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(54) **METHOD FOR MANUFACTURING HIGH-PURITY STEEL CASTING, AND TUNDISH**

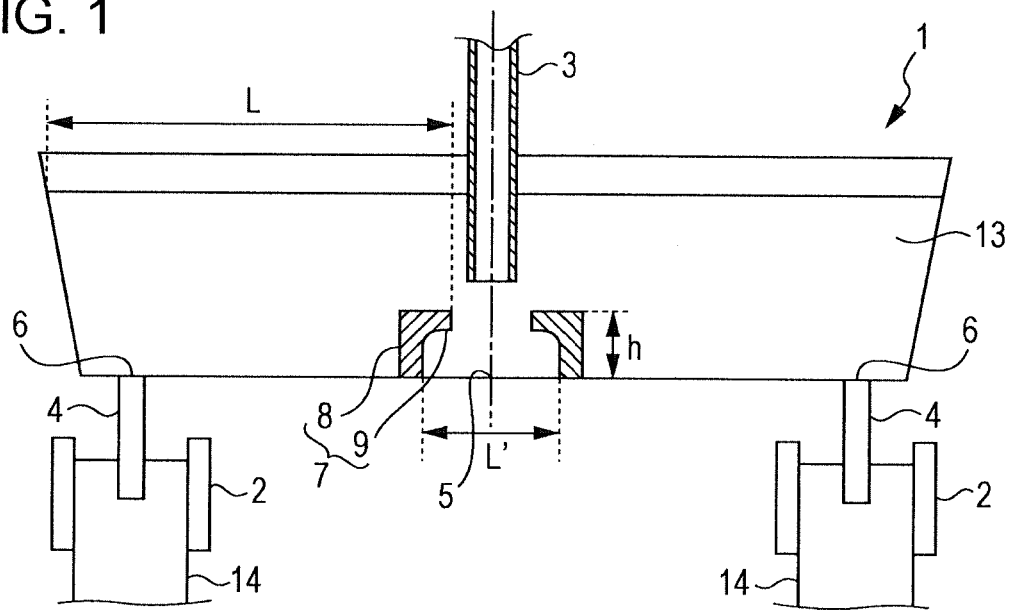
(57) The flotation separation of inclusions in molten steel is performed with increased certainty and efficiency in comparison to conventional methods using a tundish having a weir consisting of a wall part and an eave-shaped part horizontally extending from the top edge of the wall part.

Using a tundish 1 in which a weir 7 consisting of a wall part 8 extending so as to surround a molten steel charging position, an eave-shaped part 9 horizontally extending from the top edge of the wall part and at least one notch 12 is placed at a position between the molten steel charging position 5 and a molten steel discharge port 6, a steel cast piece 14 is continuously cast under conditions such that the height H of the upper surface of the molten steel in the tundish and the flow rate Q of the molten steel charged from the ladle into the tundish satisfy expression (1) below, where h represents the height of the weir, S represents the area of the upper opening of the weir, L represents the distance between the front edge on the molten steel charging position side of the eave-shaped part and the surface on the short side of the tundish, and W represents the distance between the front edge on the molten steel charging position side of the eave-shaped part and the surface on the long side of the tundish.

$$3.50 \leq \left[(H-h) \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right]^{-0.6} + \left[\frac{7L}{6} \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right] + \left[\frac{7W}{6} \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right] \leq 9.50 \quad \dots (1)$$

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FIG. 1



Description

Technical Field

[0001] The present invention relates to a method for manufacturing a high-purity or high-cleanliness steel cast piece with which the cleanliness of molten steel is increased by promoting the flotation separation of oxide-based non-metal inclusions such as deoxidation products in a tundish, and, moreover, to a continuous casting tundish with which the cleanliness of molten steel is increased by promoting the flotation separation of oxide-based non-metal inclusions such as deoxidation products in the tundish.

Background Art

[0002] In a continuous casting process for steel, a cast piece is manufactured by charging molten steel from a ladle into a tundish once and by then discharging the molten steel into a mold from the tundish while a specified amount of molten steel is retained in the tundish. The tundish has a function of supplying molten steel when a ladle is replaced during continuous casting is continued using plural ladles one after another and has a function of distributing molten steel into plural molds. In addition, by retaining a specified molten steel in the tundish, the tundish has a function of precisely controlling the amount of molten steel discharged into a mold from the tundish, and, moreover, of promoting the flotation separation of oxide-based non-metal inclusions (hereinafter, simply referred to as "inclusions") such as deoxidation products which are suspended in molten steel. In particular, since there is a demand for high-quality steel materials nowadays, techniques with which inclusions are efficiently removed in a tundish using a flotation separation method are widely used.

[0003] Among methods for removing inclusions using a flotation separation method in a tundish, a method in which a molten steel flow is controlled using weirs which are placed in a tundish is generally used. For example, Patent Literature 1 discloses a tundish in which the inside of the tundish is separated into a steel receiving zone and virtually calm steel zones by placing weirs having a penetration hole in the bottom portions of the weirs and extending from the bottom of the tundish up over the upper surface of molten steel in the tundish at two positions in the tundish so as to face each other across a zone into which molten steel is charged from a ladle in order to remove inclusions using a flotation separation method in the virtually calm steel zone.

[0004] Patent Literature 2 discloses a tundish in which the inside of the tundish is separated into a steel receiving side and a steel discharge side with a weir having two penetration holes that are in contact with the bottom of the tundish, in which a dam-like weir (referred to as "lower weir") is placed downstream of the weir, in which the ratio L/W of the length L of a long side of the tundish to the length W of the short side of the tundish is set to be 2 to 7 and in which the volume ratio of the steel receiving side to the whole tundish is set to be 10% to 40%.

[0005] Patent Literature 3 discloses a method in which the inside of a tundish is separated with a weir in which a molten steel flow channel is formed so that the flow direction is changed to a downward direction in the middle of the flow channel and in which inclusions are removed in the tundish by blowing a gas into the molten steel flow channel.

[0006] Patent Literature 4 discloses a tundish collision pad made of a heat-resistant material consisting of a base provided with a collision surface and an endless outer side wall extending upward from the base so as to completely surround an internal space having an upper opening through which a molten metal flow is received, in which the outer side wall includes a circular inside surface having at least a first part extending in the direction of the opening, inward and upward.

[0007] There are techniques proposed in order to improve the technique according to Patent Literature 4, and, for example, Patent Literature 5 discloses a flow control pad which is placed at a position where a molten metal flow charged from a ladle collides with the bottom of the tundish in order to control the flow of the molten metal in the tundish, which has a wall part surrounding the collision position of the molten metal flow and extending upward from the bottom of the tundish and an eave-shaped part extending from the top edge of the wall part toward the center of the space surrounded by the wall part and which has notches in the walls facing the surface on the long sides of the tundish.

[0008] In addition, while the collision pad according to Patent Literature 4 is an integral structure of a refractory, Patent Literature 6 discloses, instead of a collision pad, a flow control weir consisting of a wall part extending upward from the bottom of the tundish in a direction opposite to the molten metal flow from the ladle into the tundish and an eave-shaped part extending from the top edge of the wall part toward the molten metal flow, in which the height h of the wall part and the width d of the eave-shaped part satisfy the relational expression $0.1 \leq d/h \leq 1.0$.

[0009] Moreover, Patent Literature 7 discloses a method for manufacturing a high-cleanliness steel cast piece using a continuous casting method using a tundish in which a flow control pad consisting of a wall part surrounding a position where a molten steel flow from a ladle into the tundish collides with the bottom of the tundish and extending upward from the bottom of the tundish and an eave-shaped part extending from the top edge of the wall part toward the center of the space surrounded by the wall part is placed at the collision position of the molten steel flow and in which a molten

metal charging rate q (m^3/min), the area $A1$ (m^2) of the upper surface of the flow control pad other than the eave-shaped part and the area $A2$ (m^2) of the bottom of the flow control pad satisfy the relational expression $0.5 < (q/A2) \times (A1/A2) < 5.0$.

Citation List

Patent Literature

[0010]

- PTL 1: Japanese Unexamined Patent Application Publication No. 53-6231
- PTL 2: Japanese Unexamined Patent Application Publication No. 10-216909
- PTL 3: Japanese Unexamined Patent Application Publication No. 2005-957
- PTL 4: Japanese Unexamined Patent Application Publication (Translation of PCT Application) No. 9-505242
- PTL 5: Japanese Unexamined Patent Application Publication No. 2004-1077
- PTL 6: Japanese Unexamined Patent Application Publication No. 2004-98066
- PTL 7: Japanese Unexamined Patent Application Publication No. 2004-154803

Summary of Invention

Technical Problem

[0011] Since there has been a significant improvement in the flotation separation of inclusions in a tundish due to Patent Literatures 1 through 7, there has been a significant increase in cleanliness of molten steel in comparison to the cases where a weir is not used. In particular, in Patent Literatures 4 through 7, since a molten steel flow charged from a ladle into the tundish is stirred by "a circular inside surface extending in the direction toward the opening, inward and upward" or "an eave-shaped part extending from the top edge of a wall part toward the center of the space surrounded by the wall part" so that the flow goes back to a molten steel charging position, a short-circuit flow and a rapid flow in the tundish are eliminated due to a decrease in the velocity of the charged molten steel flow, which results in contribution to an improvement in the flotation separation of inclusions. It is known that the short-circuit flow and the rapid flow described above obstruct the flotation separation of inclusions in a tundish.

[0012] However, even in the cases of Patent Literatures 4 through 7, there is still room for improvement. That is, for example, in the case of Patent Literature 6, if the height of the weir, the area of the upper opening of the weir, the distances between the eave part of the weir and the surfaces on the short side and long side of the tundish and so forth are not appropriately determined in accordance with the height of the upper surface of molten steel in the tundish and the flow rate of the charged molten steel from the ladle into the tundish, since it is impossible to uniformly decrease the velocity of the molten steel flow charged from the ladle, that is, since the effect of the weir cannot be sufficiently realized, it is impossible to expect that the flotation separation of inclusions in a tundish is promoted.

[0013] The present invention has been completed in view of the situation described above, and an object of the present invention is to provide a method for manufacturing a high-cleanliness steel cast piece using a continuous casting method with which, when continuous casting is performed using a tundish in which a weir consisting of a wall part extending upward from the bottom of a tundish and an eave-shaped part horizontally extending from the top edge of the wall part toward a molten steel charging position is placed at a position between the molten steel charging position and a molten steel discharge port of the tundish, the flotation separation of inclusions can be performed with increased certainty and efficiency in the tundish in comparison to conventional methods, which results in a significant decrease in the number of product defects caused by inclusions.

[0014] Also, an object is to provide a continuous casting tundish with which, when continuous casting is performed using a tundish in which a weir consisting of the wall part and the eave-shaped part is placed, the flotation of inclusions is promoted in order to increase the cleanliness of molten steel in comparison to conventional cases, and to provide a method for manufacturing a high-cleanliness steel cast piece using a continuous casting method with which the flotation separation of inclusions can be performed with increased certainty and efficiency in the tundish in comparison to conventional methods, which results in a significant decrease in the number of product defects caused by inclusions.

Solution to Problem

[0015] The subject matter of the present invention in order to solve the problems described above is as follows.

[0016] [1] A method for manufacturing a high-cleanliness steel cast piece using a continuous casting method, the method including charging deoxidized molten steel from a ladle into a tundish once and then discharging the molten steel from the tundish into a mold in order to continuously cast a steel cast piece using a continuous casting tundish in

which a weir consisting of a wall part extending upward from the bottom of the tundish so as to surround a molten steel charging position where a molten steel flow charged from the ladle collides with the bottom of the tundish from four directions and an eave-shaped part horizontally extending from the top edge of the wall part toward the molten steel charging position is placed at a position between the molten steel charging position and a molten steel discharge port where the molten steel is discharged into the mold from the tundish, in which the wall part and the eave-shaped part have one or more notches penetrating through the wall part and the eave-shaped part and in which the height of the weir, the area of the upper opening of the weir, the distance between the front edge on the molten steel charging position side of the eave-shaped part and the surface on the short side of the tundish, the distance between the front edge on the molten steel charging position side of the eave-shaped part and the surface on the long side of the tundish, the height of the upper surface of the molten steel in the tundish and the flow rate of the molten steel charged from the ladle into the tundish satisfy expression (1) below.

[0017] [Math. 1]

$$3.50 \leq \left[(H-h) \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right]^{-0.6} + \left[\frac{7L}{6} \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right] + \left[\frac{7W}{6} \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right] \leq 9.50 \quad \dots(1)$$

[0018] Here, in expression (1), H represents the height (m) of the upper surface of the molten steel in the tundish, h represents the height (m) of the weir, S represents the area (m²) of the upper opening of the weir having an eave-shaped part, ρ represents the density (ton/m³) of the molten steel, Q represents the flow rate (ton/min) of the molten steel charged from the ladle into the tundish, L represents the distance (m) between the front edge on the molten steel charging position side of the eave-shaped part and the surface on the short side of the tundish, W represents the distance (m) between the front edge on the molten steel charging position side of the eave-shaped part and the surface on the long side of the tundish.

[0019] [2] The method for manufacturing a high-cleanliness steel cast piece using a continuous casting method according to item [1] above, in which the wall part surrounds an internal space having a shape of a rectangular solid, and in which the ratio (L' / W') of the length (L' in units of m) of the rectangular solid in the direction of the long side of the tundish to the length (W' in units of m) of the rectangular solid in the direction of the short side of the tundish is 0.3 or more and 4.0 or less.

[0020] [3] The method for manufacturing a high-cleanliness steel cast piece using a continuous casting method according to item [1] or [2] above, in which a maximum surface flow velocity (Ve) of the molten steel in the tundish is 0.10 m/s or more and 0.50 m/s or less.

[0021] [4] The method for manufacturing a high-cleanliness steel cast piece using a continuous casting method according to any one of items [1] to [3] above, in which an inert gas is blown into the molten steel in the tundish at a gas flow rate satisfying expression (2) below through a gas blowing port which is fitted to the top of the eave-shaped part in order to blow the inert gas and through a gas introduction pipe which is installed in the wall part in order to introduce the inert gas to the gas blowing port.

[0022] [Math. 2]

$$20 \leq R \leq 300 \quad \dots(2)$$

[0023] Here, in expression (2), R represents the inert gas flow rate (NL/(s×m²)) per unit area of the gas blowing port of the gas which is blown through the gas blowing port.

[0024] [5] A continuous casting tundish, the tundish having a weir consisting of a wall part extending upward from the bottom of the tundish so as to surround a molten steel charging position where a molten steel flow charged from the ladle collides with the bottom of the tundish from four directions and an eave-shaped part horizontally extending from the top edge of the wall part toward the molten steel charging position, in which the weir is placed at a position between the molten steel charging position and a molten steel discharge port where the molten steel is discharged into the mold from the tundish, in which the wall part and the eave-shaped part have one or more notches penetrating through the wall part and the eave-shaped part, and in which a gas blowing port is fitted to the top of the eave-shaped part in order to blow the inert gas and a gas introduction pipe is installed in the wall part in order to introduce the inert gas to the gas blowing port.

[0025] [6] A method for manufacturing a high-cleanliness steel cast piece using a continuous casting method, the method including charging deoxidized molten steel from a ladle into a tundish and then discharging the molten steel

from the tundish into a mold in order to continuously cast a steel cast piece using the continuous casting tundish according to item [5] above while blowing an inert gas through a gas blowing port into the molten steel in the tundish at a gas flow rate satisfying expression (2) below.

[0026] [Math. 3]

$$20 \leq R \leq 300 \quad \cdots (2)$$

[0027] Here, in expression (2), R represents the inert gas flow rate (NL/(s×m²)) per unit area of the gas blowing port of the gas which is blown through the gas blowing port.

[0028] [7] The method for manufacturing a high-cleanliness steel cast piece using a continuous casting method according to item [6] above, in which an inert gas is blown through all the positions of the eave-shaped parts on the four sides surrounding the molten steel charging position.

Advantageous Effects of Invention

[0029] According to the present invention described in item [1] above, since the shape and placement position of a weir having an eave-shaped part is optimized in accordance with casting conditions, and since the height of the upper surface of molten steel in a tundish and the flow rate of molten steel charged from a ladle into the tundish are controlled to be within the specified ranges in accordance with the shape and position of the weir, the flotation separation of inclusions in the tundish is promoted, which results in an increase in the cleanliness of molten steel to be discharged into a mold. As a result, since there is an increase in the cleanliness of a steel cast piece which is continuously cast, there is a significant decrease in the number of product defects caused by inclusions.

[0030] In addition, according to item [5] above, since an inert gas is blown from the top of the eave-shaped part, it is possible to promote the flotation of fine inclusions which are difficult to separate from molten steel with the upward flow alone of molten steel from the weir. Therefore, since the flotation separation of inclusions in a tundish is promoted in comparison to conventional cases, there is an increase in the cleanliness of a steel cast piece which is cast using a continuous casting method as a result of an increase in the cleanliness of molten steel which is charged into a mold, which results in a significant decrease in the number of product defects caused by inclusions.

Brief Description of Drawings

[0031]

[Fig. 1] Fig. 1 is a schematic elevation cross-sectional view illustrating a tundish and a mold placed below the tundish in one example of a continuous casting apparatus used in the present invention.

[Fig. 2] Fig. 2 is a plan view of the tundish illustrated in Fig. 1.

[Fig. 3] Fig. 3 is a side view of the tundish illustrated in Fig. 1.

[Fig. 4] Fig. 4 is a schematic elevation cross-sectional view illustrating a tundish and a mold placed below the tundish in another example of a continuous casting apparatus used in the present invention.

[Fig. 5] Fig. 5 is a plan view of the tundish illustrated in Fig. 4.

[Fig. 6] Fig. 6 is a side view of the tundish illustrated in Fig. 4.

[Fig. 7] Fig. 7 is a plan view illustrating an example of a tundish having repositioned gas blowing ports in eave-shaped parts.

[Fig. 8] Fig. 8 is a plan view illustrating another example of a tundish having repositioned gas blowing ports in eave-shaped parts.

[Fig. 9] Fig. 9 is a diagram illustrating the results of the investigation regarding the influence of a value calculated by expression (3) on the occurrence number density of defects caused by inclusions in a steel sheet.

[Fig. 10] Fig. 10 is a diagram illustrating the results of the investigation regarding the influence of the ratio (L'/W') between the side lengths of the internal space of a weir having a shape of a rectangular solid on the occurrence number density of defects caused by inclusions in a steel sheet.

[Fig. 11] Fig. 11 is a diagram illustrating the results of the investigation regarding the influence of the maximum surface flow velocity of molten steel in a tundish on the occurrence number density of defects caused by inclusions in a steel sheet.

[Fig. 12] Fig. 12 is a diagram illustrating the results of the investigation regarding the relationship between the flow rate of argon gas blown into molten steel in a tundish and the number density of inclusions in a cast slab.

[Fig. 13] Fig. 13 is a diagram illustrating the results of the investigation regarding the relationship between the blowing

position of argon gas blown and the number density of inclusions in a cast slab.

[Fig. 14] Fig. 14 is a diagram illustrating the results of the investigation regarding the number of inclusions in a cast piece in EXAMPLE 1 for comparison among the examples of the present invention, comparative examples and a conventional example.

[Fig. 15] Fig. 15 is a diagram illustrating the results of the investigation regarding the number of inclusions in a cast piece in EXAMPLE 2 for comparison among the examples of the present invention, comparative examples and a conventional example.

Description of Embodiments

[0032] The present invention will be specifically described with reference to the drawings hereafter.

[0033] Fig. 1 is a schematic elevation cross-sectional view illustrating a tundish and a mold placed below the tundish in one example of a continuous casting apparatus used in the present invention, Fig. 2 is a plan view of the tundish illustrated in Fig. 1 and Fig. 3 is a side view of the tundish illustrated in Fig. 1.

[0034] In Figs. 1 through 3, symbol 1 denotes a tundish, 2 denotes a mold, 3 denotes a long nozzle fitted to the bottom of a ladle (not illustrated) and 4 denotes a submerged nozzle fitted to the bottom of the tundish 1. While molten steel 13 which has been deoxidized using a deoxidation agent such as aluminum, silicon, titanium and manganese and contained in a ladle is being charged into the tundish 1 through the long nozzle 3, the molten steel 13 in the tundish is discharged into the mold 2 through the submerged nozzle 4 so that a specified amount of the molten steel 13 is retained in the tundish. The molten steel 13 which has been discharged into the mold is cooled by the mold 2 in order to manufacture a steel cast piece 14. These drawings illustrate a case where two lines (two strands) of slab pieces are continuously cast using two molds 2.

[0035] In the tundish 1, as illustrated in Figs. 1 through 3, a weir 7 is placed between a molten steel charging position 5 where a molten steel flow charged from a ladle (not illustrated) into the tundish 1 through the long nozzle 3 collides with the bottom of the tundish 1 and a molten steel discharge port 6 for discharging the molten steel from the tundish 1 into the mold 2. The weir 7 has a wall part 8 vertically extending upward from the bottom of the tundish 1 and an eave-shaped part 9 horizontally extending from the top edge of the wall part 8 toward the molten steel charging position. The outer and inner shapes of the wall part 8 projected onto a horizontal plane are rectangular. Although the connection part of the surface on the molten steel charging position side of the wall part 8 and the lower surface of the eave-shaped part 9 of the weir 7 has a smooth shape of a circular arc as illustrated in Fig. 1, the surface on the molten steel charging position side of the wall part 8 and the lower surface of the eave-shaped part 9 may bisect each other at right angles.

[0036] The weir 7 is also placed on the side of the surface on the long side of the tundish 1 so that the weir 7 surrounds the molten charging position 5 from four directions. That is, the molten steel charging position 5 is surrounded from four directions by the weir 7 whose outer and inner shapes projected onto a horizontal plane are square or rectangular. However, the weir 7 has at least one notch 12 penetrating through the wall part 8 and the eave-shaped part 9. That is, the weir 7 is configured so that the molten steel 13 in the internal space surrounded by the weir 7 is discharged through the notch 12 toward the molten steel discharge port 6 when casting is finished.

[0037] Although, in the case of the tundish 1 illustrated in Figs. 1 through 3, the notches 12 are formed at two positions, the notches 12 may be formed at one position or three or more positions. In addition, although the notches 12 are formed on the sides of the long side surfaces of the tundish 1 in Fig. 2, it is not necessary that the notches 12 be formed on the sides of the long side surfaces of the tundish 1, and the notches 12 may be formed on the sides of the short side surfaces of the tundish 1. However, in the case where the notches 12 are formed on the sides of the short side surfaces of the tundish 1, since there is concern that a short-cut flow toward the molten steel discharge port 6 may be formed by the molten steel 13 which has passed through the notches 12, which results in the flotation of inclusions being obstructed, it is preferable that the notches 12 be formed on the side of the long side surfaces of the tundish 1. Here, "short-cut flow" refers to a narrow flux of the molten steel 13, which has been charged into the molten steel charging position 5, flows from the molten steel charging portions 5 toward the molten steel discharge port 6 without spreading, that is, without diffusing in the tundish.

[0038] Fig. 4 is a schematic elevation cross-sectional view illustrating a tundish and a mold placed below the tundish in another example of a continuous casting apparatus used in the present invention, Fig. 5 is a plan view of the tundish illustrated in Fig. 4, and Fig. 6 is a side view of the tundish illustrated in Fig. 4.

[0039] The tundish 1 illustrated in Fig. 4 is similar to the tundish 1 illustrated in Fig. 1 described above with the exception of the fact that a gas blowing port 10 is placed on the top of the eave-shaped part 9 in the case of the tundish 1 illustrated in Fig. 4. Others are the same as the tundish 1 illustrated in Fig. 1.

[0040] That is, in the case of the tundish 1 illustrated in Fig. 4, a gas introducing pipe 11 is installed in the inside of the wall part 8 and the eave-shaped part 9, and the top edge of the gas introduction pipe 11 is connected to a gas blowing port 10 which is placed on the top of the eave-shaped part 9 and which is made of, for example, porous brick. That is, the tundish 1 is configured so that an inert gas such as argon gas which is introduced through the gas introduction pipe

11 from the outside of the tundish 1 is blown into the internal space of the tundish 1 through the gas blowing port 10.

[0041] In this case, although the gas introduction pipe 11 may be formed using a metal pipe or a refractory pipe, the wall part 8 and the eave-shaped part 9 which are made of refractory may only be penetrated by, for example, a thin cutting hole or a penetration hole. In addition, it is not necessary that the gas blowing port 10 be made of porous brick, and brick having a large number of thin penetration holes may be used. In addition, in Figs. 4 through 6, although the gas blowing port 10 is placed on some portion of the top of the eave-shaped part 9, the gas blowing port 10 may be placed on the entire of the top of the eave-shaped part 9. The gas introduction pipe 11 is configured so as to introduce an inert gas in a manner, for example, such that the gas introduction pipe 11 is connected to a gas feeding pipe (not illustrated) penetrating the steel shell (not illustrated) of the bottom of the tundish 1.

[0042] In addition, in Figs. 4 through 6, although the gas blowing port 10 is placed at all the positions of the eave-shaped part 9 so as to surround the molten steel charging position 5 from four directions, it is not necessary that the gas blowing port 10 be placed at all the positions of the eave-shaped part 9 so as to surround the molten steel charging position 5 in order to blow an inert gas. An inert gas may be blown only from the surfaces of the eave-shaped part 9 which are placed at a right angle to the surface on the long side of the tundish 1 as illustrated in Fig. 7, and an inert gas may be blown only from the surfaces of the eave-shaped part 9 which are placed in parallel with the surface on the long side of the tundish 1 as illustrated in Fig. 8. In the present invention, a method in which an inert gas is blown from all the position of the eave-shaped part 9 surrounding the molten steel charging position 5 as illustrated in Figs. 4 through 6 is referred to as "blowing in four directions", a method in which an inert gas is blown from the surfaces which are placed at a right angle to the surface on the long side of the tundish 1 as illustrated in Fig. 7 is referred to as "blowing at right angle to long side surface" and a method in which an inert gas is blown from the surfaces which are placed in parallel with the surface on the long side of the tundish 1 as illustrated in Fig. 8 is referred to as "blowing in parallel with the long side surface".

[0043] In the case where the tundish 1 illustrated in Fig. 4 is used, the steel cast piece 14 is continuously cast by charging the molten steel 13 from the ladle into the tundish 1 through the long nozzle 3 while an inert gas such as argon gas or helium gas (= rare gasses) is blown into the molten steel through the gas blowing port 10 and by subsequently discharging the molten steel 13 from the tundish into the mold 2.

[0044] In the case where continuous casting is performed using the tundish 1 illustrated in Fig. 1 or Fig. 4, the molten steel 13 which is charged into the molten steel charging position 5 through the long nozzle 3 flows in four directions along the bottom surface of the tundish 1 due to the falling energy of the molten steel flow after the molten steel 13 has collided with the molten steel charging position 5. The direction of this flow is changed to an upward direction as a result of collision with the wall part 8 of the weir 7, and, further, changed to the direction toward the molten steel charging position 5 by the eave-shaped part 9 which is placed on the top edge of the weir 7. Since these flows coming from four directions toward the molten steel charging position 5 collide with each other, there is a decrease in flow velocity due to the consumption of kinetic energy. That is, using the weir 7, while the velocity of the molten steel flow which is charged at a high velocity through the long nozzle 3 is significantly decreased, the molten steel flow in the tundish is homogenized. Therefore, since a shot-circuit flow and a rapid flow in the tundish are eliminated, there is a decrease in the amount of inclusions which are carried into the mold 2 through the molten steel discharge port 6 by these flows. That is, the flotation separation of inclusions in the tundish 1 is promoted.

[0045] However, in order to realize the functions and effects of the weir 7, it is necessary that, while the shape of the weir 7 is optimized, appropriate height of the upper surface of the molten steel in the tundish be maintained in accordance with the shape of the weir 7 and the molten steel 13 be charged into the tundish 1 at an appropriate flow rate in accordance with the shape of the weir 7.

[0046] The present inventors conducted investigations, in the case of the tundish 1 having the weir 7, regarding the influence of 6 factors, that is, the height of the weir 7, the area of the upper opening of the weir 7, the distance between the front edge on the molten steel charging position side of the eave-shaped part 9 and the surface on the short side of the tundish, the distance between the front edge on the molten steel charging position side of the eave-shaped part 9 and the surface on the long side of the tundish, the height of the upper surface of the molten steel in the tundish and the flow rate of the molten steel 13 which is charged from the ladle into the tundish 1, on the cleanliness of the steel cast piece 14, and, as a result, found the following facts.

[0047] That is, firstly, it is necessary that the shape and position of the weir 7 be determined in accordance with the height of the upper surface of the molten steel in the tundish and the flow rate of the molten steel 13 which is charged from the ladle into the tundish 1, and, subsequently, it is necessary that, after the weir 7 having the specified shape has been placed at the specified position, the molten steel 13 be charged into the tundish 1 while the height of the upper surface of the molten steel in the tundish is maintained in accordance with the casting conditions which has been used to determine the shape and the position of the weir 7.

[0048] The results of the investigations will be described hereafter, where the height of the upper surface of the molten steel in the tundish is represented by H (m), the flow rate of the molten steel 13 which is charged from the ladle into the tundish 1 is represented by Q (ton/min), the height of the weir 7 is represented by h (m), the area of the upper opening

of the weir 7 is represented by S (m^2), the distance between the front edge on the molten steel charging position side of the eave-shaped part 9 and the surface on the short side of the tundish is represented by L (m), the distance between the front edge on the molten steel charging position side of the eave-shaped part and the surface on the long side of the tundish is represented by W (m) and the density of the molten steel is represented by ρ (ton/m^3).

[0049] Here, the height H of the upper surface of the molten steel in the tundish is the height of the upper surface of the molten steel in the region which is surrounded by the weir 7 as illustrated in Fig. 3, the height h of the weir is the distance between the bottom of the tundish 1 and the upper surface of the eave-shaped part 9 as illustrated in Fig. 1, and the area S of the upper opening of the weir 7 is the area of the region which is surrounded by the eave-shaped part 9 from four directions as illustrated in Fig. 2. In addition, the distance L between the front edge on the molten steel charging position side of the eave-shaped part 9 and the surface on the short side of the tundish and the distance W between the front edge on the molten steel charging position side of the eave-shaped part 9 and the surface on the long side of the tundish are the distances at the height of the upper surface of the molten steel in the tundish as illustrated in Fig. 1 and Fig. 3. Since the flow distance of inclusions under the upper surface of the molten steel is important, the distance L and the distance W are defined by the distances at the height of the upper surface of the molten steel. In the present invention, the height H of the upper surface of the molten steel in the tundish is 0.4 to 1.3 m, the flow rate Q of the molten steel 13 is 4 to 18 ton/min, the height h of the weir is 0.1 to 0.6 m, the area S of the upper opening of the weir 7 is 0.1 to 0.8 m^2 , the distance L is 4 to 5 m and the distance W is 0.1 to 0.5 m. It is appropriate that the density ρ of the molten steel be about 7.0 ton/m^3 .

[0050] Fig. 9 illustrates the results of the investigation regarding the influence of a value (Z) calculated by expression (3) on the occurrence number density of defects caused by inclusions in a steel sheet, where the value calculated by expression (3) below is measured along the horizontal axis and the occurrence number density of defects caused by inclusions in a steel sheet is measured along the vertical axis.

[0051] [Math. 4]

$$Z = \left[(H-h) \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right]^{-0.6} + \left[\frac{7L}{6} \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right] + \left[\frac{7W}{6} \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right] \cdots (3)$$

[0052] Here, the term $[(H-h) \times (S \times \rho / Q)^{1.37}]^{-0.6}$ in expression (3) indicates the degree of the upward motion from the weir of the molten steel 13 which has been charged into the weir and the degree of the flotation separation of inclusions in the top of the weir. The term $[(7L/6) \times (S \times \rho / Q)^{1.37}]$ in the expression (3) indicates the degree of the flotation separation when the inclusions which has flown up to near the upper surface of the molten steel from the weir 7 flows in the direction of the long side of the tundish. The term $[(7W/6) \times (S \times \rho / Q)^{1.37}]$ in the expression (3) indicates the degree of the flotation separation when the inclusions which has flown up to near the upper surface of the molten steel from the weir 7 flows in the direction of the short side of the tundish. In addition, Fig. 9 illustrates the results under conditions such that the width of each of the two notches 12 was 30 mm.

[0053] As indicated in Fig. 9, it is clarified that there is a decrease in the occurrence number of defects caused by inclusions in the steel sheet in the case where the height H of the upper surface of the molten steel in the tundish, the flow rate Q of the molten steel 13, the height h of the weir, the area S of the upper opening of the weir 7, the distance L and the distance W satisfy expression (1) below.

[0054] [Math. 5]

$$3.50 \leq \left[(H-h) \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right]^{-0.6} + \left[\frac{7L}{6} \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right] + \left[\frac{7W}{6} \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right] \leq 9.50 \cdots (1)$$

[0055] It is not preferable that the value calculated by expression (3) be less than 3.50, because there is a decrease in the degree of the upward motion of inclusions from the upper opening of the weir, and, in addition to that, because there is a decrease in a flotation effect when the inclusions which has flown up to near the upper surface of the molten steel flows in the direction of the long side or short side of the tundish. On the other hand, it is not preferable that the value calculated by expression (3) be more than 9.50, because there is a decrease in an effect of aggregating inclusions realized by the dispersion of kinetic energy of molten steel in the weir due to an excessive large area of the opening of the weir 7, which results in a decrease in the flotation performance of inclusions. Therefore, it is necessary that the height H of the upper surface of the molten steel in the tundish, the flow rate Q of the molten steel 13, the height h of the weir,

the area S of the upper opening of the weir 7, the distance L and the distance W satisfy expression (1) above.

[0056] In addition, Fig. 10 is a diagram illustrating the results of the investigation regarding the influence of the ratio (L'/W') between the side lengths of the internal space surrounded by the wall part 8 of the weir 7 having a shape of a rectangular solid on the cleanliness of the molten steel, where the length of the side in the direction of the long side of the tundish of the inner space surrounded by the wall part 8 having a shape of a rectangular solid is represented by L' (m) and the length of the side in the direction of the short side of the tundish of the inner space surrounded by the wall part 8 having a shape of a rectangular solid is represented by W' (m). In this case, the ratio (L'/W') is a factor indicating the degree of the dissipation of the kinetic energy of the molten steel 13 which has been charged into the inside of the weir. The length (L') of the side in the direction of the long side of the tundish of the inner space having a shape of a rectangular solid is illustrated in Fig. 1, and the length (W') of the side in the direction of the short side of the tundish of the inner space having a shape of a rectangular solid is illustrated in Fig. 3.

[0057] As illustrated in Fig. 10, it is clarified that there is a decrease in the occurrence number of defects caused by inclusions, in the case where the ratio (L'/W') of the length (L') of the side in the direction of the long side of the tundish of inner space having a shape of a rectangular solid and the length (W') of the side in the direction of the short side of the tundish of inner space having a shape of a rectangular solid is 0.3 or more and 4.0 or less. In the case where the ratio (L'/W') is 0.3 or more and 4.0 or less, since there is an increase in the amount of the kinetic energy dissipated of the molten steel 13 which has been charged into the weir, the aggregation of inclusions is promoted in the weir, which results in promotion of the flotation separation of inclusions.

[0058] Moreover, Fig. 11 illustrates the results of the investigation regarding the influence of the maximum surface flow velocity of molten steel in a tundish on the cleanliness of a steel sheet. Here, in the case where the weir 7 having the eave-shaped part 9 is placed in the tundish, since the surface flow velocity of molten steel has a maximum value in the vicinity (of the circumference) of the long nozzle 3, the maximum surface flow velocity of molten steel was determined in the vicinity of the circumference of the long nozzle 3. The maximum surface flow velocity (V_e) of the molten steel in the tundish increases in proportion to the upward flow of the molten steel from the weir 7.

[0059] As illustrated in Fig. 11, it is clarified that there is a decrease in the occurrence number of defects caused by inclusions in the case where the maximum surface flow velocity (V_e) is 0.10 m/s or more and 0.50 m/s or less. In the case where the maximum surface flow velocity (V_e) is 0.10 m/s or more, since sufficient upward flow velocity from the weir 7 is achieved, there is an increase in the effect of flotation separation of the inclusions, and, on the other hand, in the case where the maximum surface flow velocity (V_e) is 0.50 m/s or less, since the maximum surface flow velocity (V_e) is not excessively large, the entrainment of tundish slag is prevented from occurring, which results in the contamination of the molten steel being prevented from occurring.

[0060] Here, it is assumed that the molten steel 13 be present over the weir 7, therefore, it is only necessary that the height h of the weir be less than the depth of the molten steel in the tundish at the position where the weir 7 is placed. In addition, it is preferable that the height h of the weir be equal to or less than $1/2$ of the height H of the upper surface of the molten steel in the tundish at the position where the weir 7 is placed. On the other hand, in the case where the height h of the weir is excessively low, since the effect of the weir 7 cannot be realized, it is preferable that the height h of the weir be 100 mm or more. That is, it is preferable that, under conditions such that the height h of the weir is 100 mm or more and equal to or less than $1/2$ of the height H of the upper surface of the molten steel in the tundish, the other factors such as the area S of the upper opening of the weir 7, the distance L and the distance W be controlled so as to satisfy expression (1).

[0061] In accordance with a planned values of the height H of the upper surface of the molten steel and the flow rate Q of the molten steel 13, the shape and position of the weir 7 are determined so that the height h of the weir 7, the area S of the upper opening of the weir 7, the distance L between the front edge on the molten steel charging position side of the eave-shaped part 9 and the surface on the short side of the tundish and the distance W between the front edge on the molten steel charging position side of the eave-shaped part 9 and the surface on the long side of the tundish satisfy expression (1) above. Then, the weir 7 having the determined shape is placed at the specified position in the tundish 1.

[0062] Subsequently, using this tundish 1, and by performing continuous casting while the height H of the upper surface of the molten steel and the flow rate Q of the molten steel 13 which is charged into the tundish 1 are controlled so that the height H of the upper surface of the molten steel in the tundish and the flow rate Q of the molten steel 13 which is charged into the tundish 1 satisfy relational expression (1), since inclusions in the molten steel which is charged through the long nozzle 3 is forced to flow upward by the weir 7, the inclusions flow up to the upper surface of the molten steel in the tundish and are separated. That is, since the flotation separation of the inclusions in the molten steel is promoted by the weir 7, it is possible to manufacture clean steel cast piece 14.

[0063] That is, according to the present invention, by optimizing the shape and position of the weir 7 having an eave-shaped part 9 in accordance with casting conditions, and, further by controlling the height H of the upper surface of the molten steel in the tundish and the flow rate Q of the molten steel which is charged from the ladle into the tundish 1 to be within the specified ranges in accordance with the shape and position of the weir 7, the flotation separation of inclusions

in the tundish 1 is promoted to a much higher degree in comparison to the conventional cases. As a result, since there is an increase in the cleanliness of the molten steel 13 which is discharged into the mold 2, there is an increase in the cleanliness of the steel cast piece 14 which is continuously cast, which results in a significant decrease in the number of product defects caused by inclusions.

[0064] In addition, in the case where the tundish 1 illustrated in Fig. 4 is used, by blowing an inert gas into molten steel through the gas blowing port 10 when continuous casting is performed, fine inclusions which are difficult to remove from the molten steel 13 using a flotation separation method due to its low flowing-up velocity are trapped by the bubbles of the inert gas so as to flow up to the upper surface of the molten steel in the tundish with the bubbles of the inert gas.

[0065] That is, it is possible to deliver the molten steel 13 having only a small amount of inclusions into the mold 2 with combination of the effect of the weir 7 and the effect of the inert gas blown through the gas blowing port 10. In addition, in the case where the weir 7 having a shape satisfying expression (1) is placed, where casting is performed under casting conditions satisfying the relation of expression (1), and where an inert gas is blown through the gas blowing port 10 into the molten steel, there is a further decrease in the number of inclusions in the molten steel.

[0066] However, in order to realize the effect of blowing an inert gas from the top of the eave-shaped part 9, it is necessary to optimize the blowing flow rate through the gas blowing port 10.

[0067] Fig. 12 is a diagram illustrating the results of the investigation regarding the relationship between the flow rate of argon gas and the number density of inclusions in a cast slab when the argon gas was blown from all the positions of the eave-shaped part 9 surrounding the molten steel charging position 5, that is, when the argon gas was blown using a method of "blowing in four directions", under condition such that the flow rate per unit area of the gas blowing port 10 of the argon gas which was blown from the top of the eave-shaped part 9 was controlled in a range of 10 to 330 NL/(s×m²). Here, "the area of the gas blowing port 10" refers to the total area of the gas blowing part 10 in a plan view as illustrated in Fig. 5, and the area of the region indicated by two diagonal lines crossing each other in Fig. 5, Fig. 7 and Fig. 8.

[0068] A tundish 1 having a capacity of 80 tons in terms of molten steel was used in the investigations, and a weir 7 having a length of a side in the direction of the long side of the tundish 1 (this side is referred to as a "weir long side") of 1200 mm, a length of a side in the direction of the short side of the tundish 1 (this side is referred to as a "weir short side") of 600 mm and a height of the weir of 230 mm was placed in the tundish 1. This weir 7 has one notch 12 having a width of 10 mm on each of the sides on the long side of the tundish 1. Moreover, the weir has two gas blowing ports 10 having a length of 0.3 m and a width of 0.01 m across the notch 12 on the top of the eave-shaped part 9 on each of the weir long sides and one gas blowing port 10 having a length of 0.3 m and a width of 0.01 m on the top of the eave-shaped part 9 on each of the weir short sides. The total area of the gas blowing ports 10 is 0.018 m² (= 6 ports×0.3 m×0.01 m).

[0069] In addition, Fig. 12 illustrates the results of the investigation regarding the influence of the position of an argon gas blowing port on the number density of inclusions in a cast slab, by adding the results of an argon gas blowing test in which, using a tundish having a weir 7 having the same shape as described above, argon gas was blown from the bottom of the tundish outside the weir 7. In the case of the test where argon gas was blown from the bottom of the tundish, one gas blowing port having an area of 0.009 m² was placed between the weir 7 and the molten steel discharge port 6 on each of both sides of the weir 7 (the total area of the gas blowing ports = 0.018 m²) so that the total area of the gas blowing ports was equal to that in the case where the gas blowing ports 10 were placed on the eave-shaped part 9.

[0070] As illustrated in Fig. 12, it is clarified that there is a high effect of decreasing the number of inclusions in the case where the flow rate of argon gas which was blown through the gas blowing port 10 placed on the eave-shaped part 9 was within the range of expression (2) below.

$$20 \leq R \leq 300 \quad \dots(2)$$

[0071] Here, in expression (2), R represents the inert gas flow rate (NL/(s×m²)) per unit area of the gas blowing port of the gas which is blown through the gas blowing port 10 placed on the top of the eave-shaped part 9.

[0072] In the case where the inert gas flow rate (R) is less than 20 NL/(s×m²), since the gas flow rate is excessively small, there is a decrease in the effect of trapping inclusions using gas bubbles. On the other hand, in the case where the inert gas flow rate (R) is more than 300 NL/(s×m²), since there is an increase in the surface flow velocity of the molten steel in the tundish due to an excessive increase in the strength of the upward flow of the molten steel 13, the entrainment and cutting-in of tundish slag which is present on the molten steel in the tundish occur, which results in a decrease in the cleanliness of molten steel on the contrary.

[0073] In addition, as illustrated in Fig. 12, it is clarified that, in comparison to the case where a gas is blown from the bottom of the tundish 1, there is a higher effect of decreasing the number of inclusions in the case where a gas is blown from the top of the eave-shaped part 9. This is because, by blowing the gas from the top of the eave-shaped part 9, the spreading of the distribution of the gas bubbles can be prevented and the separation of the trapped inclusions from the

gas bubbles can be prevented, which results in inclusions being efficiently trapped.

[0074] In addition, using three methods of blowing a gas from the eave-shaped part 9 described above, that is, "blowing in four directions", "blowing at right angle to long side surface" and "blowing in parallel with long side surface", the influence of these three blowing methods on the inclusion number density in a steel cast piece was investigated. The investigation results are illustrated in Fig. 13.

[0075] In this case, a tundish 1 having a total area of gas blowing ports 10 of 0.018 m² was used for "blowing in four directions". This tundish 1 is the same as the tundish 1 used to investigate the data illustrated in Fig. 12. Although the tundish 1 which was used for "blowing in four directions" was used for "blowing at right angle to long side surface", a gas was not blown through the gas blowing ports 10 placed on the top of the eave-shaped part 9 on the weir long side, and an argon gas was blown only through the gas blowing ports 10 placed on the top of the eave-shaped part 9 on the weir short side. In this case, the total area of the gas blowing ports 10 is 0.006 m² (= 2 ports × 0.3 m × 0.01 m). In addition, although the tundish 1 which was used for "blowing in four directions" was used for "blowing in parallel with long side surface", a gas was not blown through the gas blowing ports 10 placed on the top of the eave-shaped part 9 on the weir short side, and an argon gas was blown only through the gas blowing ports 10 placed on the top of the eave-shaped part 9 on the weir long side. In this case, the total area of the gas blowing ports 10 is 0.012 m² (= 4 ports × 0.3 m × 0.01 m).

[0076] As illustrated in Fig. 13, it is clarified that, in the case where a gas is blown from all positions of the eave-shaped part 9 surrounding the molten steel charging position 5, that is, in the case of "blowing from four directions", there is a maximum effect of flotation separation of inclusions. However, even in the case of "blowing at right angle to long side surface" and "blowing in parallel with long side surface", an inclusion number density was less than 0.30 number/m². In reference to Fig. 12, since the inclusion number density was 0.30 number/m² or more in the case where an inert gas was blown from the bottom of the tundish 1, in comparison to this case, it is clarified that there was a large effect of decreasing the number of inclusions.

[0077] That is, according to the present invention, by blowing an inert gas from the top of the eave-shaped part 9, it is possible to promote the flotation of fine inclusions which are difficult to separate from the molten steel 13, the flotation separation of inclusions in the tundish 1 is promoted in comparison to conventional cases.

[0078] In addition, in the case where the shape of the weir 7 is optimized in accordance with expression (1) and further, an inert gas is blown from the top of the eave-shaped part 9, since the flotation separation of inclusions in the tundish 1 is promoted to a higher degree, it is possible to manufacture a steel cast piece 14 having a significantly high cleanliness.

[0079] Incidentally, in the case where the opening width of the notch 12 is less than 0.5 mm, since the flow rate of molten steel which passes through the notch 12 is excessively small, there is a case where some of the molten steel 13 is left in the space surrounded by the weir 7. Therefore, it is preferable to ensure that the opening width of the notch 12 be 0.5 mm or more.

[0080] In addition, since the molten steel charging position 5 is not a "point" and actually has an area to some extent, in order to surround such molten steel charging position from four directions while ensuring that the weir 7 surround a sufficient absolute amount of a space, the length of the upper opening of the weir 7 in the direction of the long side of the tundish is set to be at least equivalent to the inner diameter of the bottom edge of the long nozzle 3, preferably more than the inner diameter. Here, in Fig. 1 and Fig. 4, the center of the molten steel charging position which has an area is used to indicate the molten steel charging position 5.

EXAMPLE 1

[0081] In a continuous casting test, about 250 tons of aluminum killed ultralow-carbon steel which had been smelted by performing carburization refining using a converter furnace and by then performing vacuum degassing refining using an RH vacuum degassing refining system was cast into a steel cast slab using a slab continuous casting apparatus having a tundish of a 2 strand type which had a capacity of 80 tons and which was configured as illustrated in Fig. 1.

[0082] At that time, by changing the height H of the upper surface of the molten steel in the tundish, the flow rate Q of the molten steel charged from the ladle into the tundish, the height h of the weir, the area S of the upper opening of the weir, the distance L between the front edge on the molten steel charging position side of the eave-shaped part and the surface on the short side of the tundish, and the distance W between the front edge on the molten steel charging position side of the eave-shaped part and the surface on the long side of the tundish, tests (the examples of the present invention 1 through 14) in which the ranges according to the present invention were satisfied and tests (comparative examples 1 through 3) in which the ranges according to the present invention were not satisfied were carried out.

[0083] In addition, at that time, the ratio (L'/W') between the length (L') of the side in the direction of the long side of the tundish of the inner space of the weir having a shape of rectangular solid and the length (W') of the side in the direction of the short side of the tundish of the inner space were changed within a range of 0.25 to 4.5. For all the tundishes, the opening width of each of the two notches was 20 mm, the extension length of the eave-shaped part (the extension length from the inner wall surface of the wall part) was 0.12 m, and the radius of the circular arc connecting the wall part and the eave-shaped part was 0.06 m. The maximum surface flow velocity (V_e) was within a range of 0.08

to 0.52 m/s in accordance with the shape of the weir.

[0084] In addition, for comparison, a test (conventional example 1) was carried out using a tundish which was the same as that used in the tests described above with exception of the fact this tundish did not have a weir.

[0085] The height of the upper surface of the molten steel in the tundish, the flow rate of the molten steel charged from the ladle into the tundish, the shape of the weir of the used tundish are given in Table 1. In addition, the value of expression (3) which was determined from the height of the upper surface of the molten steel in the tundish, the flow rate of the molten steel charged from the ladle into the tundish and the shape of the weir are also given in Table 1. Moreover, the ratio (L'/W') and the maximum surface flow velocity (V_e) of the molten steel in the tundish which was determined by the tilting angle of a bar which was dipped in the molten steel in the tundish are given in Table 1.

[Table 1]

	H (m)	Q (ton/min)	h (m)	S (m ²)	L (m)	W (m)	L' (m)	W' (m)	Value of Relational Expression (3)	L'/W	Ve (m/s)
Conventional Example 1	1.0	3.0	-	-	-	-	-	-	-	-	0.45
Example 1	1.0	4.0	0.20	0.40	3.80	0.46	1.20	0.61	4.60	1.97	0.30
Example 2	1.1	5.0	0.20	0.50	3.95	0.46	0.90	0.61	4.61	1.48	0.48
Example 3	1.0	4.0	0.20	0.10	3.95	0.46	0.90	0.61	5.24	1.48	0.45
Example 4	1.3	5.0	0.20	0.27	4.20	0.46	0.90	0.61	3.54	1.48	0.30
Example 5	1.0	5.0	0.20	0.42	4.10	0.53	0.90	0.61	4.39	1.48	0.15
Example 6	0.8	5.0	0.40	0.10	4.03	0.59	0.88	0.61	9.04	1.44	0.44
Example 7	0.7	3.4	0.20	0.15	4.13	0.53	0.88	0.61	5.05	1.44	0.40
Example 8	1.0	6.0	0.30	0.25	4.04	0.54	0.88	0.61	4.39	1.44	0.32
Example 9	1.0	5.0	0.20	0.80	3.60	0.62	0.86	0.52	6.84	1.65	0.08
Example 10	1.0	6.5	0.15	0.07	3.62	0.64	0.86	0.52	9.32	1.65	0.52
Example 11	1.0	4.6	0.34	0.10	3.95	0.92	0.90	0.20	6.43	4.50	0.45
Example 11	1.0	4.0	0.20	0.10	4.20	0.35	0.20	0.80	5.25	0.25	0.45
Example 13	1.1	6.5	0.34	0.08	4.15	1.12	0.90	0.20	9.01	4.50	0.52
Example 14	1.05	5.2	0.20	0.55	3.90	0.30	0.20	0.80	4.68	0.25	0.09
Comparative Example 1	1.15	6.5	0.08	0.33	3.10	0.40	1.50	0.25	3.23	6.00	0.55
Comparative Example 2	1.3	6.5	0.05	0.50	3.00	0.40	1.40	0.25	3.16	5.60	0.09
Comparative Example 3	1.5	6.0	0.05	0.50	3.05	0.58	1.42	0.27	3.28	5.26	0.09

[0086] After casting had been performed, the number of inclusions in the cast piece was investigated by performing ultrasonic flaw inspection. Fig. 14 illustrates the results of the investigation on the number of inclusions. Here, in Fig. 14, the results are illustrated in the form of an index which was determined using the number of inclusions determined in conventional example 1 in which a tundish having no weir was used as a standard (= 1.0).

[0087] As illustrated in Fig. 14, it is clarified that, using the present invention, there was a significant decrease in the number of inclusions in a steel cast slab. That is, it is clarified that, using the present invention, it is possible to significantly promote the flotation effect of inclusions in the tundish.

EXAMPLE 2

[0088] In a continuous casting test, about 250 tons of aluminum killed ultralow-carbon steel which had been smelted by performing carburization refining using a converter furnace and by then performing vacuum degassing refining using an RH vacuum degassing refining system was cast into a steel cast slab using a slab continuous casting apparatus having a tundish of a 2 strand type which was configured as illustrated in Fig. 4.

[0089] The used tundish had a capacity of 80 tons in terms of molten steel, and a weir having an eave-shaped part and having a length of weir long side of 1200 mm, a length of the weir short side of 600 mm and a height of the weir of 230 mm was placed in the tundish. Two gas blowing ports having a length of 0.3 m and a width of 0.01 m were placed across a notch on the top of the eave-shaped part on the each of the weir long sides. In addition, one gas blowing port having a length of 0.3 m and a width of 0.01 m was placed on the top of the eave-shaped part on the each of the weir short sides. The total area of the gas blowing ports was 0.018 m² (= 6 ports×0.3 m×0.01 m). This weir had one notch having a width of 10 mm on each of the weir long sides.

[0090] Using this tundish, in "blowing in four directions", argon gas was blown through all the gas blowing ports (total area = 0.018 m²) as an inert gas. In "blowing at right angle to long side surface", an inert gas was not blown through the gas blowing ports placed on the top of the eave-shaped part on the weir long sides, and argon gas was blown only through the gas blowing ports placed on the top of the eave-shaped part on the weir short sides (total area = 0.006 m²). In addition, in "blowing in parallel with long side surface", an inert gas was not blown through the gas blowing ports placed on the top of the eave-shaped part on the weir short sides, and argon gas was blown only through the gas blowing ports placed on the top of the eave-shaped part on the weir long sides (total area = 0.012 m²).

[0091] The gas blowing ports were made of porous brick, and the gas blowing ports were formed by embedding the porous brick in the eave-shaped part.

[0092] In the test, by changing the flow rate of argon gas which was blown through the gas blowing ports on the eave-shaped part, tests (the examples of the present invention 21 through 28) in which the ranges according to the present invention were satisfied and tests (comparative examples 22 through 26) in which the ranges according to the present invention were not satisfied were carried out. In addition, a test (comparative example 21) in which argon gas was blown from the positions on the bottom of the tundish which were placed away from the eave-shaped part toward the molten steel discharge ports. In comparative example 21, the total area of the gas blowing ports were 0.018 m². Moreover, for comparison, a test (conventional example 21) was carried out using a tundish which was the same as that used in the tests described above with exception of the fact this tundish did not have a weir. The flow rate and blowing position of the argon gas blown into the molten steel in the tundish are given in Table 2.

[Table 2]

	Argon Gas Flow Rate (NL/(s×m ²))	Gas Blowing Position
Conventional Example 21	-	-
Example 21	50	Eave-shaped Part: Blowing in Four Directions
Example 22	100	Eave-shaped Part: Blowing in Four Directions
Example 23	150	Eave-shaped Part: Blowing in Four Directions
Example 24	300	Eave-shaped Part: Blowing in Four Directions
Example 25	50	Eave-shaped Part: Blowing at Right Angle to Long Side Surface
Example 26	150	Eave-shaped Part: Blowing at Right Angle to Long Side Surface

(continued)

	Argon Gas Flow Rate (NL/(s×m ²))	Gas Blowing Position
Example 27	50	Eave-shaped Part: Blowing in Parallel with Long Side Surface
Example 28	150	Eave-shaped Part: Blowing in Parallel with Long Side Surface
Comparative Example 21	150	Bottom of Tundish
Comparative Example 22	350	Eave-shaped Part: Blowing at Right Angle to Long Side Surface
Comparative Example 23	350	Eave-shaped Part: Blowing in Four Directions
Comparative Example 24	330	Eave-shaped Part: Blowing in Four Directions
Comparative Example 25	350	Eave-shaped Part: Blowing in Four Directions
Comparative Example 26	0	-

[0093] After casting had been performed, the number of inclusions in the cast piece was investigated by performing ultrasonic flaw inspection. Fig. 15 illustrates the results of the investigation on the number of inclusions.

[0094] As illustrated in Fig. 15, it is clarified that, using the present invention, there was a significant decrease in the number of inclusions in a steel cast slab. That is, it is clarified that, using the present invention, it is possible to significantly promote flotation effect of inclusions in the tundish.

Reference Signs List

[0095]

- 1 tundish
- 2 mold
- 3 long nozzle
- 4 submerged nozzle
- 5 molten steel charging position
- 6 molten steel discharge port
- 7 weir
- 8 wall part
- 9 eave-shaped part
- 10 gas blowing port
- 11 gas introduction pipe
- 12 notch
- 13 molten steel
- 14 steel cast piece

Claims

1. A method for manufacturing a high-cleanliness steel cast piece using a continuous casting method, the method comprising charging deoxidized molten steel from a ladle into a tundish once and then discharging the molten steel from the tundish into a mold in order to continuously cast a steel cast piece using a continuous casting tundish in which a weir consisting of a wall part extending upward from the bottom of the tundish so as to surround a molten steel charging position where a molten steel flow charged from the ladle collides with the bottom of the tundish from four directions and an eave-shaped part horizontally extending from the top edge of the wall part toward the molten steel charging position is placed at a position between the molten steel charging position and a molten steel discharge port where the molten steel is discharged into the mold from the tundish, wherein the wall part and the eave-shaped part have one or more notches penetrating through the wall part and the eave-shaped part and wherein the height of the weir, the area of the upper opening of the weir, the distance between the front edge on

the molten steel charging position side of the eave-shaped part and the surface on the short side of the tundish, the distance between the front edge on the molten steel charging position side of the eave-shaped part and the surface on the long side of the tundish, the height of the upper surface of the molten steel in the tundish and the flow rate of the molten steel charged from the ladle into the tundish satisfy expression (1) below:

$$3.50 \leq \left[(H-h) \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right]^{-0.6} + \left[\frac{7L}{6} \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right] + \left[\frac{7W}{6} \times \left(\frac{S \times \rho}{Q} \right)^{1.37} \right] \leq 9.50 \quad \dots(1),$$

where, in expression (1), H represents the height (m) of the upper surface of the molten steel in the tundish, h represents the height (m) of the weir, S represents the area (m²) of the upper opening of the weir having an eave-shaped part, ρ represents the density (ton/m³) of the molten steel, Q represents the flow rate (ton/min) of the molten steel charged from the ladle into the tundish, L represents the distance (m) between the front edge on the molten steel charging position side of the eave-shaped part and the surface on the short side of the tundish, W represents the distance (m) between the front edge on the molten steel charging position side of the eave-shaped part and the surface on the long side of the tundish.

2. The method for manufacturing a high-cleanliness steel cast piece using a continuous casting method according to Claim 1, wherein the wall part surrounds an internal space having a shape of a rectangular solid, and wherein the ratio (L' / W') of the length (L' in units of m) of the rectangular solid in the direction of the long side of the tundish to the length (W' in units of m) of the rectangular solid in the direction of the short side of the tundish is 0.3 or more and 4.0 or less.
3. The method for manufacturing a high-cleanliness steel cast piece using a continuous casting method according to Claim 1 or 2, wherein a maximum surface flow velocity (Ve) of the molten steel in the tundish is 0.10 m/s or more and 0.50 m/s or less.
4. The method for manufacturing a high-cleanliness steel cast piece using a continuous casting method according to any one of Claims 1 to 3, wherein an inert gas is blown into the molten steel in the tundish at a gas flow rate satisfying expression (2) below through a gas blowing port which is fitted to the top of the eave-shaped part in order to blow the inert gas and through a gas introduction pipe which is installed in the wall part in order to introduce the inert gas to the gas blowing port:

$$20 \leq R \leq 300 \quad \dots(2),$$

where, in expression (2), R represents the inert gas flow rate (NL/(s×m²)) per unit area of the gas blowing port of the gas which is blown through the gas blowing port.

5. A continuous casting tundish, the tundish having a weir consisting of a wall part extending upward from the bottom of the tundish so as to surround a molten steel charging position where a molten steel flow charged from the ladle collides with the bottom of the tundish from four directions and an eave-shaped part horizontally extending from the top edge of the wall part toward the molten steel charging position, wherein the weir is placed at a position between the molten steel charging position and a molten steel discharge port where the molten steel is discharged into the mold from the tundish and in which the wall part and the eave-shaped part have one or more notches penetrating through the wall part and the eave-shaped part, and wherein a gas blowing port is fitted to the top of the eave-shaped part in order to blow the inert gas and a gas introduction pipe is installed in the wall part in order to introduce the inert gas to the gas blowing port.
6. A method for manufacturing a high-cleanliness steel cast piece using a continuous casting method, the method comprising charging deoxidized molten steel from a ladle into a tundish and then discharging the molten steel from the tundish into a mold in order to continuously cast a steel cast piece using the continuous casting tundish according to Claim 5 while blowing an inert gas through a gas blowing port into the molten steel in the tundish at a gas flow rate satisfying expression (2) below:

$$20 \leq R \leq 300 \quad \dots(2) ,$$

where, in expression (2), R represents the inert gas flow rate (NL/(s×m²)) per unit area of the gas blowing port of the gas which is blown through the gas blowing port.

7. The method for manufacturing a high-cleanliness steel cast piece using a continuous casting method according to Claim 6, wherein an inert gas is blown through all the positions of the eave-shaped parts on the four sides surrounding the molten steel charging position.

FIG. 1

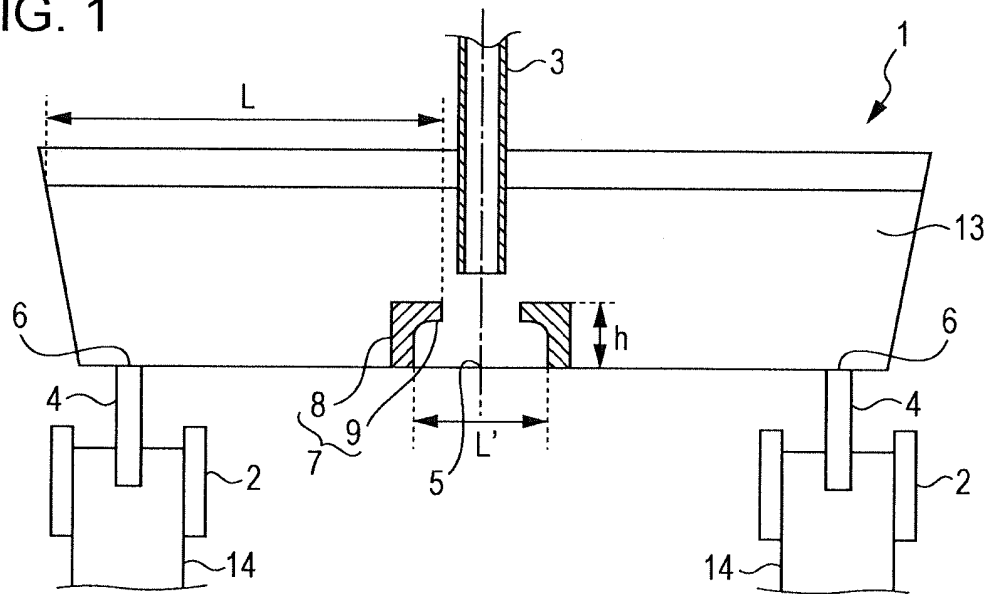


FIG. 2

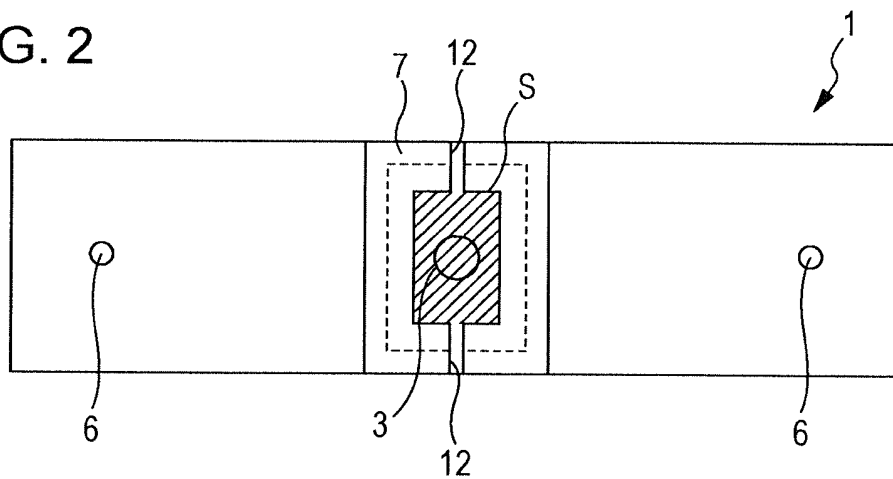


FIG. 3

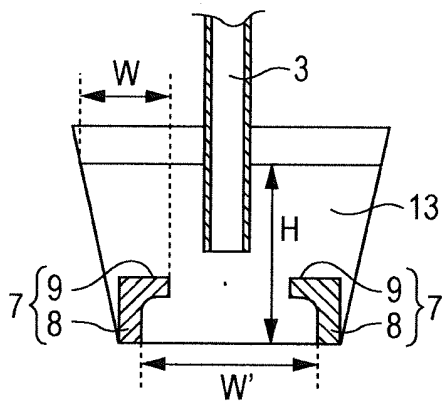


FIG. 4

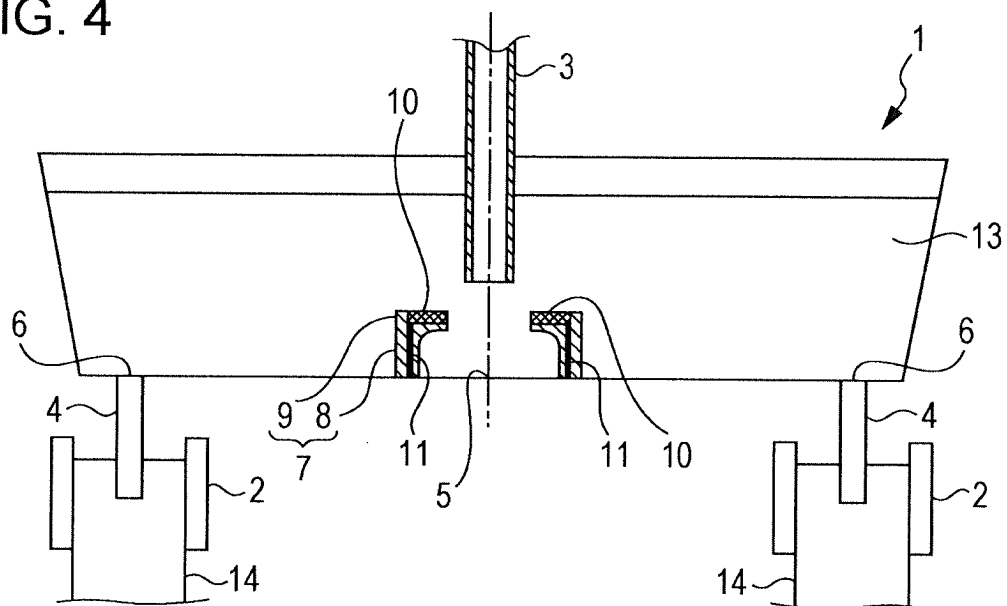


FIG. 5

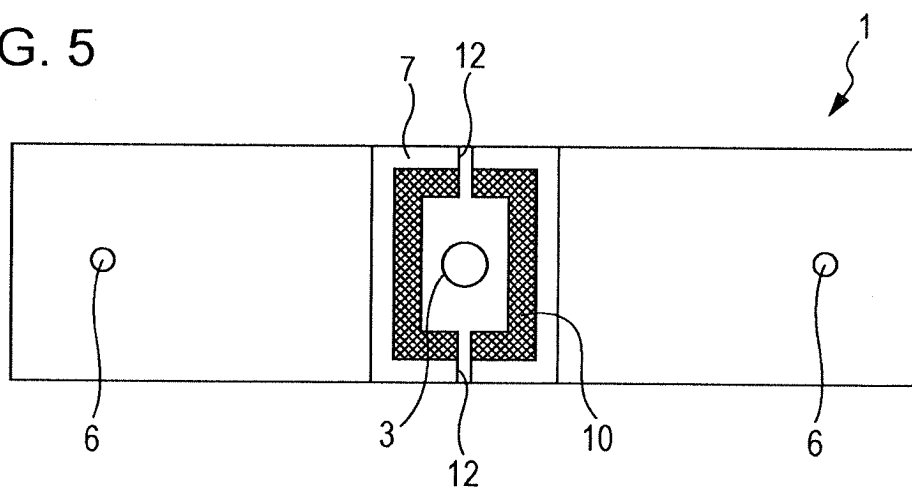


FIG. 6

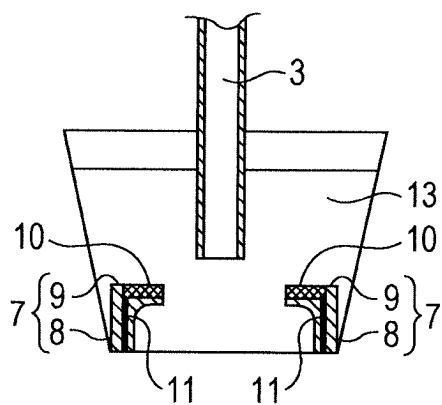


FIG. 7

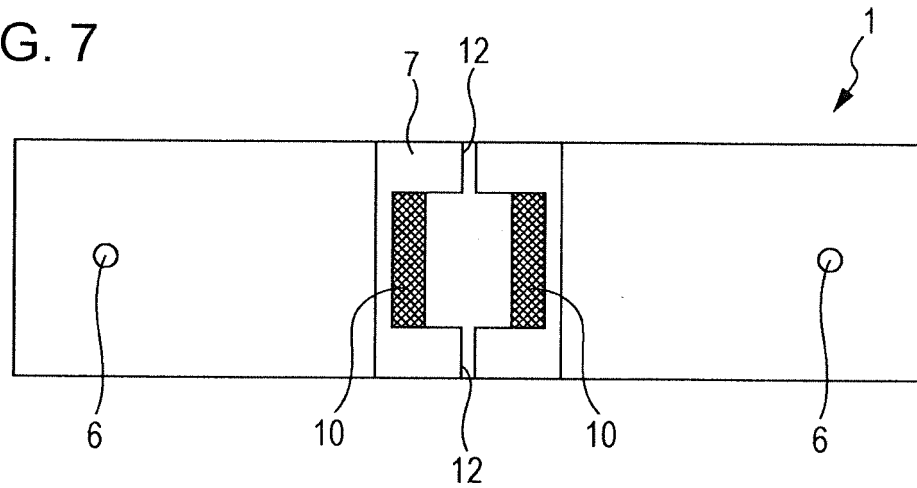


FIG. 8

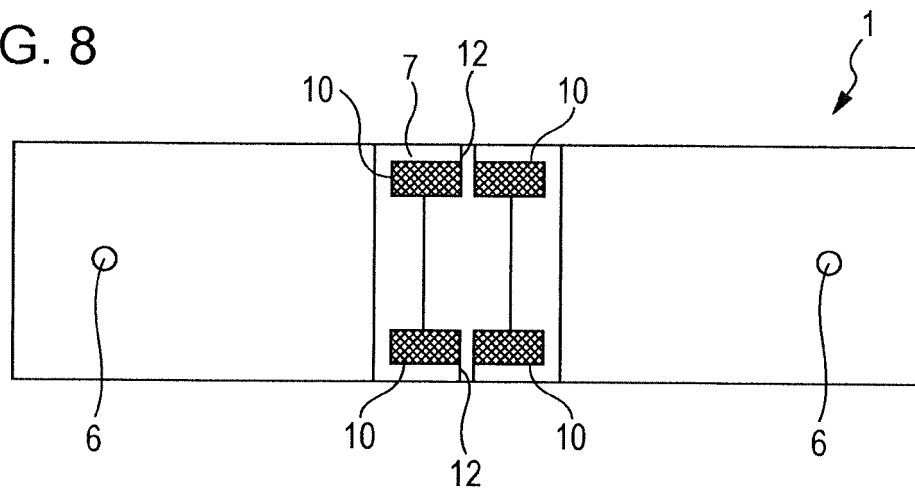


FIG. 9

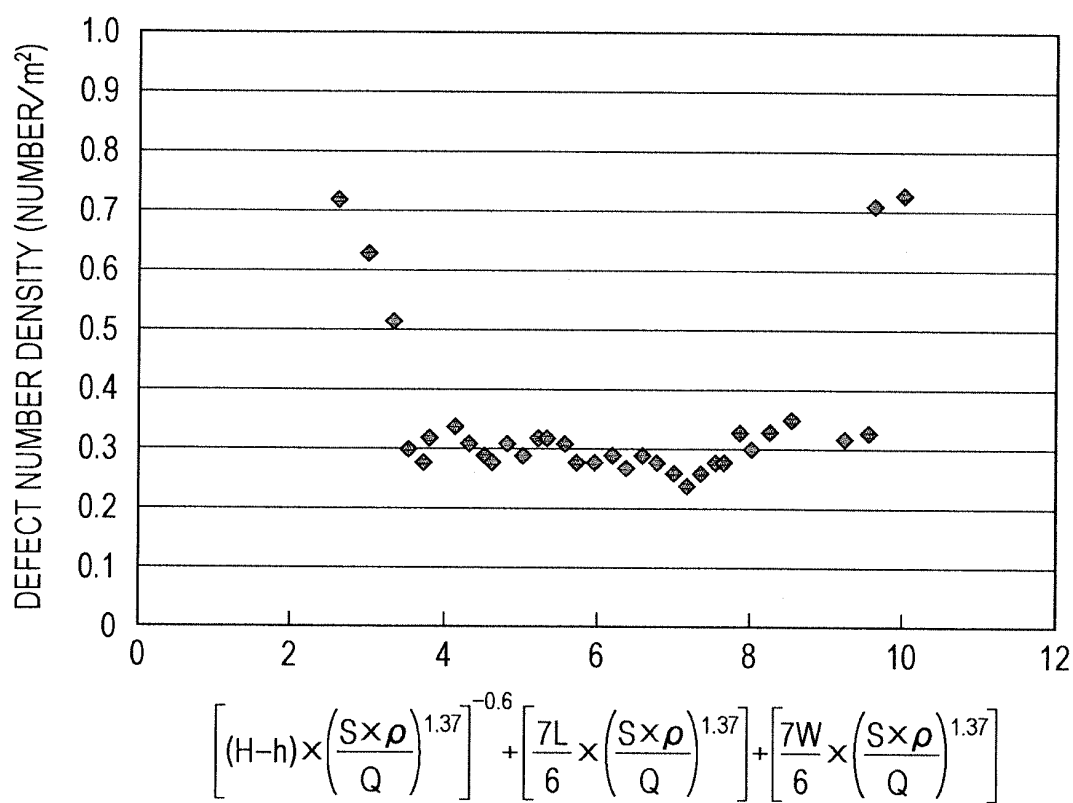


FIG. 10

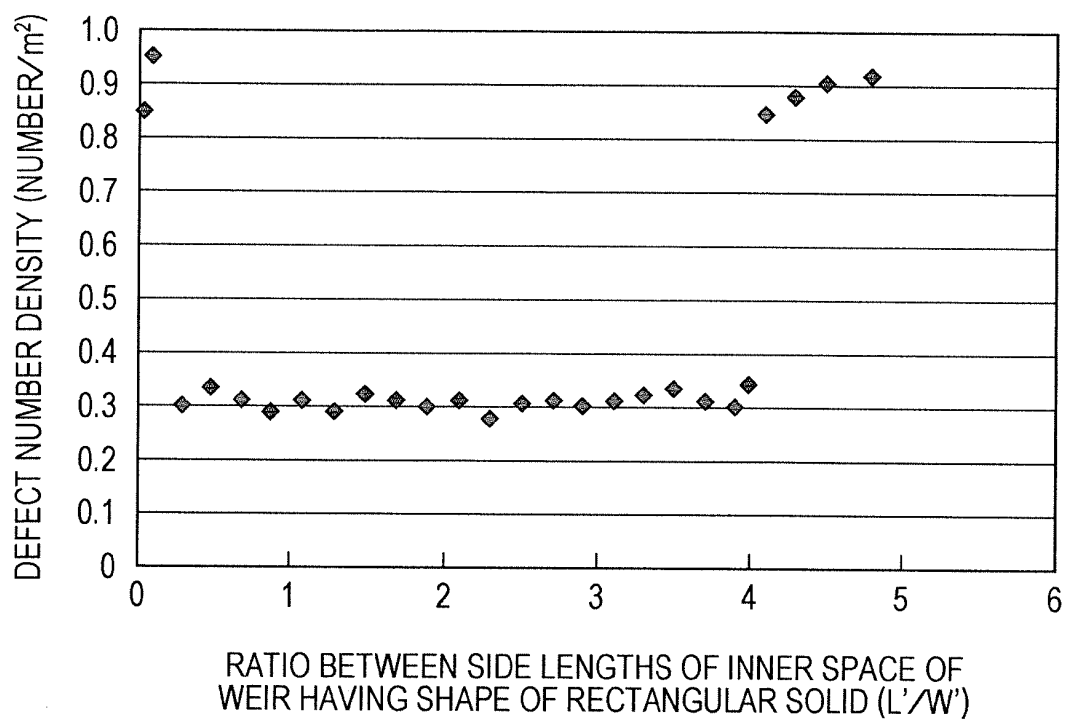


FIG. 11

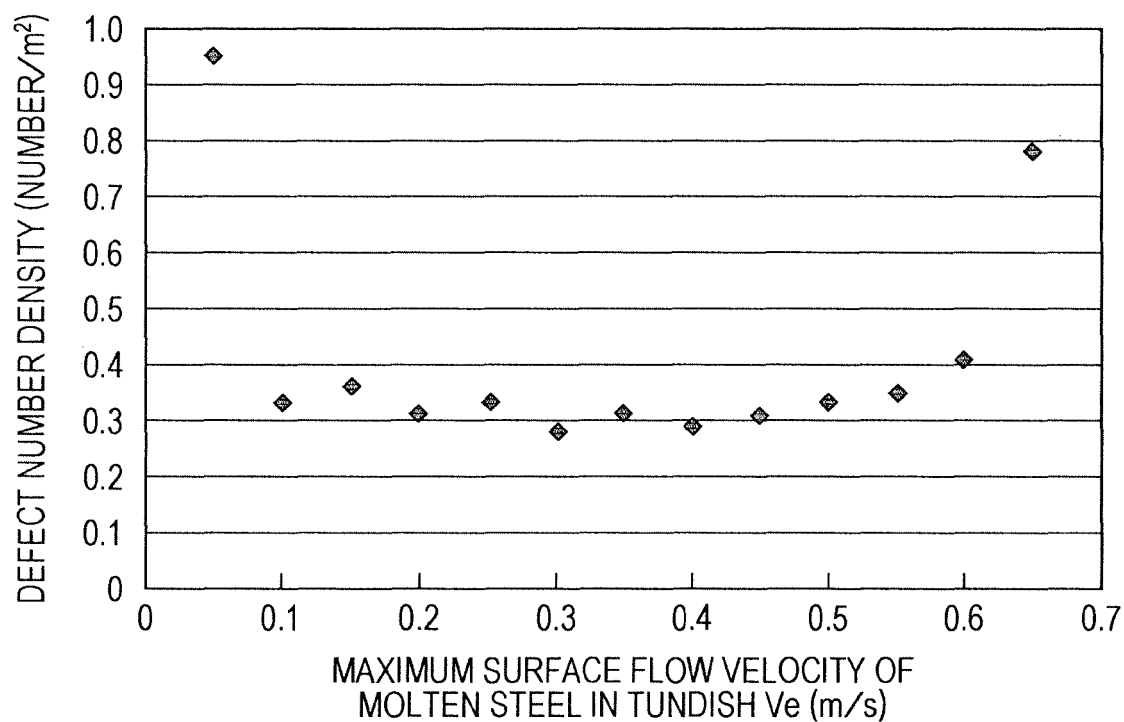


FIG. 12

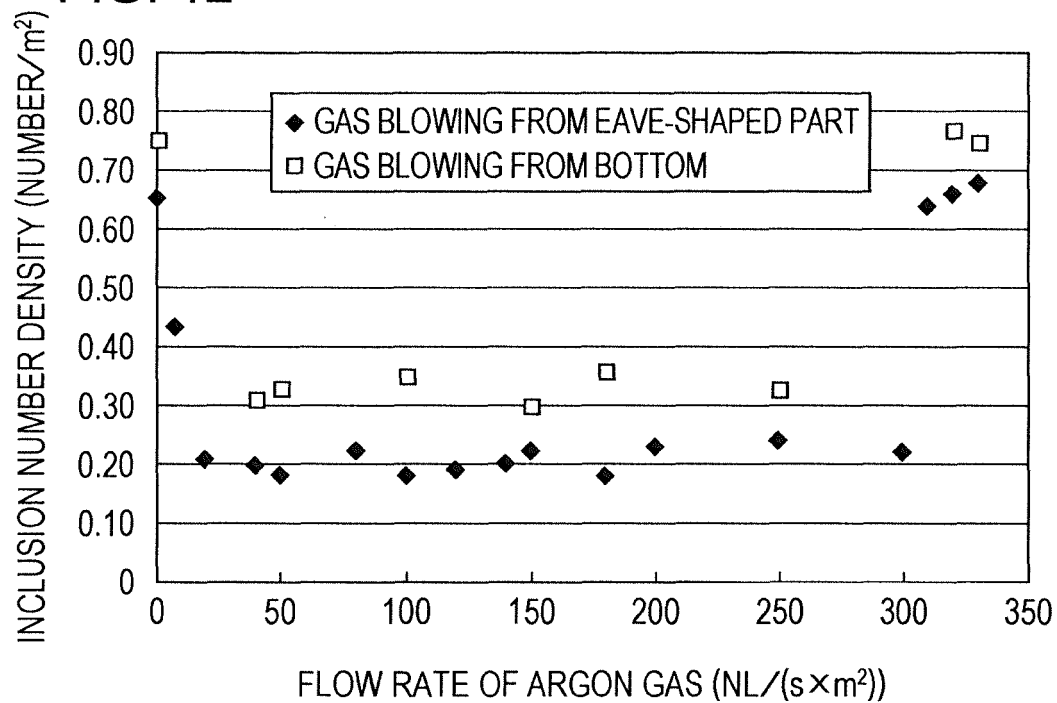


FIG. 13

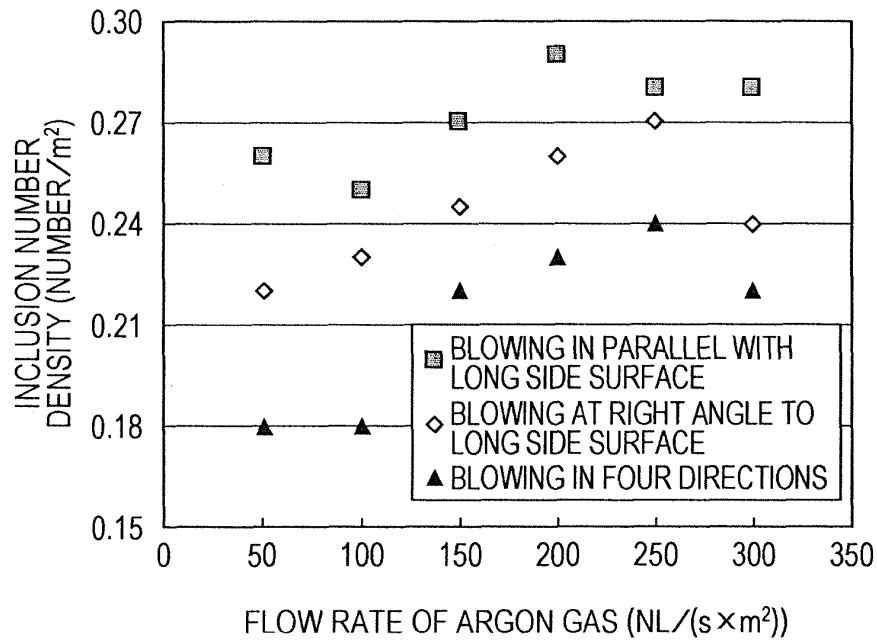


FIG. 14

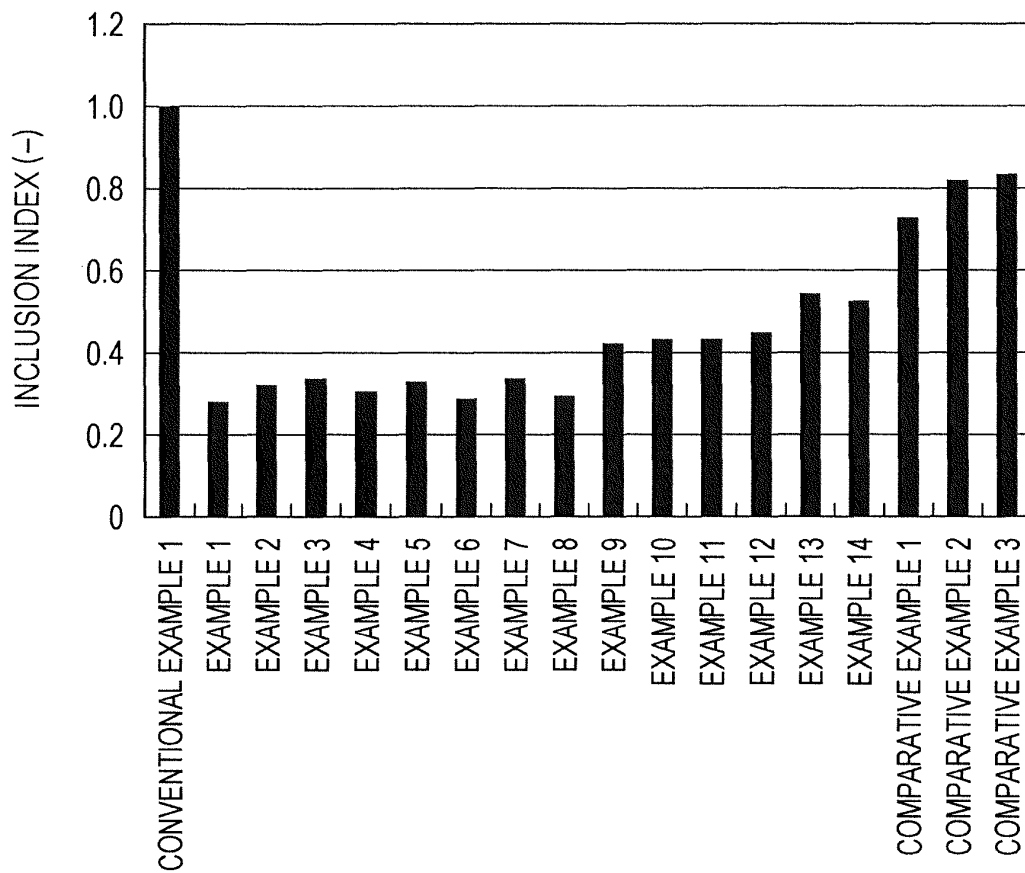
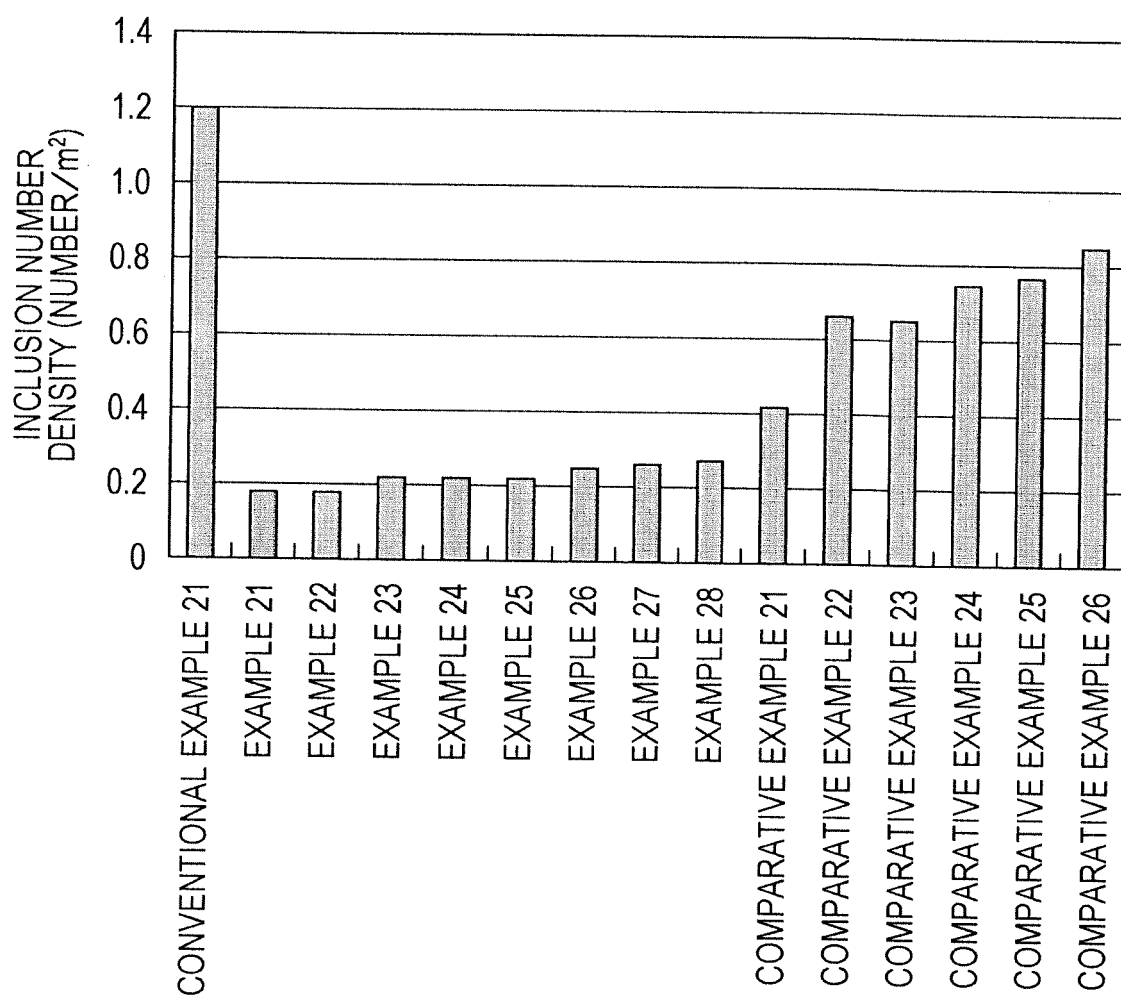


FIG. 15



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/003632

A. CLASSIFICATION OF SUBJECT MATTER
B22D11/10 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B22D11/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2013
Kokai Jitsuyo Shinan Koho 1971-2013 Toroku Jitsuyo Shinan Koho 1994-2013

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.
Y	WO 00/50190 A1 (FOSECO INTERNATIONAL LTD.), 31 August 2000 (31.08.2000), entire text	5-7
Y	JP 2004-1077 A (JFE Steel Corp.), 08 January 2004 (08.01.2004), claims	5-7
A	JP 2012-20315 A (JFE Steel Corp.), 02 February 2012 (02.02.2012), entire text	1-7
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☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search
21 June, 2013 (21.06.13)

Date of mailing of the international search report
02 July, 2013 (02.07.13)

Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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