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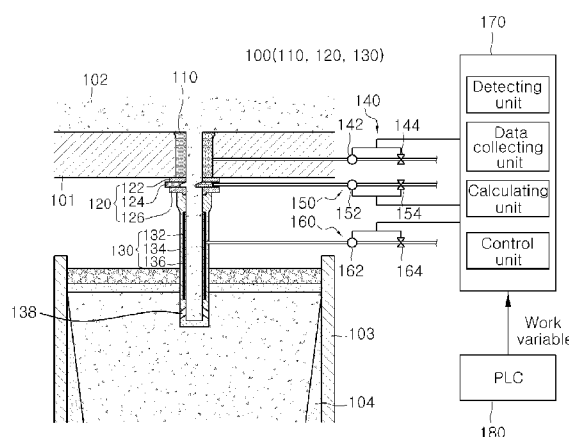
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(54) **Title:** APPARATUS FOR PREVENTING NOZZLE CLOGGING, APPARATUS FOR CONTINUOUS CASTING HAVING THE SAME, METHOD FOR PREVENTING NOZZLE CLOGGING AND METHOD FOR CONTINUOUS CASTING USING THE SAME

[Fig. 1]



(57) **Abstract:** The present invention relates to an apparatus for preventing nozzle clogging, which rapidly estimates the degree of nozzle clogging when molten steel is supplied from a tundish to a mold and then controls a casting state according to the estimation result, an apparatus for continuous casting having the same, a method for preventing nozzle clogging and a method for continuous casting using the same. The present invention includes measuring backpressure of inert gas supplied to a casting nozzle in real time; and calculating a nozzle status index from the measured actual backpressure. There are effects in that it is possible to rapidly and accurately estimate the location and degree of nozzle clogging based on a backpressure change of inert gas supplied to a casting nozzle, to detect leakage of the inert gas, and to improve a casting yield and quality of strands by suitably controlling inert gas supplied to a casting nozzle.

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Description

APPARATUS FOR PREVENTING NOZZLE CLOGGING, APPARATUS FOR CONTINUOUS CASTING HAVING THE SAME, METHOD FOR PREVENTING NOZZLE CLOGGING AND METHOD FOR CONTINUOUS CASTING USING THE SAME

Technical Field

- [1] The present invention relates to an apparatus for preventing nozzle clogging, an apparatus for continuous casting having the same, a method for preventing nozzle clogging and a method for continuous casting using the same, and more particularly, to an apparatus for preventing nozzle clogging, which rapidly estimates the degree of nozzle clogging when molten steel is supplied from a tundish to a mold and then controls a casting state according to the estimation result, an apparatus for continuous casting having the same, a method for preventing nozzle clogging and a method for continuous casting using the same.

Background Art

- [2] Generally, a tundish installed to a general continuous casting apparatus is used for receiving molten steel from a ladle and continuously injecting the molten steel to a mold. An upper nozzle, a sliding gate and a submerged nozzle are installed between a tundish bottom and a mold subsequently from the tundish bottom toward the mold such that molten steel can be supplied to the mold without any contact with air, so that a casting nozzle for injecting the molten steel stored in the tundish into the mold is installed.
- [3] At the initial stage of casting, the molten steel supplied to the casting nozzle comes into contact with the inner wall of the nozzle, and the molten steel is cooled and solidified on the inner wall of the casting nozzle. Thus, as the casting process progresses, the sticking layer grows and thus makes the flow of molten steel irregular, thereby causing the casting nozzle to clog. The sticking layer growing on the inner wall of the casting nozzle as mentioned above is separated by the molten steel stream or makes the molten steel in the submerged nozzle irregularly flow. In addition, the molten steel stream discharged through a discharge hole of the submerged nozzle is deflected to one side to disturb the flow of the molten steel stream, thereby causing fluctuation on a surface of the molten steel in the mold. If the fluctuation occurs on the surface of the molten steel as mentioned above, mold powder on the surface is collected in a solidification layer in the mold, which is referred to as "strand defect". If

the sticking layer is formed in the casting nozzle as mentioned above to cause nozzle clogging, the casting process is interrupted, thereby deteriorating the casting yield. That is, the number of ladles for continuous casting using one tundish (a ladle continuous casting ratio) is decreased to thereby cause increase of costs of a tundish refractory material, so that clogging of the casting nozzle should be minimized.

- [4] Thus, in a prior art, a pipe for supplying inert gas into the casting nozzle was installed to form a gas curtain between the inner wall of the casting nozzle and the molten steel, thereby restraining non-metal inclusions in the molten steel from being brought into contact with the wall of the submerged nozzle.
- [5] However, the method of minimizing nozzle clogging by supplying inert gas into the nozzle as mentioned above has problems in that since locations and time points of nozzle clogging occurring at respective portions of the casting nozzle are controlled depending on experiences of operators, supply location and amount of inert gas are greatly changed at every portion of the nozzle according to the determination and skill of operators.
- [6] More specifically, in order to decrease clogging of a casting nozzle, the amount of supplied inert gas should be increased at a suitable location where a sticking layer is formed in the casting nozzle from the time when the sticking layer is initially formed in the casting nozzle, and in this case, the nozzle clogging can be effectively prevented. However, if a time point when the amount of inert gas increases and a supply location of inert gas are incorrect due to the erroneous determination of an operator, it is impossible to prevent the casting nozzle from clogging.
- [7] For example, in a case where the amount of inert gas is increased earlier than the point when a sticking layer grows in the casting nozzle, air bubbles of inert gas are collected in a solidification layer within the mold, so that hole defects occur in the strand, thereby deteriorating the quality of strand. In a case where the amount of inert gas is increased later than the point when a sticking layer grows in the casting nozzle, the sticking layer is formed thicker in the casting nozzle, and thus, even though the amount of inert gas is increased, a gas curtain is not formed between the inner wall of the casting nozzle and the molten steel, thereby not preventing nozzle clogging.
- [8] In order to previously detect such nozzle clogging, a method of detecting an increase in fluctuation of a surface of molten steel during a casting process, a method of detecting an increase of an opening ratio, a method of detecting a relative change of backpressure of inert gas during a casting process, a method of detecting temperature of a thermocouple, and the like are proposed as a conventional nozzle clogging detecting method.
- [9] In the method of detecting an increase in fluctuation of a surface of molten steel, generation of high frequency fluctuation of a surface of molten steel and increase of

amplitude thereof are detected when nozzle clogging occurs during a casting process. In the method of detecting an increase of an opening ratio, a nozzle clogging time point is detected using a relative increase of a linear opening ratio during a casting process or an increase of a linear opening ratio that is a difference between an actual opening ratio and a theoretic opening ratio. In the method of detecting thermocouple temperature, a thermocouple is in contact with an outer surface of a submerged nozzle to detect a clogging thickness in the submerged nozzle by a temperature change. However, the above methods are all disadvantageous in that it is difficult to find out a clogging location in the nozzle and also it is impossible to detect leakage of inert gas.

- [10] Further, in the method of detecting a relative change of backpressure of inert gas during a casting process, although it is possible to know a generation location and initial point of nozzle clogging, there is a problem in that the reliability lowers and a quantitative degree of nozzle clogging cannot be estimated because backpressure is also changed when casting variables are changed during the casting process.

Disclosure of Invention

Technical Problem

- [11] The present invention is conceived to solve the aforementioned problems. The present invention is to provide an apparatus for preventing nozzle clogging, which can rapidly estimate the degree of clogging of a casting nozzle during a continuous casting process, detect leakage of inert gas supplied to the casting nozzle and control the amount of supplied inert gas, thereby improving a casting yield and quality of strands; an apparatus for continuous casting having the same; a method for preventing nozzle clogging; and a method for continuous casting using the same.

Technical Solution

- [12] According to the present invention for achieving the objects, there is provided an apparatus for preventing nozzle clogging, which includes a gas pipe connected to a casting nozzle to supply inert gas thereto; and a controller for measuring backpressure of the inert gas in real time to calculate a nozzle status index.
- [13] Here, the nozzle status index may include at least one of an inert gas leakage index, a nozzle clogging index and a nozzle clogging thickness.
- [14] The controller may include a sensing unit for measuring backpressure of the inert gas in the gas pipe; a data collecting unit for collecting the measured backpressure of the inert gas; a calculating unit for calculating the nozzle status index using the collected backpressure of the inert gas; and a control unit for controlling a flow rate of the inert gas, wherein the nozzle status index may be a nozzle clogging index or a nozzle clogging thickness.
- [15] An apparatus for continuous casting according to the present invention includes a

tundish; a mold; a casting nozzle installed between the tundish and the mold; and an apparatus for preventing nozzle clogging including a gas pipe connected to the casting nozzle to supply inert gas thereto, and a controller for measuring backpressure of the inert gas in real time to calculate a nozzle status index.

[16] Here, the casting nozzle may include an upper nozzle, a sliding gate and a submerged nozzle, and the gas pipe is connected to at least one of the upper nozzle, the sliding gate and the submerged nozzle.

[17] In addition, the apparatus may include a regulator connected to the continuous casting apparatus to collect work variables, wherein the regulator is connected to the controller to provide the collected work variables.

[18] Further, the controller may include a sensing unit for measuring backpressure of the inert gas in the gas pipe; a data collecting unit for collecting the measured backpressure of the inert gas; a calculating unit for calculating the nozzle status index using the collected backpressure of the inert gas; and a control unit for controlling a flow rate of the inert gas.

[19] A method for preventing nozzle clogging according to the present invention includes measuring backpressure of inert gas supplied to a casting nozzle in real time; and calculating a nozzle status index from the measured actual backpressure.

[20] Here, the nozzle status index may include at least one of an inert gas leakage index, a nozzle clogging index and a nozzle clogging thickness.

[21] At this time, the inert gas leakage index may include a function of a ratio between a supply flow rate of the inert gas and the measured actual backpressure.

[22] Also, the nozzle clogging index or the nozzle clogging thickness may be calculated from theoretic backpressure. The nozzle clogging index may include a difference between the theoretic backpressure and the actual backpressure. The nozzle clogging thickness may include a difference between the actual backpressure and a sum of an initial backpressure and an increase or decrease of theoretic backpressure.

[23] It is preferred that the method for preventing nozzle clogging may further include increasing or decreasing a flow rate of the inert gas according to the nozzle status index.

[24] A method for continuous casting according to the present invention includes measuring backpressure of inert gas supplied to a casting nozzle in real time, the casting nozzle being installed between a tundish and a mold; and calculating a nozzle status index from the measured actual backpressure.

[25] Here, calculating a nozzle status index may include receiving work variable data of the continuous casting process; and calculating theoretic backpressure from the work variable of the continuous casting process.

[26] At this time, the theoretic backpressure may be calculated with at least one of a flow

rate of the inert gas, a flow rate of molten steel, and the amount of molten steel in the tundish.

- [27] Preferably, the method for continuous casting may include controlling a flow rate of the inert gas according to the nozzle status index, and in controlling the flow rate of the inert gas, the flow rate of the inert gas may be controlled by at least one of intermittent method in which an increase and a decrease of the flow rate thereof are repeated, a composite method in which a stepped increase and an instant decrease of the flow rate thereof are repeated, and a simple increasing method.

Advantageous Effects

- [28] According to an apparatus for preventing nozzle clogging, an apparatus for continuous casting having the same, a method for preventing nozzle clogging and a method for continuous casting using the same, it is possible to rapidly and accurately estimate the location and degree of nozzle clogging based on a backpressure change of inert gas supplied to a casting nozzle and also to detect leakage of the inert gas.
- [29] In addition, according to the present invention, it is possible to improve a casting yield and quality of strands by suitably controlling inert gas supplied to a casting nozzle.

Brief Description of the Drawings

- [30] Fig. 1 is a schematic view showing an apparatus for preventing nozzle clogging according to an embodiment of the present invention.
- [31] Fig. 2 is a graph showing a change of backpressure and flow rate of the inert gas supplied to a casting nozzle according to casting time.
- [32] Fig. 3 is a graph showing relationship between a nozzle clogging index and clogging thickness.
- [33] Fig. 4 is a flowchart illustrating a method for preventing nozzle clogging according to the embodiment of the present invention.
- [34] Fig. 5 is a graph showing a relationship for a clogging area ratio of an upper nozzle to inert gas backpressure.
- [35] Fig. 6 is a graph showing a clogging area ratio of the upper nozzle in Embodiments 1 and 2.
- [36] Fig. 7 is a graph showing a clogging area ratio of an upper nozzle in a conventional case and the embodiment.
- [37] Fig. 8 is a graph showing an increase/decrease in nozzle clogging index according to months during which the continuous casting apparatus is used.
- [38] [Explanation of Reference Numerals for Major Portions Shown in Drawings]
- [39] 100: Casting nozzle 101: Tundish
- [40] 102: Molten steel 103: Mold

- [41] 104: Solidification layer in mold 110: Upper nozzle
- [42] 120: Sliding gate 122: Upper plate
- [43] 124: Intermediate plate 126: Lower plate
- [44] 130: Submerged nozzle 132: Inner wall of submerged nozzle
- [45] 134: Gas pool 136: Outer wall of submerged nozzle
- [46] 140: First gas pipe 142: First backpressure measuring device
- [47] 144: First control valve 150: Second gas pipe
- [48] 152: Second backpressure measuring device
- [49] 154: Second control valve 160: Third gas pipe
- [50] 162: Third backpressure measuring device
- [51] 164: Third control valve 170: Controller

Best Mode for Carrying Out the Invention

- [52] Hereinafter, exemplary embodiments of the present invention will be described in detail with reference to the accompanying drawings. However, the present invention is not limited to the embodiments disclosed below but may be implemented into different forms. These embodiments are provided only for illustrative purposes and for full understanding of the scope of the present invention by those skilled in the art. Throughout the drawings, like reference numerals are used to designate like elements.
- [53] Fig. 1 is a schematic view showing an apparatus for continuous casting, which is provided with an apparatus for preventing nozzle clogging according to an embodiment of the present invention.
- [54] Referring to Fig. 1, a casting nozzle 100 that is a supply channel of molten steel 102 is installed between a tundish 101 and a mold 103 such that the molten steel 102 in the tundish 101 can be stably supplied to the mold 103 without any contact with the air. The casting nozzle 100 includes an upper nozzle 110, a sliding gate 120 and a submerged nozzle 130.
- [55] The upper nozzle 110 is made of a porous refractory material and installed through a bottom of the tundish 101, and a first gas pipe 140 is connected to the upper nozzle 110 so as to inject inert gas such as argon (Ar) into the upper nozzle 110. The first gas pipe 140 is provided thereon with a first control valve 144 for controlling a flow rate of the inert gas and a first backpressure measuring device 142 for measuring backpressure of the inert gas supplied to the upper nozzle 110 in real time.
- [56] In addition, the sliding gate 120 is installed at a lower surface of the upper nozzle 110 so as to control a flow rate of the molten steel 102 supplied to the mold. The sliding gate 120 includes an upper plate 122 fixed to the lower surface of the upper nozzle 110, a lower plate 126, and an intermediate plate 124 that is horizontally movable between the upper plate 122 and the lower plate 126. A second gas pipe 150

is connected to the sliding gate 120 to supply the inert gas into the sliding gate 120 such that the air introduced into the sliding gate 120 can be intercepted. The second gas pipe 150 is provided thereon with a second control valve 154 for controlling a flow rate of the inert gas and a second backpressure measuring device 152 for measuring backpressure of the inert gas supplied to the sliding gate 120 in real time. At this time, the second gas pipe 150 may be connected to a portion between the intermediate plate 124 and the lower plate 126 of the sliding gate 120.

[57] In addition, the submerged nozzle 130 is installed at a lower surface of the sliding gate 120. The immersion gate 130 includes an inner wall 132 and an outer wall 136, whose lower surfaces are inserted into the mold 103 and which has a hollow tube shape. In order to prevent growth of a sticking layer which is formed by the solidification of the molten steel 102 on the inner wall of the submerged nozzle 130, the inner wall 132 of the submerged nozzle 130 is made of a porous refractory material, and an empty space, i.e., a gas pool 134, is provided between the inner wall 132 and the outer wall 136. In particular, a third gas pipe 160 for supplying inert gas is connected to the gas pool 134, and the third gas pipe 160 is provided thereon with a third control valve 164 for controlling a flow rate of the inert gas and a third backpressure measuring device 162 for measuring backpressure of the inert gas supplied to the submerged nozzle 130 in real time.

[58] A controller 170 includes a detecting and data collecting unit for detecting and collecting backpressure information of inert gas, a calculating unit for processing the collected backpressure information of inert gas and calculating a backpressure changing value and a difference between the measured actual backpressure and theoretic backpressure, and a control unit for controlling the first, second and third control valves 144, 154 and 164 automatically or manually by an operator. Also, in order to receive casting variable information, the controller 170 is configured to be connected to a regulator 180, such as a programmable logic controller (PLC), which receives information of a continuous casting process including casting variable information and also controls the process, wherein the casting variable information includes the kind of steel for tundish casting, the number of tundish casting, molten steel weight and opening ratio of ladle and tundish, casting width, casting speed, casting temperature and casting thickness. Further, the controller 170 may further include a display for providing an operator with the casting variable information and the collected backpressure information and calculation information of inert gas.

[59] Here, in order for the calculating unit of the controller 170 to calculate a difference between an actual backpressure and a theoretic backpressure of inert gas, the theoretic backpressure may be input in advance by an operator or calculated in real time from the casting variable information.

- [60] In the embodiment of the present invention, the first, second and third control valves 144, 154 and 164 have been illustrated, but additional valves may be further provided according to a demanded process or control condition. Further, an additional gas pipe may be further provided at another configuration of the casting nozzle 100 or another location in addition to the first, second and third gas pipes 140, 150 and 160. For example, in addition to the third gas pipe 160 on the submerged nozzle 130, an additional gas pipe may be further provided at a location other than a portion in which the third gas pipe 160 is configured.
- [61] A method for preventing nozzle clogging and a method for continuous casting using the nozzle clogging preventing apparatus configured as above according to the embodiment of the present invention will be described. A stopper (not shown), which has closed the upper nozzle 110 installed at the bottom of the tundish 101, is opened, whereby the molten steel 102 in the tundish 101 is supplied to the sliding gate 120 through the upper nozzle 110. At this time, the intermediate plate 124 of the sliding gate 120 is in an open state, and the molten steel 102 is supplied to the mold 103 through the sliding gate 120 and the submerged nozzle 130, so that the molten steel 102 is stably supplied to the mold 103 through the casting nozzle 100 installed between the tundish 101 and the mold 103 without any contact with the air.
- [62] As mentioned above, when the molten steel 102 is supplied to the mold 103 through the supply channel formed in the casting nozzle 100 at the initial stage of casting, the molten steel 102 supplied to the casting nozzle 100 is brought into contact with the inner wall of the casting nozzle 100 to be reduced in temperature, thereby forming a sticking layer by the solidification of the molten steel on the inner wall of the nozzle 100. In particular, the sticking layer solidified on the inner wall of the casting nozzle 100 grows as the casting process progresses. Thus, in order to prevent the growth of the sticking layer, inert gas is supplied through the first, second and third gas pipes 140, 150 and 160 installed at the upper nozzle 110, the sliding gate 120 and the submerged nozzle 130 to form a gas curtain between the molten steel 102 and the inner wall of the casting nozzle 100.
- [63] More specifically, at the initial stage of casting, inert gas is supplied through the first, second and third gas pipes 140, 150 and 160 installed at the corresponding locations of the casting nozzle 100, and a flow rate of the inert gas is controlled by the first, second and third control valves 144, 154 and 164 to the extent that air bubbles of the inert gas are not collected in a solidification layer 104 in the mold 103 and thus hole defects do not occur. At this time, the first, second and third backpressure measuring devices 142, 152 and 162 respectively installed on the first, second and third gas pipes 140, 150 and 160 measure backpressure of the inert gas in real time and then transmit the measurement results to the controller 170.

[64] The detecting unit of the controller 170 receives the backpressure of the inert gas measured in real time, and the received actual backpressure of the inert gas is stored in the data collecting unit. The actual backpressure information stored in the data collecting unit is calculated together with theoretic backpressure or initial backpressure in the calculating unit.

[65] Here, the initial backpressure may be a pressure at the time when the inert gas is initially introduced into any one of the first, second and third gas pipes 140, 150 and 160, and the theoretic backpressure may be a value set by an operator or calculated from continuous casting work variables. Of course, it will be preferred to calculate the theoretic backpressure from the work variables so as to cope with the purpose of the present invention that is directed to measuring backpressure of inert gas in real time and reflecting the same in the process. For example, the theoretic backpressure may be a function dependent on a flow rate of inert gas, a flow rate of molten steel and the amount of molten steel as expressed by the following equation.

[66]

$$[67] \quad P_{\text{theoretic}} = f(Q_{\text{Ar_flow_rate}}, Q_{\text{molten_steel_flow_rate}}, TD_{\text{molten_steel_amount}}) \quad (1)$$

[68]

[69] where $P_{\text{theoretic}}$ is a theoretic backpressure, $Q_{\text{Ar_flow_rate}}$ is a flow rate of inert gas, $Q_{\text{molten_steel_flow_rate}}$ is a flow rate of molten steel, $TD_{\text{molten_steel_amount}}$ is the amount of molten steel in a tundish.

[70] The relationships between the initial backpressure, the theoretic backpressure and the actual backpressure are shown in Fig. 2.

[71] Fig. 2 is a graph showing a change of backpressure and flow rate of the inert gas supplied to a casting nozzle according to casting time.

[72] Referring to Fig. 2, a flow rate of inert gas has an initial value at the time when the casting is initiated. An actual backpressure at every casting time is drawn with a solid line. If a predetermined time passes after the casting is initiated, a sticking layer grows on the inner wall of the casting nozzle 100 due to various work variables such as a changed casting speed or molten steel state, so that the casting nozzle 100 is clogged. At this time, an actual backpressure is dropped. In Fig. 2, the theoretic backpressure is drawn with a dotted line. Since the theoretic backpressure is changeable due to the work variables and also calculated with the changed work variables reflected in real time, the theoretic backpressure may also be changed in real time. A difference between the theoretic backpressure and the actual backpressure after the clogging is initiated is increased rather than a difference between the theoretic backpressure and the actual backpressure before the clogging is initiated, and it is proportional to the degree of clogging.

[73] At this time, the detecting unit of the controller 170 detects the change of

backpressure measured in real time by the first, second and third backpressure measuring devices 142, 152 and 162. Then, if the degree of nozzle clogging is increased, the controller 170 increases a flow rate of inert gas according to each location.

[74] Here, the flow rate of the supplied inert gas may be controlled by any one of an intermittent method in which an increase and a decrease of the flow rate thereof are repeated as shown in A), a simple increasing method in which the flow rate thereof is continuously increased as shown in B), and a composite method in which a stepped increase and an instant decrease of the flow rate thereof are repeated as shown in C).

[75] In a case where a sticking layer is formed and grows on the inner wall of the sliding gate 120, the backpressure of the initially supplied inert gas is changed. Thus, the inert gas that should be supplied to the internal channel of the sliding gate 120 through the porous material of the intermediate plate 124 is blocked by the sticking layer not to easily injected, so that an injection pressure remains therein. The second backpressure measuring device 152 measures the injection pressure while the casting progresses, and transmits the measurement result to the controller 170. Accordingly, the controller 170 evaluates the degree of nozzle clogging at the sliding gate 120 according to the change of backpressure measured by the second backpressure measuring device 152. At this time, the criterion for evaluating the degree of nozzle clogging occurring at the sliding gate 120 may be a difference between the theoretic backpressure of the inert gas to be supplied to the sliding gate 120 and the actual backpressure of the inert gas supplied to the sliding gate 120.

[76] The difference between theoretic backpressure and actual backpressure is obtained from a nozzle clogging index, and the nozzle clogging index is increased as the difference between the theoretic backpressure calculated from the work variables and the changeable actual backpressure is greater. That is, the nozzle clogging index can be expressed by the following equation.

[77]

$$[78] \quad \text{Nozzle clogging index} = P_{\text{theoretic}} - P_{\text{actual}} \quad (2)$$

$$[79] \quad \text{Nozzle clogging index} = P_{\text{initial}} + \Delta P_{\text{theoretic}} - P_{\text{actual}} \quad (2)'$$

[80]

[81] where P_{actual} is an actual backpressure input to the detecting unit of the controller 170, $P_{\text{theoretic}}$ can be calculated using the equation (1) from $Q_{\text{Ar_flow_rate}}$, $Q_{\text{molten_steel_flow_rate}}$, and $TD_{\text{molten_steel_amount}}$, and $\Delta P_{\text{theoretic}}$ is an increase or decrease of theoretic backpressure expressed by the following equation.

[82]

$$[83] \quad \Delta P_{\text{theoretic}} = f(\Delta Q_{\text{Ar_flow_rate}}, \Delta Q_{\text{molten_steel_flow_rate}}, \Delta TD_{\text{molten_steel_amount}}) \quad (3)$$

[84]

[85] where $\Delta Q_{Ar_flow_rate}$ is an increase or decrease of a flow rate of inert gas, $\Delta Q_{molten_steel_flow_rate}$ is an increase or decrease of a flow rate of molten steel, $\Delta T_{molten_steel_amount}$ is an increase or decrease of molten steel in a tundish, which respectively represent an increased or decreased value in comparison to an initial value. That is, $\Delta P_{theoretic}$ represents an increase or decreased value in comparison to $P_{initial}$ at a state where there is no nozzle clogging at the initial casting. Thus, $\Delta P_{theoretic}$ becomes $(P_{current_theoretic} - P_{initial_theoretic})$, and if the initial theoretic value, i.e., initial theoretic backpressure, is identical to an initial value, i.e., an initial backpressure, the nozzle clogging index becomes $(P_{current_theoretic} - P_{actual})$, so that it can be finally expressed by one identical to Equation (2). As seen from the aforementioned equations, it could be understood that the nozzle clogging index is increased as the difference between the theoretic backpressure dependent on the work variables and the changeable actual backpressure is greater. That is, as the actual backpressure is farther from the theoretic backpressure, the nozzle clogging index is increased. Meanwhile, in a case where P_{actual} exceeds $P_{theoretic}$, i.e., the actual backpressure is greater than the theoretic backpressure, it can be evaluated that the nozzle wears off. This is because the backpressure of the inert gas is increased due to the wear of the nozzle.

[86] The relationship between the nozzle clogging index obtained by the above equations and nozzle clogging thickness is shown in Fig. 3. The nozzle clogging thickness is obtained by disassembling the clogged nozzle and then actually measuring its clogging thickness. The nozzle clogging thickness corresponding to the nozzle clogging index is drawn with a dot, and a plurality of dots are interpolated to be expressed with a line. As shown in Fig. 3, it would be found that the nozzle clogging index is substantially proportional to the maximum nozzle clogging thickness, and the correlation between the nozzle clogging index and the maximum nozzle clogging thickness can be expressed by the following equation.

[87]

[88]
$$\text{Nozzle clogging thickness} = a(P_{initial} + \Delta P_{theoretic} - P_{actual}) + b \quad (4)$$

[89]

[90] where $P_{initial}$ is an initial backpressure, and $\Delta P_{theoretic}$ is an increase or decrease of theoretic backpressure expressed by Equation (3). Thus, $\Delta P_{theoretic}$ becomes $(P_{current_theoretic} - P_{initial_theoretic})$, and if the initial theoretic value, i.e., an initial theoretic backpressure, is identical to an initial value, i.e., an initial backpressure, the nozzle clogging thickness becomes $a(P_{current_theoretic} - P_{actual}) + b$, so that it can be finally expressed by $a(\text{nozzle clogging index}) + b$. Here, a and b are optional constants obtainable from the relationship of Fig. 3, which may be changed depending on used molten steel, a continuous casting apparatus, and the like.

[91] If the nozzle clogging thickness is estimated from the nozzle clogging index as

mentioned above, an operator controls the flow rate of the inert gas supplied to the casting nozzle 100 to restrain separation or growth of the sticking layer from or on the inner wall of the casting nozzle, thereby controlling the casting state to improve a casting yield and quality of strands. For example, if the nozzle clogging thickness is estimated in at least one of the first, second and third backpressure measuring devices 142, 152 and 162, the flow rate of the inert gas supplied to at least one of the first, second and third gas pipes 140, 150 and 160 corresponding to the estimated clogging is increased. Here, in a case where the degree of nozzle clogging (or, the nozzle clogging index) at the sliding gate 120 is an actual number greater than 0, the second control valve 154 installed on the second gas pipe 150 is controlled to increase the flow rate of the inert gas supplied to the sliding gate 120 in proportion to the degree of nozzle clogging, thereby increasing the flow rate of the supplied inert gas to separate the sticking layer or restrain its growth.

[92] Meanwhile, it is also possible to evaluate the degree of leakage of the inert gas generated at the first, second and third gas pipes 140, 150 and 160 by detecting a flow rate and actual backpressure of the inert gas from the detecting unit of the controller 170 and then collecting the detected data in the data collecting unit. The leakage of the inert gas decreases an effective supply of the inert gas at the nozzle and thus decreases a sticking restraining effect of non-metal inclusions by the gas curtain on the wall of the nozzle, so that it is required to control the leakage of the inert gas for the detection of nozzle clogging. Leakage of the inert gas can be obtained using the following equation from the relationship between the actual backpressure and the flow rate of the inert gas before the nozzle clogging occurs.

[93]

[94] Inert gas leakage index = $f(P_a / Q_{Ar})$ (5)

[95]

[96] where P_a is an actual backpressure of inert gas, and Q_{Ar} is a flow rate of inert gas.

[97]

If the actual backpressure of inert gas is decreased while the inert gas is supplied at a certain flow rate, the leakage of inert gas is increased. This means that the actual backpressure is decreased due to the leakage of inert gas for a certain flow rate of inert gas. According to the generation of leakage of inert gas, an effective supply of inert gas at the nozzle, i.e., the amount of the inert gas ejected from the nozzle in comparison to an introduced inert gas, is decreased. Thus, the inert gas leakage index can be considered as an inert gas effective supply index.

[98]

If the nozzle is clogged while no leakage of inert gas occurs, the flow rate and actual backpressure of inert gas are decreased at the same time, so that the inert gas leakage index representing their rates may not be changed. Thus, it is possible to distinguish the nozzle clogging and the inert gas leakage from each other.

- [99] The method for preventing nozzle clogging according to the present invention as mentioned above is shown in Fig. 4.
- [100] Referring to Fig. 4, inert gas is supplied to a nozzle when casting is initiated (S1), and flow rate and backpressure of the supplied inert gas are measured in real time (S2). The measured flow rate and backpressure of the inert gas are collected together with various work variables (S3), and a casting status index is obtained from the collected work variables (S4).
- [101] Inert gas leakage is calculated from the measured flow rate and backpressure of the inert gas as mentioned above, a nozzle clogging index is calculated from actual backpressure and theoretic backpressure of the inert gas, and nozzle clogging thickness can be calculated through operation between the actual backpressure and a sum of initial backpressure and an increase or decrease of theoretic backpressure. The control unit of the controller 170 increases or decreases the supply amount of inert gas according to the calculated inert gas leakage, nozzle clogging index and nozzle clogging thickness (S5).
- [102] Each data and calculated value may be displayed to an operator, and the operator may conduct necessary manual maintenance works in addition to the control of the supply amount of inert gas by reflecting such data or value in the work.
- [103] Hereinafter, the present invention will be explained in more detail.
- [104] [Detection of Inert Gas Leakage]
- [105] In order to detect leakage of inert gas, a structure for supplying inert gas to the upper nozzle 110, the sliding gate 120 and the submerged nozzle 130 as shown in Fig. 1 was used. As an embodiment of the present invention, a method using a change of backpressure of inert gas during a casting process, i.e., using a difference between theoretic backpressure and actual backpressure, was utilized.
- [106] If the leakage of inert gas occurs in a section from the inert gas pipe to the nozzle, the backpressure is changed. This will be described with reference to Fig. 5, if comparing a case (A) of low backpressure with a case (B) of high backpressure when inert gas is supplied at a certain flow rate, it could be understood that nozzle clogging thickness is thicker in the case (A) of low backpressure. This is because if the leakage of inert gas occurs, the amount of effective inert gas is decreased, and thus, an effect of restraining non-metal inclusions from sticking by the gas curtain on the nozzle wall is decreased. Thus, the inert gas leakage can be detected at a ratio of actual backpressure to a flow rate of inert gas.
- [107] That is, in a case where the ratio of actual backpressure to the fixed flow rate of inert gas is decreased, the leakage of inert gas occurs. The degree of leakage of inert gas is proportional to the degree of decrease of the ratio of actual backpressure to the flow rate of inert gas, and nozzle clogging is increased as the degree of leakage of inert gas

is increased. If such leakage of inert gas occurs, the ratio of actual backpressure to the flow rate of inert gas and the effective supply of inert gas can be maintained in a state before the nozzle clogs by increasing a flow rate of the supplied inert gas. Also, an operator may be informed of the occurrence or not of leakage such that the operator repairs it manually.

[108] [Detection Time of Nozzle Clogging]

[109] In order to detect nozzle clogging, a structure for supplying inert gas to the upper nozzle 110, the sliding gate 120 and the submerged nozzle 130 as shown in Fig. 1 was used. As a comparative example, a method of evaluating the degree of nozzle clogging using a difference between an actual opening ratio and a theoretic opening ratio was used, and as an embodiment of the present invention, a method using a difference between an actual backpressure and a real-time increased or decreased amount of theoretic backpressure of inert gas during a casting process was used.

[110] The results of the comparative example and the embodiment are shown in the following table 1.

[111]

[112] Table 1

[Table 1]

[Table]

	Comparative Example	Embodiment
Clogging detection time (min.)	180	30

[113]

[114] In the comparative example using the difference between an actual opening ratio and a theoretic opening ratio, since the nozzle has a greater caliber than the opening ratio of the intermediate plate 124, nozzle clogging is initiated and then detected after the point of time when an actual caliber of the nozzle is gradually decreased and then is smaller than the opening ratio of the intermediate plate. That is, it is impossible to detect the nozzle clogging at a point of time when the nozzle clogging is initiated, but nozzle clogging can be detected after 180 minutes, which is later than the point of time when the nozzle clogging becomes smaller than the opening ratio of the intermediate plate.

[115] On the contrary, in the embodiment of the present invention that detects a change of backpressure of inert gas, backpressure of inert gas is changed from the point of time when nozzle clogging is initiated, and the clogging detection time is 30 minutes, which ensures more rapid detection of nozzle clogging than the comparative example whose clogging detection time is 180 minutes.

[116] [Estimation of Nozzle Clogging and Control of Flow Rate of Inert Gas]

[117] In the embodiment of the present invention, in a case where nozzle clogging is

estimated, a flow rate of inert gas is varied and then supplied so as to prevent nozzle clogging. A phase of changing the degree of nozzle clogging according to the variable pattern of a flow rate of inert gas was compared and observed.

[118] First, a flow rate of inert gas was simply increased or decreased in Embodiment 1, and a flow rate of inert gas was intermittently supplied in Embodiment 2. The degree of solving the nozzle clogging through Embodiments 1 and 2 is shown in Fig. 6. In fact, Embodiment 1 shows a gas supply of inert gas with a pattern like B) of Fig. 2, and Embodiment 2 shows a gas supply of inert gas with a pattern like A) of Fig. 2.

[119] Referring to Fig. 6, it would be found that the nozzle clogging was decreased by about 20% in Embodiment 2 as compared with Embodiment 1, and its deviation was also decreased. In a case where a flow rate of inert gas is simply increased or decreased as in Embodiment 1, acceleration of the inert gas is applied to the sticking layer just one time. However, if the inert gas is intermittently supplied, acceleration of the inert gas is applied to the sticking layer at every intermittent supply, so that more large force can be supplied for a unit time.

[120] [Nozzle Clogging Index]

[121] The degrees of nozzle clogging according to an embodiment of the nozzle clogging preventing method according to the present invention and a conventional example are shown in Fig. 7. In the conventional example, the opening ratio difference detecting method explained as a comparative example in the section [Detection Time of Nozzle Clogging] was used.

[122] Referring to Fig. 7, it would be understood that an area ratio of nozzle clogging in the embodiment of the present invention is decreased by about 25% on average rather than the conventional example. As explained above, the opening ratio difference detecting method of the conventional example cannot efficiently cope with nozzle clogging since the clogging detection time is very late after the nozzle clogging is initiated. However, in the embodiment of the present invention, since actual backpressure of the inert gas is changed from the point of time when the nozzle clogging is initiated, it is possible to relatively rapidly cope with the change accordingly, so that an area ratio of nozzle clogging can be effectively reduced.

[123] Fig. 8 shows an increase/decrease in nozzle clogging index according to months during which the continuous casting apparatus is used. In Fig. 8, the nozzle clogging preventing method according to the embodiment of the present invention is applied after 8 months.

[124] Referring to Fig. 8, it would be understood that before the nozzle clogging preventing method according to the embodiment of the present invention is applied, the nozzle clogging index shows a tendency of gradually increasing, and the nozzle clogging comes to the peak 8 months later. After 8 months, i.e., from the point of time

when the embodiment of the present invention is applied, it would be found that the nozzle clogging index is rapidly dropped and thus stabilized in a low level of 0.5 or below.

[125] [Comparison with Conventional Methods]

[126] Comparisons between Conventional Examples 1, 2, 3 and 4 and Embodiments 3 and 4 are shown in the following table 2.

[127] Table 2

[Table 2]

[Table]

	Conventional Example 1	Conventional Example 2	Conventional Example 3	Conventional Example 4	Embodiment 3	Embodiment 4
Measurement method	Surface frequency detecting method	Thermocouple method	Opening ratio difference detecting method	Relative comparison of inert gas backpressure	Absolute comparison of inert gas backpressure	Absolute comparison of inert gas backpressure difference
Measurement principle	High frequency surface amplitude change	Thermocouple detection	Relative opening ratio change (initial opening ratio - current opening ratio)	Initial backpressure - current backpressure	Theoretic backpressure - current backpressure ($P_{\text{theoretic}} - P_{\text{actual}}$)	Initial backpressure + theoretic backpressure - current backpressure ($(P_{\text{initial}} + \Delta P_{\text{theoretic}} - P_{\text{actual}})$)
Determination of nozzle clogging location	Unable	Unable	Unable	Able	Able	Able
Detection of nozzle clogging initiating time	-	After 80 minutes	After 180 minutes	After 30 minutes	After 30 minutes	After 30 minutes
Hit rate of nozzle clogging determination (%)	-	-	13	45	73	95

Detection of nozzle clogging thickness when work conditions are changed during casting	Unable	Unable	Unable	Unable	Able	Able
Detection of inert gas leakage of nozzle	Unable	Unable	Unable	Able	Able	Able
Automatic control of flow rate of inert gas when nozzle clogging	Unable	Unable	Unable	Unable	Able	Able

[128] As seen from Table 2, Conventional Examples 1, 2 and 3 detect surface, nozzle outer surface, and opening ratio, thereby just determining the presence or not of nozzle clogging and not being able to determine nozzle clogging location. It is also impossible to detect inert gas leakage of the nozzle.

[129] In order to determine nozzle clogging location and inert gas leakage of the nozzle, it is advantageous to inject inert gas to each portion of the nozzle and then detect it. This method is employed in Conventional Example 4 and Embodiments 3 and 4.

[130] In detection of nozzle clogging initiating time, it is advantageous to measure and detect inert gas successively introduced during the casting. It would be understood that Conventional Example 3 using an opening ratio difference takes 180 minutes and Conventional Example 2 using a thermocouple takes 80 minutes, which are greatly later than 30 minutes of Conventional Example 4 and Embodiments 3 and 4.

[131] It would be understood that the detection of nozzle clogging thickness when casting conditions are changed during the casting cannot be allowed in Conventional Examples 1, 2, 3 and 4 since casting variables are not reflected therein, but Embodiments 3 and 4 may detect nozzle clogging thickness.

[132] In addition, the means for automatic control of a flow rate of inert gas when nozzle clogging is not provided in Conventional Examples 1, 2, 3 and 4 but provided in only Embodiments 3 and 4, so that Embodiments 3 and 4 can rapidly cope with the nozzle clogging.

[133] The hit rate of nozzle clogging (%), which is a percentage of the number of nozzles, which are accurately determined to have or not a sticking layer by a user at the end of the casting, with respect to the entire number of subject nozzles is higher in Embodiment 4 than Embodiment 3. This is because actual backpressure is changed to be different from the initial backpressure though the nozzle is not clogged if work variables are changed during the casting, and thus the backpressure increased or decreased by nozzle clogging cannot be exactly found out. However, it could be understood that Embodiments 3 and 4 exhibit superior hit rates of nozzle clogging as compared with Conventional Examples 1, 2, 3 and 4.

[134] The present invention is not limited to the aforementioned embodiments, but modifications and changes can be made thereto within the scope not departing from the spirit of the present invention, and such changes and modifications should also be considered as being included in the scope of the present invention.

[135]

[136]

[137]

[138]

[139]

[140]

[141]

[142]

[143]

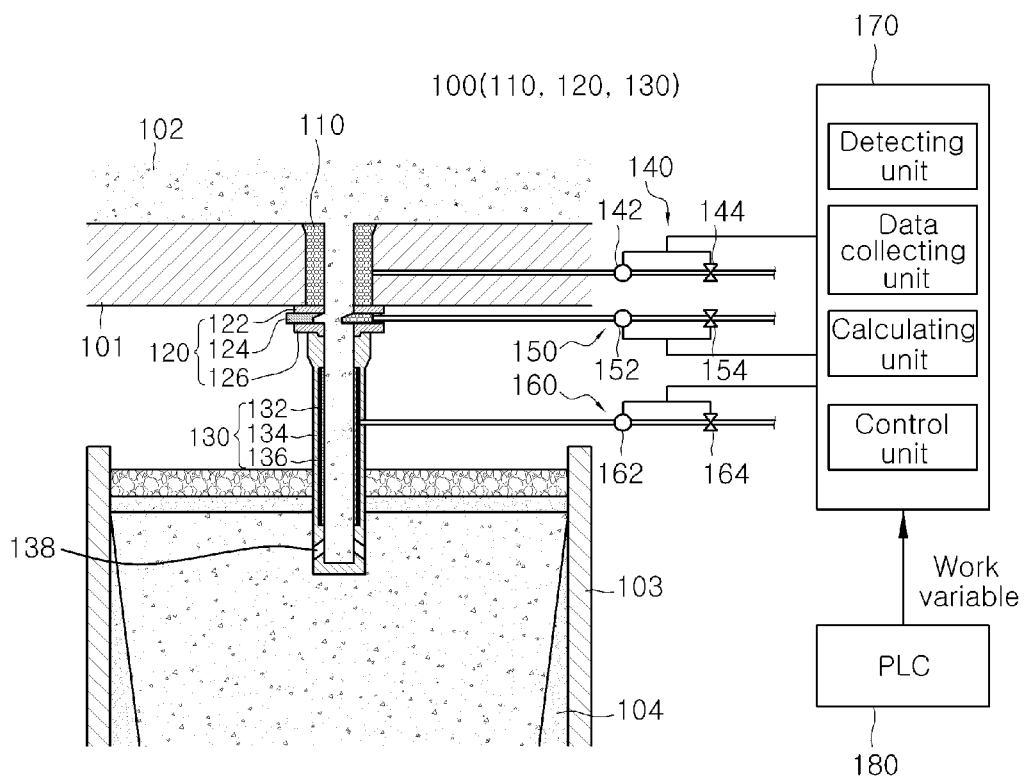
Claims

- [1] An apparatus for preventing nozzle clogging, comprising:
a gas pipe connected to a casting nozzle to supply inert gas thereto; and
a controller for measuring backpressure of the inert gas in real time to calculate a nozzle status index.
- [2] The apparatus for preventing nozzle clogging as claimed in claim 1, wherein the nozzle status index includes at least one of an inert gas leakage index, a nozzle clogging index and a nozzle clogging thickness.
- [3] The apparatus for preventing nozzle clogging as claimed in claim 1, wherein the controller includes:
a sensing unit for measuring backpressure of the inert gas in the gas pipe;
a data collecting unit for collecting the measured backpressure of the inert gas;
a calculating unit for calculating the nozzle status index using the collected backpressure of the inert gas; and
a control unit for controlling a flow rate of the inert gas.
- [4] The apparatus for preventing nozzle clogging as claimed in claim 3, wherein the nozzle status index is a nozzle clogging index or a nozzle clogging thickness.
- [5] An apparatus for continuous casting, comprising:
a tundish;
a mold;
a casting nozzle installed between the tundish and the mold; and
an apparatus for preventing nozzle clogging including a gas pipe connected to the casting nozzle to supply inert gas thereto, and a controller for measuring backpressure of the inert gas in real time to calculate a nozzle status index.
- [6] The apparatus for continuous casting as claimed in claim 5, wherein the casting nozzle includes an upper nozzle, a sliding gate and a submerged nozzle, and the gas pipe is connected to at least one of the upper nozzle, the sliding gate and the submerged nozzle.
- [7] The apparatus for continuous casting as claimed in claim 5, comprising a regulator connected to the continuous casting apparatus to collect work variables, wherein the regulator is connected to the controller to provide the collected work variables.
- [8] The apparatus for continuous casting as claimed in claim 5, wherein the controller includes:
a sensing unit for measuring backpressure of the inert gas in the gas pipe;
a data collecting unit for collecting the measured backpressure of the inert gas;
a calculating unit for calculating the nozzle status index using the collected

- backpressure of the inert gas; and
a control unit for controlling a flow rate of the inert gas.
- [9] A method for preventing nozzle clogging, comprising:
measuring backpressure of inert gas supplied to a casting nozzle in real time; and
calculating a nozzle status index from the measured actual backpressure.
- [10] The method for preventing nozzle clogging as claimed in claim 9, wherein the
nozzle status index includes at least one of an inert gas leakage index, a nozzle
clogging index and a nozzle clogging thickness.
- [11] The method for preventing nozzle clogging as claimed in claim 10, wherein the
inert gas leakage index includes a function of a ratio between a supply flow rate
of the inert gas and the measured actual backpressure.
- [12] The method for preventing nozzle clogging as claimed in claim 10, wherein the
nozzle clogging index or the nozzle clogging thickness is calculated from
theoretic backpressure.
- [13] The method for preventing nozzle clogging as claimed in claim 12, wherein the
nozzle clogging index includes a difference between the theoretic backpressure
and the actual backpressure.
- [14] The method for preventing nozzle clogging as claimed in claim 12, wherein the
nozzle clogging thickness includes a difference between the actual backpressure
and a sum of an initial backpressure and an increase or decrease of theoretic
backpressure.
- [15] The method for preventing nozzle clogging as claimed in claim 9, further
comprising increasing or decreasing a flow rate of the inert gas according to the
nozzle status index.
- [16] A method for continuous casting, comprising:
measuring backpressure of inert gas supplied to a casting nozzle in real time, the
casting nozzle being installed between a tundish and a mold;
calculating a nozzle status index from the measured actual backpressure; and
controlling a flow rate of the inert gas according to the nozzle status index.
- [17] The method for continuous casting as claimed in claim 16, wherein calculating a
nozzle status index includes:
receiving work variable data of the continuous casting process; and
calculating theoretic backpressure from the work variable of the continuous
casting process.
- [18] The method for continuous casting as claimed in claim 17, wherein the theoretic
backpressure is calculated with at least one of a flow rate of the inert gas, a flow
rate of molten steel, and the amount of molten steel in the tundish.
- [19] The method for continuous casting as claimed in claim 16, wherein in controlling

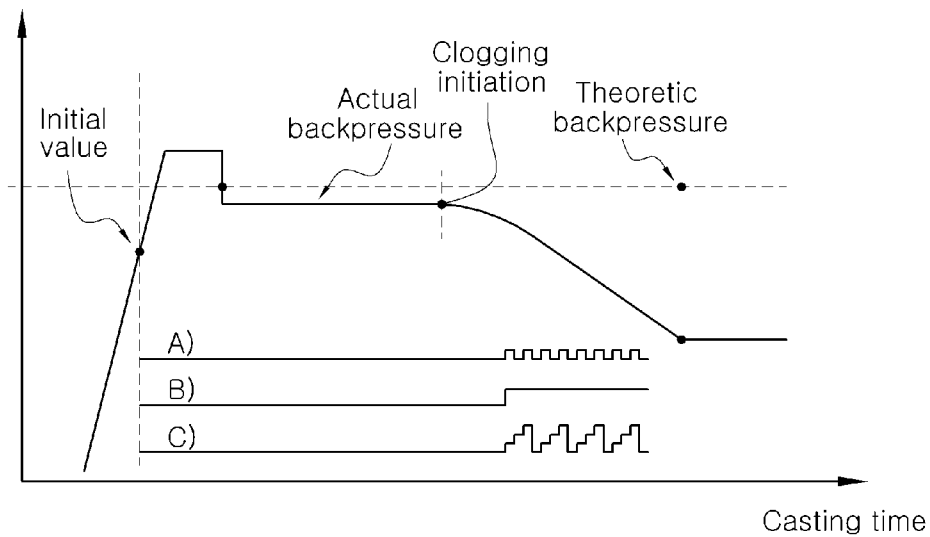
the flow rate of the inert gas, the flow rate of the inert gas is controlled by at least one of intermittent method in which an increase and a decrease of the flow rate thereof are repeated, a composite method in which a stepped increase and an instant decrease of the flow rate thereof are repeated, and a simple increasing method.

[Fig. 1]

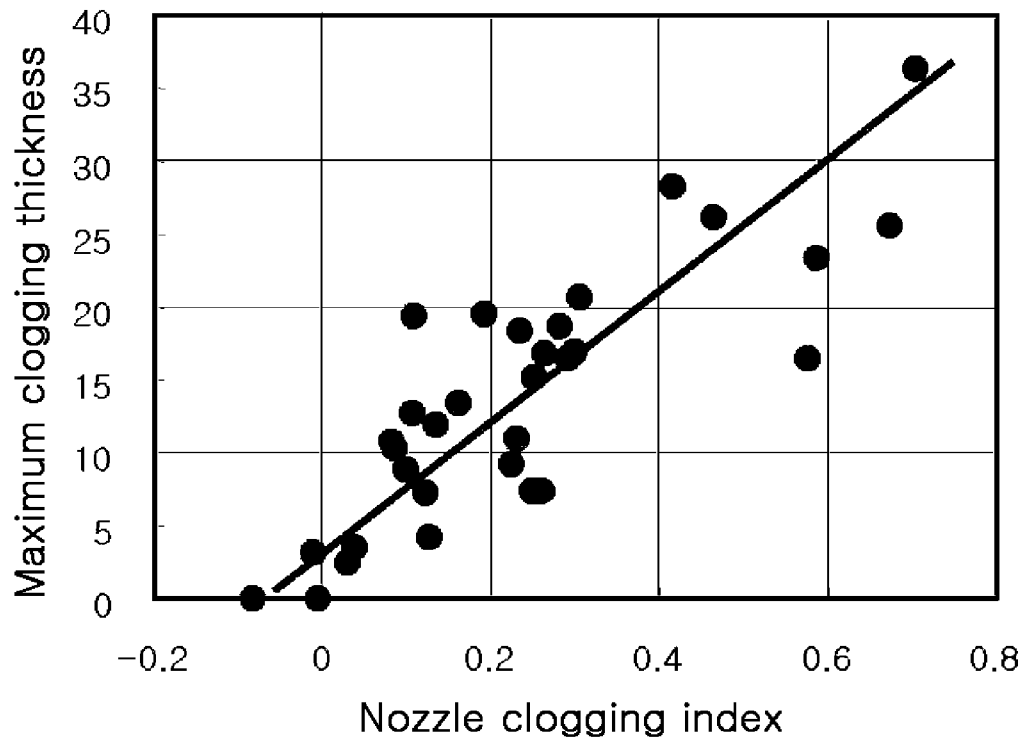


[Fig. 2]

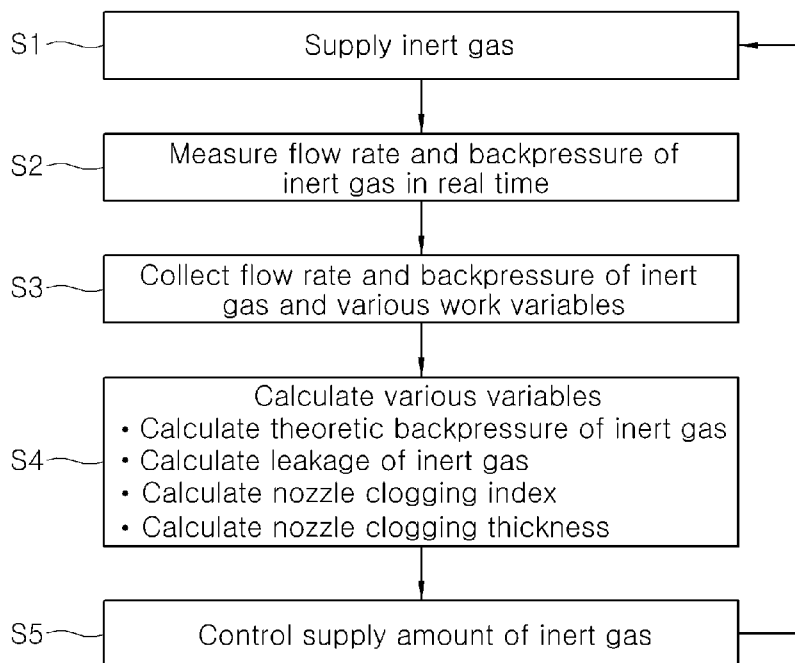
Backpressure (Flow rate)



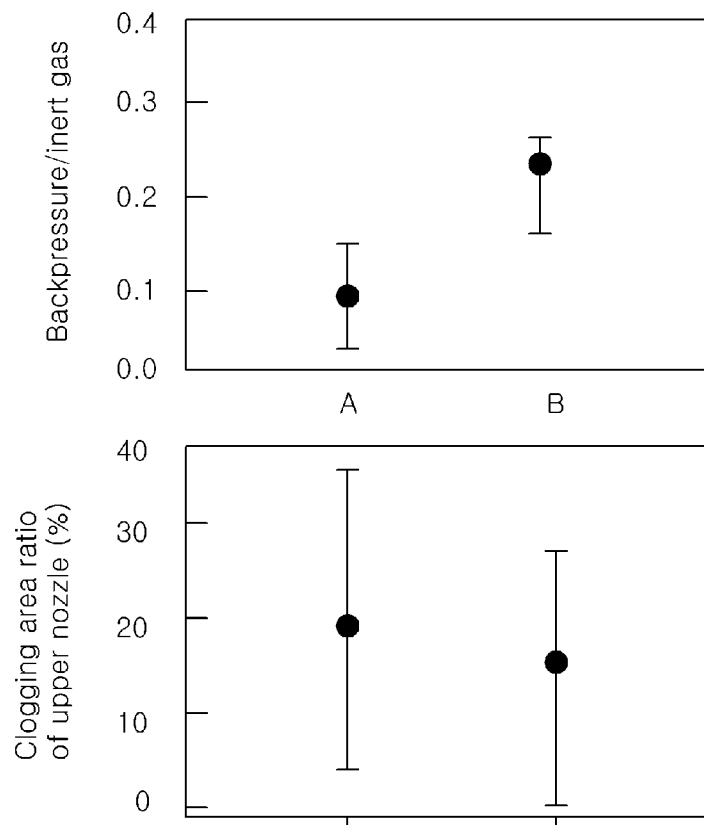
[Fig. 3]



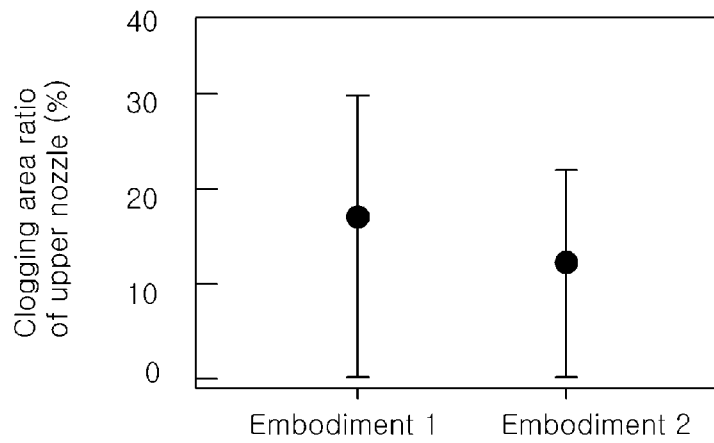
[Fig. 4]



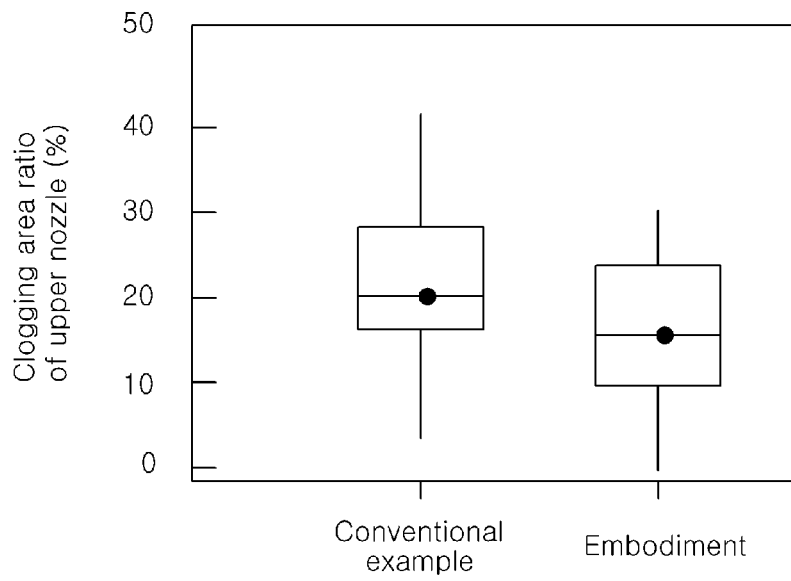
[Fig. 5]



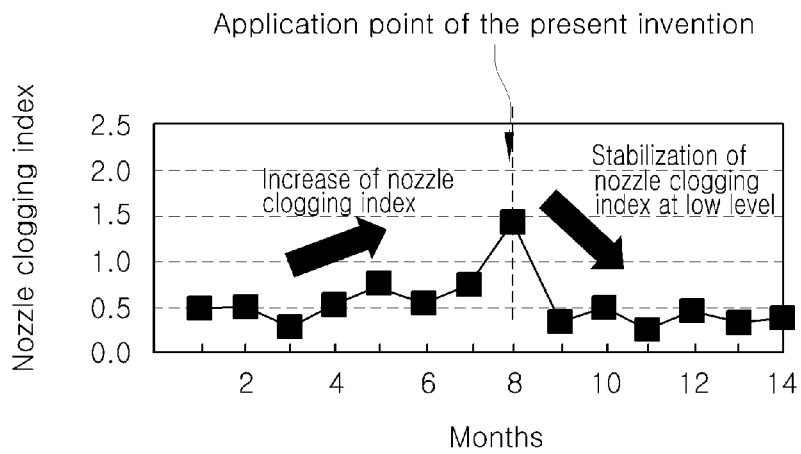
[Fig. 6]



[Fig. 7]



[Fig. 8]



A. CLASSIFICATION OF SUBJECT MATTER***B22D 11/10(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)

IPC 8 : B22D 11/00

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 since 1975

Japanese Utility Models and applications for Utility Models since 1975

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

eKIPASS(KIPO internal) "nozzle", "clogging", "pressure"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 07-112253 A (NIPPON STEEL CORP.) 2 MAY 1995 See claims 1 -3 ; Figures 1,2	3,4,7,8, 12, 17
Y X	KR 10-2000-0045533 A (POSCO LTD.) 15 JULY 2000 See claim 1-2 ; Figures 1, 8-11	3,4,7,8,12, 17 1,2,5,6,9,10,15,16
A	JP 18-150453 A (HERAEUS ELECTRO-NITE INTERNATL. NV) 15 JUNE 2006 See abstract ; Figure 1	1-19

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

* Special categories of cited documents:

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Date of the actual completion of the international search

21 NOVEMBER 2008 (21.11.2008)

Date of mailing of the international search report

21 NOVEMBER 2008 (21.11.2008)

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Authorized officer

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Telephone No. 82-42-481-5520



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2008/003672

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 07-112253	02-05-1995	None	
KR 10-2000-0045533	15-07-2000	None	
JP 18-150453	15-06-2006	None	