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(71) Applicant: **Krosakiharima Corporation**
Kitakyushu-shi, Fukuoka 806-8586 (JP)

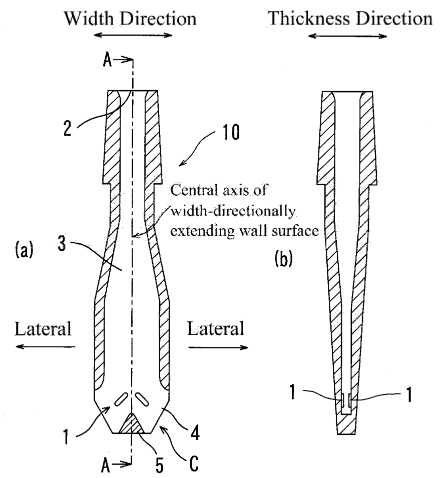
(72) Inventors:
- **FUKUNAGA, Shinichi**
  Kitakyushu-shi,
  Fukuoka 806-8586 (JP)
- **KATSUKI, Kazuhisa**
  Kitakyushu-shi,
  Fukuoka 806-8586 (JP)
- **YANO, Junya**
  Kitakyushu-shi,
  Fukuoka 806-8586 (JP)
- **FURUKAWA, Hiroki**
  Kitakyushu-shi,
  Fukuoka 806-8586 (JP)

(74) Representative: **Vossius & Partner**
Patentanwälte Rechtsanwälte mbB
Siebertstraße 3
81675 München (DE)

(54) IMMERSION NOZZLE

(57) It is intended to provide a flat immersion nozzle capable of stabilizing a molten steel discharge flow to stabilize an in-mold bath surface, i.e., reduce the fluctuation of the in-mold bath surface. Provided is an immersion nozzle having a flat portion whose inner bore has a thickness Tn and a width Wn greater than the thickness Tn, wherein two lateral protrusions 1 each protruding in a thickness direction are provided on each of opposed walls of the flat portion extending in a width direction. The lateral protrusions 1 are arranged at axial symmetrical positions with respect to a longitudinal central axis of the width-directionally extending walls, in pairs, such that each of them extends obliquely downwardly in the width direction, wherein two pairs of the lateral protrusions are arranged, respectively, on the opposed width-directionally extending walls, in opposed relation.

[Fig 1]



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Description

TECHNICAL FIELD

[0001] The present invention relates to an immersion nozzle for use in continuous casting to pour molten steel from tundish into a mold, and more particularly to an immersion nozzle, such as those used for continuous casting of a thin slab, a medium-thick slab or the like, which is flat in terms of transverse cross-section (cross-section in a direction perpendicular to a vertical direction) near a discharge port of the immersion nozzle.

BACKGROUND ART

[0002] In a continuous casting process for forming a slab having a given shape by continuously subjecting molten steel to cooling and solidification, molten steel is poured into a mold via an immersion nozzle for continuous casting (hereinafter also referred to simply as "immersion nozzle") installed with respect to the bottom of a tundish.

[0003] Generally, the immersion nozzle is composed of a bottomed tubular body which has an upper end serving as an inlet of molten steel, and a molten steel flow passage (inner bore) internally formed to extend downwardly from the molten steel inlet, wherein a pair of discharge ports communicated with the molten steel flow passage (inner bore) are formed in a lateral wall of a lower portion of the tubular body in opposed relation to each other. The immersion nozzle is used in a state in which the lower portion thereof is immersed in molten steel in a mold. This is intended to prevent scattering of poured molten steel, and further block contact of the molten steel with the atmosphere, thereby preventing oxidation thereof. Further, the use of the immersion nozzle is intended to allow the flow of molten steel in the mold to be straightened, thereby preventing impurities such as slag or non-metal inclusions floating on the surface of the molten steel from being entrained into the molten steel.

[0004] In recent years, there has been a growing tendency toward manufacturing thinned slabs such as a thin slab and a medium-thick slab during continuous casting. In order to cope with a thin mold for this type of continuous casting, the immersion nozzle needs to be flattened. For example, the below-mentioned Patent Document 1 discloses a flat immersion nozzle in which a discharge port is provided in a short-side lateral wall; and in the below-mentioned Patent Document 2 discloses a flat immersion nozzle in which a discharge port is further provided in a lower end wall. Generally, such a flat immersion nozzle is configured such that the width of an inner bore thereof is increased between a molten steel inlet thereof and the discharge port in a direction from the molten steel inlet toward a mold.

[0005] However, when the inner bore has a region where it is increased in terms of width, and flattened, the flow of molten steel inside the immersion nozzle becomes more likely to be disordered, and thus a discharge flow toward the mold also becomes more likely to be disordered. Resulting turbulence of the molten steel flow becomes a factor causing defective quality of slabs, an increase in danger during casting operation, etc., such as an increase in fluctuation of the surface of (molten steel) bath in the mold (in-mold bath surface), entrainment of a mold powder into a slab, or unevenness in temperature. Therefore, it is necessary to stabilize a molten steel flow inside the immersion nozzle and a molten steel flow during discharge.

[0006] With a view to stabilizing the above molten steel flows, for example, the below-mentioned Patent Document 3 discloses an immersion nozzle formed with at least two bending facets extending from a point (center) on a plane in a lower region of an inner bore toward a lower edge of a discharge port. The Patent Document 3 also discloses an immersion nozzle comprising a flow divider for dividing a molten steel flow into two streams. In the flat immersion nozzle disclosed in the Patent Document 3, the stability of the molten steel flow inside the immersion nozzle are enhanced, as compared with the immersion nozzles disclosed in the Patent Documents 1 and 2, in which there is not any means to change a flow direction/pattern in an internal space thereof.

[0007] However, the means to divide the molten steel flow in a right-left direction is still likely to cause a situation where the fluctuation of the molten steel discharge flow between right and left discharge ports is increased, and thereby the fluctuation of the in-mold bath surface is increased.

[0008] Under the above background, the present inventors have invented a flat immersion nozzle disclosed in the below-mentioned Patent Document 4, thereby contributing to stabilizing an in-mold bath surface, etc.

CITATION LIST

[Patent Document]

[0009]

Patent Document 1: JP-A H11-005145
Patent Document 2: JP-A H11-047897

Patent Document 3: JP-A 2001-501132
Patent Document 4: WO-A2017/081934

SUMMARY OF INVENTION

[Technical Problem]

[0010] However, the present inventors has found that, in continuous casting carried out under casting conditions, particularly, a condition of a molten steel flow rate of about 0.04 (t / (min·cm^2)) or more, as measured with reference to the position of minimum cross-sectional area in a region around an upper end of the immersion nozzle where a transverse cross-section of the inner bore is a circular shape, even the flat immersion nozzle disclosed in the Patent Document 4 is still insufficient in terms of the intended effects such as stabilization of an in-mold bath surface.

[0011] Therefore, a problem to be solved by the present invention is to provide a flat immersion nozzle capable of stabilizing an in-mold bath surface, i.e., reducing the fluctuation of the in-mold bath surface.

[Solution to Technical Problem]

[0012] In the flat immersion nozzle disclosed in the Patent Document 4, primarily, a protrusion (protruding portion) is provide in a central region of an inner bore (inner hole) of the nozzle, as a basic configuration, and optionally a protrusion having a protruding thickness equal to or less than that of the central protrusion is provide beside the central protrusion to finely adjust a discharge flow direction, a discharge flow/pattern, or the like.

[0013] Differently, in the present invention, symmetrical lateral (laterally-offset) protrusions are provided, wherein a space having no protrusion is defined between the lateral protrusions, as a basic configuration, and optionally a protrusion having a protruding length less than that of each of the lateral protrusion is provided.

[0014] In the structure of the flat immersion nozzle disclosed in the Patent Document 4, the molten steel flow inside the inner bore is guided such that the flow rate thereof becomes larger in a lateral direction (which means a width direction of a flat portion of the nozzle. this is also applied to the following description) than in a central and vertically downward direction. In this case, the flow velocity of molten steel discharged from the discharge port tends to be increased, and, under the condition that a molten steel flow rate per unit time or per unit area is relatively large, the fluctuation of the in-mold bath surface is likely to be increased.

[0015] Differently, in the structure of the flat immersion nozzle of the present invention, the molten steel flow inside the inner bore is guided, while being adjusted to increase the flow rate thereof in the central and vertically downward direction, thereby relatively reducing the flow rate thereof in the lateral direction. In other words, the ratio of the flow rate in the central and vertically downward direction / the flow rate in the lateral direction is relatively increased as compared with that in the structure of the flat immersion nozzle disclosed in the Patent Document 4.

[0016] It should be noted here that the above adjustment is made in relation to the ratio of the flow rate in the central and vertically downward direction / the flow rate in the lateral direction, but is not necessarily made to establish the relationship of the central and vertically downward direction

> the flow rate in the lateral direction.

[0017] The present invention intended to obtain the above flow pattern provides a flat immersion nozzle having features described in the following sections 1 to 8.

1. An immersion nozzle having a flat portion whose inner bore has a thickness Tn and a width Wn greater than the thickness Tn, and which comprises opposed short-side lateral walls and opposed long-side walls extending in a width direction of the flat portion, wherein a pair of discharge ports are provided, respectively, in lower parts of the short-side lateral walls. The immersion nozzle comprises two portions provided on each of the width-directionally extending walls, and arranged at axial symmetrical positions with respect to a longitudinal central axis of the width-directionally extending walls, in pairs, wherein each of the portions extends obliquely downwardly in the width direction and protruding in a thickness direction of the flat portion (the portion will hereinafter be referred to as "lateral protrusion"), wherein two pairs of the lateral protrusions are arranged, respectively, on the width-directionally extending walls, in opposed relation, and wherein two sets of opposed lateral protrusions in the two pairs of lateral protrusions have a same value falling within a range of 0.18 to 0.90 in terms of a total protruding length Ts in the thickness direction, expressed as an index on the basis of 1 indicative of a thickness of the inner bore at a position where the opposed lateral protrusions are provided.
2. The immersion nozzle as described in the section 1, which further comprises a protrusion provided on each of the width-directionally extending walls at a position between two lateral protrusions in each of the two pairs of lateral

protrusions (this protrusion will hereinafter be referred to as "central protrusion"), wherein the central protrusion has a thickness-directional protruding length less than that of the lateral protrusion, and wherein two central protrusions in the two pairs of lateral protrusions have a value of 0.40 or less (not including zero) in terms of a total protruding length Tp in the thickness-direction, expressed as an index on the basis of 1 indicative of the thickness of the inner bore at the position where the opposed lateral protrusions are provided.

3. The immersion nozzle as described in the section 2, wherein an upper end surface of the central protrusion has one selected from the group consisting of a shape extending horizontally in the width direction, a curved shape having a top at a midpoint thereof, and an upwardly protruding shape including a bending point.

4. The immersion nozzle as described in any one of the sections 1 to 3, wherein an upper end surface of the lateral protrusion or the central protrusion has a shape extending horizontally in a direction toward a center of the inner bore, or a planar or curved shape extending obliquely downwardly in the direction toward the center of the inner bore.

5. The immersion nozzle as described in any one of the sections 1 to 4, wherein one or each of the lateral protrusion and the central protrusion has a shape in which the thickness-directional protruding length thereof is constant, or becomes shorter linearly, curvilinearly or stepwisely in a direction toward a center of the width-directionally extending wall.

6. The immersion nozzle as described in any one of the sections 1 to 5, wherein one or each of the lateral protrusion, and the lateral protrusion combined with the central protrusion is provided plurally in an up-down direction.

7. The immersion nozzle as described in any one of the sections 1 to 6, which comprises a protrusion provided around a center of a bottom of the inner bore to protrude upwardly.

8. The immersion nozzle as described in any one of the sections 1 to 7, which is used for continuous casting carried out under conditions including a molten steel flow rate of 0.04 (t / (min·cm^2)) or more, as measured with reference to a position of minimum cross-sectional area in a region around an upper end of the immersion nozzle where a transverse cross-section of the inner bore has a circular shape.

[0018] In the present invention, the terms "width Wn" and "thickness Tn" of the inner bore means, respectively, a width (length in a long-side direction) and a thickness (length in a short-side direction) at positions of upper ends of the pair of discharge ports provided in the short-side lateral wall of the immersion nozzle.

[Effect of Invention]

[0019] The flat immersion nozzle of the present invention can control a molten steel flow to gradually increase/reduce the flow rate thereof in a continuous manner, without fixedly or completely separating the direction of the molten steel flow over the range from a central region to a lateral region inside the immersion nozzle, thereby ensuring an appropriate balance of molten steel flows within the immersion nozzle. Thus, even in continuous casting carried out under casting conditions, particularly, a condition of a molten steel flow rate of about 0.04 (t / (min·cm^2)) or more, as measured with reference to the position of minimum cross-sectional area in a region around an upper end of the immersion nozzle where a transverse cross-section of the inner bore is a circular shape, wherein the continuous casting tends to cause a situation where a high-speed or high-volume molten steel flow is generated on the side of each of the lateral discharge ports, it becomes possible to appropriately suppress the flow velocity or flow rate of molten steel discharged from the discharge ports to stabilize the in-mold bath surface or the like, i.e., reduce the fluctuation of the in-mold bath surface or the like.

[0020] Then, since the fluctuation of the in-mold bath surface is suppressed, it becomes possible to reduce entrainment of a mold powder or the like into the mold, and promote floating of in-molten steel inclusions, thereby improving quality of slabs. Further, since an excessive molten steel flow toward lateral walls of the mold is suppressed, it becomes possible to reduce a risk of the occurrence of accident such as breakout.

BRIEF DESCRIPTION OF DRAWINGS

[0021]

FIG. 1 is a conceptual diagram showing an example of an immersion nozzle of the present invention (an immersion nozzle according to a first embodiment of the present invention), which is provided with two pairs of lateral protrusions, wherein FIG. 1(a) is a schematic sectional view taken along a vertical plane passing through the center of a short side of a flat portion of the immersion nozzle, and FIG. 1(b) is a schematic sectional view taken along a vertical plane passing through the center of a long side of the flat portion (taken along the line A-A in FIG. 1(a)).

FIG. 2 is a conceptual diagram showing another example of the immersion nozzle of the present invention (an immersion nozzle according to a second embodiment of the present invention), which is provided with the two pairs of lateral protrusions (lower lateral protrusions) in FIG. 1 and two pairs of upper lateral protrusions each at a position on the upper side of a respective one of the two pairs of lower lateral protrusions, wherein FIG. 2(a) is a schematic sectional view taken along a vertical plane passing through the center of a short side of a flat portion of the immersion nozzle, and FIG. 2(b) is a schematic sectional view taken along a vertical plane passing through the center of a long side of the flat portion (taken along the line A-A in FIG. 2(a)).

FIG. 3 is a conceptual diagram showing yet another example of the immersion nozzle of the present invention (an immersion nozzle according to a third embodiment of the present invention), which is provided with the two pairs of lateral protrusions in FIG. 1 and two central protrusions each at a position between a respective one of the two pairs of lateral protrusions, wherein FIG. 3(a) is a schematic sectional view taken along a vertical plane passing through the center of a short side of a flat portion of the immersion nozzle, and FIG. 3(b) is a schematic sectional view taken along a vertical plane passing through the center of a long side of the flat portion (taken along the line A-A in FIG. 3(a)).

FIG. 4 is a conceptual diagram showing still another example of the immersion nozzle of the present invention (an immersion nozzle according to a fourth embodiment of the present invention), which is provided with the two pairs of lateral protrusions (lower lateral protrusions) and the two central protrusions in FIG. 3 and two pair of upper lateral protrusions each at a position on the upper side of a respective one of the pair of lower lateral protrusions, wherein FIG. 4(a) is a schematic sectional view taken along a vertical plane passing through the center of a short side of a flat portion of the immersion nozzle, and FIG. 4(b) is a schematic sectional view taken along a vertical plane passing through the center of a long side of the flat portion (taken along the line A-A in FIG. 4(a)).

FIG. 5 is a schematic sectional view taken along the vertical plane passing through the center of the short side in FIG. 3 or 4, enlargedly showing a region where the central protrusion is provided between the pair of lateral protrusions, wherein a central part of the central protrusion is convexed upwardly to form a linear reverse-V or chevron shape, and a central part of a bottom protrusion is convexed upwardly to form a linear reverse-V or chevron shape.

FIG. 6 is a schematic top view of an inner bore of the immersion nozzle in FIG. 5, showing a relationship between a set of opposed lateral protrusions and a set of opposed central protrusions.

FIG. 7 is a schematic sectional view taken along a vertical plane passing through the center of a short side of a flat portion of a modification of the immersion nozzle in FIG. 5, wherein an upper end of the central protrusion has a curved surface

FIG. 8 is a schematic sectional view taken along a vertical plane passing through the center of a short side of a flat portion of a modification of the immersion nozzle in FIG. 5, wherein the upper end of the central protrusion has a flat surface

FIG. 9 is a schematic sectional view taken along a vertical plane passing through the center of a long side of a flat portion of a modification of the immersion nozzle in FIG. 3 or 4, wherein an upper surface of the lateral protrusion or the central protrusion is configured to extend obliquely downwardly in a direction toward the center of the inner bore.

FIG. 10 is a schematic top view showing a modification of the immersion nozzle in FIG. 5, where the protruding length of the upper surface of each of the lateral protrusion and the central protrusion is constant (an inner bore-side edge of each of the lateral protrusion and the central protrusion is parallel to an width-directionally extending wall of the flat portion.

FIG. 11 is a schematic top view showing a modification of the immersion nozzle in FIG. 5, where the protruding length of the upper surface of the central protrusion is linearly reduced toward a central region of the width-directionally extending wall.

FIG. 12 is a schematic top view showing a modification of the immersion nozzle in FIG. 5, where the protruding length of the upper surface of the central protrusion is curvilinearly reduced toward the central region of the width-directionally extending wall.

FIG. 13 is a schematic top view showing a modification of the immersion nozzle in FIG. 5, where the protruding length of the upper surfaces of the lateral protrusion and the central protrusion is linearly and continuously reduced toward the central region of the width-directionally extending wall.

FIG. 14 is a schematic sectional view taken along a vertical plane passing through the center of a short side of a flat portion of a modification of the immersion nozzle in FIG. 5, where the bottom protrusion has a flat upper surface.

FIG. 15 is a schematic sectional view taken along a vertical plane passing through the center of a short side of a flat portion of a modification of the immersion nozzle in FIG. 5, where the bottom protrusion has a curved upper surface.

FIG. 16 is a schematic sectional view taken along a vertical plane passing through the center of a short side of a flat portion of a modification of the immersion nozzle in FIG. 5, where the bottom protrusion is formed such that an upper surface thereof has a convex part on a central region thereof, and the diameter thereof gradually increases toward the bottom of the inner bore.

FIG. 17 is a schematic sectional view taken along a vertical plane passing through the center of a short side of a flat portion of a modification of the immersion nozzle in FIG. 5, where the bottom protrusion is also provided with a molten steel discharge port.

FIG. 18 is a conceptual diagram showing a mold and the fluctuation of an in-mold bath surface (molten steel surface), wherein FIG. 18(a) is a schematic top view of the vicinity of a bath surface (inner surface) of a mold, and FIG. 18(b) is a schematic sectional view (one half in a longitudinal direction) of the vicinity of the bath surface (inner surface) of the mold, taken along a vertical plane passing through the center of a short side of the mold.

FIG. 19 is a graph showing the fluctuation (maximum value, average of right and left regions) of the in-mold bath surface (molten steel surface) in Inventive Example 3 in Table 1.

DESCRIPTION OF EMBODIMENTS

[0022] Molten steel flows toward width-directional ends can be formed to a certain degree by providing the flow dividing means as disclosed in the aforementioned Patent Document 3. However, such fixed and complete flow dividing is likely to generate molten steel flows separated in each region, i.e., in each small area, of an inner bore, leading to a situation where the flow direction and the flow velocity vary in each position of the inner bore. Particularly, when the flow direction or the flow rate changes due to molten steel flow rate control or the like, significant turbulence is likely to occur in a discharge flow from the inside of an immersion nozzle into a mold, a bath surface, etc.

[0023] Therefore, in the present invention, for example, as shown in a first embodiment thereof illustrated in FIG. 1, a pair of lateral protrusions 1 are first provided on one of opposed (long-side) walls extending in a width direction of a flat portion of an immersion nozzle 10, axially symmetrically with respect to a central axis of the width-directionally extending wall (see FIG. 1(a), etc.; the pair of lateral protrusions will hereinafter be also referred to simply as "axial symmetrical lateral protrusions"),

[0024] Each of the pair of lateral protrusions 1 is configured such that an upper surface thereof is extends from a center-side end of the lateral protrusions 1 obliquely downwardly in the width direction of the flat portion, i.e., obliquely downwardly toward a respective one of a pair of discharge ports 4. Such an inclined surface makes it possible to gently change the flow velocity and flow pattern of molten steel from the inside of an inner bore 3 or the discharge port 4, while suppressing the occurrence of a vortex flow or the like, thereby optimizing the flow velocity and flow pattern of the molten steel.

[0025] The pair of axial symmetrical lateral protrusions are also provided on the other width-directionally extending wall across the inner bore, in plane-symmetrical relation with respect to a thickness direction of the flat portion (see FIG. 1(b); each of two sets of the lateral protrusions arranged in plane-symmetrical relation will hereinafter be also referred to simply as "plane-symmetrical lateral protrusions"). In the present invention, for example, as shown in FIG. 6, the total length Ts in the thickness direction of the plane-symmetrical lateral protrusions is set in the range of 0.18 to 0.90, when expressed as an index on the basis of 1 indicative of the thickness Tn of the inner bore at a position where the plane-symmetrical lateral protrusions are provided. That is, there is a space allowing molten steel to pass therethrough, between the plane-symmetrical lateral protrusions.

[0026] By providing the space having such a spacing, the flow direction and flow velocity of molten steel passing therethrough is gently controlled without fixedly and completely separating a molten steel flow in the inner bore. This makes it possible to mitigate a situation where molten steel flows toward the discharge ports with a clear boundary.

[0027] Further, by adjusting the position, length, direction, etc., of each lateral protrusion, it becomes possible to avoid a molten steel flow concentrating on around the center or lateral sides, and diverge the molten steel flow into two directions toward width-directional ends, i.e., the discharge ports, and a direction toward the central region, while giving adequate balance to the diverged flows. In addition, differently from simple divergence, since respective regions around the lateral protrusions are spatially communicated with each other, the molten steel flow will be diverged, while forming a moderate boundary therebetween, and uniforming flow under gentle mixing, instead of a completely divided state.

[0028] The position, length, direction, etc., of each lateral protrusion can be appropriately adjusted, as mentioned above. For example, in a second embodiment illustrated in FIG. 2, in addition to the two pairs of lateral protrusions (assigned with the reference code 1a in FIG. 2; each of the lateral protrusions 1a will hereinafter be referred to as "lower lateral protrusion"), two pairs of lateral protrusions (assigned with the reference code 1b in FIG. 2; each of the lateral protrusions 1b will hereinafter be referred to as "upper lateral protrusion") are provided, respectively, above the two pairs of lower lateral protrusions.

[0029] Further, in the present invention, a protrusion (central protrusion) having a protruding length less than that of each of the axial symmetrical lateral protrusions may be provided between the axial symmetrical lateral protrusions, as in third and fourth embodiments illustrated FIGS. 3 and 4. More specifically, in the third embodiment illustrated FIG. 3, the central protrusion 1p is provided between the axial symmetrical lateral protrusions 1 illustrated in FIG. 1, and, in the fourth embodiment illustrated FIG. 4, the central protrusion 1p is provided between the axial symmetrical lower lateral protrusions 1 illustrated in FIG. 2.

[0030] This structure brings out an effect opposite to that of a structure in which a protrusion (protrusion portion) having a protruding length greater than that of each of the axial symmetrical lateral protrusions is provided in the Patent Document 4 to allow the flow rate of a molten steel flow toward the lateral ends to become greater than that of a molten steel flow toward between the axial symmetrical lateral protrusions, i.e., an effect of increasing the ratio of the flow rate of the molten steel flow toward between the axial symmetrical lateral protrusions (central region) / the flow rate of the molten steel flow toward the lateral ends. In continuous casting having a relatively large molten steel flow rate (about 0.04 (t / (min·cm^2)) or more), it is effective to increase the ratio of the flow rate of the molten steel flow toward between the axial symmetrical lateral protrusions (central region) / the flow rate of the molten steel flow toward the lateral ends.

[0031] The balance of the molten steel flows to the central region and the lateral ends can be optimized by adjusting the magnitude of the molten steel flow velocity (molten steel flow rate per unit tine or per unit sectional area), a drawing speed, the size and shape of a mold, an immersion depth, a nozzle structure such as the area of the discharge port, etc. Specifically, it is possible to employ a method of adjusting the width-directional or downward angle, width-directional length, protruding length, etc., of each lateral protrusion, a method of selecting the presence or absence of the central protrusion between the axial symmetric lateral protrusion, a method of adjusting the protruding length (height) of the central protrusion, a method of adjusting the shape of an upper end surface of the central protrusion, etc.

[0032] For example, with regard to the protruding length of the central protrusion, as exemplified in FIG. 6, the protruding length Tp/2 thereof is set to be less than the protruding length Ts/2 of the lateral protrusion 1, wherein a total protruding length Tp expressed as an index on the basis of 1 indicative of the thickness of the inner bore at the position where the plane-symmetrical or opposed lateral protrusions are provided. In other words, $Tp < Ts$, wherein $Tp/Tn \leq 0.40$.

[0033] Further, the upper end surface of the central protrusion may be formed in a shape extending horizontally in the width direction, as shown in FIG. 8, or a curved shape having a top at a midpoint thereof, as shown in FIG. 5, or an upwardly protruding shape including a bending point, as shown in FIG. 7. These shapes make it possible to further change the flow velocity and flow pattern of molten steel, thereby optimizing the flow velocity and flow pattern.

[0034] Further, an upper end surface of the lateral protrusion or the central protrusion may be formed in a shape extending from a top thereof at a boundary with the width-directionally extending (long-side) wall of the flat portion of the immersion nozzle, obliquely downwardly in a direction toward a thickness-directional center of the flat portion of the immersion nozzle, i.e., a direction toward the center of the inner bore (toward a space). This inclination makes it possible to further change the flow velocity and flow pattern of molten steel, thereby optimizing the flow velocity and flow pattern.

[0035] Further, the protruding length of the upper end of the lateral protrusion or the central protrusion may be formed to be constant, as shown in FIG. 10, or may be formed to become shorter in a direction toward the center of the width-directionally extending (long-side) wall of the flat portion of the immersion nozzle, as shown in FIGS. 11 to 13. These inclinations make it possible to further change the flow velocity and flow pattern of molten steel, thereby optimizing the flow velocity and flow pattern.

[0036] In the flat immersion nozzle, the discharge port in each of the short-side lateral walls is configured to have an opening which is long in the longitudinal direction. Thus, the discharge flow velocity is likely to be reduced in an upper region of the discharge port, and, particularly in the vicinity of an upper edge of the discharge port, a backflow phenomenon that molten steel is sucked into the immersion nozzle is often observed. Therefore, in the present invention, for example, as shown in FIGS. 2 and 4, in addition to the aforementioned axial symmetrical and plain-symmetrical lower protrusions 1a, one or more sets of axial symmetrical and plain-symmetrical protrusions (upper protrusions) 1b may be provided thereabove. The axial symmetrical and plain-symmetrical upper protrusions 1b may be formed in a similar optimizing configuration to that of the axial symmetrical and plain-symmetrical lower protrusions 1a.

[0037] The axial symmetrical and plain-symmetrical upper protrusions 1b have a function of suppressing, particularly, decrease of the flow velocity in the upper region of the discharge port, or turbulence of a molten steel flow such as the backflow in the vicinity of the upper edge of the discharge port, to complement a function of uniforming the distribution of flow velocity in respective longitudinal positions of the discharge port, and a function of adjusting flow rate balance toward an upper limit.

[0038] A central protrusion may be provided between the axial symmetrical protrusions 1b in a similar manner to the central protrusion between the axial symmetrical protrusions 1a.

[0039] A bottom 5 of the immersion nozzle may be formed as a wall serving simply as a partition wall with respect to a mold without forming any discharge port around the center thereof, as shown in FIG. 14, or may be formed in a configuration comprising a protrusion provided around the center thereof to protrude upwardly, as shown in FIGS. 1 to 5, 7, 8, 15 and 16. Further, a discharge port 6 may be additionally in the bottom 5, as shown in FIG. 17. Such a protrusion of the bottom is useful in changing the flow direction/pattern, flow velocity, etc., when changing a molten steel flow directed toward the ventral region to directions toward the discharge ports.

[0040] Next, the present invention will be described with reference to examples.

[Example A]

[0041] Example A is a result of water model experiments, showing a relationship between the ratio Ts/Tn or Tp/Tn of the protrusion length Ts of the opposed lower lateral protrusions 1a toward a space of the inner bore of the immersion nozzle or the protrusion length Tp of the opposed central protrusions 1p toward the space of the space of the inner bore (the total length of the plane-symmetrical protrusions) to the thickness (length in the short-side direction) Tn of the inner bore of the immersion nozzle, and a degree of fluctuation of the in-mold bath surface (in-mold uneven flow index, in-mold bath surface fluctuation height), with respect to each immersion nozzle according to the second embodiment of the present invention illustrated in FIG. 2, which is provided with the two-stage axial symmetrical and plane-symmetrical lateral protrusions 1a, 1b wherein the central protrusion 1p is not provided between each of the two pairs of lower lateral protrusions 1a, and according to the fourth embodiment of the present invention illustrated in FIG. 4, which is provided with the two-stage axial symmetrical and plane-symmetrical lateral protrusions 1a, 1b are provided, wherein the central protrusion 1p is not provided between each of the two pairs of lower lateral protrusions 1a.

[0042] Specifications of the immersion nozzles are as follows.

▪ Overall length :	1165 mm
▪ Molten steel inlet :	φ 86 mm
▪ Width of inner bore (Wn) at upper edge of discharge port :	255 mm
▪ Thickness of inner bore (Tn) at upper edge of discharge port :	34 mm
▪ Height of upper edge of discharge port from nozzle lower edge face :	146.5 mm
▪ Height of central protrusion (from nozzle lower edge face) :	155 mm:
▪ Thickness of wall of immersion nozzle :	about 25 mm
▪ Thickness of (central top of) bottom of immersion nozzle :	height 100 mm
▪ Upper lateral protrusion (1b)	: Length in width direction of immersion nozzle = 25 mm (In each of right and left upper lateral protrusions)
	Ratio Ts/Tn = 0.74
	Inclination angle toward discharge port = 45 degrees
	Posture of upper end surface in width direction and thickness direction of immersion nozzle = horizontal
	Distance between right and left upper lateral protrusions = 100 mm
	No center protrusion
▪ Lower lateral protrusion (1a)	: Length in width direction of immersion nozzle = 40 mm (In each of right and left lower lateral protrusions)
	Ratio Ts/Tn = 0.1 to 1.0 (no space)
	Inclination angle toward discharge port = 45 degrees
	Posture of upper end surface in width direction and thickness direction of immersion nozzle = horizontal
	Distance between right and left left lateral protrusions = 60 mm
	Ratio Tp/Tn of central protrusions = 0 (no central protrusions) to 0.7

[0043] Conditions of a mold and a fluid are as follows.

▪ Width of mold :	1650 mm
▪ Thickness of mold :	65 mm
	(Central top: 185 mm)
▪ Immersion depth (from upper edge of discharge port to water level):	83 mm
▪ Fluid supply speed :	0.065 t (min·cm^2)

* Value converted to molten steel

[0044] Here, when an in-mold uneven flow index expressed on the basis of 1 indicative of a state in which there is no uneven flow satisfies the following relationship: 0.8 ≤ in-mold uneven flow index ≤ 1.2, and an in-mold bath surface fluctuation height (mm) is equal to or less than 15 mm, an effect capable of solving the problem addressed by the present invention was deemed to be obtained. This was used as evaluation criterion.

[0045] The in-mold uneven flow index means a result obtained by measuring a flow velocity at a set bath surface (at an under-water position of 30 mm from a set upper surface of water) around each of the right and left discharge ports of the immersion nozzle in a mold, in the water model experiment, and expressing the right and left flow velocities as a ratio (absolute value), i.e., an absolute value of the left flow velocity / the right flow velocity (or the right flow velocity / the left flow velocity), and the in-mold bath surface fluctuation height means a maximum value of Sw in FIG. 18.

[0046] A result of evaluation is shown in Table 1.

TABLE 1

[0047] As seen in Table 1, when the ratio of Ts to Tn (Ts/Tn) regarding the lateral protrusions is in the range of 0.18 to 0.90, the in-mold uneven flow index and the in-mold bath surface fluctuation height can satisfy the criterion.

[0048] Further, in the case of the center protrusions are provided, when the protruding length thereof is less than that of the lateral protrusions, and the ratio of Tp to Tn (Tp/Tn) is 0.4 or less, the in-mold uneven flow index and the in-mold bath surface fluctuation height can satisfy the criterion.

[Example B]

[0049] Example B is a result of water model experiments, showing a degree of in-mole bath surface fluctuation when the upper end surface of each of the lower lateral protrusion 1a and the central protrusion 1p is formed in a planar shape extending obliquely downwardly toward the center of the inner bore, as shown in FIG. 9, in the forth embodiment of the present invention illustrated in FIG. 4.

[0050] Here, the ratio Ts/Tn regarding the lower lateral protrusions and the ratio Tp/Tn regarding the central protrusions were set, respectively, to 0.74 and 0.18, and two cases where the inclination angle (θ in FIG. 9) of each of the lower lateral protrusion and the central protrusion toward the center of the inner bore was set to 0 degree (horizontal) and 45 degrees were compared with each other. The remaining conditions are the same as those of Example A.

[0051] A result is shown in FIG. 19. The vertical axis of FIG. 19 represents an average value of maximum bath surface fluctuation values Sw (mm) around the right and left discharge ports, in both the cases where the inclination angle is 0 degree and 45 degrees.

[0052] FIG. 19 shows that, in both the cases where the inclination angle is 0 degree and 45 degrees, the in-mold bath surface fluctuation height is significantly smaller than 15 mm as the criterion, and, in the case where the inclination angle is 45 degrees, the in-mold bath surface fluctuation height is reduced to 2.0 (mm), which is about 1/2 of 3.75 (mm) in the case where the inclination angle is 0 degree.

LIST OF REFERENCE SIGNS

[0053]

10: immersion nozzle

1: lateral protrusion

1a: lower lateral protrusion

1b: upper lateral protrusion

1p: central protrusion

2: molten steel inlet

3: inner bore (molten steel flow passage)

4: discharge port (short side wall)

5: bottom

6: discharge port (bottom)

7: bath surface

20: mold

Wn: width of inner bore of immersion nozzle (length in long-side direction)

Wp: width between opposite ends of lateral protrusion

Wc: width of central protrusion

Tn: thickness of inner fore of immersion nozzle (length in short-side direction)

Ts: protruding length of opposed lateral protrusions toward space (total protruding length of opposed ones)

Tp: protruding length of opposed central protrusions toward space (total protruding length of opposed ones)

ML: width of mold (long side)

Ms: thickness of mold (short side, lateral end)

Mc: thickness of mold (short side, central region)

Sw: fluctuation range of in-mold bath surface (size between top and bottom)

Claims

1. An immersion nozzle having a flat portion whose inner bore has a thickness Tn and a width Wn greater than the thickness Tn, and which comprises opposed short-side lateral walls and opposed long-side walls extending in a width direction of the flat portion, wherein a pair of discharge ports are provided, respectively, in lower parts of the short-side lateral walls, the immersion nozzle comprising

   two portions provided on each of the width-directionally extending walls, and arranged at axial symmetrical positions with respect to a longitudinal central axis of the width-directionally extending walls, in pairs, each of the portions extending obliquely downwardly in the width direction and protruding in a thickness direction of the flat portion (the portion will hereinafter be referred to as "lateral protrusion"),
   wherein two pairs of the lateral protrusions are arranged, respectively, on the width-directionally extending walls, in opposed relation, and
   wherein two sets of opposed lateral protrusions in the two pairs of lateral protrusions have a same value falling within a range of 0.18 to 0.90 in terms of a total protruding length Ts in the thickness direction, expressed as an index on the basis of 1 indicative of a thickness of the inner bore at a position where the opposed lateral protrusions are provided.

2. The immersion nozzle as claimed in claim 1, which further comprises a protrusion provided on each of the width-directionally extending walls at a position between two lateral protrusions in each of the two pairs of lateral protrusions (this protrusion will hereinafter be referred to as "central protrusion"),

   wherein the central protrusion has a thickness-directional protruding length less than that of the lateral protrusion, and
   wherein two central protrusions in the two pairs of lateral protrusions have a value of 0.40 or less (not including zero) in terms of a total protruding length Tp in the thickness-direction, expressed as an index on the basis of 1 indicative of the thickness of the inner bore at the position where the opposed lateral protrusions are provided.

3. The immersion nozzle as claimed in claim 2, wherein an upper end surface of the central protrusion has one selected from the group consisting of a shape extending horizontally in the width direction, a curved shape having a top at a midpoint thereof, and an upwardly protruding shape including a bending point.

4. The immersion nozzle as claimed in any one of claims 1 to 3, wherein an upper end surface of the lateral protrusion or the central protrusion has a shape extending horizontally in a direction toward a center of the inner bore, or a planar or curved shape extending obliquely downwardly in the direction toward the center of the inner bore.

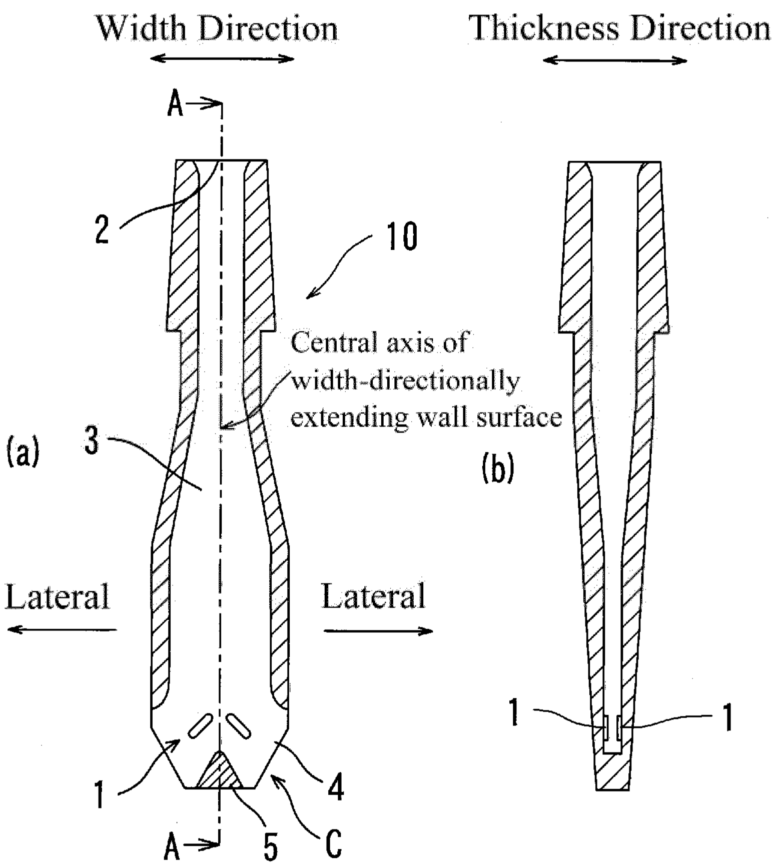
5. The immersion nozzle as claimed in any one of claims 1 to 4, wherein one or each of the lateral protrusion and the central protrusion has a shape in which the thickness-directional protruding length thereof is constant, or becomes shorter linearly, curvilinearly or stepwisely in a direction toward a center of the width-directionally extending wall.

6. The immersion nozzle as claimed in any one of claims 1 to 5, wherein one or each of the lateral protrusion, and the lateral protrusion combined with the central protrusion is provided plurally in an up-down direction.

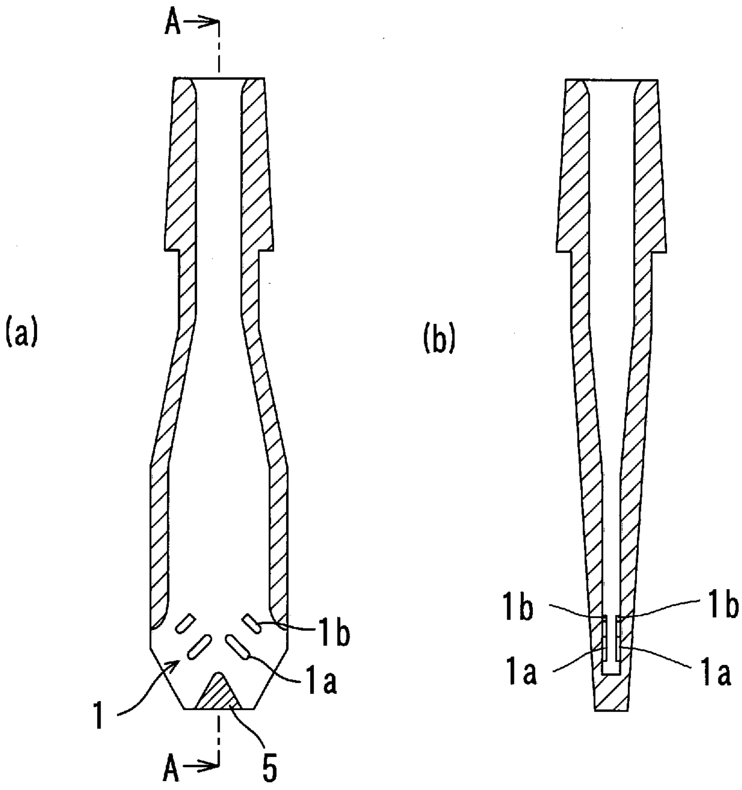
7. The immersion nozzle as claimed in any one of claims 1 to 6, which comprises a protrusion provided around a center of a bottom of the inner bore to protrude upwardly.

8. The immersion nozzle as claimed in any one of claims 1 to 7, which is used for continuous casting carried out under conditions including a molten steel flow rate of 0.04 ($t / (min \cdot cm^2)$) or more, as measured with reference to a position of minimum cross-sectional area in a region around an upper end of the immersion nozzle where a transverse cross-section of the inner bore has a circular shape.

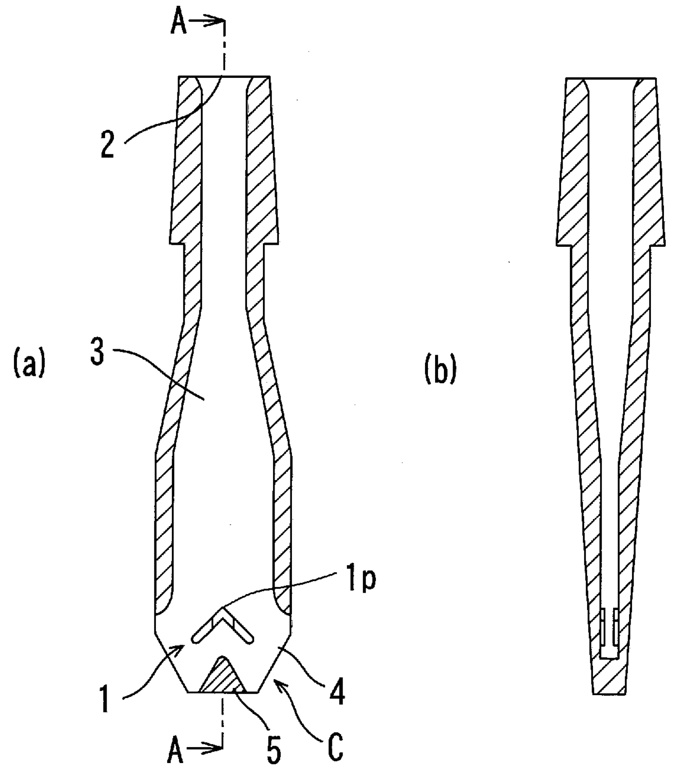
[Fig 1]


Width Direction
Thickness Direction
A
2
10
Central axis of width-directionally extending wall surface
(a)
3
(b)
Lateral
Lateral
1
1
1
4
5
C
A

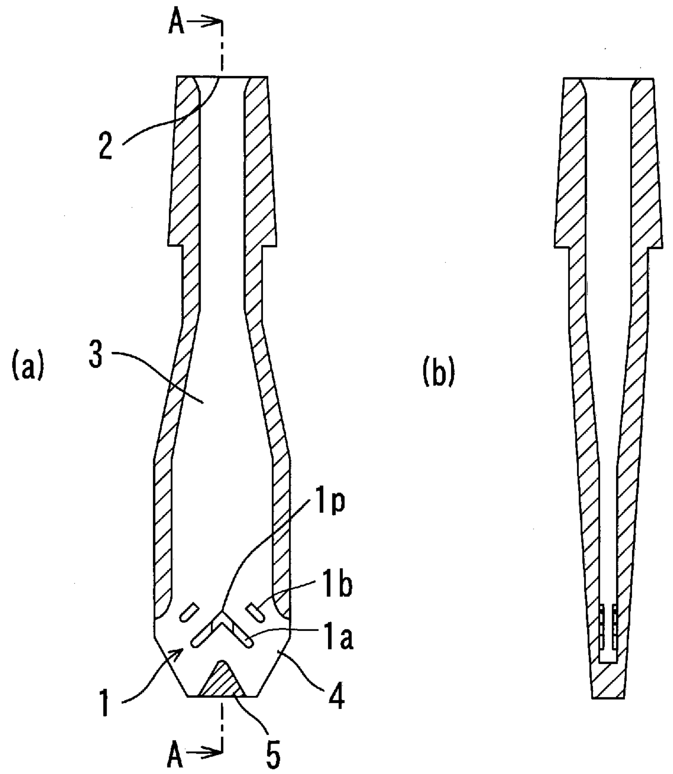
[Fig 2]


A
(a)
(b)
1b
1a
1
5
A
1b
1b
1a
1a

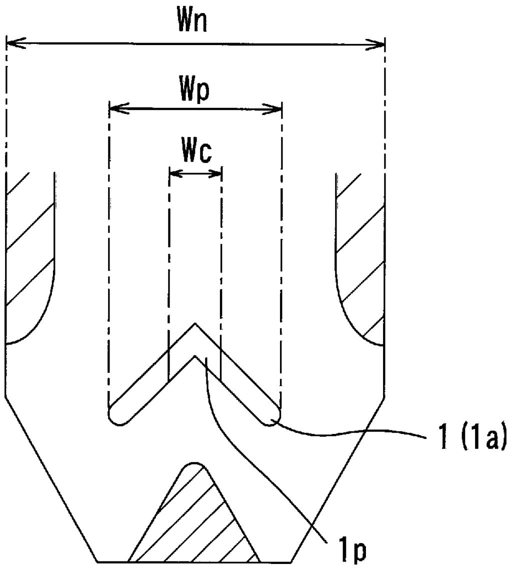
[Fig 3]



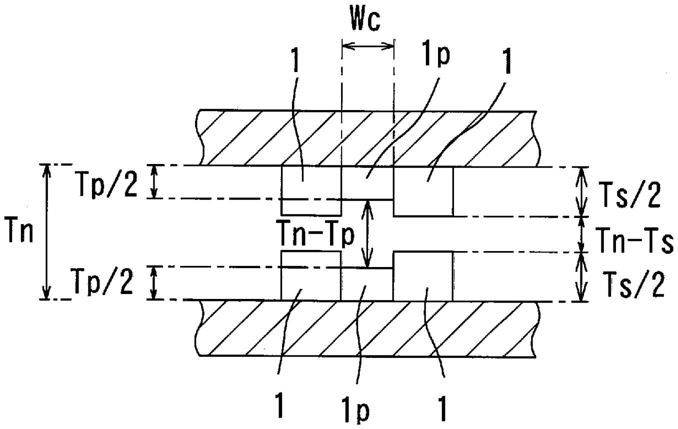
[Fig 4]



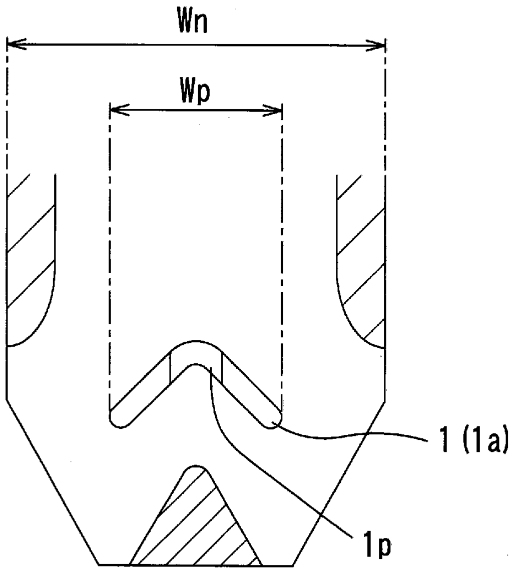
[Fig 5]



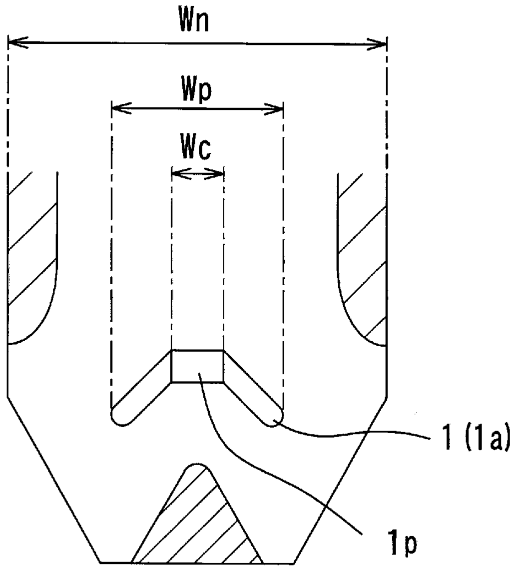
[Fig 6]



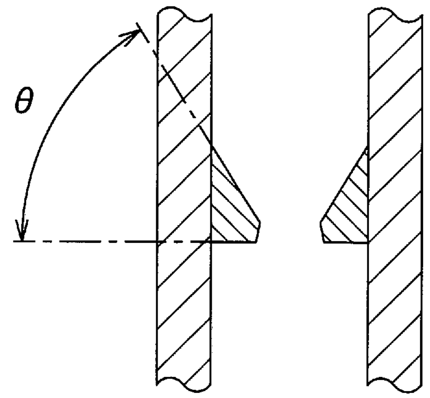
[Fig 7]



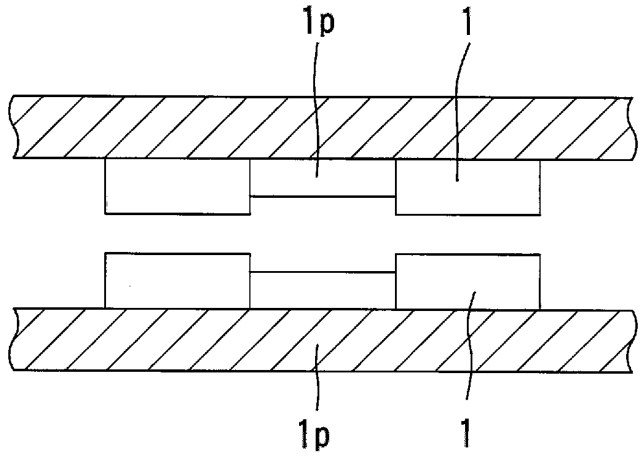
[Fig 8]



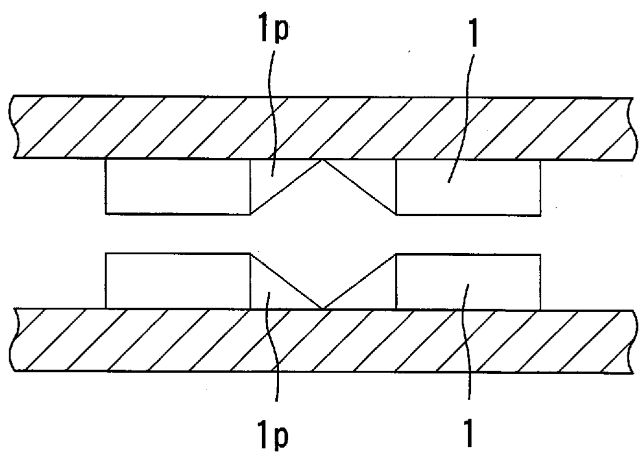
[Fig 9]



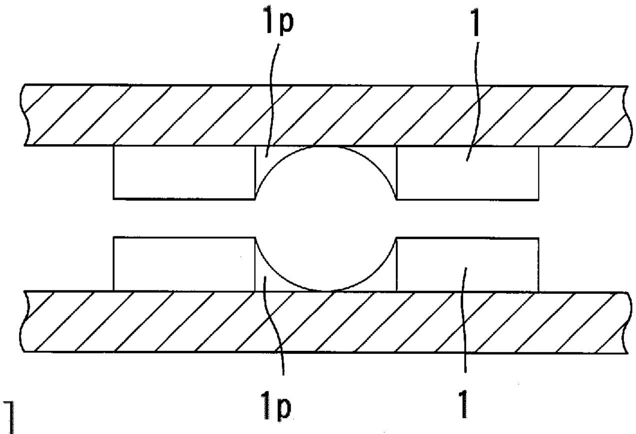
[Fig 10]



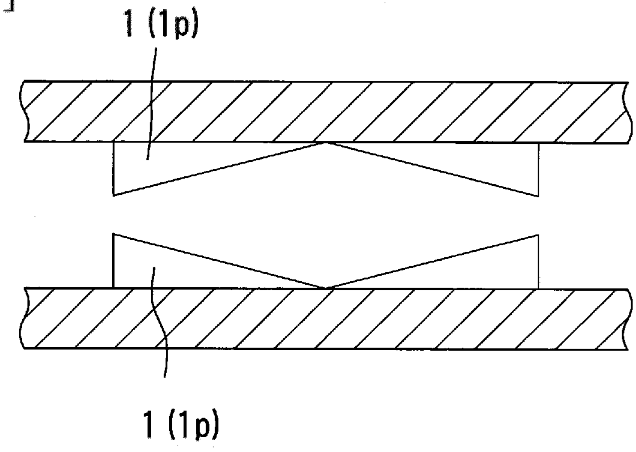
[Fig 11]



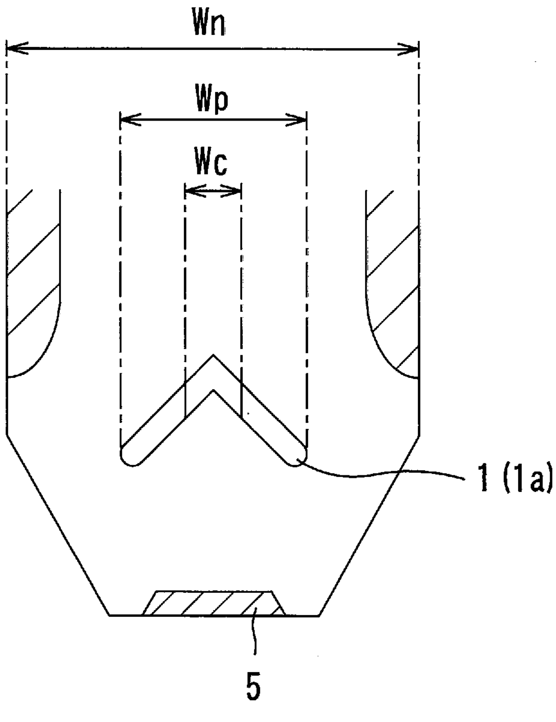
[Fig 12]



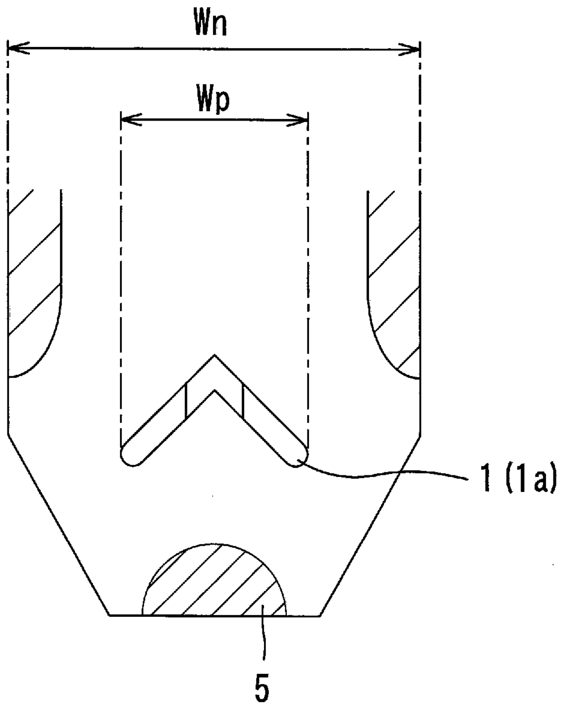
[Fig 13]



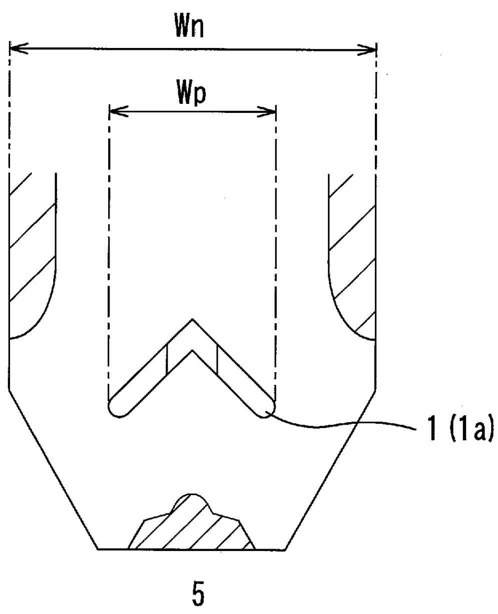
[Fig 14]



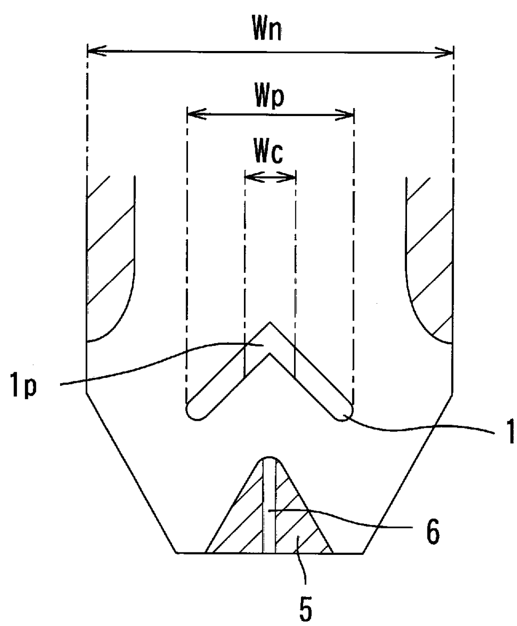
[Fig 15]



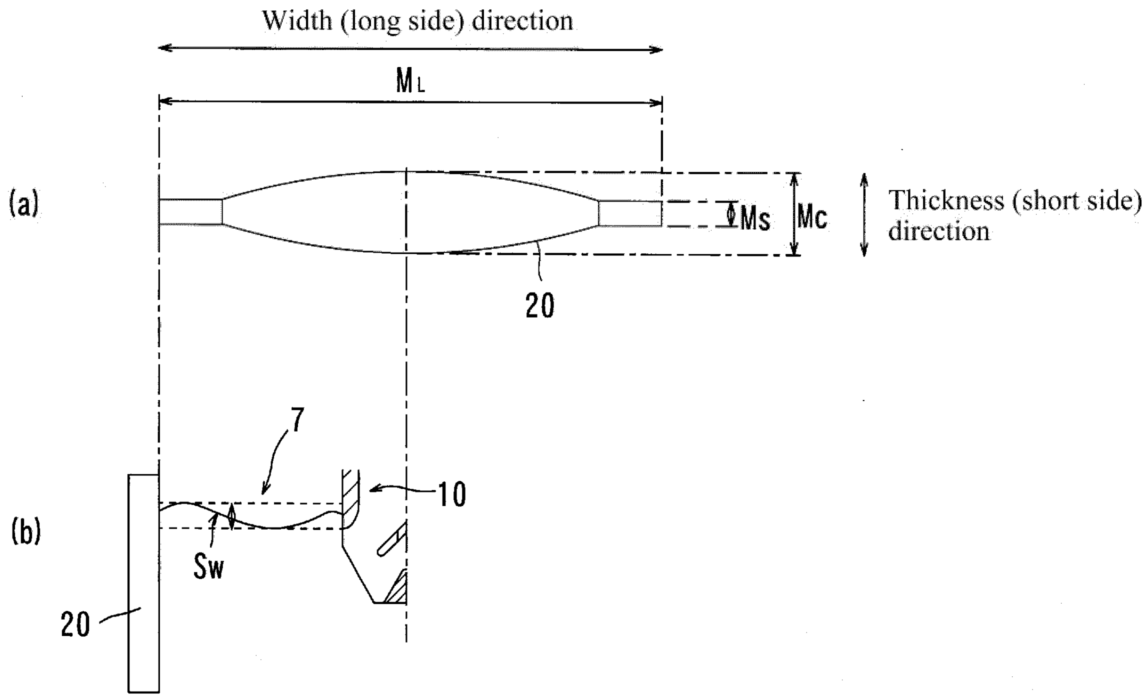
[Fig 16]



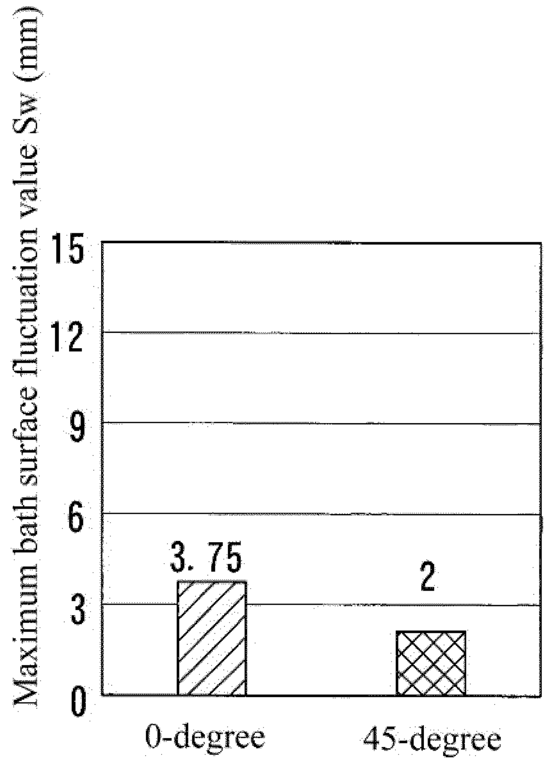
[Fig 17]



[Fig 18]



[Fig 19]


Maximum bath surface fluctuation value Sw (mm)
15
12
9
6
3
0
3. 75
2
0-degree
45-degree

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/001078

A. CLASSIFICATION OF SUBJECT MATTER
B22D 11/10(2006.01)i; B22D 41/50(2006.01)i
FI: B22D11/10; B22D41/50
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)
B22D11/10; B22D41/50

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 2012-183544 A (KROSAKI HARIMA CORPORATION) 27.09.2012 (2012-09-27) paragraphs [0023]-[0025], fig. 1-3	1-8
A	WO 2017/081934 A1 (KROSAKI HARIMA CORPORATION) 18.05.2017 (2017-05-18) paragraphs [0017]-[0023], fig. 1-4	1-8

☐ 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

Date of the actual completion of the international search	Date of mailing of the international search report
30 January 2020 (30.01.2020)	10 February 2020 (10.02.2020)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application no.
PCT/JP2020/001078

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2012-183544 A	27 Sep. 2012	(Family: none)	
WO 2017/081934 A1	18 May 2017	EP 3375545 A1 paragraphs [0017]-[0023], fig. 1-4 KR 10-2018-0037249 A CN 108025352 A	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP H11005145 A **[0009]**
- JP H11047897 A **[0009]**
- JP 2001501132 A **[0009]**
- WO 017081934 A2 **[0009]**