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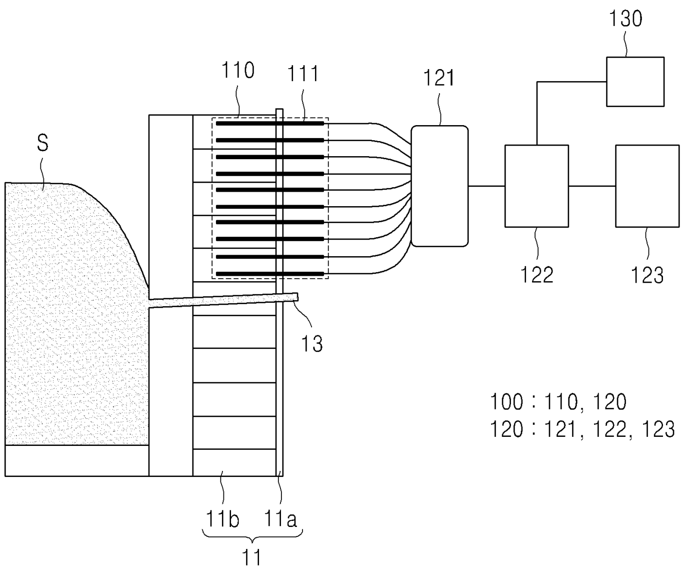
(54) **DEVICE AND METHOD FOR MEASURING SURFACE LEVEL OF MOLTEN METAL**

(57) The present invention is a device for calculating the surface level of a molten metal accommodated in a container provided with an outlet, the device comprising: a measuring unit installed in the container so as to measure, at different heights, an induced electromotive force generated by the motion of the molten metal; and a processing unit for determining the surface level of the molten metal by using values measured based on the vertical level. The present invention can accurately measure the surface level of a molten metal.

FIG. 2



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an apparatus and a method for measuring a surface level, and more specifically, to an apparatus and a method for accurately measuring a surface level of molten metal.

RELATED ART

[0002] Generally, a blast furnace operation includes a process of charging iron ore and coke to an upper portion of a blast furnace, a process of blowing hot blast into a tuyere defined in the blast furnace to combust the coke, a process of removing impurities and oxygen from the iron ore with heat and gas generated by combusting the coke to produce molten iron. The molten iron in a liquid state is stored in a lower portion of the blast furnace and is discharged through a tap hole after a certain period of time.

[0003] In this connection, when the molten iron is stored at a level equal to or higher than a certain level in the lower portion of the blast furnace because a discharging operation is not performed properly, the hot blast supplied through the tuyere may not be smoothly supplied into the blast furnace, thereby increasing a blowing pressure. When this phenomenon becomes worse, channeling may occur in the blast furnace, thereby deteriorating an efficiency of the blast furnace operation. In addition, the molten iron may flow reversely to the tuyere and damage the tuyere, and the entire blast furnace operation may be interrupted. Therefore, it is necessary to measure the level of the molten iron in the blast furnace, and maintain the level properly.

[0004] Conventionally, the level of the molten iron in the blast furnace was predicted by comparing amounts of raw materials such as the iron ore, the coke, and the like charged into the blast furnace with an amount of the molten iron that is discharged in order to measure the level of the molten iron. However, there is a limit to accurately calculate the amounts of the raw materials charged into the blast furnace, so that the level of the molten iron may not be accurately predicted.

[0005] Alternatively, stress transferred to an outer surface of the blast furnace was measured using a strain sensor or an amount of current returned from the blast furnace was measured to speculate the level of the molten iron. However, accuracy is low such that usability is very low. Therefore, there is a need for a technology that may accurately measure the level of the molten iron in the blast furnace.

(Related Art Document)

[0006] Korean patent application publication No. 2001-0019977

[0007] Korean patent application publication No. 2010-0071347

SUMMARY

[0008] The present disclosure provides an apparatus and a method for accurately measuring a surface level of molten metal.

[0009] The present disclosure provides an apparatus and a method for accurately measuring a surface level of molten metal that may reliably perform a molten metal discharging operation.

[0010] An apparatus for measuring a surface level of molten metal accommodated in a container having an outlet according to an embodiment of the present disclosure includes: a measuring unit installed on the container to measure induced electromotive forces caused by motion of the molten metal based on vertical levels; and a processing unit configured for determining a surface level of the molten metal using the electromotive force values measured based on the vertical levels.

[0011] The measuring unit includes a plurality of measuring instruments arranged in a vertical direction.

[0012] A tuyere from which hot blast is supplied is defined in the container, and the plurality of measuring instruments are disposed between the outlet and the tuyere.

[0013] The outlet includes a plurality of outlets, and the measuring unit includes a plurality of measuring instruments respectively installed for the plurality of outlets.

[0014] The processing unit includes a processor configured for determining a maximum value among the induced electromotive force values measured based on the vertical levels and for selecting a vertical level corresponding to the maximum value as the surface level of the molten metal.

[0015] The apparatus further includes a controlling unit connected to the processing unit to control opening and closing of the outlet.

[0016] The controlling unit includes: a comparator configured for comparing the vertical level corresponding to the maximum induced electromotive force with a predetermined vertical level range; and a controller configured for adjusting an opening duration of the outlet when the vertical level is out of the predetermined vertical level range.

[0017] The outlet includes a plurality of outlets, and the controller controls a concurrent opening duration of the plurality of outlets.

[0018] A method for measuring a surface level of molten metal inside a container according to an embodiment of the present disclosure includes: opening an outlet defined in the container; discharging the molten metal inside the container; closing the outlet; measuring induced electromotive forces generated by motion of the molten metal based on vertical levels; and deriving a surface level of the molten metal using the measured induced electromotive force.

[0019] The deriving of the surface level of the molten metal includes: determining a maximum value among the induced electromotive force values measured based on the vertical levels; and selecting a vertical level corresponding to the maximum value as the surface level of the molten metal.

[0020] The outlet includes a plurality of outlets, and the measuring of the induced electromotive forces based on the vertical levels includes measuring each induced electromotive force for each outlet.

[0021] The determining of the maximum value among the induced electromotive force values measured based on the vertical levels includes: determining one outlet using each induced electromotive force measured for each outlet and determining the maximum value for the determined outlet.

[0022] The outlet includes a plurality of outlets, and the measuring of the induced electromotive forces based on the vertical levels includes measuring the induced electromotive force for an outlet being opened and closed among the plurality of outlets.

[0023] The method further includes: after deriving the surface level of the molten metal, comparing the derived level value with a predetermined vertical level range; and adjusting an amount of the molten metal to be discharged when the derived vertical level is outside the predetermined level range.

[0024] The adjusting of the amount of the molten metal to be discharged includes adjusting an opening duration of the outlet.

[0025] Opening durations of the plurality of outlets may overlap with each other, and the adjusting of the opening duration of the outlet includes adjusting at least one of an opening duration of each outlet or a concurrent opening duration of the plurality of outlets.

[0026] The measuring of the induced electromotive forces based on the vertical levels includes sequentially and vertically upwardly measuring the induced electromotive forces.

[0027] The container includes a blast furnace or a FINEX melting furnace, and the molten metal includes molten iron.

[0028] According to embodiments of the present disclosure, when the discharging of the molten iron stored in the container is stopped, the induced electromotive forces caused by the horizontal motion of the molten metal may be measured based on the vertical levels. Thus, the surface level of the molten metal may be accurately measured using the measured induced electromotive force.

[0029] In addition, since the surface level of the molten metal may be accurately measured, the amount of the molten metal to be discharged may be determined such that the adequate amount of the molten metal is stored in the container. Thus, the discharging of the molten metal may be stably performed to maintain the amount of the molten metal in the container adequately. Therefore, the increase of the blowing pressure in the container, the occurrence of the channeling, or the backflow of the molten metal to the tuyere may be suppressed or prevented.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030]

FIG. 1 illustrates a structure of a blast furnace installation according to an embodiment of the present disclosure.

FIG. 2 illustrates an apparatus for measuring a surface level of molten metal according to an embodiment of the present disclosure.

FIG. 3 illustrates change in a level of molten steel above an outlet according to an embodiment of the present disclosure.

FIG. 4 is a flowchart showing a method for measuring a surface level of molten metal according to an embodiment of the present disclosure.

FIG. 5 illustrates a discharging schedule of a plurality of outlets according to an embodiment of the present disclosure.

FIG. 6 is a graph showing a measurement result of induced electromotive forces measured based on vertical levels according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0031] Hereinafter, exemplary embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. However, the present disclosure is not limited to the embodiments disclosed below, but may be implemented in various forms. The embodiments of the present disclosure are provided to make the disclosure of the present disclosure complete and fully inform those skilled in the art to which the present disclosure pertains of the scope of the present disclosure. The drawings may be exaggerated to illustrate the present disclosure in detail, wherein like reference numerals refer to like elements throughout.

[0032] FIG. 1 illustrates a structure of a blast furnace installation according to an embodiment of the present disclosure. The embodiment of the present disclosure exemplifies that an apparatus for measuring a surface level of molten metal is provided in a blast furnace 11, but the scope of application is not limited thereto. The apparatus for measuring the surface level of the molten metal may be installed on various containers such as a FINEX melting furnace and the like that stores the molten metal.

[0033] Referring to FIG. 1, the blast furnace 11 is a facility that continuously produces molten iron using iron ore and coke. The blast furnace 11 may be formed in a container shape having an open top and an internal space defined therein. An outer surface of the blast furnace 11 is made of a steel plate 11a, and a refractory material may be used to build a structure inside the steel plate 11a. When the iron ore, the coke, and the like are charged into the open top of the blast furnace 11 together and heated to about 1500 °C by blowing hot blast, molten metal (or molten iron or slag) may be stored in a lower portion of the internal space of the blast furnace 11.

[0034] A tuyere 12 may be defined in a lower portion of the blast furnace 11. The tuyere 12 may be connected to a hot blast supply line 20 and may blow hot blast supplied from the hot blast supply line 20 into the blast furnace 11. The tuyere 12 may include a plurality of tuyeres arranged radially along a periphery of the blast furnace 11.

[0035] The hot blast supply line 20 may include an annular tube 21 surrounding the periphery of the blast furnace 11 so as to uniformly supply the hot blast supplied from a hot blast furnace (not shown) to the internal space of the blast furnace 11, and a blowing branch pipe 22 branched from the annular pipe 21 to each tuyere 12. Therefore, the hot blast supplied from the hot blast furnace may be uniformly introduced into the blast furnace 11 through the plurality of tuyeres 12.

[0036] An outlet 13 may be formed at a lower portion of the blast furnace 11. The outlet 13 is located below the tuyere 12. The outlet 13 may include a plurality of outlets. For example, four outlets may be provided and arranged in four directions along the periphery of the blast furnace 11, respectively. The outlet 13 is openable and closable. Therefore, when the outlet 13 is closed, an amount of the molten metal stored in the blast furnace 11 may increase, and when the outlet 13 is opened, the molten metal stored in the blast furnace 11 may be discharged. However, the number of the outlets and a structure of the blast furnace 11 are not limited thereto and may vary.

[0037] In this connection, when the molten metal is stored at a level equal to or higher than a certain level in the lower portion of the blast furnace 11, the hot blast supplied through the tuyere 12 may not be smoothly supplied into the blast furnace 11 such that blowing pressure may be increased. When this phenomenon becomes worse, channeling may occur in the blast furnace 11, thereby deteriorating an efficiency of the blast furnace operation. In addition, the molten metal may flow reversely to the tuyere 12 and damage the tuyere 12, and the entire blast furnace operation may be interrupted. Therefore, it is necessary to measure a level of the molten iron in the blast furnace 11, and maintain the level properly.

[0038] FIG. 2 illustrates an apparatus for measuring a surface level of molten metal according to an embodiment of the present disclosure. Further, FIG. 3 illustrates change in a level of molten steel above an outlet according to an embodiment of the present disclosure.

[0039] Referring to FIG. 2, an apparatus 100 for measuring a surface level of molten metal according to an embodiment of the present disclosure measures a surface level of molten metal accommodated in the container provided with the outlet 13. The apparatus 100 for measuring a surface level of molten metal includes a measuring unit 110 installed on the container so as to measure, based on vertical levels, induced electromotive forces generated by a motion of the molten metal and a processing unit 120 for determining the surface level of the molten metal using values measured based on the vertical levels. Further, the apparatus 100 for measuring a surface level of molten metal may further include a controlling unit 130 connected to the processing unit 120 to control opening and closing of the outlet 13. In this connection, the container may be the blast furnace 11 or the FINEX melting furnace, and the molten metal may be molten iron S.

[0040] The measuring unit 110 measures the induced electromotive forces resulted from the motion of the molten iron S in the blast furnace 11 based on the vertical levels. The measuring unit 110 includes a plurality of measuring instruments 111 arranged in a vertical direction.

[0041] The measuring instruments 111 may measure the induced electromotive force. The outer surface of the blast furnace 11 is made of the steel plate 11a and an inner surface of the blast furnace 11 is made of a refractory material 11b. The measuring instruments 111 may be installed passing through the steel plate 11a and the refractory material 11b from the outside of the blast furnace 11. Thus, the measuring instruments 111 may be brought close to the molten iron S, and the measuring instruments 111 may more accurately measure changes in the induced electromotive force.

[0042] Further, the measuring instruments 111 may be respectively made of an electrode penetrating the refractory material 11b of the blast furnace 11 and a conducting wire connected to the electrode. The refractory material 11b may protect the electrode from high temperature of the molten iron S. However, the present disclosure is not limited thereto, and the measuring instruments 111 may be formed in a single conducting wire such as a platinum wire.

[0043] The measuring instruments 111 may be removably installed at the blast furnace 11. Therefore, when the measuring instruments 111 are broken because of a long period use, the measuring instruments 111 may be easily removed from the blast furnace 11 and replaced. Therefore, maintenance of the measuring unit 110 may be facilitated.

[0044] In this connection, a phenomenon that a current is induced, by a relative motion of a magnet and a coil, in the coil is called an electromagnetic induction phenomenon. Electromotive force generated by the electromagnetic induction phenomenon is called induced electromotive force. When the molten iron S moves, an induced magnetic field may be generated. Further, the measuring instruments 111 may measure induced electromotive force generated at this time.

[0045] For example, when the molten iron in the blast furnace 11 is discharged as shown in FIG. 3, due to a viscosity and a surface tension of the molten iron S, only a portion of the molten iron S near the outlet 13 may be discharged through the outlet 13, and the molten iron S in other regions may not move smoothly to the outlet 13.

Therefore, a surface level of the molten iron S above the outlet 13 may be relatively lower than a surface level of the molten iron S in other regions. Thus, when the outlet 13 is closed, due to a nature of the molten iron S in the blast furnace 11 to be leveled, the molten iron S above the outlet 13, temporarily lowered during the discharging, horizontally restores to an upper side. Therefore, the molten iron S above the outlet 13 may be leveled with the molten iron S in other regions.

[0046] When the molten iron S is moving horizontally, the plurality of measuring instruments 111 may measure magnitudes of the induced electromotive forces caused by the motion of the molten iron S based on the vertical levels. Since a surface of the molten iron S moves vertically and upwardly to be restored, the induced electromotive force may be sequentially measured by the plurality of measuring instruments 111, from a bottommost measuring instrument 111 to a topmost measuring instrument 111. The surface levels of the molten iron S may be measured using measured values from the measuring instruments 111.

[0047] The blast furnace 11 is formed with the tuyere 12 through which the hot blast may be supplied and the outlet 13 through which the molten iron S is discharged. The plurality of measuring instruments 111 may be disposed between the tuyere 12 and the outlet 13. The plurality of measuring instruments 111 may be arranged in a line in the vertical direction and may measure the induced electromotive forces based on the vertical levels. The surface levels of the molten iron S from above the outlet 13 to below the tuyer 12 may be measured using the measuring instruments 111. Therefore, the surface level of the molten iron S above the outlet 13 may be measured. Further, whether the amount of the molten iron S in the blast furnace 11 has reached a vertical level of the tuyere 12 may be monitored.

[0048] In this connection, since positions of the measuring instruments 111 are predetermined, a distance between a bottom face of the blast furnace 11 and the bottommost measuring instrument may be known in advance. The vertical level values measured using the measuring instruments 111 start from above the outlet 13. Therefore, the surface level of the molten iron S from the bottom face of the blast furnace 11 may be measured by adding the distance value between the bottommost measuring instrument 111 and the bottom face to the measured vertical level value.

[0049] In addition, the number of measuring instruments 111 to be provided may be adjusted as needed. For example, when spacings between the measuring instruments 111 are narrowed by increasing the number of measuring instruments 111, the number of positions at which the induced electromotive force is measured increases, thereby more accurately calculating the surface levels of the molten iron S. Thus, the spacings between the measuring instruments 111 may be adjusted to adjust or improve a measurement accuracy.

[0050] The blast furnace 11 may be provided with the plurality of outlets 13, and the measuring unit 110 may include the plurality of measuring instruments 111 respectively installed for the plurality of outlets 13. The outlets 13 may all be positioned at the same vertical level.

[0051] The processing unit 120 determines the surface level of the molten iron S using the measured values from the measuring unit 110. The processing unit 120 includes a processor 122 for determining a maximum value among the induced electromotive force values measured based on the vertical levels and for selecting a vertical level corresponding to the maximum value as the surface level of the molten metal. The processing unit 120 may also include an amplifier 121 for amplifying the measured values from the measuring unit 110 and an indicator 123 for indicating a calculated result from the processor 122 to an operator.

[0052] The amplifier 121 is connected to the measuring instruments 111. The amplifier 121 may amplify the induced electromotive force values measured by the measuring instruments 111. Since the magnitude of the induced electromotive force input from the measuring instruments 111 is small, the measured induced electromotive force may be amplified by the amplifier 121 and be output. Accordingly, all the induced electromotive force input from the measuring instruments 111 may be amplified and output to the processor 122.

[0053] In addition, a noise may be removed from the amplifier 121 to improve a calculation accuracy of the processor 122. That is, a function of a low-pass filter may be added to the amplifier 121. The surface of the molten iron S may move for other reasons besides the horizontal motion. For example, the measuring instruments 110 installed above one outlet 13 may measure the induced electromotive force generated by the motion of the molten iron S surface as a noise when the other outlet 13 is opened or closed. Thus, the noise is removed such that the processor 122 is prevented from wrongly calculating the surface level of the molten iron S.

[0054] The processor 122 is connected to the amplifier 121. The processor 122 may determine the surface level of the molten iron S in the blast furnace 11 using the measured induced electromotive force values amplified by the amplifier 121. The processor 122 compares the measured induced electromotive force values measured based on the vertical levels and selects the vertical level at which the largest induced electromotive force is measured. Thus, the processor 122 may determine that the selected vertical level is the surface level of molten iron S.

[0055] The indicator 123 is connected to the processor 122. The indicator 123 may indicate the surface level of the molten iron S calculated at the processor 122. For example, the indicator 123 may be a display and visually indicate the surface level of the molten iron S. However, the way the indicator 123 informs the operator of the surface level is not limited thereto and may vary.

[0056] The controlling unit 130 may be connected to the processing unit 120 to control the opening and closing of the outlet 13. The controlling unit 130 includes a comparator (not shown) for comparing the vertical level corresponding to the maximum induced electromotive force with a predetermined vertical level range and a controller (not shown) for adjusting opening duration of the outlet 13 when the vertical level value is out of the predetermined vertical level range.

[0057] The comparator is connected to the processor 122. The comparator may compare the surface level value of the given molten iron S with the predetermined vertical level range. The predetermined vertical level range may be varied by the operator. The comparator may determine that, when the surface level value of the given molten iron S is within the predetermined vertical level range or outside the predetermined vertical level range, the surface level value is normal or defective.

[0058] When the surface level value of the given molten iron S is above the predetermined vertical level range, it may be determined that an amount of the molten iron S stored in the blast furnace 11 is too large. Further, when the surface level value of the given molten iron S is below the predetermined vertical level range, it may be determined that the amount of molten iron S in the blast furnace 11 is too small. Therefore, it may be determined that the amount of the molten iron stored in the blast furnace 11 is not adequate.

[0059] In this connection, the comparator may be connected to the indicator 123. Therefore, when the amount of molten iron S in the blast furnace 11 is too small or too large, the comparator may transmit a warning signal to the operator. Therefore, the operator may monitor whether the amount of molten iron S in the blast furnace 11 is adequate.

[0060] The controller is connected to the comparator. The controller may adjust the opening duration of the outlet 13 based on the determination result from the comparator. Alternatively, opening durations of the plurality of outlets 13 may be adjusted respectively to overlap the opening durations of the plurality of outlets 13. The overlap duration may be adjusted to increase or decrease the amount of molten iron S to be discharged. Therefore, the controller may be adjusted so that the surface level of the molten iron S stored in the blast furnace 11 is within the predetermined vertical level range.

[0061] For example, when the surface level value of the calculated molten iron S is above the predetermined vertical level range, the amount of the molten steel to be discharged from the outlet 13 may be increased. That is, a concurrent opening duration of the plurality of outlets 13 may be increased. Thus, the amount of the molten iron S discharged from the blast furnace 11 increases as the duration during which the molten iron is simultaneously discharged through the plurality of outlets 13 increases. Therefore, the amount of the molten iron S stored in the blast furnace 11 may be greatly decreased. Thus, the surface level of the molten iron S in the blast furnace 11 may be lowered.

[0062] On the other hand, when the calculated surface level of the molten iron S is below the predetermined vertical level range, the amount of the molten iron to be discharged from the outlet 13 may be decreased. That is, the concurrent opening duration of the plurality of outlets 13 may be decreased. Thus, the amount of the molten iron S discharged from the blast furnace 11 decreases as the duration during which the molten iron S is discharged through the plurality of outlets 13 decreases. Therefore, the amount of the molten iron S stored in the blast furnace 11 may be slightly decreased. Thus, the lowering of the surface level of the molten iron S in the blast furnace 11 may be suppressed.

[0063] Likewise, when the discharging of the molten iron stored in the blast furnace 11 is stopped, the induced electromotive forces caused by the horizontal motion of the molten iron S may be measured based on the vertical levels. Thus, the surface level of the molten iron S may be accurately measured using the measured induced electromotive force.

[0064] In addition, since the surface level of the molten iron S may be accurately measured, the amount of the molten iron S to be discharged may be determined so that the molten iron S is stored in the blast furnace 11 in an adequate amount. Thus, the discharging of the molten iron S may be stably performed to maintain the amount of the molten iron S in the blast furnace 11 adequately. Therefore, the increase of the blowing pressure in the blast furnace 11, the occurrence of the channeling, or the backflow of the molten iron S to the tuyere 12 may be suppressed or prevented.

[0065] FIG. 4 is a flowchart showing a method for measuring a surface level of molten metal according to an embodiment of the present disclosure. Further, FIG. 5 illustrates a discharging schedule of a plurality of outlets according to an embodiment of the present disclosure. Further, FIG. 6 is a graph showing a measurement result of induced electromotive forces measured based on vertical levels according to an embodiment of the present disclosure.

[0066] Referring to FIG. 4, a method for measuring the surface level of the molten metal according to an embodiment of the present disclosure includes opening the outlet provided on the container (S100), discharging the molten metal inside the container (S200), closing the outlet (S300), measuring the induced electromotive forces generated by the motion of the molten metal based on the vertical levels (S400), and deriving the surface level of the molten metal using the measured values (S500).

[0067] In this connection, the container may be the blast furnace or the FINEX melting furnace, and the molten metal may be the molten iron. Therefore, the method for measuring the surface level may be a method for calculating the surface level of the molten iron accommodated in the blast furnace. Further, the closing of the outlet and the measuring of the induced electromotive forces caused by the motion of the molten metal based on the vertical levels may be performed simultaneously or sequentially.

[0068] For example, when the molten iron S in the blast furnace 11 is discharged, due to the viscosity and the surface tension of the molten iron S, only the portion of the molten iron S near the outlet 13 may be discharged through the outlet 13, and the molten iron S in other regions may not move smoothly to the outlet 13. Therefore, the surface level of the molten iron S above the outlet 13 may be relatively lower than the surface level of the molten iron S in other regions.

[0069] When the outlet 13 is closed, due to the nature of the molten iron S in the blast furnace 11 to be leveled, the molten iron S above the outlet 13, temporarily lowered during the discharging, horizontally restores to the upper side. Therefore, the molten iron S above the outlet 13 may be leveled with the molten iron S in the other region. The induced electromotive force generated by the motion of this molten iron S may be measured to measure the surface level of the molten iron S.

[0070] That is, the maximum value of the induced electromotive forces measured based on the vertical levels may be determined. For example, the maximum value may be selected by comparing the induced electromotive force values measured based on the vertical levels. Then, the vertical level corresponding to the maximum value may be selected as the surface level of the molten iron S. Since the molten iron S moves vertically and upwardly, the induced electromotive force may be sequentially and vertically upwardly measured.

[0071] In this connection, the blast furnace 11 may be provided with the plurality of outlets 13. The plurality of measuring instruments 111 may be installed above the plurality of outlets 13. Before measuring the induced electromotive force with measuring instruments 111, information on a discharging schedule may be provided. That is, information on the time when the plurality of outlets 13 are opened and closed may be provided. Accordingly, a time at which the induced electromotive force is measured by each measuring unit 110 may be selected based on a schedule of each of the outlets.

[0072] For example, as shown in FIG. 5, two or four outlets 13 may be provided on the blast furnace 11. While determining the surface level of the molten iron S using the induced electromotive force at one outlet 13 measured when one outlet 13 is opened and closed, another outlet 13 may be opened to discharge the molten iron S. Thus, the surface level of the molten iron S may be continuously determined while performing the discharge of the molten iron S to the plurality of outlets 13.

[0073] When the outlet 13 includes two outlets, the blast furnace 11 may be provided with a first outlet 13a and a second outlet 13b. The first outlet 13a and the second outlet 13b may be alternately opened and closed to discharge the molten iron S. Thus, the induced electromotive force may be measured by the measuring unit 110 disposed above the first outlet 13a after the first outlet 13a is opened to discharge the molten iron and then the first outlet 13 is closed.

[0074] While determining the surface level of the molten iron S using the values measured by the measuring unit 110 disposed above the first outlet 13a, the second outlet 13b may be opened to continue the discharging of the molten iron S. In this connection, the first outlet 13a may be opened before the second outlet 13b is closed, and the first outlet 13a and the second outlet 13b may be opened together.

[0075] Thus, opening durations of the first outlet 13a and the second outlet 13b may overlap. Increasing the overlap duration may greatly decrease the amount of the molten metal S in the blast furnace 11, and reducing the overlap duration may slightly decrease the amount of the molten metal S in the blast furnace 11. Therefore, when it is determined that the surface level of the molten iron S calculated by opening and closing the first outlet 13a is high, the second outlet 13 may be opened further than the original opening duration to perform a Lap discharging. The concurrent opening duration of the first outlet 13a and the second outlet 13b are opened together may be increased to increase the amount of the molten iron S to be discharged.

[0076] Then, when the second outlet 13b is closed, the induced electromotive force may be measured by the measuring unit 110 located above the second outlet 13b. While determining the surface level of the molten iron S using the values measured by the measuring unit disposed above the second outlet 13b, the molten iron S may be continuously discharged through the first outlet 13a.

[0077] The second outlet 13b may be opened before the first outlet 13a is closed, and the first outlet 13a and the second outlet 13b may be opened together. A concurrent opening duration of the first outlet 13a and the second outlet 13b may be adjusted based on a second predetermined value to adjust the amount of the molten iron stored in the blast furnace 11. Thus, the discharging of the molten iron S and the determining of the surface level of the molten iron S may continue to be performed.

[0078] Further, when the outlet 13 includes four outlets, the blast furnace 11 may be provided with the first outlet 13a, the second outlet 13b, a third outlet 13c, and a fourth outlet 13d. When a maintenance work is performed on the fourth outlet 13d, the molten iron S may be discharged while sequentially opening and closing the first outlet 13a, the second outlet 13b, and the third outlet 13c. Thus, after the first outlet 13a is opened and closed, the induced electromotive force may be measured by the measuring unit 110 disposed above the first outlet 13a.

[0079] While calculating the values measured by the measuring unit 110 disposed above the first outlet 13a to determine the surface level of the molten iron S, the second outlet 13b may be opened to continue the discharging of the molten iron S. At this time, the first outlet 13a may be opened before the second outlet 13b is closed, and the first outlet 13a and the second outlet 13b may be opened together.

[0080] Thus, the opening durations of the first outlet 13a and the second outlet 13b may overlap. Increasing the overlap duration may greatly decrease the amount of the molten metal S in the blast furnace 11, and reducing the overlap duration may slightly decrease the amount of the molten metal S in the blast furnace 11. Therefore, when it is determined that the surface level of the molten iron S determined by opening and closing the first outlet 13a is high, the concurrent opening duration of the first outlet 13a and the second outlet 13b may be increased to increase the amount of the molten iron S to be discharged.

[0081] Then, when the second outlet 13b is closed, the induced electromotive force may be measured by the measuring unit 110 disposed above the second outlet 13b. Further, while determining the surface level of the molten iron S using the values measured by the measuring unit 110 disposed above the second outlet 13b, the discharging of the molten iron S through the third outlet 13c may continue to be performed.

[0082] The first outlet 13b may be opened before the third outlet 13a is closed, and the first outlet 13a and the third outlet 13c may be opened together. A concurrent opening duration of the first outlet 13a and the third outlet 13b may be adjusted based on the second predetermined value to adjust the amount of the molten iron stored in the blast furnace 11. Thus, the discharging of the molten iron S and the determining of the surface level of the molten iron S may continue to be performed. However, the number of the outlets and opening and closing order of the outlets are not limited thereto and may vary.

[0083] Further, when the outlet 13 includes the plurality of outlets, the induced electromotive force may be measured for each outlet. One outlet 13 may be determined using the induced electromotive force measured for each outlet, and the maximum value may be determined for the determined outlet 13.

[0084] For example, when one of the plurality of outlets 13 is opened for closed, and the molten iron S horizontally moves, not only the measuring instruments 111 above the open outlet 13 but also the measuring instruments 111 above the another outlet 13 may measure the induced electromotive force. Thus, the induced electromotive force may be measured at a plurality of positions. However, the induced electromotive force measured at the outlet opened and closed among the plurality of outlets 13 may be greater than the induced electromotive force measured at other positions. Therefore, the induced electromotive force measured at other positions may be processed as the noise, and the maximum value among the induced electromotive force measured above the outlet 13 opened and closed may be determined to determine the surface level of the molten iron S.

[0085] Alternatively, when the outlet 13 include the plurality of outlets, the induced electromotive force may be measured at the outlet 13 which is opened or closed among the plurality of outlets 13. That is, the induced electromotive force may be measured only by the measuring instruments 111 located above the outlet 13 opened and closed, and the induced electromotive force may not be measured by the measuring instruments 111 located above the other outlets 13. Thus, the surface level of the molten iron S may be accurately measured at a desired position. Therefore, the values measured at the plurality of positions may not be processed all at once to prevent an inaccurate surface level from being measured.

[0086] Once the surface level of the molten iron S has been determined, the determined level value and the predetermined vertical level range may be compared. The amount of the molten metal to be discharged may be adjusted when the determined level value is outside the predetermined vertical level value. That is, the opening time of the outlet 13 may be adjusted in order to adjust the amount of molten iron S discharged from the blast furnace 11.

[0087] For example, increasing the opening duration of each outlet may greatly increase the amount of the molten metal S discharged from the blast furnace 11, and reducing the opening duration of each outlet 13 may slightly decrease the amount of the molten metal S discharged from the blast furnace 11. Thus, the surface level of the molten iron S in the blast furnace 11 may be adequately adjusted.

[0088] Alternatively, the opening durations of the plurality of outlets 13 may overlap with each other. The concurrent opening duration of the plurality of outlets 13 may be adjusted. Therefore, as the concurrent opening duration of the plurality of outlets 13 increases, the amount of molten iron S discharged from the blast furnace 11 increases, so that the surface level of the molten iron S may be greatly decreased. As the concurrent opening duration of the plurality of outlets decreases, the amount of molten iron S discharged from the blast furnace 11 decreases, so that the surface level of the molten iron S may be slightly decreased.

[0089] Thus, when the discharging of the molten iron stored in the blast furnace 11 is stopped, the induced electromotive forces caused by the horizontal motion of the molten iron S may be measured based on the vertical levels. Thus, the surface level of the molten iron S may be accurately measured using the measured induced electromotive force.

[0090] In addition, since the surface level of the molten iron S may be accurately measured, the amount of the molten iron S to be discharged may be determined such that the adequate amount of the molten iron S is stored in the blast furnace 11. Thus, the discharging of the molten iron S may be stably performed to maintain the amount of the molten iron S in the blast furnace 11 adequately. Therefore, the increase of the blowing pressure in the blast furnace 11, the occurrence of the channeling, or the backflow of the molten iron S to the tuyere 12 may be suppressed or prevented.

[0091] Although the present disclosure has been described in reference with specific embodiments, various modifications may be made thereto within a spirit and scope of the present disclosure. Therefore, the scope of the present disclosure should not be limited to the embodiments described, but should be determined by the appended claims, as well as equivalents to the appended claims.

Claims

1. An apparatus for measuring a surface level of molten metal accommodated in a container having an outlet, the apparatus comprising:

a measuring unit installed on the container to measure induced electromotive forces caused by motion of the molten metal based on vertical levels; and
a processing unit configured for determining a surface level of the molten metal using the electromotive force values measured based on the vertical levels.

2. The apparatus of claim 1, wherein the measuring unit includes a plurality of measuring instruments arranged in a vertical direction.

3. The apparatus of claim 2, wherein a tuyere from which hot blast is supplied is defined in the container, and
wherein the plurality of measuring instruments are disposed between the outlet and the tuyere.

4. The apparatus of claim 1, wherein the outlet includes a plurality of outlets, and
wherein the measuring unit includes a plurality of measuring instruments respectively installed for the plurality of outlets.

5. The apparatus of claim 1, wherein the processing unit includes:
a processor configured for determining a maximum value among the induced electromotive force values measured based on the vertical levels and for selecting a vertical level corresponding to the maximum value as the surface level of the molten metal.

6. The apparatus of claim 5, further comprising:
a controlling unit connected to the processing unit to control opening and closing of the outlet.

7. The apparatus of claim 6, wherein the controlling unit includes:

a comparator configured for comparing the vertical level corresponding to the maximum induced electromotive force with a predetermined vertical level range; and
a controller configured for adjusting an opening duration of the outlet when the vertical level is out of the predetermined vertical level range.

8. The apparatus of claim 7, wherein the outlet includes a plurality of outlets, and
wherein the controller controls a concurrent opening duration of the plurality of outlets.

9. A method for measuring a surface level of molten metal inside a container, the method comprising:

opening an outlet defined in the container;
discharging the molten metal inside the container;
closing the outlet;
measuring induced electromotive forces generated by motion of the molten metal based on vertical levels; and
deriving a surface level of the molten metal using the measured induced electromotive force.

10. The method of claim 9, wherein the deriving of the surface level of the molten metal includes:

determining a maximum value among the induced electromotive force values measured based on the vertical levels; and
selecting a vertical level corresponding to the maximum value as the surface level of the molten metal.

11. The method of claim 10, wherein the outlet includes a plurality of outlets, and
wherein the measuring of the induced electromotive forces based on the vertical levels includes measuring each induced electromotive force for each outlet.

12. The method of claim 11, wherein the determining of the maximum value among the induced electromotive force values measured based on the vertical levels includes:
determining one outlet using each induced electromotive force measured for each outlet and determining the maximum value for the determined outlet.

13. The method of claim 10, wherein the outlet includes a plurality of outlets, and
wherein the measuring of the induced electromotive forces based on the vertical levels includes measuring the induced electromotive force for an outlet being opened and closed among the plurality of outlets.

14. The method of any one of claims 11 to 13, further comprising: after deriving the surface level of the molten metal,
comparing the derived level value with a predetermined vertical level range; and
adjusting an amount of the molten metal to be discharged when the derived vertical level is outside the predetermined level range.

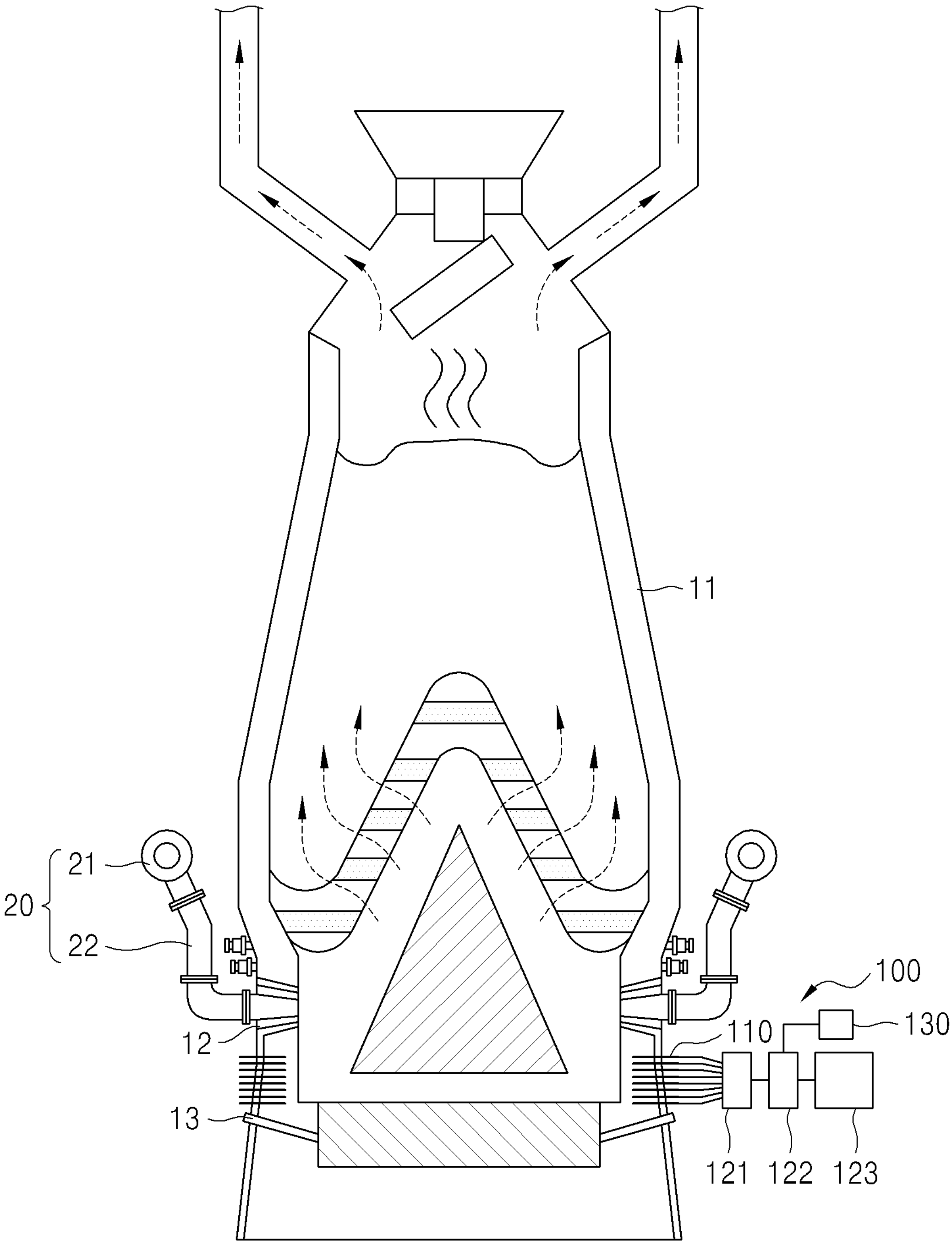
15. The method of claim 14, wherein the adjusting of the amount of the molten metal to be discharged includes adjusting an opening duration of the outlet.

16. The method of claim 15, wherein opening durations of the plurality of outlets overlap with each other, and wherein the adjusting of the opening duration of the outlet includes adjusting at least one of an opening duration of each outlet or a concurrent opening duration of the plurality of outlets.

17. The method of any one of claims 9 to 13, wherein the measuring of the induced electromotive forces based on the vertical levels includes sequentially and vertically upwardly measuring the induced electromotive forces.

18. The method of any one of claims 9 to 13, wherein the container includes a blast furnace or a FINEX melting furnace, and wherein the molten metal includes molten iron.

FIG. 1



120 : 121, 122, 123

FIG. 2

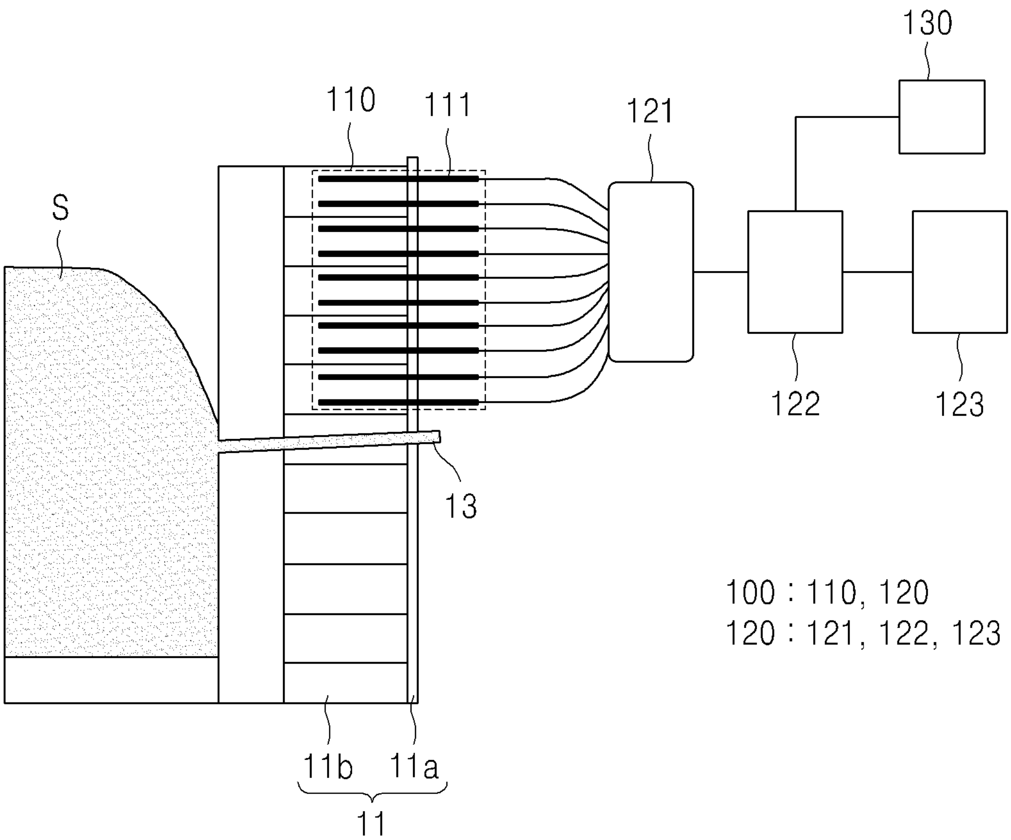

130
110
111
121
S
122
123
13
100 : 110, 120
120 : 121, 122, 123
11b
11a
11

FIG. 3

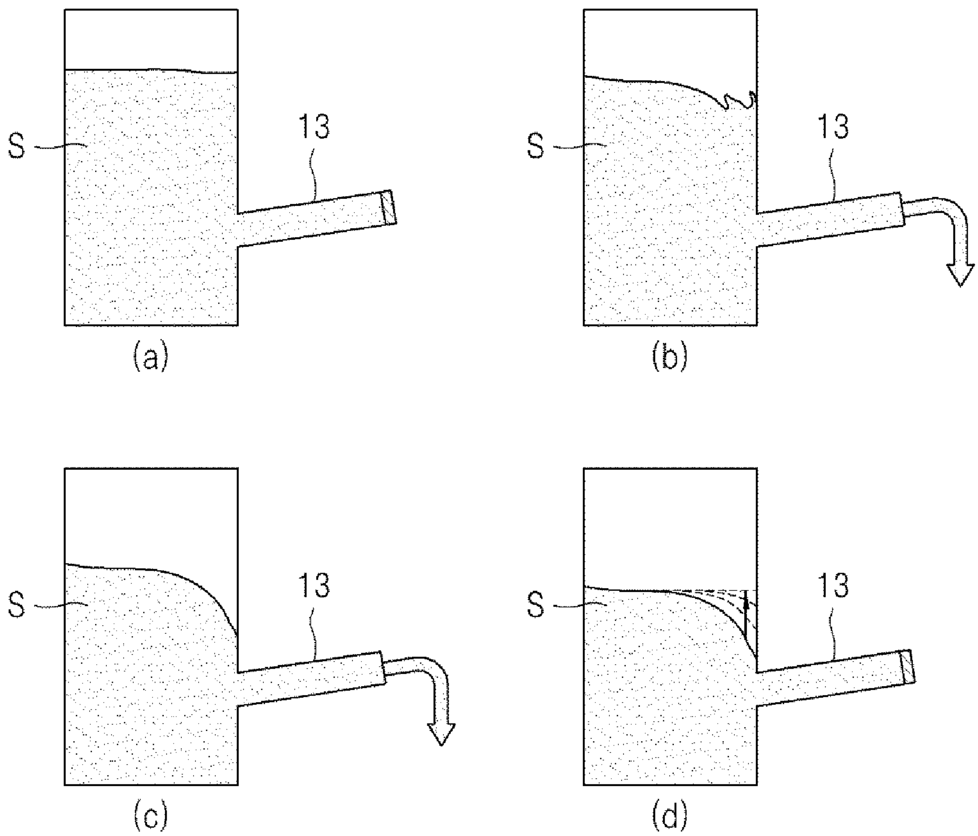


FIG. 4

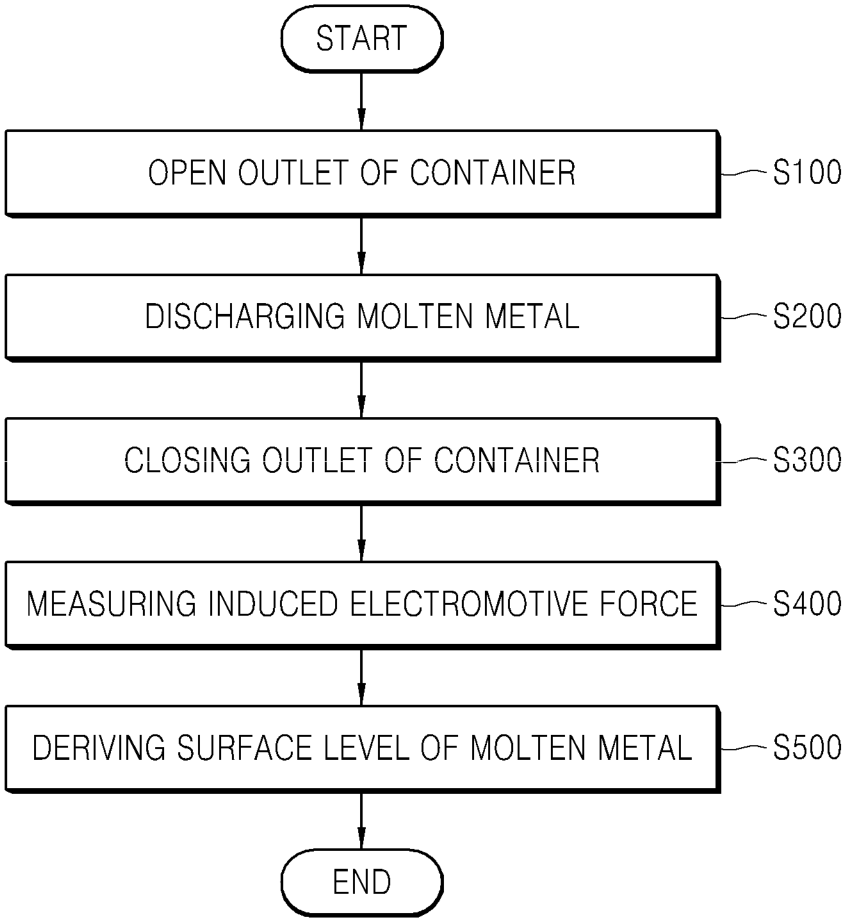

START
OPEN OUTLET OF CONTAINER
S100
DISCHARGING MOLTEN METAL
S200
CLOSING OUTLET OF CONTAINER
S300
MEASURING INDUCED ELECTROMOTIVE FORCE
S400
DERIVING SURFACE LEVEL OF MOLTEN METAL
S500
END

FIG. 5

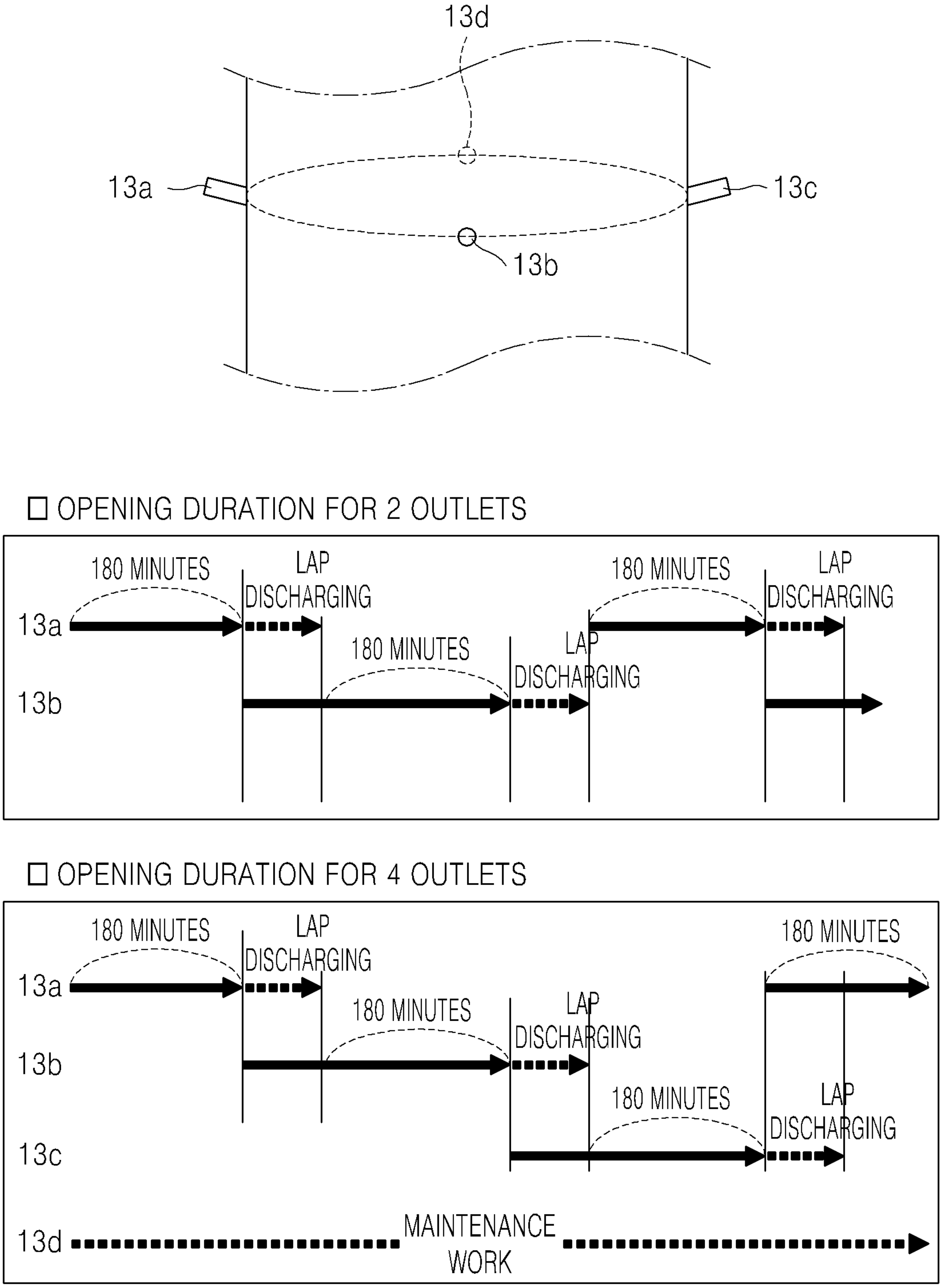
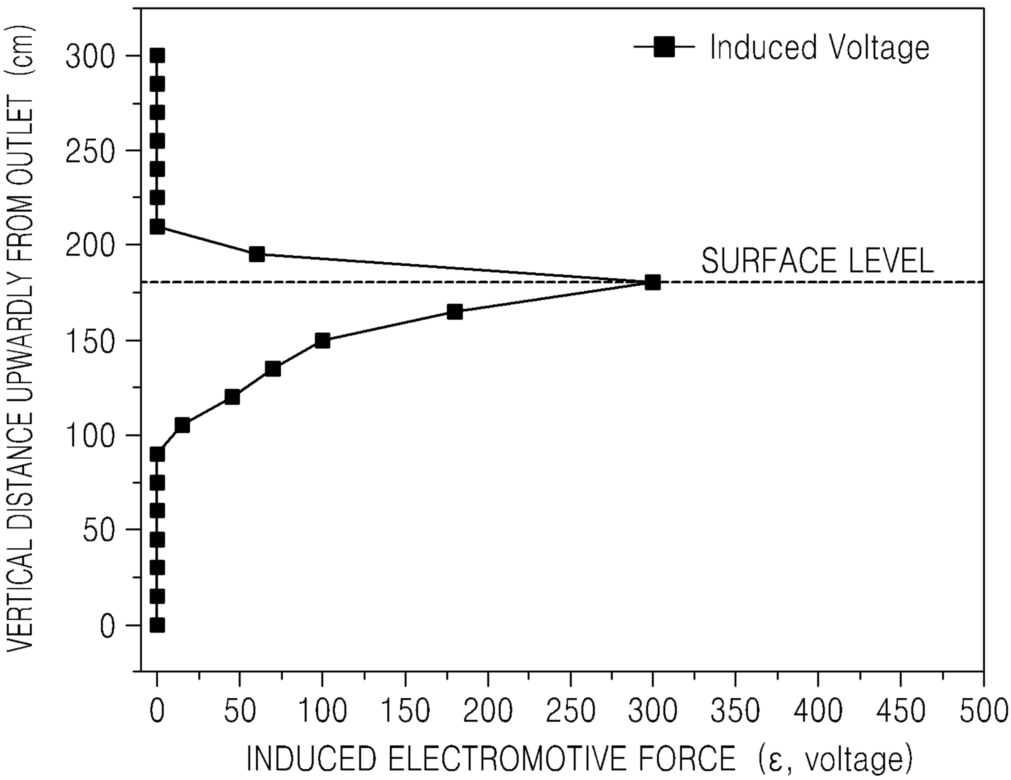

13d
13a
13c
13b
☐ OPENING DURATION FOR 2 OUTLETS
13a
13b
180 MINUTES
LAP DISCHARGING
180 MINUTES
LAP DISCHARGING
180 MINUTES
LAP DISCHARGING
☐ OPENING DURATION FOR 4 OUTLETS
13a
13b
13c
13d
180 MINUTES
LAP DISCHARGING
180 MINUTES
LAP DISCHARGING
180 MINUTES
LAP DISCHARGING
180 MINUTES
MAINTENANCE WORK

FIG. 6


Induced Voltage
SURFACE LEVEL
VERTICAL DISTANCE UPWARDLY FROM OUTLET (cm)
0
50
100
150
200
250
300
0
50
100
150
200
250
300
350
400
450
500
INDUCED ELECTROMOTIVE FORCE (ε, voltage)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2017/012307

A. CLASSIFICATION OF SUBJECT MATTER
C21B 7/24(2006.01)i, C21B 7/14(2006.01)i, F27B 1/21(2006.01)i, F27B 1/26(2006.01)i, F27D 3/14(2006.01)i, F27D 15/00(2006.01)i, F27D 21/00(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)
C21B 7/24; G01F 23/00; G01F 23/24; F27D 21/00; G01F 23/26; B22D 11/10; G01S 13/08; C22B 1/243; F27B 1/08; C21B 7/14; F27B 1/21; F27B 1/26; F27D 3/14; F27D 15/00

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: 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: molten steel, molten material, blast furnace, height, level, meniscus, induction, electric power, hot air, open, discharge, shutdown

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2001-0019977 A (POHANG IRON & STEEL CO., LTD.) 15 March 2001 See pages 2, 5 and figure 3.	1-18
Y	JP 11-304566 A (NIPPON STEEL CORP.) 05 November 1999 See paragraphs [0014], [0023] and figure 2.	1-18
A	KR 10-2013-0060206 A (HATCH LTD.) 07 June 2013 See paragraph [0148] and figures 10, 11.	1-18
A	JP 2008-163399 A (DENKA CONSULT & ENG CO., LTD.) 17 July 2008 See paragraph [0018] and figure 1.	1-18
A	KR 10-2010-0071350 A (RESEARCH INSTITUTE OF INDUSTRIAL SCIENCE & TECHNOLOGY) 29 June 2010 See paragraphs [0027], [0028] and figure 2.	1-18

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

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" 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 FEBRUARY 2018 (05.02.2018)	**05 FEBRUARY 2018 (05.02.2018)**

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2017/012307

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		CA 2795652 A1	03/11/2011
		CA 2795652 C	22/08/2017
		CN 102884388 A	16/01/2013
		CN 102884388 B	09/03/2016
		EP 2564141 A1	06/03/2013
		EP 2564141 B1	06/04/2016
		ES 2581550 T3	06/09/2016
		US 2011-0272865 A1	10/11/2011
		US 2011-0272866 A1	10/11/2011
		US 9417321 B2	16/08/2016
		US 9417322 B2	16/08/2016
		WO 2011-134052 A1	03/11/2011
		ZA 201208064 B	30/04/2014
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Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- KR 20100071347 **[0007]**