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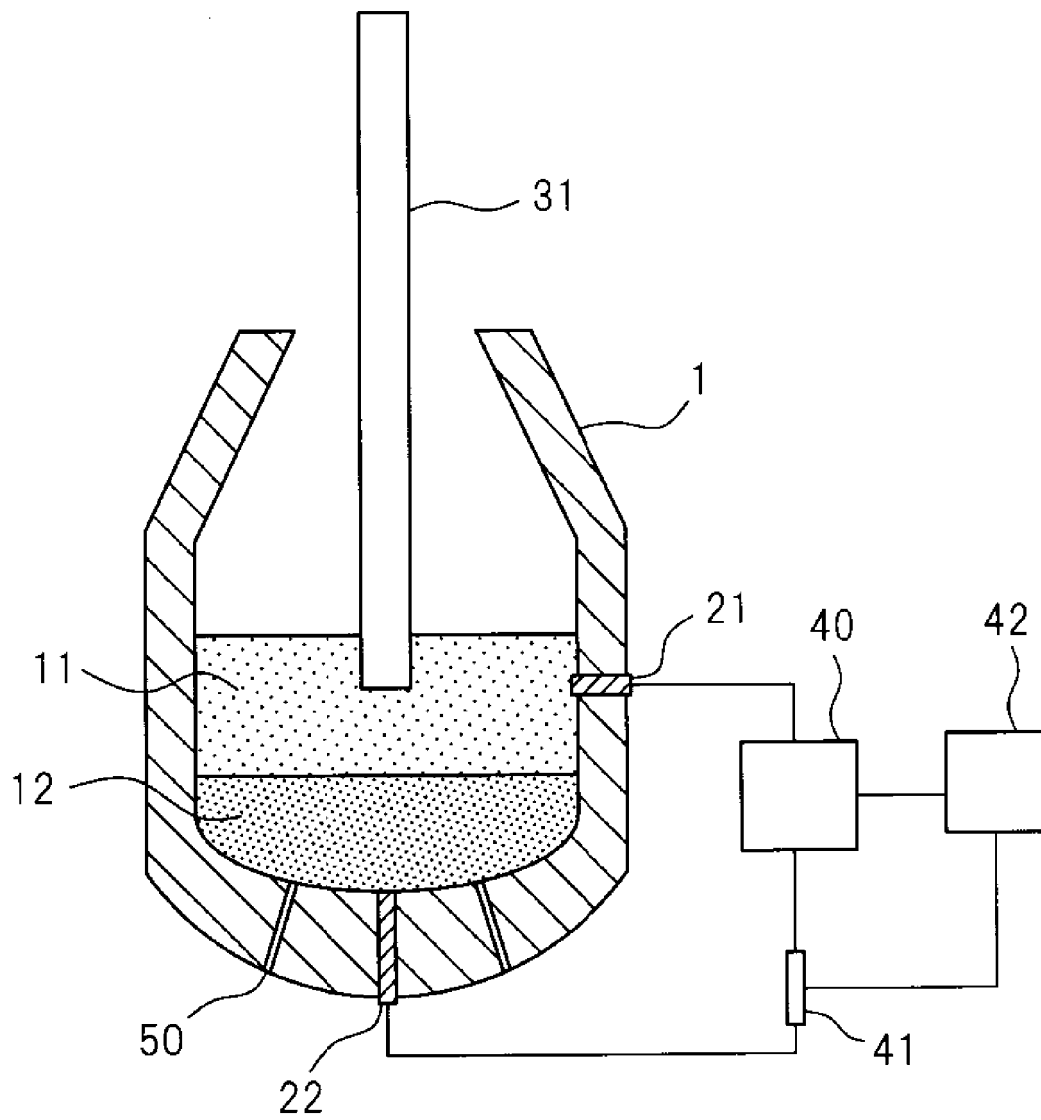
(54) **HIGHLY EFFICIENT MOLTEN IRON ALLOY REFINING METHOD**

(57) A molten iron alloy refining method is for refining a molten iron alloy bath while blowing oxygen to a molten iron alloy bath in a converter furnace, the method includes supplying a direct current between a first electrode disposed above the molten iron alloy bath and a second electrode disposed in contact with the molten iron alloy bath, in which when $I_P[A]$ represents a magnitude of an average of a direct current during an energization time when the direct current is supplied, $I_P'[A]$ represents a

magnitude of an average of the direct current during the energization time within one minute immediately before the feeding of the oxygen is stopped, $W_s[t]$ represents an amount of molten steel in the converter furnace, and $A_s[m^2]$ represents a furnace internal cross-sectional area at a furnace belly portion, at least one of equations (1) to (4) is satisfied. (1): $I_P \geq 0.125 \times W_s$, (2): $I_P \geq 1.5 \times A_s$, (3): $I_P' \geq 0.125 \times W_s$, and (4): $I_P' \geq 1.5 \times A_s$.

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FIG. 1



Description

[Technical Field of the Invention]

[0001] The present invention relates to a method of refining a molten iron alloy by a converter furnace. The present invention particularly relates to a refining method capable of reducing a metallic iron content in slag and reducing variation in the metallic iron content in slag for each charge to improve efficiency of a slag treatment.

[Related Art]

[0002] Free CaO is contained in slag (hereinafter, also referred to as "converter furnace slag") generated when molten iron alloy such as molten pig iron (hereinafter, also referred to as "hot metal") is refined in a converter furnace, the free CaO undergoes a hydration reaction and expands, and volume stability decreases.

[0003] Further, although a treatment method is related to the slag, generally, iron oxide of about 1 to 40% by mass is contained in the slag, and an external appearance of the slag becomes black. When the slag is used as an aggregate for concrete or the like, the external appearance thereof is uncomfortable.

[0004] Therefore, a use of the slag is limited to a low-grade application such as a road ground improvement material and a lower-layer roadbed material, and is difficult to use for an upper-layer roadbed material, a concrete aggregate, a stone raw material, or the like.

[0005] Accordingly, in the related art, the slag is discharged from the converter furnace into a reaction container, and in the container, a reforming material such as coal ash is added to molten converter furnace slag to perform a reforming treatment to reduce the free CaO, and thus, the slag is used for the upper-layer roadbed material, the concrete aggregate, and the like, which are higher-grade applications.

[0006] Further, as metallic iron, about several tens of mass% of granular iron is contained in the converter furnace slag in a suspended state. Carbon is present in the suspended granular iron, and when the molten slag is reformed, the carbon of the granular iron reacts with iron oxide in the molten slag or an oxygen gas for stirring, and thus, bubbles of a CO gas are generated (forming) in the molten slag, which causes various adverse effects.

[0007] Further, when the slag is reused, since the granular iron is present, strength of the slag varies due to uneven distribution of the granular iron, oxidative expansion of the granular iron, or the like.

[0008] Further, the granular iron in the slag is a factor of yield loss when focusing on converter furnace blowing, and thus, the lower a granular iron content, the more preferable.

[0009] When an amount of granular iron in the slag varies, it is difficult to measure the amount of granular iron in the slag directly and instantly. Therefore, when treating the molten slag or recovering the granular iron from the slag after cooling, there is no choice but to select a treatment on a heavy treatment side, and thus, efficiency decreases. In addition, forming during a melting/reforming treatment also varies in a treatment time, and thus, it is difficult to perform a stable treatment.

[0010] Further, for example, Patent Document 1 discloses a method in which granular iron in molten slag taken out from a converter furnace is settled in a reaction container and then subjected to a slag reforming treatment. However, even in this case, when an amount of granular iron in the slag varies, a settling time also varies, and thus, it is difficult to perform a stable treatment.

[0011] Accordingly, in the related art, after discharging the converter furnace slag to the reaction container, a treatment for reducing metallic iron in the slag in the reaction container is performed. Therefore, when the amount of the granular iron in the slag varies, there is a problem that a slag treatment time also varies.

[0012] Meanwhile, in recent years, as reported in Non-Patent Document 1, the following attempts are made. That is, when refining is performed in a converter furnace, an oxygen feeding lance is used as one electrode, a voltage is applied between the one electrode and the other electrode provided on a furnace bottom, and information on a distance between a front end of the lance and a molten metal bath surface, a thickness of a slag layer, or the like is obtained by measuring changes in a current, a voltage, and a resistance value during blowing.

[0013] However, effects of energization on properties of molten slag have not been particularly investigated.

[Prior Art Document]

[Patent Document]

[0014] [Patent Document 1] Japanese Unexamined Patent Application, First Publication No. 2006-199984

[Non-Patent Document]

[0015] [Non-Patent Document 1] Current distribution characteristics in converter furnace bath when electric potential is applied to molten steel, C. I. Semuikin, V. F. Polyakov, E. V. Semkina, 2003

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0016] An object of the present invention is to provide a molten iron alloy refining method having high efficiency capable of obtaining slag having a small metallic iron content and a small variation thereof as compared with the related art when refining a molten iron alloy in a converter furnace and then simplifying a treatment for reducing iron in the slag in a reforming treatment of the slag.

[Means for Solving the Problem]

[0017] The gist of the present invention is as follows.

[0018]

(1) According to a first aspect of the present invention, there is provided a method of refining a molten iron alloy while feeding oxygen to a molten iron alloy bath in a converter furnace, the method including: supplying a direct current between a first electrode disposed above the molten iron alloy bath and a second electrode disposed in contact with the molten iron alloy bath, in which when I_P [A] represents a magnitude of an average of a direct current during an energization time when the direct current is supplied, I_P' [A] represents a magnitude of an average of the direct current during the energization time within one minute immediately before the feeding of the oxygen is stopped, W_s [t] represents an amount of molten steel in the converter furnace, and A_s [m²] represents a furnace internal cross-sectional area at a furnace belly portion, at least one of equations (1) to (4) is satisfied.

$$(1): I_P \geq 0.125 \times W_s$$

$$(2): I_P \geq 1.5 \times A_s$$

$$(3): I_P' \geq 0.125 \times W_s$$

$$(4): I_P' \geq 1.5 \times A_s$$

(2) In the method of refining a molten iron alloy according to (1), a slag composition used for refining the molten iron alloy may have a basicity of 0.5 or greater and an iron oxide concentration of 5% or greater.

(3) In the method of refining a molten iron alloy according to (1) or (2), a silicon concentration of a molten pig iron before being treated by the refining of the molten iron alloy may be 0.25% by mass or less.

(4) In the method of refining a molten iron alloy according to any one of (1) to (3), a density of a slag used for refining the molten iron alloy may be 1.0 kg/m³ or less.

(5) In the method of refining a molten iron alloy according to any one of (1) to (4), a slag may be energized for 10 seconds or longer within one minute before an end of a preset blowing time.

(6) In the method of refining a molten iron alloy according to any one of (1) to (5), a hollow top blowing lance may be used as the first electrode, and a height of the top blowing lance may be controlled based on weight of residual slag in the furnace, weight of an input auxiliary raw material, weight of a reaction product, a slag density, and a cross-sectional area of the furnace belly portion.

(7) In the method of refining a molten iron alloy according to any one of (1) to (6), the converter furnace may have a bottom blowing tuyere.

[Effects of the Invention]

[0019] According to the present invention, when refining a molten iron alloy in a converter furnace, it is possible to

reduce a granular iron content in slag and variation thereof, and then, it is possible to improve efficiency of a reforming treatment of the slag or a bullion recovery treatment.

[Brief Description of the Drawings]

[0020]

FIG. 1 is a diagram showing an outline of an example of a converter furnace equipment according to the present invention.

FIG. 2A is a diagram showing a relationship between an average current value and a granular iron content in slag during a hot metal dephosphorization period.

FIG. 2B is a diagram showing a relationship between the average current value and the granular iron content in slag during a decarburization period.

FIG. 3 is a diagram showing an outline of another example of the converter furnace equipment according to the present invention.

[Embodiments of the Invention]

[0021] The present inventors have investigated a method for reducing a granular iron content in slag and a variation thereof when refining a molten iron alloy in a converter furnace, and focused on energizing a slag bath and a metal bath.

[0022] Then, the present inventors have found that an amount of granular iron contained in the slag and a variation thereof are reduced when a specific amount of electric charge is applied during the energization.

[0023] Hereinafter, the present invention made based on the above findings will be described with reference to the drawings.

[0024] First, converter furnace equipment used in a refining method of the present invention will be described with reference to FIG. 1. In this specification, unless otherwise specified, "%" represents "mass%" and a "current" represents a "direct current". Further, an "average of direct current" indicates a magnitude of an average value of the direct currents during a time when the direct current is applied. Strictly speaking, the "average of direct current" is a value obtained by averaging the current values at 10 or greater time points at regular time intervals during a time when the direct current is applied.

[0025] In refining in a converter furnace, hot metal from a blast furnace is poured into the converter furnace, a slag raw material containing CaO as a main component is added, and blowing for the purpose of desiliconization and or dephosphorization and blowing for the purpose of finish dephosphorization, decarburization, and temperature adjustment are performed.

[0026] In converter furnace equipment 1 used in the present invention, a first electrode 21 is installed above a molten iron alloy bath (hereinafter, also referred to as an "iron bath") 12 at a position where a frequency of contact with slag 11 increases. Further, a second electrode 22 is disposed in contact with the iron bath 12.

[0027] By disposing the electrodes in this way and connecting the electrodes to a power supply device 40 provided outside the converter furnace, an electric circuit is formed by the slag 11, the iron bath 12, the first electrode 21, and the second electrode 22. Therefore, during the refining, a voltage can be applied between the electrodes to supply an electric current to the slag 11 and the iron bath 12. The first electrode 21 may also serve as a top blowing oxygen feeding lance 31.

[0028] Generally, as the blowing in the converter furnace, there are the following methods, that is, 1) a blowing method in the related art for performing desiliconization, dephosphorization, and decarburization, 2) a blowing method in which blowing for the purpose of desiliconization and/or dephosphorization and blowing for the purpose of finish dephosphorization, decarburization, and temperature adjustment are separated from each other, and 3) a blowing method in which desiliconization is performed in a separate process, and then blowing for the purpose of dephosphorization and blowing for the purpose of finish dephosphorization, decarburization, and temperature adjustment are separated from each other.

[0029] In the cases of 2) and 3), preferably, the energization is performed during one or both of the blowing for the purpose of desiliconization and/or dephosphorization and the blowing for the purpose of finish dephosphorization, decarburization, and temperature adjustment. In the blowing of each of 1) to 3), particularly, when applied at an end of the blowing, a larger effect can be obtained.

[0030] FIGS. 2A and 2B show results in 3) the blowing method in which desiliconization is performed in a separate process, and then the blowing for the purpose of dephosphorization and the blowing for the purpose of finish dephosphorization, decarburization, and temperature adjustment are separated from each other.

[0031] In FIGS. 2A and 2B, in a 400-ton converter furnace, the first electrode 21 on a side in contact with the slag 11 is disposed on the furnace belly, and the second electrode 22 on a side in contact with the iron bath 12 is disposed on a furnace bottom, and then, with respect to a case where in the case of dephosphorization, a current of 350A or less is supplied between the electrodes for 24 seconds immediately before a stop of the blowing to perform the blowing and in

the case of decarburization, a current of 350A or less is supplied between the electrodes for 24 seconds immediately before the stop of the blowing to perform the blowing (ON), and a case where the energization is not performed between the electrodes (OFF), relationships of average current values therebetween, amounts of granular iron, and variations thereof between both cases are shown.

[0032] In each case, 5 charges of slag after the blowing were taken out and sampled by a reduction method to examine a total amount of granular iron and an amount of variation.

[0033] FIG. 2A shows an effect of the average current value on a metallic iron concentration in the slag after a hot metal dephosphorization treatment in the converter furnace, and FIG. 2B shows an effect on the metallic iron concentration in the slag after a decarburization treatment in the converter furnace. In both cases, as the current value increases, an iron content decreases and a variation in the iron content decreases.

[0034] Tables 1 and 2 show an average value (mass%) of the granular iron content (mass%) contained in the slag shown in FIGS. 2A and 2B, a specimen standard deviation, and a relative error. Here, the specimen standard deviation is a square root of the variance value obtained by the sum of squares of distances between values of each sample and the average value. Moreover, the relative error is a value obtained by dividing the standard deviation by the average value.

[Table 1]

Current value	OFF	< 50A	100 ± 50A	200 ± 50A	300 ± 50A
Average value of iron content (%)	19.0	18.5	11.0	7.5	2.9
Specimen standard deviation	11.3	10.8	5.4	3.7	1.4
Relative error	59	58	49	50	48

[Table 2]

Current value	OFF	< 50A	100 ± 50A	200 ± 50A	300 ± 50A
Average value of iron content (%)	3.3	3.1	1.9	1.3	0.7
Specimen standard deviation	2.4	2.2	0.9	0.6	0.3
Relative error	73	72	48	48	46

[0035] As shown in Tables 1 and 2, it can be seen that as the current value increases, the average value of the iron content, the specimen standard deviation, and the relative error decrease, as compared with the case where the current value is OFF. However, it can be seen that the reduction effect is particularly remarkable when the current value is 50A or greater.

[0036] Generally, the slag after a reforming treatment is crushed and the metallic iron is recovered by magnetic sorting. The results in Tables 1 and 2 show that the metallic iron content itself is reduced by supplying an electric current to the slag 11, the variation in the metallic iron is reduced, and as a result, the magnetic sorting is stable, and there is a great effect that the metallic iron in the slag can be further reduced.

[0037] It is unclear why the above-mentioned effect can be obtained by supplying an electric current to the slag 11 during the blowing, but it is presumed that this is because coagulation and coarsening of the granular iron are caused by the energization to the granular iron staying in the slag, and thus, the granular iron settles due to its own weight.

[0038] Based on test results, the present inventors have diligently studied the necessary conditions. As a result, in order to sufficiently obtain the effect of reducing granular iron, the present inventors have found that it is important that I_p [A] representing a magnitude of an average of the currents supplied into the slag 11, that is, a magnitude of a direct current during an energization time when the direct current is supplied is controlled so as to satisfy at least one of the following equations (1) and (2), where W_s [t] represents an amount of molten steel in the converter furnace, and A_s [m²] represents a furnace internal cross-sectional area at a furnace belly portion.

$$(1): I_p \geq 0.125 \times W_s [A]$$

$$(2): I_p \geq 1.5 \times A_s [A]$$

[0039] When the magnitude of the average of the currents satisfies the above conditions, there are effects that the

amount of granular iron in the slag is reduced and the variation thereof is stabilized. For example, in a case of a 400-ton converter furnace, the value of W_s is 400. Accordingly, when I_p becomes $0.125 \times 400 = 50A$ or greater, based on the specimen standard deviation, the variation in the amount of granular iron in the slag is about 9 points or less during the dephosphorization period shown in FIG. 2A (here, the point is a standard deviation of the amount of granular iron and is synonymous with "%" as a unit for expressing the content), and is about 1.6 points or less in the decarburization period.

[0040] When the variation in the amount of granular iron decreases to about 9 points in the dephosphorization period, it is possible to recover iron stably in the post process. Further, in the decarburization period, a granular iron distribution is different from that in the dephosphorization period, but when the variation is about 1.6 points or less, iron can be stably recovered in the post process.

[0041] When I_p is less than $0.125 \times W_s$, the variation in the amount of granular iron becomes greater than 1.1%, and the variation in the amount of granular iron in the slag becomes unstable. Further, when I_p is less than $1.5 \times A_s$, the variation in the amount of granular iron also increases.

[0042] As mentioned above, a required current flowing into the slag is considered to be related to weight of the molten steel. This is because the weight of the slag inevitably increases as the weight of the molten steel increases, and thus, the amount of granular iron in the slag cannot be reduced within a blowing time unless the current value increases, and as a result, a required energization amount is proportional to the weight of the molten steel.

[0043] Further, the required current flowing into the slag is considered to be related to the furnace internal cross-sectional area of the furnace belly portion of the converter furnace. A controlling factor that actually reduces the current density in the slag is the density (current density) of the current flowing into the slag. Since the slag is conductive, a current flows through the entire slag. Therefore, the density of the current flowing into the slag is a value obtained by dividing the current value flowing by the furnace internal cross-sectional area A_s in the furnace belly portion of the converter furnace, and this value becomes the required current density. That is, the required current density is I_p/A_s . Assuming that the required current density is a constant value, the required current value is proportional to the furnace internal cross-sectional area of the furnace belly portion.

[0044] As mentioned above, the required current flowing into the slag is considered to be proportional to the weight of the molten steel and the cross-sectional area in the furnace. Therefore, in order to reduce the amount of granular iron in the slag and further stabilize the variation, it is preferable to select the smaller of the required current (equation (1)) derived from the weight of the molten steel and the required current (equation (2)) derived from the internal cross-sectional area of the furnace.

[0045] Further, preferably, a slag composition before the start of energization has a basicity of 0.5 or greater and an iron oxide concentration of 5% or greater. Since SiO_2 in the slag has a strong binding force with each other, SiO_2 hinders conductivity. Meanwhile, CaO has an action of breaking the bond of SiO_2 , and thus, CaO improves the conductivity. Moreover, iron oxide also improves the conductivity.

[0046] As a result of experimentally investigating a preferable slag composition before starting energization, it was found that the variation in granular iron was further reduced by setting the basicity of the slag to 0.5 or greater and the iron oxide concentration to 5% or greater.

[0047] The basicity can be calculated and presumed from a proportion of a charge. Further, the concentration of iron oxide can be calculated from an amount of oxygen feeding, an amount of oxygen contained in an exhaust gas, and an amount of oxygen contained in the molten steel. Since these values are stored as actual values, the values can be presumed before the blowing.

[0048] The composition of the molten iron alloy to be treated is not limited to a specific composition, but it is preferable to treat the molten pig iron having a silicon concentration (Si amount) of 0.25% or less. As the amount of Si increases, the concentration of SiO_2 in the slag increases. Since SiO_2 is a factor that deteriorates conductivity, SiO_2 makes it difficult for current to flow into the slag, and acts in a direction that hinders reduction of the amount of granular iron.

[0049] Further, when the amount of Si is 0.25% or less, the amount of slag required for the blowing is reduced. Since the amount of granular iron generated is determined by the energy input into the furnace (heavy top blowing) and the amount of decarburized, when the amount of slag is small, the concentration of granular iron in the slag is relatively high. When the concentration of granular iron in the slag increases before energization, the reduction effects when energized increase, and thus, the amount of sedimentation of the granular iron increases. Therefore, when the silicon concentration of the molten pig iron is 0.25% or less, a remarkable effect can be obtained.

[0050] The slag density when energized is preferably 1.0 kg/m^3 or less, and more preferably 0.8 kg/m^3 or less. This is because when the density of the slag decreases, a sedimentation rate of the granular iron increases, and the effects of the present invention can be further obtained. Moreover, in the present specification, the slag density means weight of the slag per unit volume when energized in the converter furnace.

[0051] In the method of refining a molten iron alloy of the present invention, it is preferable that the slag is energized for 10 seconds or longer within one minute before the end of a preset blowing time. That is, it is desirable that a time during which no current is flowing at the end of blowing (after one minute before the stop of oxygen feeding) is set to 50

seconds or less. Furthermore, the shorter an interval between the end of energization and the stop of blowing, the better.

[0052] The reason for this is as follows. 1) When the power is turned off before the end of the blowing, there are concern that the granular iron may be mixed again and the granular iron in the slag may increase. 2) Before the end of the blowing, in most cases, the density of slag is 1.0 kg/m³ or less, and the slag tends to settle. 3) The amount of granular iron in the slag tends to increase at the end of the blowing when an input auxiliary raw material is sufficiently dissolved and reaction products are sufficiently generated, and when the energization starts in this state, the amount of granular iron tends to decrease.

[0053] Therefore, it is important that $I_P'[A]$ representing a magnitude of an average of the direct current during the energization time within one minute immediately before the feeding of the oxygen is stopped is controlled to satisfy at least one of equations (3) and (4), where $W_s[t]$ represents the amount of molten steel in the converter furnace, and $A_s[m^2]$ represents the furnace internal cross-sectional area at the furnace belly portion.

$$(3): I_P' \geq 0.125 \times W_s$$

$$(4): I_P' \geq 1.5 \times A_s$$

[0054] That is, the effects of the present invention can be obtained by controlling the current so as to satisfy at least one of equations (1) to (4).

[0055] Further, it is preferable that the electrode disposed above the molten iron alloy bath in the converter furnace is a hollow top blowing lance.

[0056] In this case, in order to obtain stable energization, a height of the top blowing lance is controlled based on weight of the residual slag in the furnace, weight of the input auxiliary raw material, weight of the reaction product, the slag density, and a cross-sectional area of the furnace belly portion.

[0057] Specifically, it is preferable to control the height H of the top blowing lance between 0.1 times and 10 times the height of the slag. The slag height H can be calculated by the following equation.

$$H(m) = (\text{total weight of residual slag in furnace, input auxiliary raw material, and reaction products (kg)}) / (\text{slag density (kg/m}^3\text{)} \times \text{cross-sectional area of furnace belly portion (m}^2\text{)})$$

[0058] Here, the amount of residual slag in the furnace can be obtained from past operation data, and the input auxiliary raw material and reaction product can be appropriately obtained by using a weighed value and a component value. The slag density is not limited to 1.0 kg/m³ or less, and a value of 2.0 to 3.0 kg/m³ may be used depending on the composition.

[0059] Since the slag is considered to expand about 10 times including the generated gas, it is possible that energization can be obtained even when the lance position is about 10 times the slag height obtained by the above equation. Meanwhile, when there is no problem of bullion adhesion to the lance or cooling, it is better to decrease the height of the lance to about 0.1 times the slag height to stabilize the energization.

[0060] A degree of expansion of selection from a range of 0.1 times to 10 times changes depending on blowing conditions and progress of the blowing, and thus, the degree of expansion can be determined theoretically or empirically depending on a time when the effect is desired. By setting the lance height in this way, it is possible to adjust so that the current flows into the slag only when the slag density is about 1.0 kg/m³ or less, which can promote the reduction of the amount of granular iron. In addition, a stable operation is possible because the lance does not come into contact with molten steel during operation.

[0061] Preferably, the converter furnace is a converter furnace having a bottom blowing tuyere. Since the bottom blowing strengthens the agitation of the slag, the reduction of the amount of granular iron in the slag is promoted. In addition, chances of contact between the slag and the molten steel increase, and thus, a transfer of granular iron from the slag to the molten steel is promoted. Preferably, a flow rate of a bottom-blown gas is 0.01 to 0.2 Nm³/min/ton in a case of inert gas, and 0.1 to 0.4 Nm³/min/ton in a case of blowing of oxygen.

[0062] In the refining method, in the same converter furnace, a first process of performing blowing for the purpose of desiliconization and/or dephosphorization, a second process of discharging a portion of the slag, a third process of performing blowing for the purpose of finish dephosphorization, decarburization, and a temperature adjustment, a fourth process of discharging steel adjusted to the target components and temperature, and a fifth process of discharging a portion of the slag remaining in the furnace are performed in this order.

[0063] At this time, the energization is performed for at least 10 seconds or longer during one or both of the oxygen feeding times of the first process and the third process, and when the magnitude of the average of the direct current during the energization time when the direct current is supplied is defined as I_P [A], the magnitude of the average of the direct current during the energization time within one minute immediately before the feeding of the oxygen is stopped is defined as I_P' [A], the amount of molten steel in the converter furnace is defined as W_s [t], and the furnace internal cross-sectional area at the furnace belly portion is defined as A_s [m²], it is effective to control so as to satisfy at least one of the following equations (1) to (4).

$$(1): I_P \geq 0.125 \times W_s$$

$$(2): I_P \geq 1.5 \times A_s$$

$$(3): I_P' \geq 0.125 \times W_s$$

$$(4): I_P' \geq 1.5 \times A_s$$

[0064] This is because the oxygen feeding time in the first step and the third step is a state in which the density of granular iron in the slag increases, and the amount of granular iron is reduced. Accordingly, the granular iron tends to settle in a molten iron alloy layer, and thus, the metallic iron content in the slag can be easily reduced. In particular, since the amount of granular iron is large in the first step, the variation of the granular iron can be effectively reduced.

[0065] As the first electrode 21 of the converter furnace equipment 1, for example, an electrode made of carbon-containing bricks such as MgO-C bricks can be disposed on the furnace belly of the converter furnace. As the first electrode 21, the top blowing oxygen feeding lance 31 may be used as shown in FIG. 3. A carbon-containing brick or the like can be used for the second electrode 22. Preferably, the second electrode 22 is provided in the furnace bottom or the furnace belly of the converter furnace equipment 1.

[0066] When the first electrode 21 is disposed in the furnace belly, the first electrode 21 is preferably provided 200 mm to 4000 mm above, and more preferably 200 to 400 mm above, based on a static molten metal surface of the iron bath 12 estimated from a volume of the converter furnace.

[0067] When the top blowing oxygen feeding lance 31 is used as the first electrode 21, a front end thereof may be moved up and down, and thus, a position thereof may be moved up and down by the current flowing between the electrodes so that the magnitude of the flowing current can be controlled.

[0068] Preferably, the power supply device 40 may include a mechanism that cuts off the supply of the current when a resistance value between the first electrode 21 and the second electrode 22 is equal to or greater than a preset current value or greater for a preset time after the start of the blowing. The current value is obtained by inputting a signal from the current detection unit 41 to the control device 42. Then, when the obtained current value is equal to or greater than the preset current value within the preset time after the start of the blowing, the output of the power supply device 40 is stopped and the current supply is cut off.

[0069] Immediately after the start of the blowing, there is no reaction product and the input auxiliary raw material is not dissolved. Accordingly, the slag is not formed, and thus, a situation in which the current flows stably into the slag 11 is not prepared. However, a current may flow without passing through the slag due to deposits in the furnace, disturbance of the iron bath, or leakage of electricity in a location that should be insulated due to equipment malfunction. In this case, depending on the current value, the equipment may be damaged due to heat generation. By providing the mechanism for cutting off the supply of current, it is possible to cut off the current and avoid an accident in such a case.

[0070] In order to determine whether the current flows into the slag or not, it is necessary to consider a time when the current flows and a resistance value at that time. As described above, when it is within 10 to 30 seconds after the start of the blowing and the resistance between the electrodes is in the range of 1Ω to 0.1Ω , it is highly possible that the current is applied without passing through the slag. Accordingly, it is desirable to provide the mechanism to cut off the circuit when a current meets with this condition is observed.

[0071] In addition, even when a stray current flows out of the converter furnace due to some trouble, the supply of the current can be cut off, and thus, the equipment can be operated safely.

[0072] It is even more preferable when the power supply device 40 has a function of controlling the current so as not to flow a certain amount or greater.

[0073] Further, it is preferable that the carbon concentration at the refining end point of the dephosphorization treatment is 2.5% by mass or greater. This is because, in most cases, since the refining in the region is performed with a relatively

low basicity and the treatment is completed at a low temperature, a viscosity of the slag before energization is high and the amount of granular iron contained in the slag is large, and thus, when the energization is performed, the amount of granular iron can be easily reduced.

[0074] It is preferable that a bottom blowing tuyere 50 made of porous bricks is provided on the furnace bottom and the iron bath 12 is agitated by blowing gas into the iron bath 12 from the furnace bottom during the refining. The number of bottom blowing tuyeres 50 may be one, but it is preferable to provide a plurality of bottom blowing tuyeres 50.

[0075] FIG. 1 shows an example in which the bottom blowing tuyeres 50 are provided at two locations. The gas flowing from the tuyere is not particularly limited, and any single gas such as oxygen, carbon dioxide, nitrogen, Ar, LPG, or a mixed gas of two or more types can be selected, and a pipe itself can be a single tube, a multiple tube, a collecting pipe, or the like. Further, the electrode 22 can also be used as the tuyere. However, in that case, it is necessary to properly insulate of conductive paths of the tuyere and pipe to eliminate the possibility of a large current flowing through an iron shell of a furnace body or a trunnion shaft.

[Examples]

[0076] Hereinafter, the refining method using the converter furnace equipment of the present invention will be described with a more specific example.

[0077] In a top blowing converter furnace equipment having a bottom blowing function, a total of 300 tons of hot metal and cold iron source were blown. A furnace inner diameter of a furnace belly portion of a converter furnace was 6 m. That is, a value of $0.125 \times W_s$ is 37.5, and a value of $1.5 \times A_s$ is 42.4.

[0078] MgO-C electrodes were installed on the furnace belly and the furnace bottom, a conductor connecting mechanism was provided on a furnace body side and an operating floor side so that the electrodes could be connected at a furnace hanging position, and a power supply capable of controlling so that a current of 500A or greater does not flow to an operating floor was installed.

[0079] The electrode of the furnace belly was set 250 mm above the static molten metal surface when 300 tons of the main raw material was inserted. After the start of the blowing, energization started and the current began to increase at a timing when it could be presumed from an acoustic state in the furnace that slag in a molten state was generated. After that, energization was performed until the end of the blowing.

[0080] As Experimental Examples 1 to 15, the energization timing was changed and blowing was performed based on the above experimental conditions. The blowing was not interrupted even once during the process, and the steel was discharged under the control of a predetermined composition and temperature, and the steel was discharged. Moreover, in each experimental example, the oxygen feeding time was set to 20 minutes in total.

[0081] The slag was received in a slag pan, discharged into a yard and cooled, and then fist-sized lumps were randomly collected from 10 locations and analyzed to obtain an average value of the metallic iron content. The blowing was performed by 5 charges, the average value of the amounts of granular iron in the slag at that time was calculated, and the standard deviation of 5 charges was calculated.

[0082] Results of Experimental Examples 1 to 15 are shown in Table 3.

[Table 3]

	I_P	I_P'	$0.125 \times W_S$	$1.5 \times A_S$	Equation (1)	Equation (2)	Equation (3)	Equation (4)	Standard deviation of amount of granular iron of 5 charges	Remark
Experimental Example 1	50A	50A	37.5	42.4	OK	OK	OK	OK	2.8	Invention Example
Experimental Example 2	38A	38A			OK	NG	OK	NG	6.5	Invention Example
Experimental Example 3	20A	50A			NG	NG	OK	OK	3.4	Invention Example
Experimental Example 4	50A	20A			OK	OK	NG	NG	3.7	Invention Example
Experimental Example 5	20A	20A			NG	NG	NG	NG	11.1	Comparative Example

[0083] In Experimental Examples 1 to 4 according to the Invention Example, the refining was performed under appropriate conditions, and thus, the standard deviation of the amount of granular iron could be reduced.

[0084] In Experimental Example 5 according to the comparative example, since both the current I_p and the current I_p' were low, neither of equations (1) to (4) could be satisfied, and the standard deviation of the amount of granular iron could not be reduced.

[Industrial Applicability]

[0085] According to the present invention, the granular iron contained in the slag can be coarsened and dissolved in the metal bath, the slag having a reduced metallic iron content compared with the related art can be stably obtained, and thus, efficiency in the reforming treatment of the slag can be improved. As a result, it is possible to obtain slag used not only for a road ground improvement material and a lower-layer roadbed material, but also for an upper-layer roadbed material, a concrete aggregate, a stone raw material, or the like, and thus, the present invention has great industrial applicability.

[Brief Description of the Reference Symbols]

[0086]

1: converter furnace equipment
 11: slag
 12: iron bath
 21: first electrode
 22: second electrode
 31: top blowing oxygen feeding lance
 40: power supply device
 41: current detection unit
 42: control device
 50: bottom blowing tuyere

Claims

1. A method of refining a molten iron alloy while feeding oxygen to a molten iron alloy bath in a converter furnace, the method comprising:

supplying a direct current between a first electrode disposed above the molten iron alloy bath and a second electrode disposed in contact with the molten iron alloy bath, wherein, when $I_p[A]$ represents a magnitude of an average of a direct current during an energization time when the direct current is supplied, $I_p'[A]$ represents a magnitude of an average of the direct current during the energization time within one minute immediately before the feeding of the oxygen is stopped, $W_s[t]$ represents an amount of molten steel in the converter furnace, and $A_s[m^2]$ represents a furnace internal cross-sectional area at a furnace belly portion, at least one of equations (1) to (4) is satisfied.

$$(1): I_p \geq 0.125 \times W_s$$

$$(2): I_p \geq 1.5 \times A_s$$

$$(3): I_p' \geq 0.125 \times W_s$$

$$(4): I_p' \geq 1.5 \times A_s$$

2. The method of refining a molten iron alloy according to claim 1, wherein a slag composition used for refining the molten iron alloy has a basicity of 0.5 or greater and an iron oxide

concentration of 5% or greater.

5 3. The method of refining a molten iron alloy according to claim 1 or 2,
wherein a silicon concentration of a molten pig iron before being treated by the refining of the molten iron alloy is
0.25% by mass or less.

4. The method of refining a molten iron alloy according to any one of claims 1 to 3,
wherein a density of a slag used for refining the molten iron alloy is 1.0 kg/m³ or less.

10 5. The method of refining a molten iron alloy according to any one of claims 1 to 4,
wherein a slag is energized for 10 seconds or longer within one minute before an end of a preset blowing time.

6. The method of refining a molten iron alloy according to any one of claims 1 to 5,

15 wherein a hollow top blowing lance is used as the first electrode, and
a height of the top blowing lance is controlled based on weight of residual slag in the furnace, weight of an input
auxiliary raw material, weight of a reaction product, a slag density, and a cross-sectional area of the furnace
belly portion.

20 7. The method of refining a molten iron alloy according to any one of claims 1 to 6,
wherein the converter furnace has a bottom blowing tuyere.

FIG. 1

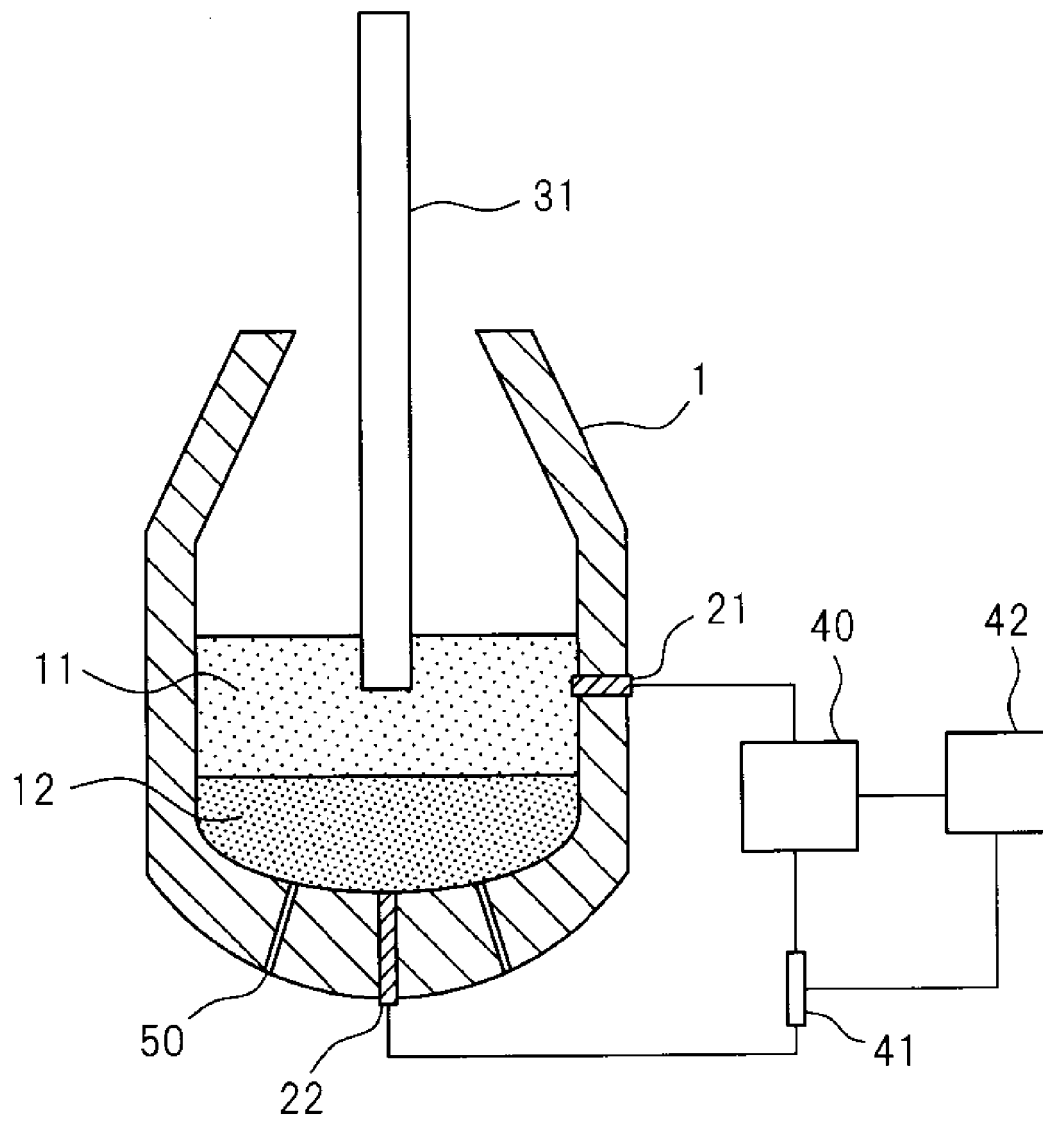


FIG. 2A

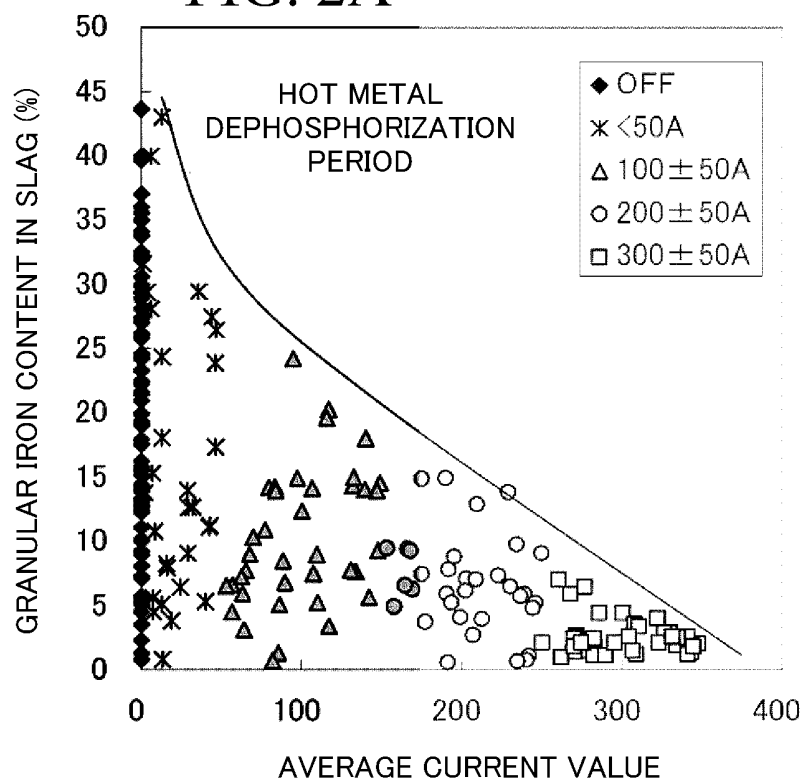


FIG. 2B

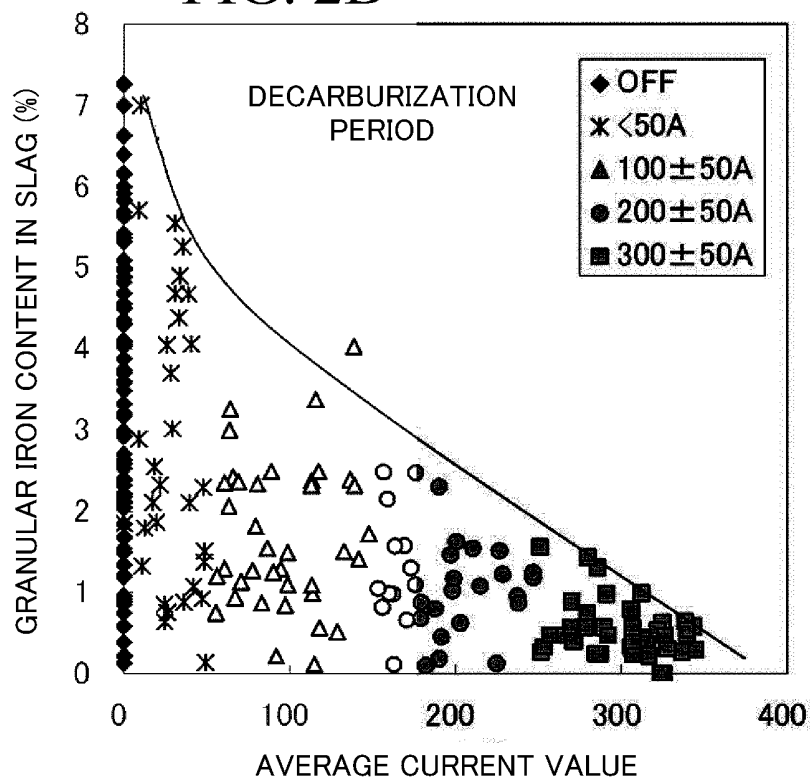
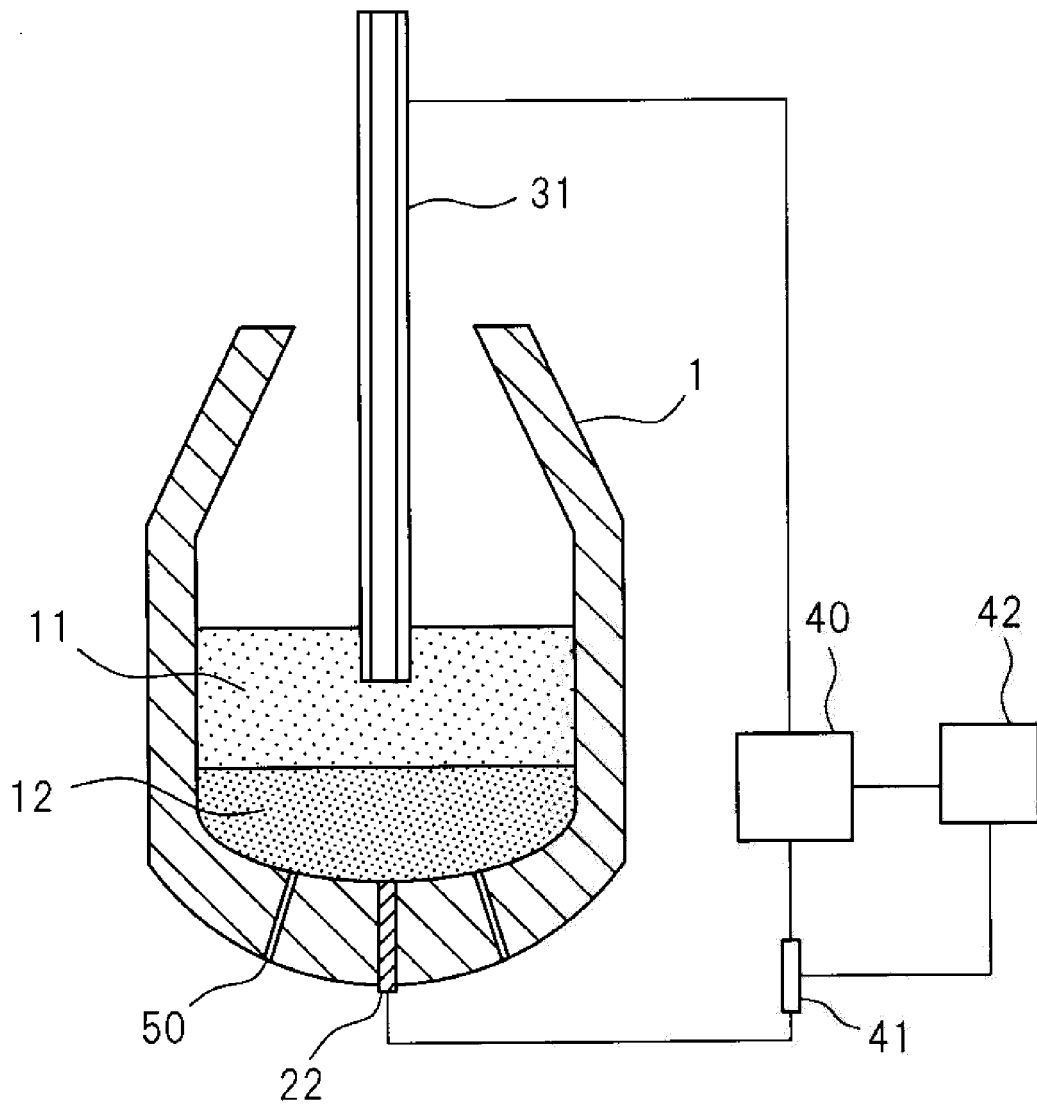


FIG. 3



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2019/015737

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. C21O5/36 (2006.01) i, C21O5/46 (2006.01) i, F27D15/00 (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)

Int. Cl. C21O5/00, C21O5/28-5/50, C21C1/00-3/00, C21C5/02-5/06, C21O5/52-5/56, F27D7/00-15/02, F27D17/00-99/00, F27B17/00-19/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2019
 Registered utility model specifications of Japan 1996-2019
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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 9-227918 A (NIPPON STEEL CORP.) 02 September 1997, claims, paragraphs [0001]-[0014], fig. 1 (Family: none)	1, 5, 7 2, 5, 7
X Y	JP 7-3323 A (VOEST-ALPINE INDUSTRIEANLAGENBAU GMBH) 06 January 1995, claims 1-12, paragraphs [0001]-[0020], fig. 1-3 & US 5454852 A, claims, column 1, line 1 to column 6, line 41, fig. 1 & EP 630977 A1 & CA 2126148 A & CN 1100145 A & RU 94021638 A	1, 5, 7 2, 5, 7
Y	JP 2013-44029 A (JFE STEEL CORP.) 04 March 2013, paragraph [0035] (Family: none)	2, 5, 7



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search
03.07.2019Date of mailing of the international search report
16.07.2019

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/015737

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2000-73111 A (NKK CORP.) 07 March 2000, paragraph [0018] (Family: none)	2, 5, 7
Y	JP 2002-371311 A (OSAKA KOUKAI KK) 26 December 2002, paragraphs [0007], [0020]-[0024] (Family: none)	2, 5, 7
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 179175/1978 (Laid-open No. 97561/1980) (SUMITOMO METAL INDUSTRIES, LTD.) 07 July 1980, page 2, lines 6-10 (Family: none)	2
A	JP 2008-266669 A (JFE STEEL CORP.) 06 November 2008, paragraph [0005] (Family: none)	2
A	CN 109097651 A (XUZHOU HONGYANG NEW MATERIAL TECHNOLOGY CO., LTD.) 27 November 2013, paragraph [0013] (Family: none)	2
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A	JP 2016-108575 A (NIPPON STEEL CORP.) 20 June 2016, entire text, all drawings (Family: none)	6
A	CN 103408013 A (SHIJIAZHUANG XINHUA ENERGY ENVIRONMENTAL PROTECTION TECHNOLOGY CO., LTD.) 27 November 2013, entire text, all drawings (Family: none)	6

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REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- **C. I. SEMUIKIN ; V. F. POLYAKOV ; E. V. SEMKI-NA.** *Current distribution characteristics in converter furnace bath when electric potential is applied to molten steel*, 2003 [0015]