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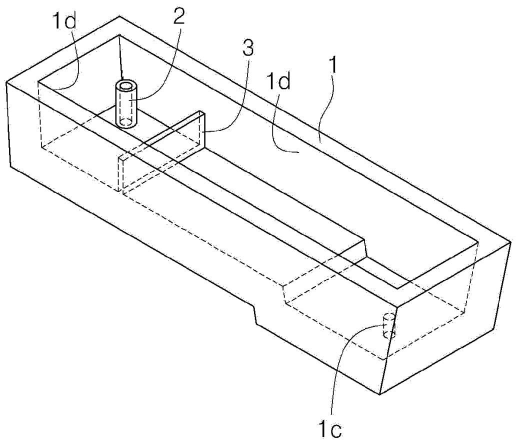
(54) **MOLTEN MATERIAL PROCESSING DEVICE**

(57) Provided is a molten material processing device including a container which includes a molten material accommodation space formed therein, a molten material inlet part disposed at one side thereof, and a molten material outlet formed at the other side thereof, and a dam which is positioned between the molten material inlet part and the molten material outlet so that one surface thereof directly faces the molten material inlet part, is mounted on a bottom of the container and connected to two longitudinal direction side walls. The dam is mounted on a drop area of a molten material formed below the molten material inlet part and has a top surface positioned in an upper portion of the molten material. The molten material processing device is capable of increasing an area that an upward flow reaches to reduce a dead volume of the molten material, thereby improving inclusion removal capacity.

FIG. 8



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Description

TECHNICAL FIELD

[0001] The present invention relates to a molten material processing device and, more particularly, to a molten material processing device in which a dead volume is reduced to improve inclusion removal capacity.

BACKGROUND ART

[0002] Continuous casting apparatuses generally include a ladle for conveying molten steel, a tundish for receiving the molten steel from the ladle and temporarily storing the molten steel, a mold for primarily solidifying the molten steel into a slab while continuously receiving the molten steel from the tundish, and a cooling zone for secondarily cooling the slab continuously drawn from the mold and performing a series of forming operations.

[0003] When performing a continuous casting process for casting slabs using such a continuous casting apparatus, it is important to retain the molten steel within the tundish for a sufficient period of time. For example, when the molten steel is retained within the tundish for a sufficient period of time, inclusions may be smoothly floated and separated from the molten steel. To retain the molten steel within the tundish for the sufficient period of time, an upward flow of the molten steel within the tundish has to be actively induced.

[0004] Patent Document 1 below proposes a method for constructing a plurality of refractory dams such as a dam, an auxiliary dam, and an induction dam within a tundish and then injecting an argon gas into molten steel through the auxiliary dam, thereby actively inducing an upward flow, rather than using a method for controlling a flow of molten steel utilizing a dam and a weir. Also, Patent Document 2 proposes a method for mounting an impact pad and a separation wall on a lower side of a shroud nozzle and allowing the molten steel to collide with the impact pad and to pass through a space between the separation wall and the impact pad, thereby actively inducing an upward flow of the molten steel.

[0005] However, in the methods proposed in Patent Documents 1 and 2, additional manufacturing costs are required to construct a plurality of dams within the tundish, and installation becomes complicated. Also, there is an increase in dead volume in which a flow rate of the molten steel is extremely low in bottom surfaces of the plurality of refractory dams and the separation wall (the surfaces toward a steel tapping hole of the tundish), and regions away from the impact pad.

[0006] Particularly, when the dead volume of the molten steel within the tundish increases, the degree to which the molten steel is retained within the dead volume becomes inappropriate, and the residence time of the molten steel may become excessively long. That is, when the dead volume of the molten steel within the tundish increases, the appropriate residence time of the molten steel within the tundish is not ensured. Also, when inclusions enter the dead volume, the inclusions are retained in a center of the dead volume due to a low flow rate of the molten steel, which prevents the inclusions from being floated and separated from the molten steel. The inclusions flow in a mold and cause inclusion-related quality failure in the slab.

[0007] Thus, in addition to ensure the sufficient residence time of the molten steel to float and separate inclusions that are present in the molten steel, it is also important to ensure the appropriate residence time of the molten steel. Also, it is important to reduce the size of the dead volume. That is, it is critical to reduce the size of the dead volume while retaining the molten steel within the tundish for the sufficient but appropriate period of time. To this end, the occurrence of the dead volume has to be minimized while actively inducing the upward flow of the molten steel within the tundish.

[0008] The background art of the invention is disclosed in the following patent documents.

(Patent Document 1) KR10-2014-0085127 A
(Patent Document 2) KR10-1602301 B1

DISCLOSURE OF THE INVENTION

TECHNICAL PROBLEM

[0009] The present invention provides a molten material processing device capable of ensuring a sufficient and appropriate residence time of a molten material accommodated in a container.

[0010] The present invention provides a molten material processing device capable of reducing a dead volume of a molten material to improve inclusion removal capacity.

[0011] The present invention provides a molten material processing device capable of widely distributing an upward flow that reaches a top surface of a molten material.

TECHNICAL SOLUTION

[0012] A molten material processing device according to an embodiments of the Invention includes: a container which includes a molten material accommodation space formed therein, a molten material inlet part disposed at one side thereof, and a molten material outlet formed at the other side thereof; and a dam which is positioned between the molten material inlet part and the molten material outlet so that one surface thereof directly faces the molten material inlet part, and which is mounted on a bottom of the container and connected to two longitudinal direction side walls, wherein the dam is mounted on a drop area of a molten material formed below the molten material inlet part and has a top surface positioned in an upper portion of the molten material.

[0013] The dam may be mounted on an edge portion of the drop area.

[0014] The other surface of the dam directly may face a width direction side wall on the molten material outlet side.

[0015] A size of the drop area may be proportional to an inner diameter of the molten material inlet part, and a distance between the one surface of the dam and the molten material inlet part may be proportional to the size of the drop area.

[0016] A distance between the one surface of the dam and the molten material inlet part may be in a range of 2.5 to 5 times an inner diameter of the molten material inlet part.

[0017] A height of the top surface of the dam may be in a range of 0.5 to 0.75 times a melt height of the molten material.

[0018] The molten material processing device may further include a through-hole formed in the dam.

[0019] The through-hole may be formed in a lower portion of the dam, defined in a direction from the one side toward the other side, and have an inner wall directly connected to the bottom.

ADVANTAGEOUS EFFECTS

[0020] According to the embodiment, the dam is mounted on the bottom of the container so as to be positioned on the edge of the pouring zone of the molten material, and the height of the top surface of the dam may be optimized, thereby optimizing the flow field of the molten material. Through this, the sufficient and appropriate residence time of the molten material accommodated in the container may be ensured, and the dead volume of the molten material may be reduced to improve the inclusion removal capacity. Also, the strong flow of the molten steel within the pouring zone is directed to the top surface of the molten material to form the upward flow, thereby widely distributing the upward flow that reaches the top surface of the molten material and further improving the inclusion removal capacity.

[0021] Thus, the inclusion in the molten material may be smoothly floated and separated to improve the cleanness of molten material, thereby improving the quality of the product made of the molten material.

[0022] Also, the additional structure for reducing the flow rate of the molten material within the container may not be necessarily mounted, and the size and the number of the refractory structures mounted within the container may be minimized and optimized to simplify the structure. Therefore, the manufacturing costs may be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

FIG. 1 is a view illustrating modeling structures for flow evaluation of molten material processing devices according to an embodiment of the present invention and comparative examples.

FIG. 2 is a view showing flow evaluation results of the molten material processing devices according to the embodiment of the present invention and the comparative examples.

FIG. 3 is a view showing quantitative numerical values of flow characteristics of the molten material derived from the flow evaluation results according to the embodiment of the present invention and the comparative examples.

FIG. 4 is a view illustrating modeling structures for flow evaluation of molten material processing devices according to embodiments of the present invention and comparative examples.

FIG. 5 is a view showing quantitative numerical values of flow characteristics of the molten material derived from the flow evaluation results according to the embodiments of the present invention and the comparative examples.

FIG. 6 is a view showing flow evaluation results according to the embodiments of the present invention.

FIGS. 7 and 8 are schematic views of a molten material processing device according to an embodiment of the present invention.

MODE FOR CARRYING OUT THE INVENTION

[0024] Hereinafter, embodiments of the present invention will be described in detail with reference to the accompanying drawings. The present invention may, however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments of the present invention are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the present invention to those skilled in the art. In the drawings, the dimensions are exaggerated for clarity of illustration, and like reference numerals refer to like elements throughout.

[0025] A molten material processing device according to an embodiment of the present invention provides a technical feature of reducing a dead volume of a molten material while increasing an area that an upward flow reaches in a top surface of the molten material, thereby improving inclusion removal capacity. The molten material processing device according to the embodiment of the present invention is used in a continuous casting process of a steel mill, and may also be used in diverse casting processes using various molten materials. The embodiment of the present invention will be described with reference to the continuous casting process.

[0026] FIGS. 7 and 8 are schematic views illustrating a molten material processing device according to the embodiment of the present invention. Here, FIG. 7 is a cross-sectional view of the molten material processing device, and FIG. 8 is a perspective view of the molten material processing device. Here, as illustrated in FIG. 7, one direction is referred to as a direction in which one width direction side wall 1a is spaced apart from the other width direction side wall 1b, and a vertical direction is referred to as a direction in which a molten material inlet part 2 extends. Also, the other direction is referred to as a direction perpendicular to both the one direction and a height direction. For example, the other direction is a direction in which a dam 3 of FIG. 8 extends. The one direction may be referred to as a longitudinal direction, the other direction may be referred to as a width direction, and the vertical direction may be referred to as the height direction.

[0027] The molten material processing device according to the embodiment of the present invention will be described with reference to FIGS. 7 and 8. The molten material processing device includes a container 1 including a molten material accommodation space formed therein, a molten material inlet part 2 disposed at one side thereof, and a molten material outlet 1c formed at the other side thereof. The molten material processing device includes a dam 3 which is positioned between the molten material inlet part 2 and the molten material outlet 1c so that one surface thereof directly faces the molten material inlet part 2, and which is mounted on a bottom of the container 1 and connected to two longitudinal direction side walls 1d.

[0028] Here, the dam 3 is mounted on a drop area of a molten material formed below the molten material inlet part 2 and has a top surface positioned in an upper portion of the molten material.

[0029] The molten material (not shown) may include molten steel. The molten material is stored in a conveyance container, for example, a ladle (not shown) and conveyed to the molten material processing device. The molten material may be positioned above the container 1 and connected to the molten material inlet part 2. The molten material may be injected into the container 1 via the molten material inlet part 2. Also, the molten material may include various materials in addition to the molten steel.

[0030] Here, a lower portion of the molten material is a section ranging from the bottom of the container 1 to a height that is less than 0.5 times the height of a melt height of the molten material. Also, an upper portion of the molten material is a section ranging from a height, which is 0.5 times the melt height of the molten material, to the melt height of the molten material. For example, when the height of the bottom of the container 1 is zero, and the melt height of the molten material is 1, the height from 0 to a height that is less than 0.5 corresponds to the lower portion of the molten material, and the height from 0.5 to 1 corresponds to the upper portion of the molten material.

[0031] Here, the melt height of the molten material is referred to as the height of the molten material that has the constant height within the container 1 in a steady state during the continuous casting process. For example, the melt height of the molten material may be referred to as a molten steel level or a melt level. Here, the steady state means that a flow of the molten material within the container 1 is in a steady state.

[0032] The molten material inlet part 2 is a refractory nozzle through which the molten material is able to pass, and may be a shroud nozzle. The molten material inlet part 2 is mounted on a manipulator (not shown), and as the manipulator rises, an opening of an upper end thereof may be coupled to a collector nozzle (not shown) of a conveyance container. The molten material inlet part 2 may be disposed at one side of the container 1 and spaced apart from the bottom of the container 1. Also, an opening of an lower end thereof may be positioned within the container 1, and at least a portion thereof may be immersed in the molten material.

[0033] A molten material-dropping area (hereinafter, referred to as a drop area) is defined below the molten material inlet part 2. The drop area is an area through which the molten material, which has passes through the molten material inlet part 2 and then has been injected into the container 1, passes first. In the drop area, the molten material, having relatively high energy after falling from the molten material inlet part 2 and colliding with the bottom of the container 1, may flow along the bottom at a predetermined flow rate. Subsequently, as moving away from the drop area, the flow rate of the molten material gradually decreases, and the molten material having relatively low energy may flow at a normal flow rate.

[0034] The drop area is formed on the bottom of the container 1, and a center c thereof is vertically aligned with a vertical central axis (not shown) passing through a center of the molten material inlet part 2. The size of the drop area, for example, the width in the one direction is proportional to the inner diameter of the molten material inlet part 2. As the inner diameter of the molten material inlet part 2 increases, the size of the drop area also increases in proportion to the inner diameter of the molten material inlet part 2. Here, the inner diameter of the molten material inlet part 2 may be an inner diameter with respect to the opening of the lower end of the molten material inlet part 2, and the one direction may be a direction from the molten material inlet part 2 toward the molten material outlet 1c, as a direction in which the container 1 extends.

[0035] A distance between an edge end of the drop area in the one direction and the center c may be 2.5 to 5 times an inner diameter d of the molten material inlet part 2. In the drop area, the molten material may actively flow within a predetermined range of flow rates. The molten material in the drop area has a meaningful flow rate.

[0036] Here, the molten material has the meaningful flow rate means that the molten material has a flow rate enough to form an upward flow instead of descending after colliding with the dam 3 and flooding. The flow of the molten material in the drop area may affect the entire flow of the molten material within the container 1, and thus the drop area may be significantly meaningful area. Here, the drop area may be referred to as a pouring zone.

[0037] The container 1 includes the accommodation space formed therein, the molten material inlet part 2 disposed at the one side thereof, and the molten material outlet 1c formed at the other side thereof. The container 1 may include, for example, a tundish. Here, the tundish may be a rectangular tundish that lengthily extending in the one direction.

[0038] The container 1 may include a rectangular bottom extending in the one direction and the other direction perpendicular to the one direction, two longitudinal direction side walls 1d which respectively extend along two long sides of edges of the bottom in the one direction and protrude vertically, and one width direction side wall 1a and the other width direction side wall 1b which respectively extend along two short sides of the edges of the bottom in the other direction and protrude vertically. The molten material inlet part 2 may be disposed relatively close to the one width direction side wall 1a, and the molten material outlet 1c may be disposed relatively close to the other side wall 1b. The bottom of the container 1 may have a stepped portion in which the height at the other side is lower than the height at the one side.

[0039] A molten material accommodation space may be formed by the bottom, the two longitudinal direction side walls Id, the one width direction side wall 1a, and the other width direction side wall 1b. The two longitudinal direction side walls 1d face each other in the other direction, and the one width direction side wall 1a and the other width direction side wall 1b face each other in the one direction.

[0040] The molten material inlet part 2 is disposed at one side of the bottom, and the molten material inlet part 2 may be vertically spaced apart from the one side of the bottom and disposed in the upper portion of the container 1. Also, the molten material outlet 1c may be formed by vertically passing through the other side of the bottom. An outlet nozzle (not shown), for example, an immersion nozzle is installed to pass through the molten material outlet 1c from below the container 1, and a mold (not shown) surrounding a lower portion of the immersion nozzle is disposed. An opening degree of the molten material outlet 1c is adjusted by a slide gate (not shown) and may discharge the molten material into the mold. In the mold, the molten material may be solidified into a slab.

[0041] A cooling zone (not shown) may be provided below the mold. In the cooling zone, a series of forming operations is performed by cooling and pushing down the slab continuously drawn from the mold. The slab that has passes through the cooling zone is cut by a cutting part, and then may be conveyed to rolling equipment or various post-processing equipment according to purposes.

[0042] The container 1 has functions of adjusting and distributing a supply of the molten material to a mold (not shown), reducing pressure due to weight of the molten material, for example, ferrostatic pressure, and removing an inclusion through a flow control of the molten material to improve the cleanness. Here, a dam 4 is mounted on the bottom of the container 1 so as to remove the inclusion. The dam 4 has a function of controlling the flow of the molten material to increase a residence time of the molten material, thereby floating the slag and the inclusion, contained in the molten material, to the top surface of the molten material, for example, to a melt surface. As the slag and inclusion floating to the top surface are separated from the molten material, the mixing of the inclusion and the slag into the mold may be minimized.

[0043] The dam 3 is positioned between the molten material inlet part 2 and the molten material outlet 1c so that one surface thereof directly faces the molten material inlet part 2, and is mounted on the bottom of the container 1, extends in the other direction, and is connected to the facing surfaces of the two longitudinal direction side walls 1d. The dam 3 may raise the flow of the molten material, which is supplied from the molten material inlet part 2 to the container 1 and flows along the bottom, toward the upper portion of the container 1.

[0044] The one surface of the dam 3 is a surface which faces the molten material inlet part 2 and one width direction side wall 1a among two side surfaces of the dam 3 extending in the width direction and the vertical direction. The other surface of the dam 3 is a surface which faces the molten material outlet 1c and the other width direction side wall 1b among the two side surfaces of the dam 3 described above. Here, the one surface of the dam 3 may be referred to as a front surface, and the other surface of the dam 3 may be referred to as a rear surface.

[0045] The feature, in which the dam 3 is positioned between the molten material inlet part 2 and the molten material outlet 1c so that one surface thereof directly faces the molten material inlet part 2, means that there are no separate structures between the dam 3 and the molten material inlet part 1. Here, the separate structures may include various wall bodies such as weirs and auxiliary dams, containers such as impact pads, and other various structures having diverse shapes. That is, since a separate structure is not mounted between the dam 3 and the molten material inlet part 2, the one surface of the dam 3 may directly face the molten material inlet part 2. The dam 3 is mounted to directly face the molten material inlet part 2 and, the flow of the molten material supplied to the drop area may be controlled by being affected directly by the dam 3 without interference. That is, after dropping to the bottom, the molten material collides with the dam 3 first, and thus the upward flow may be formed.

[0046] Here, since momentum of the molten material is reduced as moving away from the drop area, the dam 3 may be mounted on the drop area so as to effectively induce the upward flow of the molten material. Here, in order to avoid direct collision with the molten material that is being dropping, the dam 3 is mounted on an edge portion of the drop area in the other direction, facing the molten material within the drop area. At this mounting position, the dam 3 may first come into contact with the molten material that flows along the bottom of the container 1 in a direction from the one side toward the other side of the container 1. That is, at the edge portion of the drop area, the dam 3 may be directly exposed to the molten material within the drop area and may come into direct contact with the same. Here, coming into direct contact with means that, for example, the molten material first comes into contact with the dam 3 before the flow of the molten material is controlled due to the collision with a separate structure. Of course, since only the dam 3 is provided within the drop area, the molten material within the drop area may come into contact only with the dam 3 except for the bottom and the side walls of the container 1.

[0047] Here, the other surface of the dam 3 may directly face the width direction side wall 1b at the molten material outlet 1c. That is, there are also no separate structures between the dam 3 and the molten material outlet 1c. As described above, only one dam 3 is mounted within the container 1, and the flow of the molten material may be controlled by the one dam 3.

[0048] The distance between the one surface of the dam 3 and the molten material inlet part 2 may be proportional to the size of the drop area. As the size of the drop area increases, a distance L between the one surface of the dam 3 and the molten material inlet part 2 may increase. Here, the distance between the one surface of the dam 3 and the molten material inlet part 2 may be in a range of 2.5 to 5 times an inner diameter d of the molten material inlet part. Accordingly, at least one surface of the dam 3 may be positioned on the edge portion of the drop area. The top surface of the dam 3 may be positioned in the upper portion of the molten material. With respect to the bottom in the vicinity of the one side of the container 1, the height H of the top surface of the dam 3 may be in a range of 0.5 to 0.75 times the melt height of the molten material. When the height of the top surface of the dam 3 is less than 0.5 times the melt height of the molten material, a smooth upward flow may not be formed, and it is difficult for the molten material to widely rise to the melt surface. When exceeding 0.75 times the melt height of the molten material, the dam 3 may prevent the molten material from being widely spread to the melt surface. Particularly, when the height of the top surface of the dam 3 exceeds 0.75 times the melt height of the molten material, the molten material rises over the current melt level and overflows. Thus, the molten material may flow to the outside of the container 1.

[0049] The molten material processing device described above is referred to as a molten material processing device according to a first embodiment. Hereinafter, a molten material processing device according to a second embodiment of the present invention will be described. The molten material processing device according to the second embodiment of the present invention includes the components described in the molten material processing device according to the first embodiment, and further include a through-hole (not shown) to be formed in the dam 3.

[0050] The through-hole may be formed in a lower portion of the dam 3, defined in a direction from the one side toward the other side of the container 1, and have an inner wall directly connected to the bottom of the container 1.

[0051] According to the embodiments of the present invention, only the dam 3 is mounted within the container 1. Also, the mounting position thereof is set to be the edge portion of the drop area, and the top surface thereof is positioned in the upper portion of the molten material. The inner profile of the container 1 is designed as described above, and the flow of the molten material is controlled. Thus, the upward flow may be generated from the drop area, and the flow of the molten material may be induced so that the dead volume within the container 1 is less than 10%. Through this, the inclusion removal efficiency may be improved by 50% or more when compared to the related art. In addition, manufacturing costs for refractories may be reduced due to the non-use of the weir, and manufacturing costs for molten steel may be reduced. The dam structure of the molten material processing device according to the embodiments of the present invention described above may be referred to as, for example, a tundish dam structure having the dead volume of 10% or less for manufacturing ultra clean steel.

[0052] Hereinafter, it will be described in detail that, when compared to comparative examples, the molten material processing device according to the embodiments of the present invention described above may widely distribute the upward flow that reaches the top surface of the molten material while reducing the dead volume of the molten material to improve the inclusion removal capacity.

[0053] FIG. 1 is a view illustrating modeling structures for flow evaluation of molten material processing devices according to an embodiment of the present invention and comparative examples. FIG. 2 is a view showing flow evaluation results of the molten material processing devices according to the embodiment of the present invention and the comparative examples. FIG. 3 is a view showing quantitative numerical values of flow characteristics of the molten material derived from the flow evaluation results according to the embodiment of the present invention and the comparative examples.

[0054] The molten material processing device according to the embodiments of the present invention is a device for ultimately reducing an inclusion in a molten material according to shapes and design parameters of a dam in a continuous casting process. In the device, various types of structures are constructed within a container 1, and then the flow characteristics are analyzed. Thus, the inner shape within the container 1, for example, the shape and design parameters of a dam 3 are designed with an optimal profile.

[0055] In (a) of FIG. 1, provided is a modeling structure of a molten material processing device according to a embodiment 1 of the present invention. Here, a height of a top surface of a dam 3 is 2/3 of a melt height of a molten material, for example, 600 mm. In (b) of FIG. 1, provided is a modeling structure of a molten material processing device according to a comparative example 1. There is no integral structure within a container 1. In (c) of FIG. 1, provided is a modeling structure of a molten material processing device according to a comparative example 2 in which an impact pad 4 is mounted right below a molten material inlet part 2, and in (d), provided is a modeling structure of a molten material processing device according to a comparative example 3 in which an auxiliary dam 5 having a height of a top surface as low as 40 mm is mounted in a drop area, and a dam including a through-hole is mounted behind the auxiliary dam. Here, in the comparative example 3, the dam including the through-hole is not mounted to directly face a molten material inlet part 2. Here, a top surface of the dam including the through-hole is 1/2 of a melt height of a molten material, for example, 450 mm, and the mounting position is outside a drop area. Also, the dam including the through-hole is designated by a reference numeral 3' to be distinguished from the dam 3 of the embodiment 1.

[0056] In (e) of FIG. 1, provided is a modeling structure of a molten material processing device according to a comparative example 4 of the present invention. Only an auxiliary dam 5 is mounted within a drop area. In (f) of FIG. 1, provided is a modeling structure of a molten material processing device according to a comparative example 5 of the present invention. An auxiliary dam 5 is mounted away from a drop area and closer to a molten material outlet 1c than a molten material inlet part 2, for example, at a position where the distance from a center of the drop area is 1500 mm. Here, inner diameters of molten material inlets in the modeling structures of FIG. 1 are set to 160 mm.

[0057] In (a) to (f) of FIG. 2, provided are respective numerical analysis results for internal flows of the containers 1 in the modeling structures in (a) to (f) of FIG. 1. In a case of (c) illustrating the comparative example 2, it may be confirmed that the upward flow facing the melt surface of the molten material is formed strongly, but an area A that the upward flow reaches is less than that of the embodiment 1. In a case of (a) illustrating the embodiment 1, it may be confirmed that an area A that the upward flow reaches are most widely distributed. Thus, it may be confirmed that the contact opportunity between a slag on the melt surface and an inclusion of the molten material in the embodiment is higher when compared to the comparative examples.

[0058] When comparing embodiment 1 in (a) of FIG. 2 with comparative example 3 in (d), it may be confirmed that, when only the dam 3 is mounted within the drop area, and the dam 3 comes into contact with the molten material earlier than does the auxiliary dam 5, the area A that the upward flow reaches is efficiently increased. When comparing embodiment 1 in (a) of FIG. 2 with comparative example 4 in (e), it may be confirmed that the design parameter of the height of the dam 3 in the embodiment is significantly effective to increase the area A that the upward flow reaches. When comparing embodiment 1 in (a) of FIG. 2 with comparative example 3 in (d) and comparative example 5 in (f), it may be found that it is important to mount the dam 3 within the drop area.

[0059] The structure of the dam 3 of the molten material processing device according to the embodiments of the present invention has an optimized profile to increase a plug volume within the molten material and reduce a dead volume. The inclusion removal capacity in the molten material may be evaluated through a residence time distribution graph.

[0060] FIG. 3 shows quantitative numerical values with which flow characteristics of the molten material may be analyzed through the residence time distribution graph for modeling shapes of the embodiment and the comparative examples shown in FIG. 1.

[0061] First, a continuous casting apparatus for a numerical model experiment is configured, the numerical model experiment for a continuous casting process is performed, a certain amount of an experimental solution (a dye) is injected for 2 to 3 seconds, and the concentration of the solution is detected at the outlet over a time. The results are plotted on a dimensionless time axis, and thus the residence time distribution curve is made.

[0062] That is, the residence time distribution curve may be a standard concentration graph over a dimensionless time measured at an outlet when a dye is input to an inlet of the flow. Of course, the curve may be derived using numerical analysis not the numerical model experiment. Using the residence time distribution curve, a mixing degree of the molten steel and an inclusion floating/separating effect, for example, according to changes in capacity and inner shape of the tundish may be determined.

[0063] In the drawing, a Min. Time is a time when the concentration of experimental solution is detected first. A peak time is a time when the concentration of experimental solution is highest. A mean time is a value obtained by dividing the inner volume of the container 1 by the input flow rate of the molten material int the molten material inlet part 2. The input flow rates of the molten material are equal to each other in the embodiment and comparative examples, but the inner volumes of the containers 1 are different from each other according to the inner profiles of the containers 1.

[0064] An active mean residence time is a value obtained by dividing an area of the curve by an average residence time when a dimensionless value of a measured average time is 2 or higher. An active region fraction or an active volume fraction is a fraction of regions in which the molten steel is mixed, and includes a plug volume fraction and a mixed volume fraction. A dead region fraction or a dead volume fraction is a fraction of regions in which the molten material very slowly flows for a time twice as long as the average residence time of the molten material within the container.

[0065] For example, the molten steel volume within the tundish is divided into an active volume and a dead volume. The active volume is a region in which the molten steel is mixed, but the dead volume is a region in which the mixing does not occur. The active volume is divided into a plug volume and a mixed volume. In the plug volume, the molten steel flows at a constant flow rate in a pipe flow, and mixing in the flow direction, that is, in the horizontal direction occurs over the entire regions without interlayer mixing. The mixed volume is a region in which the mixing is highest, and mechanical agitation occurs. The dead volume is referred to as a stagnation region, and is a region where a fluid moves very slowly within the container and stays for a time twice as long as the average residence time. Here, in the drawing, Vp is referred to as the plug volume fraction, Vd is referred to as the dead volume fraction, and Vm is referred to as the mixed volume fraction.

[0066] In the drawing, as the dead volume fraction is small, it is advantageous to float and separate the inclusion. As the Vp/Vd value and Vp/Vm value is large, it is advantageous to float and separate the inclusion. Since the residence time distribution curve and the quantitative numerical values of flow characteristics derived therefrom are well known in a flow analysis field, detailed description thereof will be omitted.

[0067] The peak time is related to the plug volume, and it may be confirmed that the highest value is shown in the embodiment. That is, embodiment 1 shows the best result. Referring to a ratio of the dead volume, it may be confirmed that embodiment 1 and comparative example 2 show a value of less than 10%. It may be confirmed that other comparative examples have greater than 10%. When comparing the embodiment 1 with comparative example 1, it may be confirmed that there is an effect of reduction in dead volume of 4.7% to 5.8%. In terms of the inclusion removal capacity, there is an effect of the inclusion removal of 41% to 50%. Also, to effectively remove the inclusion, the fraction of plug volume has to be high, and the fraction of dead volume has to be low. Embodiment 1 and comparative example 2 show the best results.

[0068] However, referring to FIG. 2 and taking into consideration the area that the upward flow reaches, it may be confirmed that the embodiment is more effective than comparative example 2. Also, comparative example 2 is complicated to manufacture, costs thereof rise, and the durability is weak. Thus, it is verified that the embodiment reduces the dead volume, has a simple structure, and may widely distribute the upward flow on the melt surface.

[0069] FIG. 4 is a view illustrating modeling structures for flow evaluation of molten material processing devices according to embodiments of the present invention and comparative examples. FIG. 5 is a view showing quantitative numerical values of flow characteristics of the molten material derived from the flow evaluation results according to the embodiments of the present invention and the comparative examples. FIG. 6 is a view showing flow evaluation results according to the embodiments of the present invention.

[0070] Hereinafter, with a design parameter of a top surface height of a dam 3 according to an embodiment of the present invention, flow evaluation was further performed while changing a mounting position, the number of dams, and existence of a through-portion.

[0071] In the drawing, PI is a mounting position of the dam 3 according to embodiment 1, P2 is a position spaced L from PI in a rearward direction, and P3 is a position spaced 2L from PI in the rearward direction. Here, L is set to 500 mm, and the flow evaluation was performed.

[0072] A position in FIG. 5 is a mounting position of the dam 3. For example, P1+P2 in comparative example 10 and comparative example 11 means that dams 3 are mounted at both PI position and P2 position. Similarly, others represent mounting positions. A hole existence means that whether there is a through-hole or not.

[0073] In (a) of FIG. 6, a numerical analysis result of an internal flow of a container 1 for embodiment 1 of FIG. 5 is shown. In (b), a numerical analysis result of an internal flow of a container 1 for embodiment 2 is shown.

[0074] Examining a value of a dead region, it may be confirmed that embodiment 1 and embodiment 2 have very small values. That is, when the dam is constructed as in embodiment 1, and the through-hole is provided, it may be confirmed that the inclusion removal capacity is further improved. On the other hand, referring to comparative examples 6 to 17, it may be confirmed that, when a dam is mounted farther, or several dams are mounted in places in addition to the drop area, the inclusion removal capacity is adversely affected. Thus, when one dam is mounted on the edge portion of the drop area within the container 1, and the height of the top surface thereof is in the upper portion of the molten material as in the embodiment of the present invention, it may be confirmed that the size of the dead volume is significantly reduced to about 5%, the upward flow reaches a large area of the melt surface as illustrated in (a) and (b) of FIG. 6, and the inclusion is ultimately reduced.

[0075] Here, further explaining in a different way the design factors of the dam 3 designed as above, the distance between the center c of the drop area and the one width direction side wall 1a has to be greater than the distance between the center c of the drop area and the one surface of the dam 3 and smaller than the distance between the center c of the drop area and the other surface of the dam 3. The width of the dam 3 in the one direction, for example, the thickness has to be 50 mm to 200 mm. Of course, the height of the top surface of the dam 3 has to be lager than 1/2 and smaller than 3/4 of the melt height of the molten material. When the dam 3 is designed with these design parameters, the size of dead volume is reduced, and the distribution area of upward flow is widened. Thus, the inclusion may be effectively reduced as described earlier in the flow evaluation results.

[0076] As described above, according to the embodiment of the present invention, the distance between the one surface of the dam 3 and the molten material inlet part 2 may be in a range of 2.5 to 5 times the inner diameter of the molten material inlet part 2, and the height of the top surface of the dam 3 is in a range of 0.5 to 0.7 times the melt height of the molten material. Therefore, before turbulent flow energy of the molten material that flows in the pouring zone is dissipated, the turbulent flow of the molten material within the pouring zone is controlled using the dam 3. Accordingly, the molten material may overflow the upper portion of the dam 3, and the sufficient upward flow may be stably formed. Thus, the size of the dead volume of the molten material may be reduced to a half level when compared to the related art, and in the continuous casting process in which the molten material processing device is used, the inclusion removal capacity may be improved when compared to the related art.

[0077] For example, the molten material processing device was used in the continuous casting process, and a continuous casting process for a plurality of charges was performed to cast slabs. The cast slabs were sampled, and inclusions were inspected. As a result, the total number of inclusions was reduced by approximately 40% on average compared to the related art, and the large scale inclusions having a size exceeding 20 μm were reduced by approximately 51% compared to the related art. Also, the inclusions having a size of 10 μm to 15 μm were reduced by approximately 35% compared to the related art, and the inclusions having a size of 15 μm to 20 μm were reduced by approximately 40% compared to the related art. That is, there is also an effect of reducing fine inclusions.

[0078] The above embodiments of the present invention have been made for describing the present invention, but are not intended to limit the present invention. It should be noted that the configurations and methods disclosed in the above embodiments of the present invention may be modified into various forms by combining or crossing same, and these modified embodiments may also be considered within the scope of the present invention. That is, the present invention may be embodied in various forms within the scope of the claims and equivalents thereof, and it will be understood by those skilled in the art that various embodiments can be made within the scope of the technical idea of the present invention.

Claims

1. A molten material processing device comprising:

   a container which comprises a molten material accommodation space formed therein, a molten material inlet part disposed at one side thereof, and a molten material outlet formed at the other side thereof; and
   a dam which is positioned between the molten material inlet part and the molten material outlet so that one surface thereof directly faces the molten material inlet part, and which is mounted on a bottom of the container and connected to two longitudinal direction side walls,
   wherein the dam is mounted on a drop area of a molten material formed below the molten material inlet part and has a top surface positioned in an upper portion of the molten material.

2. The molten material processing device of claim 1, wherein the dam is mounted on an edge portion of the drop area.

3. The molten material processing device of claim 1, wherein the other surface of the dam directly faces a width direction side wall on the molten material outlet side.

4. The molten material processing device of claim 1, wherein a size of the drop area is proportional to an inner diameter of the molten material inlet part, and a distance between the one surface of the dam and the molten material inlet part is proportional to the size of the drop area.

5. The molten material processing device of claim 1, wherein a distance between the one surface of the dam and the molten material inlet part is in a range of 2.5 to 5 times an inner diameter of the molten material inlet part.

6. The molten material processing device of claim 1, wherein a height of the top surface of the dam is in a range of 0.5 to 0.75 times a melt height of the molten material.

7. The molten material processing device of any one of claims 1 to 6, further comprising a through-hole formed in the dam.

8. The molten material processing device of claim 7, wherein the through-hole is formed in a lower portion of the dam, is defined in a direction from the one side toward the other side, and has an inner wall directly connected to the bottom.

FIG. 1

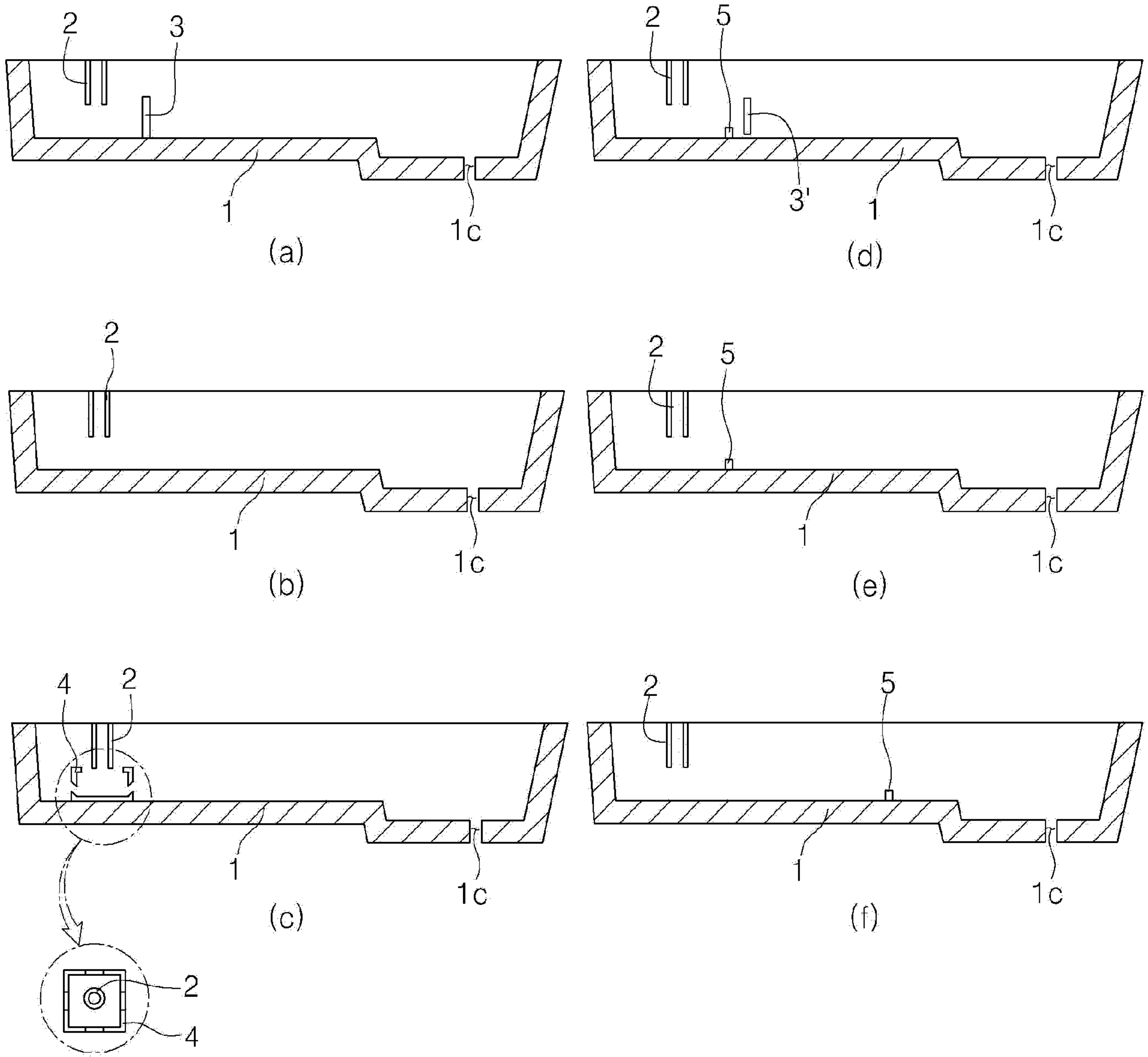


FIG. 2

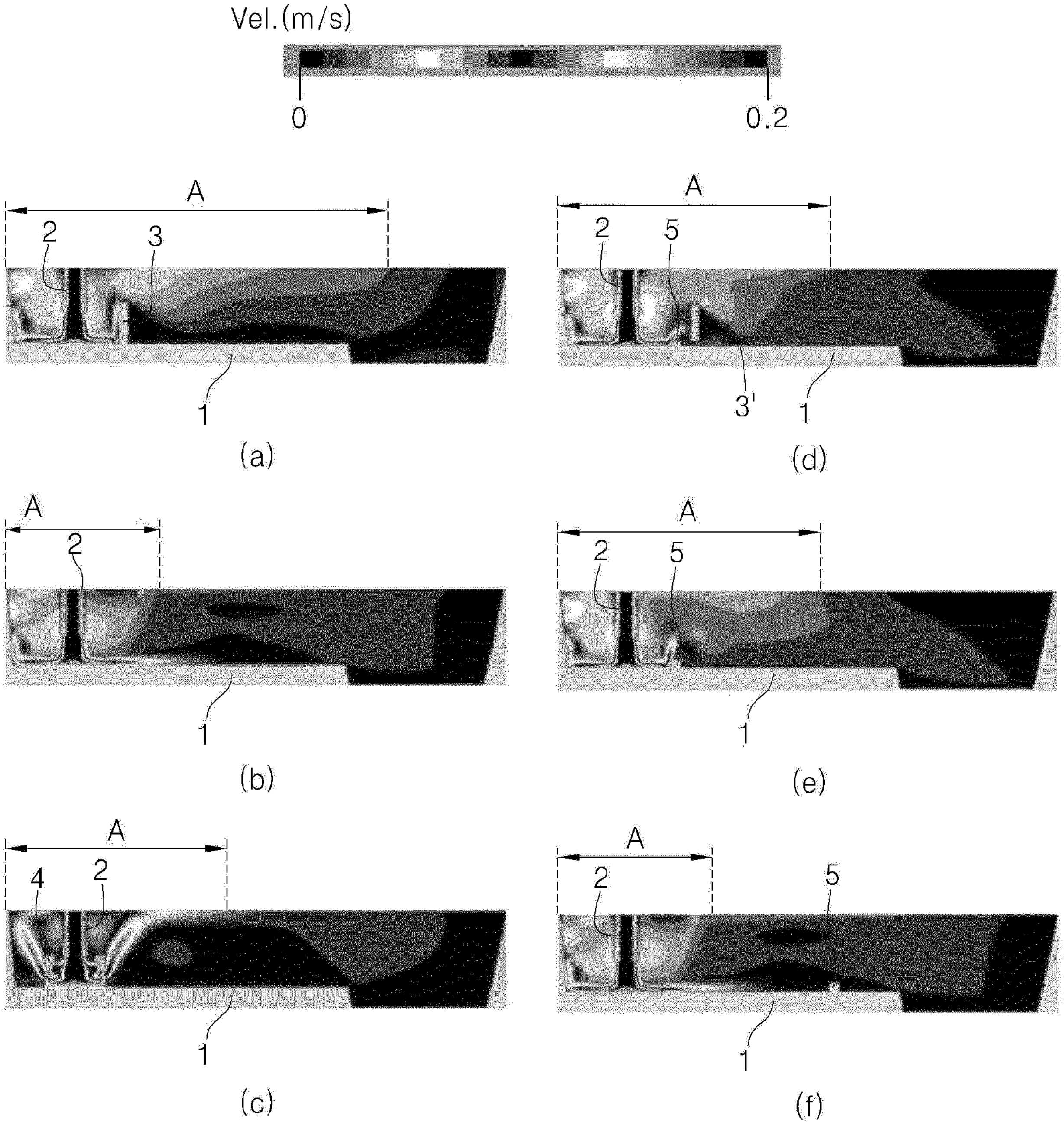


FIG. 3

CLASSIFICATION		EMBODIMENT1	COMPARATIVE EXAMPLE1	COMPARATIVE EXAMPLE2	COMPARATIVE EXAMPLE3	COMPARATIVE EXAMPLE4	COMPARATIVE EXAMPLE5
Min. Time (sec)		74	62	68	70	72	62
Peak Time (sec)		398	276	368	338	316	356
Mean Time (sec)		478.37	498.21	464.51	466.05	469.64	491.54
Active Mean residence time (sec)		459.71	464.05	457.99	459.69	463.02	463.34
Active volume fraction (%)		94.3	88.5	93.2	87.7	86.4	88.3
	Plug volume fraction (%)	16.1	13.4	14.9	15.2	15.6	13.4
	Mixed volume fraction (%)	78.2	75.1	78.4	72.5	70.8	74.9
Dead volume fraction (%)		5.7	11.5	6.8	12.3	13.6	11.7
Vp/Vd		2.82	1.17	2.19	1.24	1.15	1.15
Vp/Vm		0.21	0.18	0.19	0.21	0.22	0.18

FIG. 4

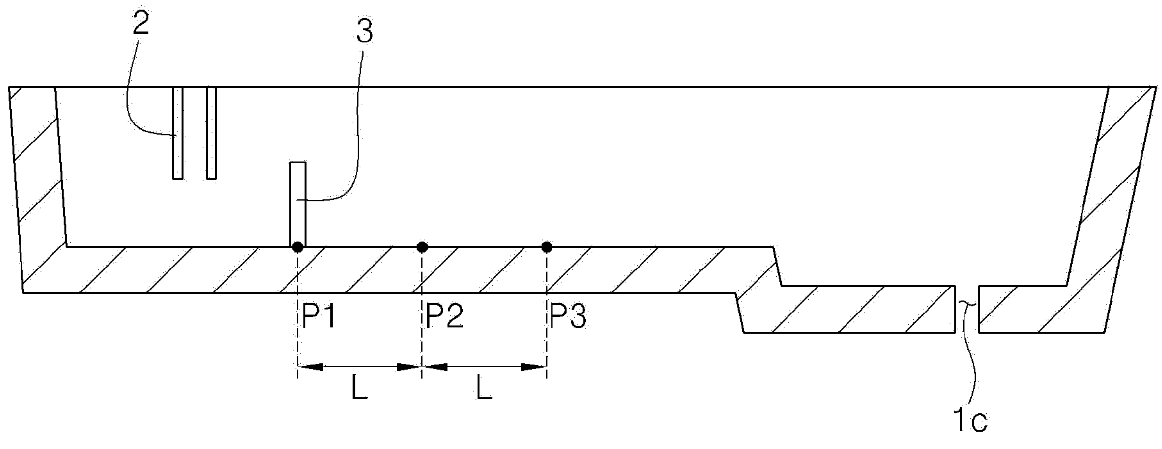


FIG. 5

CLASSIFICATION	EMBODIMENT1	EMBODIMENT2	COMPARATIVE EXAMPLE6	COMPARATIVE EXAMPLE7	COMPARATIVE EXAMPLE8	COMPARATIVE EXAMPLE9	COMPARATIVE EXAMPLE10	COMPARATIVE EXAMPLE11	COMPARATIVE EXAMPLE12	COMPARATIVE EXAMPLE13	COMPARATIVE EXAMPLE14	COMPARATIVE EXAMPLE15	COMPARATIVE EXAMPLE16	COMPARATIVE EXAMPLE17
POSITION	P1		P2		P3		P1 + P2		P1 + P3		P2 + P3		P1 + P2 + P3	
HOLE EXISTENCE	×	○	×	○	×	○	×	○	×	○	×	○	×	○
Active region	94.3	94.8	73.5	74.7	77.0	77.8	90.0	88.1	87.6	82.9	76.6	76.9	86.6	84.0
Plug region	16.1	16.5	14.8	15.6	13.5	13.9	14.9	14.0	12.7	13.1	16.2	16.6	13.3	12.8
Mixed region	78.2	78.3	58.7	59.1	63.5	63.9	75.1	74.0	74.9	69.8	60.4	60.3	73.3	71.2
Dead region	5.7	5.2	26.5	25.3	23.0	22.2	10.0	11.9	12.4	17.1	23.4	23.1	13.4	16.0
Vp/Vd	2.82	3.17	0.56	0.62	0.59	0.63	1.49	1.18	1.02	0.77	0.69	0.72	0.99	0.80
Vp/Vm	0.21	0.21	0.25	0.26	0.21	0.22	0.20	0.19	0.17	0.19	0.27	0.28	0.18	0.18

FIG. 6

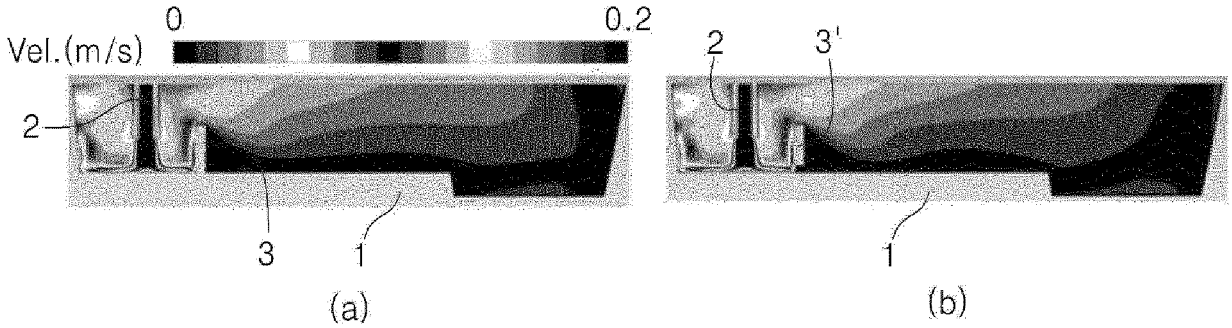


FIG. 7

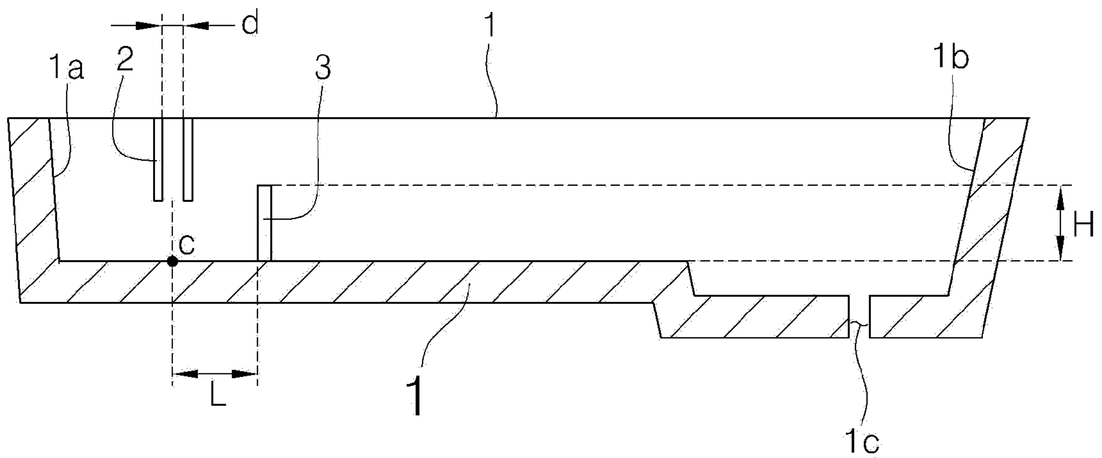
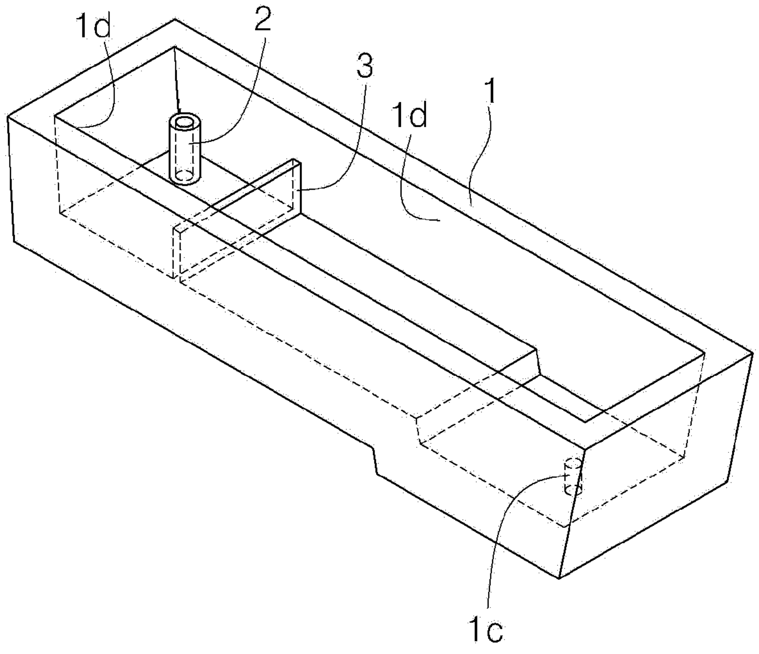


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2018/015563

A. CLASSIFICATION OF SUBJECT MATTER

B22D 11/103(2006.01)i, B22D 41/00(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)
B22D 11/103; B22D 11/00; B22D 11/06; B22D 11/10; B22D 41/00; B22D 41/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models: IPC as above
Japanese Utility models and applications for Utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS (KIPO internal) & Keywords: continuous casting, tundish, molten material, dam, emission, injection

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5882577 A (ZACHARIAS, Donald R.) 16 March 1999 See column 1, line 26-column 4, line 4; claim 1; and figures 1-3.	1-8
A	KR 10-2014-0129895 A (HYUNDAI STEEL COMPANY) 07 November 2014 See paragraphs [0019]-[0034]; and figures 1-2.	1-8
A	KR 10-2015-0022196 A (POSCO) 04 March 2015 See paragraphs [0030]-[0053]; and figures 1-3.	1-8
A	KR 10-1999-0036374 A (MANNESMANN AKTIENGESELLSCHAFT) 25 May 1999 See claims 1-5; and figures 1-2.	1-8
A	JP 11-170011 A (NIPPON STEEL CORP. et al.) 29 June 1999 See claims 1-4; and figures 1-4.	1-8

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

* Special categories of cited documents:
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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
05 MARCH 2019 (05.03.2019)	**05 MARCH 2019 (05.03.2019)**

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

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Information on patent family members

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