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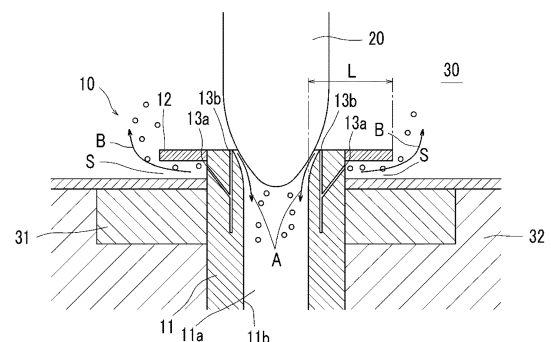
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(54) **TUNDISH NOZZLE STRUCTURE AND CONTINUOUS CASTING METHOD**

(57) Provided are a tundish upper nozzle structure and a continuous casting method which make it possible to cause inclusions to float within a tundish. In the present invention, a flange-shaped member 12 having an outside dimension greater than that of an upper end of a tundish upper nozzle 11 is provided along a part or the entirety of the circumference of the upper end of the tundish upper nozzle, and one or more gas discharge holes 13a are provided in one or more surfaces selected from the group consisting of a lower surface, an outer peripheral surface and a top surface of the flange-shaped member 12, and a region of an outer peripheral surface of the tundish upper nozzle 11 below the flange-shaped member 12. A length L in the tundish upper nozzle structure is adjusted to cause the almost the entirety of gas to float upwardly, or to adjust the flow rate of gas flowing downwardly toward the inner bore of the tundish upper nozzle, and the flow rate of gas floating upwardly.

[Fig. 1]



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a tundish upper nozzle structure having a gas blowing function, and a continuous casting method using such a tundish upper nozzle structure.

BACKGROUND ART

10 **[0002]** The operation of continuous casting of steel is often carried out under gas blowing from a tundish upper nozzle. The gas blowing is primarily intended to fulfill the following functions.

(1) It is intended to cause gas bubbles to flow downwardly from the inner bore of the tundish upper nozzle, thereby suppressing adhesion of inclusions onto the surface of the inner bore of the tundish upper nozzle or another nozzle therebelow, or clogging of the inner bore due to the adhesion of inclusions.

15 (2) It is intended to control a flow mode of molten steel in a region from a flow passage below the tundish upper nozzle to the inside of a mold.

(3) It is intended to cause inclusions to float within a container below the tundish upper nozzle or within a mold.

20 (4) It is intended to cause inclusions to float within a tundish.

[0003] These exert an influence on stability and productivity of the casting operation, and quality of slab.

[0004] For the functions (1) to (4), the gas blowing from a tundish upper nozzle has heretofore been performed in various configurations.

25 **[0005]** Mainly for the functions (1) to (3), for example, in the below-mentioned Patent Document 1, there is proposed a structure in which a gas-discharging porous portion is provided on an inner bore side of a tundish upper nozzle, and a ring-shaped refractory member is provided around the outer periphery of an upper end of the tundish upper nozzle, such that an annular flange of the ring-shaped refractory member covers a top area of the tundish upper nozzle. It is described that this structure makes it possible to reliably perform gas supply to the inner bore of the tundish upper nozzle.

30 **[0006]** Further, in the below-mentioned Patent Document 2, with a view to preventing inclusions or scull from adhering to the vicinity of a contact area between a stopper and an upper nozzle, thereby making it possible to perform stable flow rate control, and thus obtain good slab, there is proposed a stopper-receiving nozzle in the bottom of a tundish, characterized in that it comprises two porous refractory members provided to define upper-side and lower-side molten steel contact surfaces, respectively, across the contact area with the stopper, wherein the nozzle is configured to be capable of blowing argon gas from each of the porous refractory members, independently.

35 **[0007]** Further, in the below-mentioned Patent Document 3, with a focus on the function (4), there is proposed a continuous casting method which comprises blowing an inert gas from a ring-shaped upper porous refractory member provided in an upper portion of a nozzle provided in the bottom of a tundish, and blowing an inert gas from a ring-shaped lower porous refractory member provided in a lower portion of the nozzle. It is described that the upper porous refractory member makes it possible to blow the inert gas toward molten steel in the tundish, and the lower porous refractory member makes it possible to blow the inert gas toward an opening of the nozzle.

CITATION LIST

[Patent Document]

45 **[0008]**

Patent Document 1: JP-A 2003-220450

Patent Document 2: JP-AH06-297118

50 Patent Document 3: JP-A 2016-182612

SUMMARY OF INVENTION

[Technical Problem]

55 **[0009]** In order to enhance quality of slab, it is also important to cause inclusions to float within a tundish, as the function (4). A balance between each of the functions (1) to (3) and the function (4) is of a nature to be appropriately determined according to individual operation conditions (including know-how), steel grades, target quality and others.

[0010] However, it has been found that, in the gas blowing method and the like of conventional techniques such as the above-mentioned Patent Documents, a blown gas mostly flows toward the inner bore of the tundish upper nozzle, and thus fails to float upwardly, i.e., in molten steel within the tundish.

[0011] As means to fulfill the function (4), i.e., to cause inclusions to float within the tundish, a method is conceivable that comprises blowing gas into the tundish at any position of the bottom of the tundish other than the position of the tundish upper nozzle.

[0012] However, in order to blow gas into the tundish at any position of the bottom of the tundish other than the position of the tundish upper nozzle, a dedicated facility therefor is required, which leads to increase in initial cost and running cost, and increase in risk of molten steel leakage during casting operation. Moreover, it is also pointed out that this method is not sufficient in terms of in-molten steel inclusion removal effect.

[0013] From this point of view, in order to remove inclusions within the tundish by means of gas blowing, it is desirable to use the tundish upper nozzle to form a floating flow of gas in molten steel within the tundish, and adjust the rate (percentage) of the floating flow.

[0014] A technical problem to be solved by the present invention is to provide a tundish upper nozzle structure configured to blow gas from a tundish upper nozzle, wherein the tundish upper nozzle structure is capable of cause the entirety of gas blown from a specific location of the tundish upper nozzle to float (upwardly from the tundish upper nozzle) within a tundish, or arbitrarily adjust a balance between the flow rate of gas flowing toward the inner bore of the tundish upper nozzle or downwardly, and the flow rate of gas floating (upwardly from the tundish upper nozzle) within the tundish, and a continuous casting method using the tundish upper nozzle structure.

[0015] It should be noted here that one tundish upper nozzle varies in terms of a discharge position, the configuration of a discharge hole, such as a porous body or a through-hole, the number of discharge holes, and others, and as used in this specification, the term "the entirety of gas blown from a specific location of the tundish upper nozzle" means the entirety of gas discharged from a single gas flow-out portion, in other words, "the entirety of gas discharged from a single through-hole, or, when focusing on a plurality of discharge holes including a porous body or the like, which are actually composed of a set of very small discharge holes configured such that a plurality of gas bubbles at the time just after discharge merge into a single gas bubble, i.e., form a single gas bubble, the entirety of gas discharged from each of the set of very small discharge holes, but does not mean the entirety of gas discharged from the one tundish upper nozzle.

[Solution to Technical Problem]

[0016] The present inventors have found that, the reason why gas blown from the vicinity of an upper end of the tundish upper nozzle mostly flows toward the inner bore of the tundish upper nozzle, and thus fails to float upwardly, i.e., in molten steel within the tundish, as in the above-mentioned Patent Publications is that in the vicinity of the gas discharge hole adjacent to the upper end of the tundish upper nozzle, a molten steel flow directed toward the inner bore of the tundish upper nozzle becomes mainstream, and is stronger than the floating flow of gas bubbles.

[0017] That is, the subject matter of the present invention is a tundish upper nozzle structure which is capable of discharging gas at a position where the flow velocity of molten steel flowing into an inner bore of a tundish upper nozzle is less than the flow velocity of a floating flow of gas bubbles, so as to allow the floating flow of gas bubbles to become stronger than a molten steel flow directed toward the inner bore of the tundish upper nozzle, and adjusting a balance between the flow rate of gas flowing toward the inner bore of the tundish upper nozzle, and the flow rate of gas floating upwardly, and a continuous casting method using the tundish upper nozzle structure.

[0018] Specifically, the present invention relates to a tundish upper nozzle structure having features described in the following sections 1 to 11, and a continuous casting method having a feature described in the following section 12.

1. A tundish upper nozzle structure comprises: a tundish upper nozzle; and a flange-shaped member having an outside dimension greater than that of an upper end of the tundish upper nozzle, the flange-shaped member being provided along a part or an entirety of a circumference of an upper end of the tundish upper nozzle, wherein the tundish upper nozzle structure has one or more gas discharge holes provided in one or more surfaces selected from the group consisting of a lower surface, an outer peripheral surface and a top surface of the flange-shaped member, and a region of an outer peripheral surface of the tundish upper nozzle below the flange-shaped member.

2. The tundish upper nozzle structure described in the section 1, wherein the gas discharge hole is provided in the flange-shaped member, wherein the gas discharge hole is an end of a gas distribution passage which is an internal space of the flange-shaped member, or a through-hole penetrating between the lower surface and the top surface of the flange-shaped member.

3. The tundish upper nozzle structure described in the section 1 or 2, wherein the lower surface of the flange-shaped member is provided with one or more grooves each allowing gas to pass therethrough.

4. The tundish upper nozzle structure described in the section 1 or 2, which is configured such that, in a state in which the tundish upper nozzle structure is attached to a tundish, a space allowing gas to pass therethrough is

defined along a part or an entirety of the lower surface of the flange-shaped member.

5. The tundish upper nozzle structure described in any one of the sections 1 to 4, which is used for operation of continuous casting of steel in which a flow rate of molten steel is controlled by a stopper, wherein a length L (mm) from a position on a vertical extension of an inner bore surface at a lower end of the tundish upper nozzle to the gas discharge hole in the top surface of the flange-shaped member or the outer peripheral surface of the flange-shaped member satisfies the following formula 1:

$$L \geq -1.875 M^2 + 26.332 M - 0.3929,$$

where M denotes a casting speed (t/min).

6. The tundish upper nozzle structure described in any one of the sections 1 to 4, which is used for operation of continuous casting of steel in which a flow rate of molten steel is controlled by a stopper, wherein a length L (mm) from a position on a vertical extension of an inner bore surface at a lower end of the tundish upper nozzle to the gas discharge hole in the top surface of the flange-shaped member or the outer peripheral surface of the flange-shaped member satisfies the following formula 2:

$$L < -1.875 M^2 + 26.332 M - 0.3929,$$

where M denotes a casting speed (t/min).

7. The tundish upper nozzle structure described in any one of the sections 1 to 5, wherein the length L (mm) from the position on the vertical extension of the inner bore surface at the lower end of the tundish upper nozzle to the gas discharge hole in the top surface of the flange-shaped member or the outer peripheral surface of the flange-shaped member is 60 mm or more.

8. The tundish upper nozzle structure described in any one of the sections 1 to 7, wherein the flange-shaped member is joined to the tundish upper nozzle.

9. The tundish upper nozzle structure described in the section 8, wherein the flange-shaped member and the tundish upper nozzle are joined together by a screw, or a bayonet structure, or an adhesive.

10. The tundish upper nozzle structure described in any one of the sections 1 to 7, wherein the flange-shaped member is fitted onto an outer periphery of the tundish upper nozzle, and joined to a tuyere adjacent to the tundish upper nozzle, or a refractory layer in a bottom of a tundish.

11. The tundish upper nozzle structure described in the section 10, wherein the flange-shaped member, and the tuyere or the refractory layer in the bottom of the tundish, are joined together by a screw, or a bayonet structure, or an adhesive.

12. A continuous casting method using the tundish upper nozzle structure described in any one of the sections 1 to 4, wherein the tundish upper nozzle structure is used for operation of continuous casting of steel in which a flow rate of molten steel is controlled by a stopper, the continuous casting method comprising: setting a length L (mm) from a position on a vertical extension of an inner bore surface at a lower end of the tundish upper nozzle to the gas discharge hole in the top surface of the flange-shaped member or the outer peripheral surface of the flange-shaped member, to be equal to or greater than a boundary length LB (mm) satisfying the following formula 3, thereby causing almost the entirety of the gas to float upwardly; or setting the length L (mm) to be less than the boundary length LB (mm), to adjust a flow rate of gas flowing downwardly toward an inner bore of the tundish upper nozzle, and a flow rate of gas floating upwardly;

$$L = -1.875 M^2 + 26.332 M - 0.3929,$$

where M denotes a casting speed (t/min).

[Effect of Invention]

[0019] In the present invention, the flange-shaped member having an outside dimension greater than that of an upper end of the tundish upper nozzle is provided along a part or the entirety of the circumference of the upper end of the tundish upper nozzle, so that it is possible to lead gas to the side of the outer periphery of the tundish upper nozzle, i.e., to a region where the flow velocity of molten steel toward the inner bore is relatively small, and direct the gas upwardly from the vicinity of the region. This makes it possible to cause the gas to float within the tundish, and obtain an effect of causing inclusions to float within the tundish. Eventually, it is possible to improve quality of slab.

[0020] Further, a length from the position on the vertical extension of the lower end of the inner bore to the gas discharge hole in the flange-shaped member having an outside dimension greater than that of the upper end of the tundish upper nozzle, or a gas discharge area, i.e., a location where gas is released upwardly after flowing along the flange-shaped member (the length L) can be arbitrarily adjusted to arbitrarily adjust the flow rate of gas flowing downwardly toward the inner bore of the tundish upper nozzle and the flow rate of gas floating within the tundish.

BRIEF DESCRIPTION OF DRAWINGS

[0021]

FIG. 1 is a schematic sectional view showing a relevant part of a tundish upper nozzle structure according to one embodiment of the present invention.

FIG. 2 is a diagram graphically showing the right-hand side of the above-mentioned formulas 1 and 2.

FIG. 3 is a diagram showing results of gas behavior analysis in the tundish upper nozzle structure illustrated in FIG. 1.

DESCRIPTION OF EMBODIMENTS

[0022] FIG. 1 shows a relevant part of a tundish upper nozzle structure according to one embodiment of the present invention.

[0023] The tundish upper nozzle structure 10 according to this embodiment is used for operation of continuous casting of steel in which the flow rate of molten steel is controlled by a stopper 20. The tundish upper nozzle structure 10 comprises: a tundish upper nozzle 11; and a flange-shaped member 12 having an outside dimension (outside diameter) greater than that of an upper end of the tundish upper nozzle, wherein the flange-shaped member is provided along the entirety of the outer periphery (circumference) of the upper end of the tundish upper nozzle. Further, the tundish upper nozzle structure 10 according to this embodiment has a plurality of (six) gas discharge holes 13a provided in a region of an outer peripheral surface of the tundish upper nozzle 11 below the flange-shaped member 12 (at even intervals in a circumferential direction of the tundish upper nozzle 11). The tundish upper nozzle structure 10 according to this embodiment also has a plurality of (twenty-four) gas discharge holes 13b provided in a top surface of the tundish upper nozzle 11 (at even intervals in the circumferential direction of the tundish upper nozzle 11).

[0024] As shown in FIG. 1, the tundish upper nozzle structure 10 is configured such that, in a state in which it is attached to a tundish 30, a space S allowing gas to pass therethrough is defined along a part or the entirety of a lower surface of the flange-shaped member 12 (during casting, the inside of the tundish is filled with molten steel, and therefore molten steel exists in this space).

[0025] As above, the tundish upper nozzle structure 10 according to this embodiment is provided with the flange-shaped member 12, so that it is possible to lead gas to the side of the outer periphery of the tundish upper nozzle 11 (in the direction of the arrowed line B), i.e., to a region where the flow velocity of molten steel toward an inner bore 11a of the tundish upper nozzle 11 (in the direction of the arrowed line A) is relatively small, and direct the gas upwardly from the vicinity of the region. This makes it possible to cause the gas to float within the tundish 30, and obtain an effect of causing inclusions to float within the tundish 30. Eventually, it is possible to improve quality of slab.

[0026] The present inventors have further found that respective rates of the flow rate of gas flowing downwardly toward the inner bore 11a and the flow rate of gas floating within the tundish 30 is highly dependent on a length L (mm) and a casting speed M (t/min) indicated in FIG. 1. Here, the length L indicated in FIG. 1 means a length from a position on a vertical extension of an inner bore surface 11b at a lower end of the tundish upper nozzle 11 to a gas discharge hole in a top surface of the flange-shaped member 12 or an outer peripheral surface of the flange-shaped member 12, and the casting speed M (t/min) indicated in FIG. 1 is synonymous with the throughput of molten steel.

[0027] The reason that this length L is measured based on the position on the vertical extension of the inner bore surface 11b at the lower end of the tundish upper nozzle 11 is that the outer periphery and the vicinity of the upper end of the tundish upper nozzle 11 can be designed to have various shapes, whereas the position of the inner bore surface at the lower end (which is approximately equivalent to an inner bore diameter) is almost unchanged at similar casting speeds, i.e., there is no significant difference in the velocity of molten steel flowing into the inner bore, and that, in stopper control, a fitting position of the stopper is located at approximately the same radial position along with the inner bore diameter.

[0028] Specifically, the present inventors have found that, when the length L (mm) satisfies the following formula 1, it is possible to cause almost the entirety of gas to float within the tundish, and the length L (mm) satisfies the following formula 2, it is possible to adjust the flow rate of gas flowing downwardly toward the inner bore (inner bore-side gas) and the flow rate of gas floating upwardly (floating gas).

$$L \geq -1.875 M^2 + 26.332 M - 0.3929 \quad \text{--- Formula 1}$$

$$L < -1.875 M^2 + 26.332 M - 0.3929 \quad \text{--- Formula 2}$$

[0029] As mentioned above, the control of the rate of the inner bore-side gas or the floating gas is performed with respect to each gas to be discharged from the respective discharge holes.

[0030] Therefore, in the case where the gas discharge hole is provided in the top surface of the flange-shaped member as one of the two reference points for determining the length L (mm), the length L is set with respect to each gas discharge hole, irrespective of whether the number of the gas discharge holes is one or plural. On the other hand, in the case where gas is released upwardly from the side of the outer periphery of the flange-shaped member after being introduced from any position of the lower surface of the flange-shaped member, or from a region of the outer peripheral surface of the tundish upper nozzle below the flange-shaped member, the length L means a length to the outer peripheral surface of the flange-shaped member.

[0031] Even if these are coexistent, with regard to each discharge gas, the ratio of the inner bore-side gas to the floating gas according to the above formulas is determined by the length L (mm). Whether or not to make them coexist, and how to set the number are related to control of the gas discharge amount and mode as the entire tundish upper nozzle structure, and may be set depending on individual operation conditions (arbitrarily).

[0032] The right-hand side of the formulas 1 and 2 can be graphically shown as FIG. 2 which means that, when the length L is on or in a region above an approximate line in FIG. 2, it is possible to cause almost the entirety of gas to float upwardly, and when the length L is in a region below the approximate line, it is possible to adjust the flow rate of gas flowing downwardly toward the inner bore and the flow rate of gas floating upwardly.

[0033] Next, a technical basis (derivation basis) of the formulas 1 and 2 or the like will be described.

[0034] First of all, a simulation was carried out by using flow analysis software (Fluent), under the following conditions:

- The inner bore diameter of the tundish upper nozzle was set to 80 mmcp;
- The space was set to about 12 mm with respect to the diameter 100 mmcp of a fitting area in a fully closed state during stopper control;
- The gas discharge hole was composed of a 0.3 mmcp through-hole → 13b (24 holes), 13a (6 holes);
- A gas bubble diameter was set to 3.5 mmcp; and
- The casting speed was set in the range of 0 to 5 t/min.

[0035] Further, a water model experiment was carried out under the following conditions:

- The inner bore diameter of the tundish upper nozzle was set to 80 mmcp;
- The space was set to about 15 mm with respect to the diameter 100 mmcp of the fitting area in the fully closed state during stopper control;
- The gas discharge hole was composed of a 0.3 mmφ through-hole (as a result, the gas bubble diameter was in the range of about 1.5 to 3.5 mmcp); and
- The casting speed was set to 3 t/min.

[0036] From results of previous experiments and actual operations, etc., the present inventors have found that when the diameter of the gas discharge hole is 0.3 mmcp, the gas bubble diameter in water (water model) is in the range of about 1.5 to 3.5 mmcp, whereas the gas bubble diameter in molten steel becomes 2 to 3 times, and that the gas bubble diameter when using the 0.3 mmφ through-hole is almost the same as the gas bubble diameter when using an alumina-graphite based porous material (so-called "porous refractory material", average pore size: about 100 to 200 μm).

[0037] Through the simulation carried out by variously changing the casting speed, the length L as a boundary value at which it is possible to cause almost the entirety of gas blown from the outer periphery (gas discharge holes 13a) to float upwardly (plots in FIG. 2) was obtained. This result was expressed as an approximate line and an approximate formula by regression analysis to obtain the following formula 3:

$$LB = -1.875 M^2 + 26.332 M - 0.3929 \quad \text{--- Formula 3}$$

[0038] In comparison between the simulation and the water model experiment, their results for the length L (mm) are approximately coincident with each other.

[0039] Rephrasing the above, the length L (mm) can be set to be equal to or greater than a boundary length LB (mm)

satisfying the formula 3 to cause almost the entirety of the gas to float upwardly, or can be set to be less than the boundary length LB (mm) to adjust the flow rate of gas flowing downwardly toward the inner bore and the flow rate of gas floating upwardly.

[0040] In FIG. 2, since the vertical axis L (mm) is a length from the position on the vertical extension of the inner bore surface 11b at the lower end of the tundish upper nozzle, it includes the wall thickness of the tundish upper nozzle at an installation position of the flange-shaped member. Thus, the presence of the flange-shaped member in the present invention is conditional on satisfying the following relationship: the wall thickness (mm) < LB (mm).

[0041] Further, in usual (many) casting operations, it is often the case that the flow rate of gas floating upwardly decreases when the casting speed per tundish upper nozzle is about 3 (t/min) or more. Considering this actual situation, as long as the length L (mm) is 60 mm or more, almost the entirety of the gas will float upwardly.

[0042] That is, in usual (many) casting operations, in order to cause almost the entirety of gas blown from the outer periphery (gas discharge holes 13a) to float upwardly, it is necessary to satisfy the relationship: $L \geq 60$ mm, and when $L < 60$ mm, the flow rate of gas flowing downwardly toward the inner bore becomes larger as the length L becomes smaller (see FIG. 3).

[0043] Some modifications of the above embodiment (FIG. 1) will be described below.

[0044] (A) In the above embodiment, the flange-shaped member 12 is provided along the entirety of the outer periphery (circumference) of the upper end of the tundish upper nozzle 11. Alternatively, the flange-shaped member 12 may be provided along a part of the outer periphery (circumference) of the upper end of the tundish upper nozzle 11. Even if the flange-shaped member 12 is provided along a part of the outer periphery of the upper end of the tundish upper nozzle 11, it is possible to obtain the effect of causing gas to float within the tundish (the effect of causing inclusions to float within the tundish) more than a little.

[0045] Further, a plan-view shape of the flange-shaped member 12 is not limited to a circular shape, but may be, e.g., an elliptical shape or a polygonal shape.

[0046] (B) In the above embodiment, the gas discharge hole 13a is provided plurally (six at even intervals in the circumferential direction) in a region of the outer peripheral surface of the tundish upper nozzle 11 below the flange-shaped member 12. Alternatively, the gas discharge hole 13a may be provided by the number of one or more, in one or more of the lower surface, the outer peripheral surface and the top surface of the flange-shaped member 12. In the case where the gas discharge hole 13a is provided in the flange-shaped member 12 in this manner, the gas discharge hole 13a of the flange-shaped member 12 may be an end of a gas distribution passage which is an internal space of the flange-shaped member 12, or a through-hole penetrating between the lower surface and the top surface of the flange-shaped member 12.

[0047] (C) In the above embodiment, the space S allowing gas to pass therethrough is defined along the lower surface of the flange-shaped member 12. Alternatively or additionally, the lower surface of the flange-shaped member 12 may be provided with one or more grooves each allowing gas to pass therethrough.

[0048] In this case, the groove includes a configuration in which the lower surface of the flange-shaped member 12 is curved in the circumferential direction such that a part of the lower surface in the circumferential direction is formed as an upwardly concave portion, and the upwardly concave portion is extended in the radial direction. That is, the groove may have a structure serving as a gas distribution passage capable of causing gas to flow in a direction toward the outer periphery of the flange-shaped member 12 in a concentrated manner.

[0049] Further, in place of the space S, a porous refractory material having high gas-permeability may be provided at the position of the space S.

[0050] (D) In the above embodiment, the flange-shaped member 12 is joined to the tundish upper nozzle 11 by an adhesive. Alternatively, the flange-shaped member 12 may be joined to the tundish upper nozzle 11 by a screw, or a bayonet structure,

[0051] Further, the flange-shaped member 12 may be fitted onto the outer periphery of the tundish upper nozzle 11, and joined to a tuyere 31 adjacent to the tundish upper nozzle 11, or a refractory layer 32 in the bottom of the tundish (tundish bottom refractory layer 32). In this case, the joining may be achieved by a screw, or a bayonet structure, or an adhesive.

[0052] (E) The tundish upper nozzle structure 10 according to the above embodiment is used for operation of continuous casting of steel in which the flow rate of molten steel is controlled by the stopper 20. Alternatively, the tundish upper nozzle structure of the present invention may be used for operation of continuous casting of steel in which the flow rate of molten steel is controlled by a sliding nozzle device. That is, the present invention may be applied to a structure in which there is no so-called obstruction for changing the flow of molten steel, above the tundish upper nozzle.

EXAMPLES

[0053] Under the below-mentioned casting conditions and tundish upper nozzle conditions, a steel continuous casting test in which the flow rate of molten steel is controlled by a stopper was carried out using a conventional structure devoid

of the flange-shaped member 12 (Comparative Example) and inventive structures provided with the flange-shaped member 12, wherein the length L (mm) was changed in the range of 30 to 60 cm (Inventive Examples), and the thickness of adhered alumina inside the tundish upper nozzle, and the number of occurrences of a surface defect of a coil as a product were evaluated. Specifically, the thickness of adhered alumina inside the tundish upper nozzle in each of the inventive structures was indexed on the assumption that the thickness of adhered alumina inside the tundish upper nozzle in the conventional structure was set to 100. A smaller value of the index of the thickness of adhered alumina inside the tundish upper nozzle means a smaller value of the thickness of adhered alumina inside the tundish upper nozzle. Further, the number of occurrences of the surface defect of the coil in each of the inventive structures was indexed on the assumption that the number of occurrences of the surface defect of the coil in the conventional structure was set to 1.0. A smaller value of the index of the number of occurrences of the surface defect of the coil means a smaller value of the number of occurrences of the surface defect of the coil, i.e., better quality of slab.

< Casting Conditions >

[0054]

- Steel grade: general aluminum killed steel
- Cast size: 250 mm (thickness) × 1250 mm (width)
- Casting speed (throughput of molten steel): about 3 (t/min)

< Tundish Upper Nozzle Conditions >

[0055]

- Inner bore diameter: 80 mm
- Diameter × number of gas discharge holes: 0.3 (mm) × 13b (24 holes), 13a (6 holes)
- Discharge rate of gas (Ar): 10 (L/min)
- Discharge velocity of gas (Ar): 1.56 (m/min)

[0056] Table 1 shows a result of the continuous casting test. In this continuous casting test, since the casting speed (throughput of molten steel) is about 3 (t/min), the boundary length LB in the formula 3 is about 60 mm.

[0057] The floating volume (rate) of gas bubbles is an index on the assumption that the total flow of gas is set to 100, and is based on an estimated value (Inventive Examples) from visual observation, water model experiment or the like, wherein 100 means that almost the entirety of gas bubbles floats upwardly, and 0 means that the entirety of gas bubbles flows toward the inner bore.

[TABLE 1]

	Comparative Example	Inventive Example		
	1	1	2	3
L (mm)	-	30	45	60
Floating volume (rate) of gas bubbles discharged from holes 13b	0	0	0	0
Floating volume (rate) of gas bubbles discharged from holes 13a	0	10	40	100
Index of thickness of adhered alumina inside nozzle	1.0	1.0	0.9	0.7
Index of number of occurrences of surface defect of coil	1.0	0.95	0.9	0.6

[0058] As shown in Table 1, in the inventive structure (Inventive Example 3) in which the length L is equal to or greater than the boundary length LB (about 60 mm), the thickness of adhered alumina inside the tundish upper nozzle became smaller, and the number of occurrences of the surface defect of the coil also became smaller, as compared with the conventional structure 'Comparative Example 1).

[0059] The inventive structure (Inventive Examples 1 and 2) in which the length L is less than the boundary length LB (about 60 mm) shows that the length L (mm) can be adjusted to adjust the ratio of the floating volume of gas bubbles to the inner bore-side volume of gas bubbles, thereby adjusting quality of slab.

LIST OF REFERENCE SIGNS

[0060]

- 5 10: tundish upper nozzle structure
11: tundish upper nozzle
11a: inner bore
11b: inner bore surface
12: flange-shaped member
10 13a, 13b: discharge hole
20: stopper
30: tundish
31: tuyere
32: tundish bottom refractory layer
15 S: space

Claims

- 20 1. A tundish upper nozzle structure comprising: a tundish upper nozzle; and a flange-shaped member having an outside
dimension greater than that of an upper end of the tundish upper nozzle, the flange-shaped member being provided
along a part or an entirety of a circumference of the upper end of the tundish upper nozzle, wherein the tundish
upper nozzle structure has one or more gas discharge holes provided in one or more surfaces selected from the
group consisting of a lower surface, an outer peripheral surface and a top surface of the flange-shaped member,
25 and a region of an outer peripheral surface of the tundish upper nozzle below the flange-shaped member.
- 30 2. The tundish upper nozzle structure as claimed in claim 1, wherein the gas discharge hole is provided in the flange-
shaped member, wherein the gas discharge hole is an end of a gas distribution passage which is an internal space
of the flange-shaped member, or a through-hole penetrating between the lower surface and the top surface of the
flange-shaped member.
- 35 3. The tundish upper nozzle structure as claimed in claim 1 or 2, wherein the lower surface of the flange-shaped
member is provided with one or more grooves each allowing gas to pass therethrough.
- 40 4. The tundish upper nozzle structure as claimed in claim 1 or 2, which is configured such that, in a state in which the
tundish upper nozzle structure is attached to a tundish, a space allowing gas to pass therethrough is defined along
a part or an entirety of the lower surface of the flange-shaped member.
5. The tundish upper nozzle structure as claimed in any one of claims 1 to 4, which is used for operation of continuous
casting of steel in which a flow rate of molten steel is controlled by a stopper, wherein a length L (mm) from a position
on a vertical extension of an inner bore surface at a lower end of the tundish upper nozzle to the gas discharge hole
in the top surface of the flange-shaped member or the outer peripheral surface of the flange-shaped member satisfies
the following formula 1:

$$L \geq -1.875 \, M^2 + 26.332 \, M - 0.3929,$$

where M denotes a casting speed (t/min).

- 50 6. The tundish upper nozzle structure as claimed in any one of claims 1 to 4, which is used for operation of continuous casting of steel in which a flow rate of molten steel is controlled by a stopper, wherein a length L (mm) from a position on a vertical extension of an inner bore surface at a lower end of the tundish upper nozzle to the gas discharge hole in the top surface of the flange-shaped member or the outer peripheral surface of the flange-shaped member satisfies the following formula 2:

$$L < -1.875 M^2 + 26.332 M - 0.3929,$$

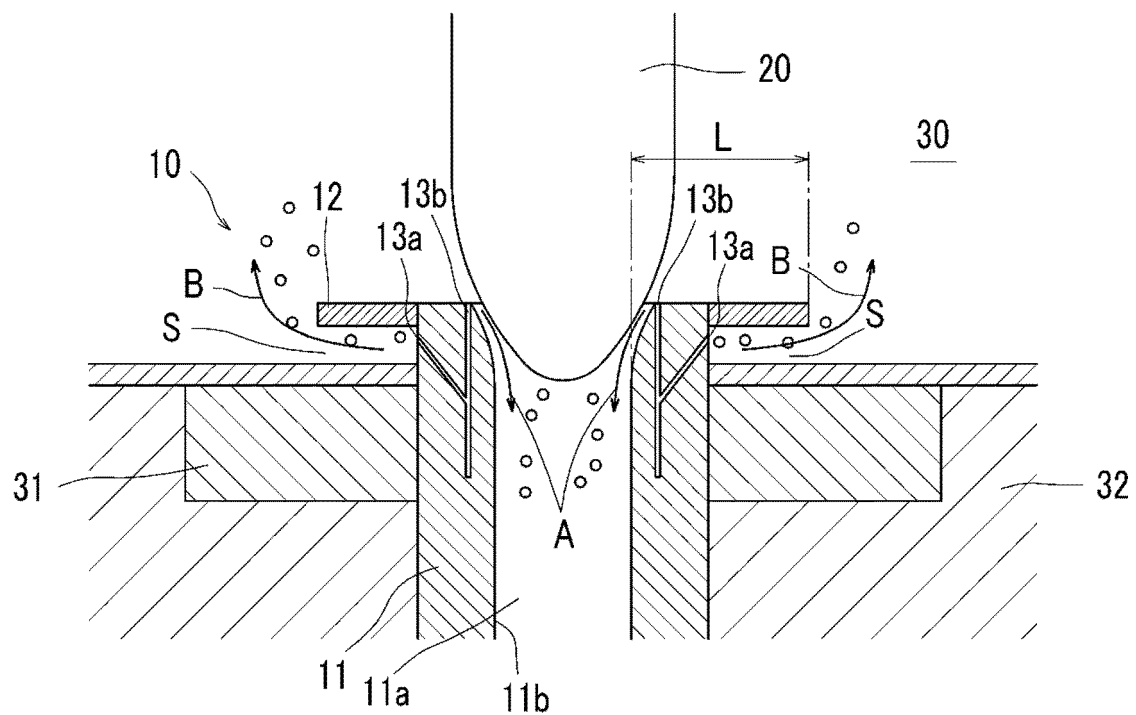
where M denotes a casting speed (t/min).

7. The tundish upper nozzle structure as claimed in any one of claims 1 to 5, wherein the length L (mm) from the position on the vertical extension of the inner bore surface at the lower end of the tundish upper nozzle to the gas discharge hole in the top surface of the flange-shaped member or the outer peripheral surface of the flange-shaped member is 60 mm or more.
8. The tundish upper nozzle structure as claimed in any one of claims 1 to 7, wherein the flange-shaped member is joined to the tundish upper nozzle.
9. The tundish upper nozzle structure as claimed in claim 8, wherein the flange-shaped member and the tundish upper nozzle are joined together by a screw, or a bayonet structure, or an adhesive.
10. The tundish upper nozzle structure as claimed in any one of claims 1 to 7, wherein the flange-shaped member is fitted onto an outer periphery of the tundish upper nozzle, and joined to a tuyere adjacent to the tundish upper nozzle, or a refractory layer in a bottom of a tundish.
11. The tundish upper nozzle structure as claimed in claim 10, wherein the flange-shaped member, and the tuyere or the refractory layer in the bottom of the tundish, are joined together by a screw, or a bayonet structure, or an adhesive.
12. A continuous casting method using the tundish upper nozzle structure as claimed in any one of claims 1 to 4, wherein the tundish upper nozzle structure is used for operation of continuous casting of steel in which a flow rate of molten steel is controlled by a stopper, the continuous casting method comprising: setting a length L (mm) from a position on a vertical extension of an inner bore surface at a lower end of the tundish upper nozzle to the gas discharge hole in the top surface of the flange-shaped member or the outer peripheral surface of the flange-shaped member, to be equal to or greater than a boundary length LB (mm) satisfying the following formula 3, thereby causing almost the entirety of the gas to float upwardly; or setting the length L (mm) to be less than the boundary length LB (mm), to adjust a flow rate of gas flowing downwardly toward an inner bore of the tundish upper nozzle, and a flow rate of gas floating upwardly;

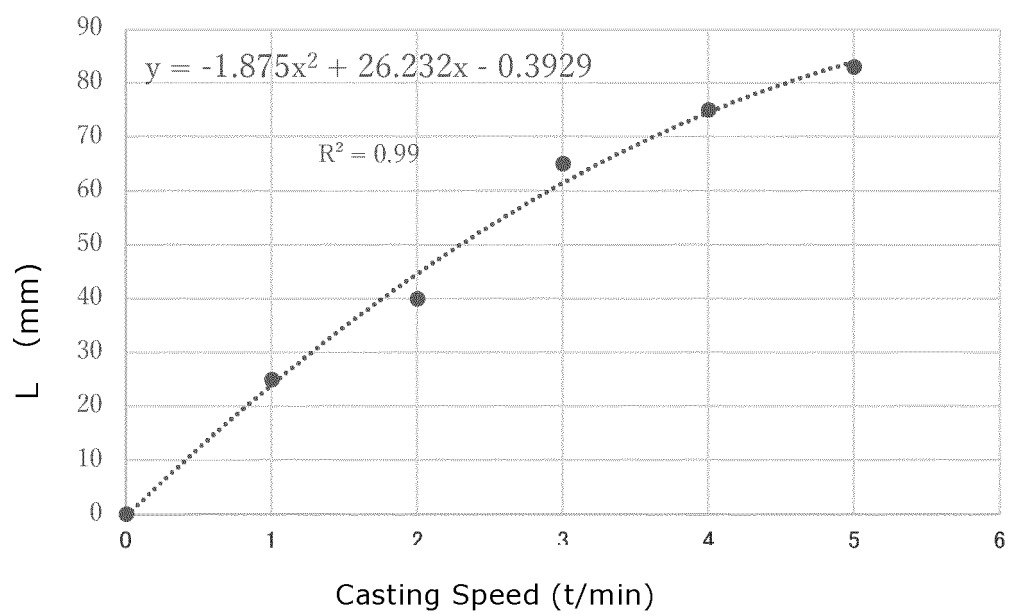
$$L = -1.875 M^2 + 26.332 M - 0.3929,$$

where M denotes a casting speed (t/min).

【Fig.1】

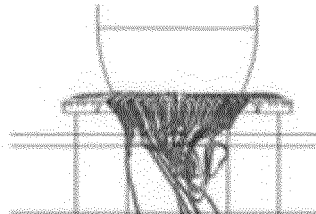


【Fig.2】

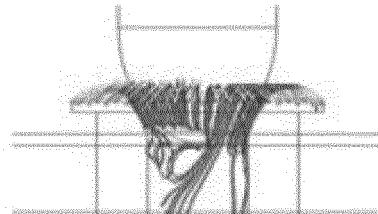


【Fig.3】

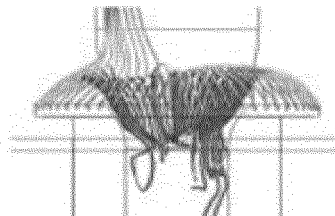
①L=20mm



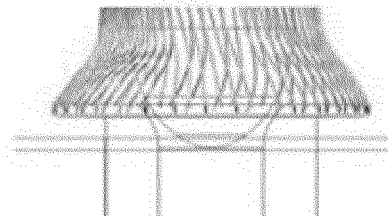
②L=30mm



③L=40mm



④L=60mm



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/035165

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A. CLASSIFICATION OF SUBJECT MATTER

B22D 1/00 (2006.01)i; B22D 11/10 (2006.01)i; B22D 11/11 (2006.01)i; B22D 41/16 (2006.01)i; B22D 41/58 (2006.01)i

FI: B22D11/10 320F; B22D11/11 B; B22D11/10 360Z; B22D41/16; B22D41/58; B22D1/00 P

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

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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B22D1/00; B22D11/10; B22D11/11; B22D41/16; B22D41/58

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4360190 A (ATO, Junichi) 23 November 1982 (1982-11-23) claims, column 1, line 67 to column 4, line 24, fig. 1-4	1-12
X	EP 0059805 A1 (ATO, Junichi) 15 September 1982 (1982-09-15) page 3, line 10 to page 9, line 13, fig. 1-4	1-12
Y	JP 2006-61943 A (KROSAKI HARIMA CORPORATION) 09 March 2006 (2006-03-09) paragraphs [0001]-[0009], [0048]-[0067], fig. 1-6	1, 5-12
Y	JP 5-4933 Y2 (NISSHIN STEEL CO., LTD.) 08 February 1993 (1993-02-08) claims, column 3, line 4 to column 4, line 29, fig. 1	1, 5-12

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Further documents are listed in the continuation of Box C.



See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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Date of the actual completion of the international search
27 November 2020 (27.11.2020)Date of mailing of the international search report
08 December 2020 (08.12.2020)

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Telephone No.

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

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INTERNATIONAL SEARCH REPORT		International application No. PCT/JP2020/035165
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2000-254772 A (NISSHIN STEEL CO., LTD.) 19 September 2000 (2000-09-19) paragraphs [0001], [0006]-[0010], fig. 1-2	1, 5-12
A	JP 01-284473 A (TOSHIBA CERAMICS CO., LTD.) 15 November 1989 (1989-11-15) entire text, all drawings	1-12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/JP2020/035165

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
US 4360190 A	23 Nov. 1982	(Family: none)	
EP 0059805 A1	15 Sep. 1982	(Family: none)	
JP 2006-61943 A	09 Mar. 2006	(Family: none)	
JP 5-4933 Y2	08 Feb. 1993	(Family: none)	
JP 2000-254772 A	19 Sep. 2000	(Family: none)	
JP 01-284473 A	15 Nov. 1989	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

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- JP 2003220450 A [0008]
- JP H06297118 A [0008]
- JP 2016182612 A [0008]