387 B [0023]
- JP 2605329 B [0023]

Non-patent literature cited in the description

- **OGIBAYASHI et al.** Dynamic Behavior in Continuous Casting. *The Iron and Steel Institute-Joint Society on Iron and Steel Basic Research*, 1985, 184 [0024]