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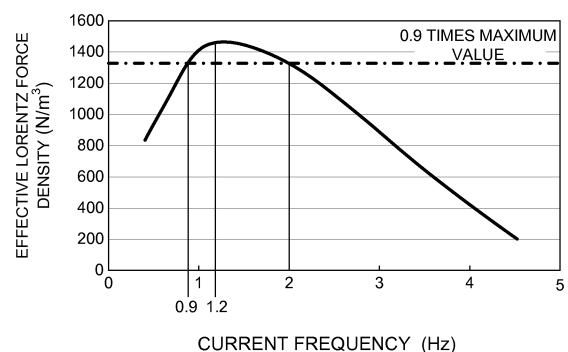
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(54) **CONTINUOUS STEEL CASTING METHOD**

(57) The primary object of the present invention is to provide a method for continuously casting steel which further suppresses pinhole defects.

The present invention is a method for continuously casting steel wherein, in a case where: an average value of Lorentz force density components in a direction parallel to a long side of a mold 11 within existence of an iron core 13a is L_x (N/m³), the iron core being a component of an electromagnetic stirrer 13; and an average value of Lorentz force density components in a direction parallel to a short side of the mold 11 within existence of the iron core 13a is L_y (N/m³), a relationship between effective Lorentz force density F (N/m³) that is calculated by $F = L_x - \alpha \cdot L_y$, and current frequency (Hz) of the electromagnetic stirrer 13 is obtained, and current frequency of the electromagnetic stirrer 13 within the range of a maximum value F_{max} to 0.9 F_{max} of the effective Lorentz force density F is used.

FIG. 7



Description

Technical Field

5 **[0001]** This invention relates to a method for optimally operating an electromagnetic stirrer disposed in a mold, to continuously cast steel.

Background Art

10 **[0002]** One of the main causes of making the quality of a superficial slab manufactured by continuous casting deteriorate is a pinhole defect. Such a pinhole defect is generated by such Ar gas as to be brown into a submerged nozzle for suppressing blocking up of the submerged nozzle in continuous casting, to enter molten steel in a mold, and to be captured by a solidified shell.

15 **[0003]** It is effective to dispose an electromagnetic stirrer in a mold as a method for suppressing pinhole defects. Operation factors of this electromagnetic stirrer include the flow velocity of molten steel, a submerged nozzle, a molten steel throughput and the Lorentz force.

[0004] For example, the following arts are disclosed as they make these operation factors within proper ranges.

[0005] For example, Patent Literature 1 discloses the art of making the flow velocity of electromagnetic stirring at a meniscus 10 to 60 cm/s in order to decrease the generation rate of defects on a surface of a slab to be obtained.

20 **[0006]** Patent Literature 2 discloses the art of making surface defects on a slab due to attachment of air bubbles to a solidified shell, a certain count or less, using parameters such as a distance between an immersion nozzle and a long side of a mold, a length in a casting direction of a molten steel discharge opening of the immersion nozzle, a throughput quantity of molten steel, and the magnetic field density at a solidification interface. Patent Literature 2 describes that the distance between the immersion nozzle and a long side of the mold is controlled by changing the shape of the immersion
25 nozzle and the shape of the mold.

[0007] Patent Literature 3 discloses the art of imparting electromagnetic forces so that the average value of an electromagnetic force in a direction parallel to a major side of a casting mold is 3,000 to 12,000 N/m³, the localized value of an electromagnetic force in a direction parallel to a minor side of the casting mold is -2,000 to 2,000 N/m³, and the localized value of an electromagnetic force in a perpendicular downward direction is -1,000 to 1,000 N/m³ in order to
30 accelerate float of bubbles of Ar gas and avoid contamination of mold powder into molten steel.

[0008] Application of the above described arts disclosed in Patent Literatures 1 to 3 suppresses pinhole defects to some extent. However, pinhole defects do not completely disappear. Users more and more strictly demand the quality of surfaces of steel plates, which necessitates an art of further suppressing pinhole defects.

35 **[0009]** An electromagnetic stirrer is a device that is the most effective for suppressing pinhole defects in continuously steel casting. In the above described arts disclosed in Patent Literatures 1 to 3, electromagnetic forces generated by electromagnetic stirrers and proper ranges of the flow velocities of molten steel generated by the electromagnetic forces are also examined in detail.

40 **[0010]** Here, an electromagnetic stirrer is a device that generates the Lorentz force in molten steel in a mold, to make the molten steel flow. This Lorentz force is generated only in molten steel having conductivity, but not generated in what generally called insulators, which have extremely low conductivity such as air bubbles of Ar gas.

[0011] Thus, air bubbles of Ar gas move relatively in the opposite direction to the movement of molten steel in a mold. That is, an electromagnetic force generated by an electromagnetic stirrer also includes a negative component that gathers air bubbles of Ar gas on a superficial slab as shown in FIG. 8, to increase pinhole defects.

45 **[0012]** This component of an electromagnetic force, gathering air bubbles of Ar gas which are included in molten metal on a superficial slab is called "electromagnetic repulsion" or "electromagnetic Archimedes force", which is described in Non Patent Literature 1 in detail. In FIG. 8, 1 represents a wall surface of a mold, 2 represents a solidified shell, 3 represents a solidification interface and 4 represents an air bubble of Ar gas; the arrow pointing the top from the bottom on the page represents the Lorentz force, and the arrow pointing the bottom from the top on the page represents
50 electromagnetic repulsion. Non Patent Literature 2 discloses thermal fluid simulation in view of Lorentz force density acting on molten steel in continuous casting.

Citation List

Patent Literature

55 **[0013]**

Patent Literature 1: JP H6-605A

Patent Literature 2: JP 2007-216288A

Patent Literature 3: JP 2010-240687A

Non Patent Literature

[0014]

Non Patent Literature 1: Tetsu-to-hagané, Vol. 83 (1997), No. 1, pp. 30-35

Non Patent Literature 2: K. Takatani: ISIJ International, Vol. 43, 2003, No. 6, pp. 915-922

Summary of Invention

Technical Problem

[0015] A problem to be solved by this invention is that in conventional arts, there is no concept of determining preferable conditions for electromagnetic stirring, focusing on electromagnetic repulsion generated by an electromagnetic stirrer, in electromagnetic stirring of molten steel in a mold upon continuously casting steel.

Solution to Problem

[0016] An object of the present invention is to determine the best current frequency of an electromagnetic stirrer so as to make electromagnetic repulsion generated upon electromagnetic stirring of molten steel in a mold as low as possible, to further suppress pinhole defects.

[0017] The present invention was made based on the results of the inventor's study described below, and its primary feature is: in continuously casting steel using an electromagnetic stirrer disposed in a mold, in a case where: an average value of Lorentz force density components in a direction parallel to a long side of the mold within existence of an iron core is L_x (N/m³), the iron core being a component of the electromagnetic stirrer; and an average value of Lorentz force density components in a direction parallel to a short side of the mold within existence of the iron core is L_y (N/m³), a relationship between effective Lorentz force density F (N/m³) that is calculated by the following formula, and current frequency (Hz) of the electromagnetic stirrer is obtained, and current frequency of the electromagnetic stirrer within a range of a maximum value F_{max} to $0.9 F_{max}$ of the effective Lorentz force density F is used, where $F = L_x - \alpha L_y$, and in this formula, α is a coefficient indicating bad influence of electromagnetic repulsion ($= 3$ to 7).

[0018] In the above described present invention, the best current frequency of the electromagnetic stirrer is determined so as to make electromagnetic repulsion generated upon electromagnetic stirring of the molten steel in the mold as low as possible. Thus, it can be suppressed as far as possible to gather air bubbles of Ar gas on a superficial slab.

Advantageous Effects of Invention

[0019] According to the present invention, pinhole defects can be further suppressed compared with methods for continuously casting steel using conventional arts because it can be suppressed as far as possible to gather air bubbles of Ar gas on the superficial slab.

Brief Description of Drawings

[0020]

FIG. 1 is a view to explain a mold and an electromagnetic stirrer used in the method for continuously casting steel of the present invention, seen from the top of the mold.

FIG. 2 shows the distribution of Lorentz force density at the center position of an iron core in a slab drawing direction, obtained by numerical simulation.

FIG. 3 shows the relationship between average values L_x of Lorentz force density components in the direction parallel to a long side of the mold within the existence of the iron core of the electromagnetic stirrer, and current frequencies.

FIG. 4 shows the relationship between average values L_y of Lorentz force density components in the direction parallel to a short side of the mold within the existence of the iron core of the electromagnetic stirrer, and current frequencies.

FIG. 5 shows the relationship between L_y/L_x and current frequencies.

FIG. 6 shows the findings of change in the number of pinholes per unit area (number/m²) on a solidification interface

according to current frequencies, based on numerical analysis.

FIG. 7 shows frequency dependency of effective Lorentz force density F in a case where a coefficient α that indicates bad influence of electromagnetic repulsion is 5.

FIG. 8 is a view to explain electromagnetic repulsion.

Description of Embodiments

[0021] The present invention realizes the object of determining the best current frequency of an electromagnetic stirrer so as to make electromagnetic repulsion generated upon electromagnetic stirring of molten steel in a mold as low as possible, to further suppress pinhole defects.

[0022] Upon operating a continuous casting machine where an electromagnetic stirrer is disposed in a mold therein, the inventor found as a result of his specific study on electromagnetic repulsion generated in the mold that pinhole defects can be reduced by suppressing the electromagnetic repulsion.

[0023] Then, as a result of the inventor's further study on a method for applying an electromagnetic force which suppresses the electromagnetic repulsion so as to keep bubbles of Ar gas away from the vicinity of a solidification interface, it turned out that there exists a proper current frequency upon applying the electromagnetic force.

[0024] The mold and the electromagnetic stirrer used in the above studies are same as those described in Patent Literature 3, which have ordinary shapes and polarities as shown in FIG. 1 when the mold is seen from the top. In FIG. 1, 11 represents a copper mold (hereinafter may be referred to as a mold), 12 represents a submerged nozzle, 13 represents an electromagnetic stirrer, 13a represents an iron core constituting the electromagnetic stirrer 13, 13aa represents a teeth part formed on the iron core 13, and 13b represents a winding that is wound around the outer circumference of the iron core 13a.

[0025] FIG. 2 shows the distribution of Lorentz force density at the center position of the iron core in a slab drawing direction, obtained by numerical simulation. Here, Lorentz force density represents an electromagnetic force per unit volume of molten steel (N/m^3).

[0026] The distribution of Lorentz force density shown in FIG. 2 resulted from the numerical simulation under the conditions where the size of a slab was 1200 mm in width $\times$ 250 mm in thickness, a copper plate forming the mold was 25 mm in thickness, and the conductivity of the mold was 1.9×10^7 S/m.

[0027] The distribution of Lorentz force density shown in FIG. 2 is the distribution of stirring the molten steel in the mold counterclockwise. The large Lorentz force along the direction of a long side of the mold 11 is generated in the vicinity of the wall surface of the mold 11.

[0028] As is clear from FIG. 2, the above described Lorentz force along the wall surface of the mold also includes a lot of components directed toward the inside of the mold. Such a kind of the Lorentz force directed toward the inside of the mold functions as electromagnetic repulsion directed toward the wall surface of the mold for bubbles of Ar gas. That is, the electromagnetic repulsion transmits bubbles of Ar gas to the vicinity of the interface of a solidified shell, and pinhole defects are increased.

[0029] Distribution of the Lorentz force density does not change even if an EMS (Electro-Magnetic Stirrer) current value becomes larger. That is, in a case where the current value of an electromagnetic stirrer is made to be larger, to speed up the flow velocity, the effect of suppressing pinhole defects can be obtained by a cleaning effect on pinholes captured by the interface of a solidified shell; on the other hand, electromagnetic repulsion makes bubbles of Ar gas moving to the interface of the solidified shell increase and thus, pinhole defects increase.

[0030] As a result of the inventor's study, it was very effective for reducing the components of the Lorentz force directed toward the inside of the mold to change the current frequency of the electromagnetic stirrer, as described below.

[0031] FIG. 3 shows the relationship between average values L_x (N/m^3) of the Lorentz force density components in the direction parallel to a long side of the mold within the existence of the iron core of the electromagnetic stirrer, and current frequencies (Hz). The above described values L_x in the direction parallel to a long side of the mold were calculated assuming that the Lorentz force in the direction same as the revolution of the molten steel due to electromagnetic stirring was positive and the Lorentz force in the direction opposite thereto was negative.

[0032] Specifically, the values L_x were calculated assuming that the Lorentz force density in the left direction on the page of FIG. 2 was positive and the Lorentz force density in the right direction thereon was negative in the area of the page upper than the center of a short side of the mold; and the Lorentz force density in the right direction on the page was positive and the Lorentz force density in the left direction on the page was negative in the area of the page lower than the center of a short side of the mold.

[0033] According to FIG. 3, the maximum of the above described value L_x in the direction parallel to a long side of the mold exists in the range of 2.3 to 2.5 Hz in current frequency; and the current frequency should be selected out of this range of 2.3 to 2.5 Hz for making the stirring flow velocity maximum.

[0034] FIG. 4 shows the relationship between average values L_y (N/m^3) of Lorentz force density components in the direction parallel to a short side of the mold within the existence of the above described iron core, and current frequencies

(Hz). The above described values L_y in the direction parallel to a short side of the mold were calculated assuming that the Lorentz force density directed toward the inside of the mold was positive and the Lorentz force density directed toward the outside of the mold was negative.

[0035] Specifically, the values L_y were calculated assuming that downward Lorentz force density that was leaving away from the wall surface in a long side of the mold was positive in the area of the page of FIG. 2 upper than the center of a short side of the mold, in and upward Lorentz force density that was leaving away from the wall surface in a long side of the mold was positive in the area of the page lower than the center of a short side of the mold.

[0036] That is, the above described value L_y in the direction parallel to a short side of the mold represents a component of the Lorentz force density which makes the molten steel in the mold move from the wall surface in a long side of the mold to the center of a short side, and represents electromagnetic repulsion which makes bubbles of Ar gas move to the wall surface of the mold. As is clear from FIG. 4, as the current frequency of the electromagnetic stirrer is high, the above described value L_y in the direction parallel to a short side of the mold gets large.

[0037] FIG. 5 shows the ratio L_y/L_x of the above described value L_y in the direction parallel to a short side of the mold to the above described value L_x in the direction parallel to a long side of the mold. As is seen from FIG. 5, as the value of L_y/L_x is small, the electromagnetic repulsion component in the Lorentz force density generated in the molten steel in the mold is a little.

[0038] As is seen from FIGS. 4 and 5, it is effective for reducing electromagnetic repulsion to decrease the current frequency. As is seen from FIG. 3, it is necessary for securing the stirring flow velocity originating from electromagnetic stirring to make the above described value L_x in the direction parallel to a long side of the mold a certain value or more. As a result of the examination on fluid simulation, which is described later, it was confirmed that the Lorentz force was not enough in a case where the current frequency was 0.4 Hz or less.

[0039] According to the above, it was assumed that there should exist the optimal current frequency between the current frequency where the above described value L_x in the direction parallel to a long side of the mold was maximum and the current frequency where electromagnetic stirring was improper. Numerical simulation on electromagnetic fields and fluid was examined to obtain this optimal current frequency.

[0040] Electromagnetic field simulation was carried out by calculating the distribution of the Lorentz force density generated in the molten steel by the electromagnetic stirrer according to the method as described above. Fluid simulation was carried out using the obtained Lorentz force density, to evaluate the number of bubbles of Ar gas captured by the solidified shell. Thermal fluid simulation was carried out according to the method described in Non Patent Literature 2, to calculate a flow of the molten steel, heat transmission, solidification and bubbles of Ar gas.

[0041] The thermal fluid simulation according to the method described in Non Patent Literature 2 make it possible to obtain information on the flow velocity, the speed of the solidification, the distribution of bubbles of Ar gas and so on in the molten steel in the continuous casting machine. Thus, the problem was how bubbles of Ar gas captured by the solidified shell were evaluated.

[0042] As described in Patent Literature 1, it is known that bubbles of Ar gas are not captured by the solidified shell if the flow velocity of the molten steel on the solidification interface is 10 to 60 cm/s. That is, calculation may be carried out assuming that in a case where the flow velocity of the molten steel on the solidification interface is the flow velocity where bubbles of Ar gas are captured (hereinafter referred to as the capture flow velocity) or below, bubbles of Ar gas existing on this location are captured.

[0043] Generally speaking, a threshold of the above capture flow velocity is 20 cm/s. However, the accurate value is unknown. In addition, it is considered to be unnatural that such calculation is carried out assuming that when the flow velocity of the molten steel is 19.9 cm/s, bubbles of Ar gas are not captured by the solidified shell and when the flow velocity thereof is 20.1 cm/s, the bubbles are captured thereby.

[0044] Thus, the inventor invented a method of evaluating the probability that bubbles of Ar gas were captured by the solidified shell as a continuous function as represented by the following formula (1). Here, $P_g(-)$ is the probability that bubbles of Ar gas are captured by the solidified shell, C_0 is a fixed number, and U (m/s) is the flow velocity of the molten steel on the solidification interface.

[0045] In a case where the fixed number C_0 in the following formula (1) is 100, the capture probability P_g when the flow velocity of the molten steel is 20 cm/s is no more than 10^{-8} . This is such probability that one of a million bubbles of Ar gas is captured by the solidified shell, and this value of the probability is considered to be 0 on numerical simulation. It is noted that any of 10 to 1000 is a proper value for C_0 used in numerical simulations.

[Math. 1]

$$P_g = \exp(-C_0 \cdot U) \quad \dots \text{Formula (1)}$$

[0046] The speed η_g (number/m³·s) where bubbles of Ar gas are captured by the solidified shell is represented as the

following formula (2), with the number density n_g (number/m³) of bubbles of Ar gas on the solidification interface, the solidification speed R_s (1/s) and the capture probability P_g (-).
[Math. 2]

$$\eta_g = n_g \cdot R_s \cdot P_g \quad \dots \text{Formula (2)}$$

[0047] The number density of bubbles of Ar gas in the solidified shell S_g (number/m³) is calculated from the following formula (3). Here, U_s is the movement speed (m/s) of the solidified shell in the slab drawing direction.
[Math. 3]

$$\frac{\partial S_g}{\partial t} + \nabla \cdot (U_s S_g) = \eta_g \quad \dots \text{Formula (3)}$$

[0048] The number density S_g (number/m³) of bubbles of Ar gas in the solidified shell obtained from the above formula (3) was time-averaged, to evaluate the number of bubbles of Ar gas. At this time, it was considered that the capture flow velocity naturally varied according to diameters of bubbles of Ar gas, but the relationship therebetween is unknown. Then, the examination was carried out under the condition where each bubble of Ar gas existing mainly in the mold of the continuous casting machine is 1 mm in diameter. The evaluation was carried out within the range of 2 mm from the superficial slab, as a range where bubbles of Ar gas of 1 mm in diameter influenced on the surface of the slab.

[0049] FIG. 6 shows the results of examining the relationship between the current frequency and the number of pinholes per unit area (number/m²) on the solidification interface, based on numerical analysis.

[0050] It becomes clear from FIG. 6 that the number of pinholes in a case where the current frequency is 1.2 Hz is less than a case where the current frequency is 2.3 Hz, where the Lorentz force density is the maximum; and the number of pinholes largely increases as the current frequency is 0.8 Hz and below.

[0051] The reason why the number of pinholes per unit area on the solidification interface is the minimum, 43 (number/m²) in a case where the current frequency is 1.2 Hz is that while the Lorentz force density decreases due to electromagnetic stirring, the decrease of the electromagnetic repulsion produces a large effect of decreasing bubbles of Ar gas near the wall surface of the mold. However, pinholes increase as the current frequency decreases to 1.2 Hz and below because the Lorentz force density for stirring the molten steel in the mold is not enough.

[0052] Generally, the current frequency where the Lorentz force density is the maximum is selected for the current frequency of an electromagnetic stirrer. In the electromagnetic stirrer shown in FIG. 1, the current frequency where the Lorentz force density is the maximum is 2.3 Hz, which is read in FIG. 3. The number of pinholes in a case where the current frequency is 2.3 Hz, which is selected according to prior arts is 57 (number/m²) as shown in FIG. 6. Thus, as is seen from FIG. 6, pinhole defects can be suppressed more than prior arts at any current frequency within the range of 0.9 Hz to 2.3 Hz.

[0053] Therefore, the inventor obtained the knowledge under the conditions where the size of the slab was 1200 mm in width $\times$ 250 mm in thickness, the copper mold was 25 mm in thickness, and the conductivity of the copper mold was 1.9×10^7 S/m, the proper range of the frequency where the number of pinholes can be suppressed more than conventional arts was 0.9 to 2.3 Hz.

[0054] It takes a relatively long time to carry out such fluid analysis for evaluating pinholes compared with electromagnetic field analysis. Thus, the inventor studied a method for selecting the optimal frequency from the result of electromagnetic field analysis.

[0055] The Lorentz force L_x (N/m³) necessary for electromagnetic stirring functions as a positive factor for the number of pinholes, and the electromagnetic repulsion L_y (N/m³) functions as a negative factor therefor. Therefore, effective Lorentz force density F (N/m³) is defined as represented by the following formula (4). Here, α is a coefficient that indicates bad influence of the electromagnetic repulsion.

[Math. 4]

$$F = L_x - \alpha \cdot L_y \quad \dots \text{Formula (4)}$$

[0056] Since the above described α is a coefficient that indicates bad influence in the direction parallel to a short side of the mold, this influence varies according to the length of a short side of the mold. The inventor examined α with which the evaluation using the above formula (4) was equivalent to that shown in FIG. 6 concerning 200 mm to 300 mm of a short side of the mold in length as a common continuous casting machine. As a result, the inventor obtained the knowledge

that α in the range of 3 to 7 is proper. In a case where α is less than 3, the Lorentz force parallel to a short side of the mold is underestimated, and in a case where α is beyond 7, the Lorentz force parallel to a short side of the mold is overestimated.

[0057] FIG. 7 shows frequency dependency of the effective Lorentz force density F (N/m^3) in a case where the coefficient α that indicates bad influence of electromagnetic repulsion is 5. It is seen from FIG. 7 that the effective Lorentz force density F (N/m^3) takes the maximum value in a case where the current frequency is 1.2 Hz.

[0058] In view of FIGS. 3 to 6, pinhole defects can be suppressed more than conventional arts in a case where the current frequency is within the range of 0.9 Hz to 2.3 Hz. This range corresponds to a range of the maximum value F_{max} to 0.9 F_{max} of the effective Lorentz force density F (the current frequency is in the range of 0.9 to 2.0 Hz). As described above, using the above formula (4) makes it possible to determine the best frequency of the electromagnetic stirrer only with the result of the electromagnetic field analysis.

[0059] The present invention was made based on the above results of inventor's studies, and is a method for continuously casting steel using an electromagnetic stirrer disposed in a mold, wherein, in a case where: an average value of Lorentz force density components in a direction parallel to a long side of the mold within existence of an iron core is L_x (N/m^3), the iron core being a component of the electromagnetic stirrer; and an average value of Lorentz force density components in a direction parallel to a short side of the mold within existence of the iron core is L_y (N/m^3), a relationship between effective Lorentz force density F (N/m^3) that is calculated by the above described Formula (4), and current frequency (Hz) of the electromagnetic stirrer is obtained, and current frequency of the electromagnetic stirrer within a range of a maximum value F_{max} to 0.9 F_{max} of the effective Lorentz force density F is used.

[0060] According to the present invention described above, the best current frequency of the electromagnetic stirrer, where the electromagnetic repulsion generated when electromagnetic stirring is carried out on the molten steel in the mold can be made to be as little as possible can be determined only from the result of the electromagnetic analysis. Therefore, it can be suppressed as far as possible to gather bubbles of Ar gas on the superficial slab, and pinhole defects can be further suppressed.

[0061] The present invention is of course not limited to the above described examples, and needless to say, embodiments thereof can be properly modified as long as such modification is within the scope of the technical concepts of the claims.

[0062] While the inventor carried out fluid simulation with the method described in Non Patent Literature 2, it is needless to say that thermal fluid simulation can be carried out not only with the method described in Non Patent Literature 2 but also with another method.

Reference Signs List

[0063]

- 11 mold
- 13 electromagnetic stirrer
- 13a iron core

Claims

1. A method for continuously casting steel using an electromagnetic stirrer disposed in a mold, wherein, in a case where:

an average value of Lorentz force density components in a direction parallel to a long side of the mold within existence of an iron core is L_x (N/m^3), the iron core being a component of the electromagnetic stirrer; and an average value of Lorentz force density components in a direction parallel to a short side of the mold within existence of the iron core is L_y (N/m^3),

a relationship between effective Lorentz force density F (N/m^3) that is calculated by the following formula, and current frequency (Hz) of the electromagnetic stirrer is obtained, and current frequency of the electromagnetic stirrer within a range of a maximum value F_{max} to 0.9 F_{max} of the effective Lorentz force density F is used, where

$$F = Lx - \alpha \cdot Ly,$$

and α is a coefficient indicating bad influence of electromagnetic repulsion (= 3 to 7).

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FIG. 1

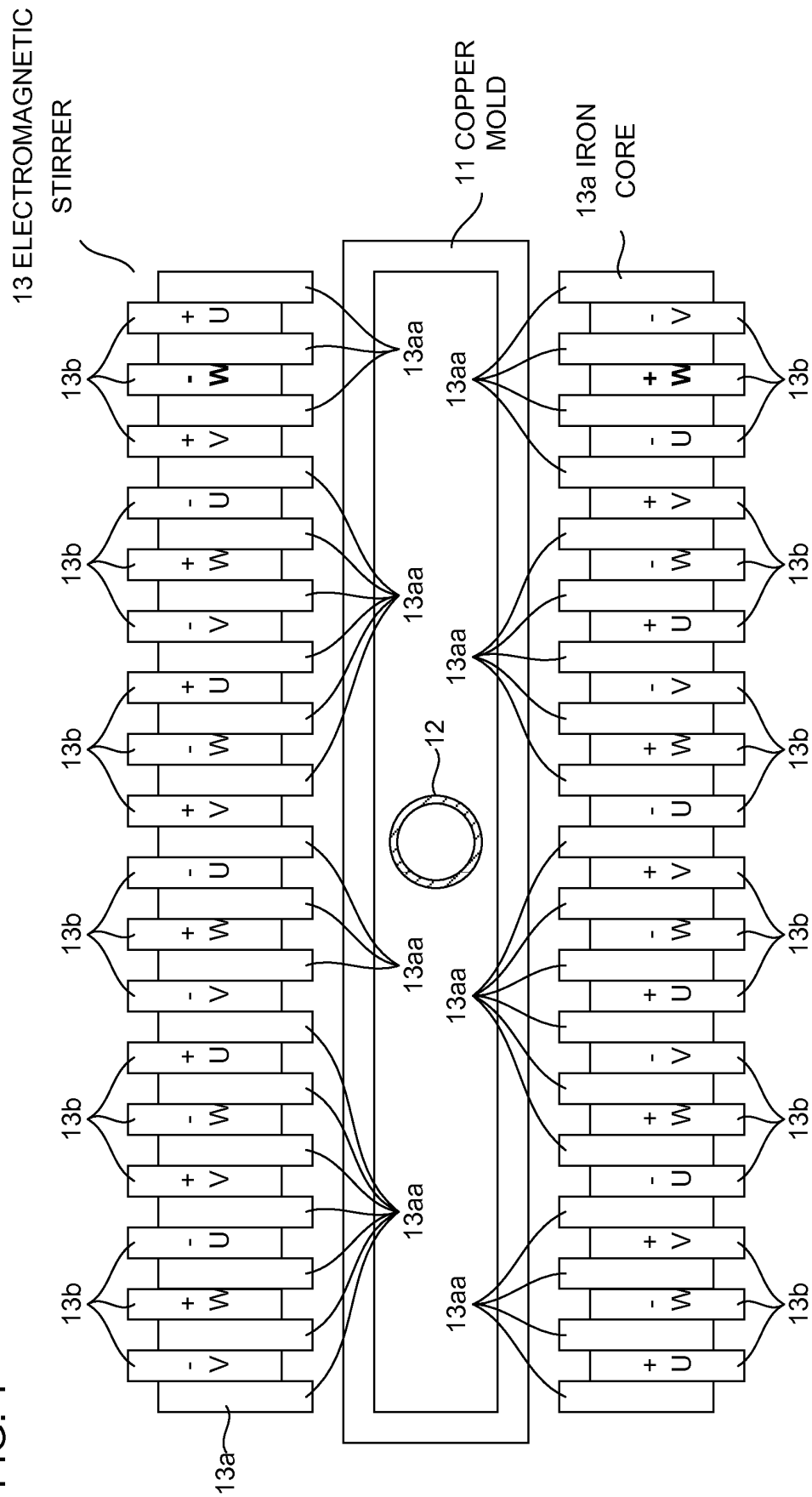


FIG. 2

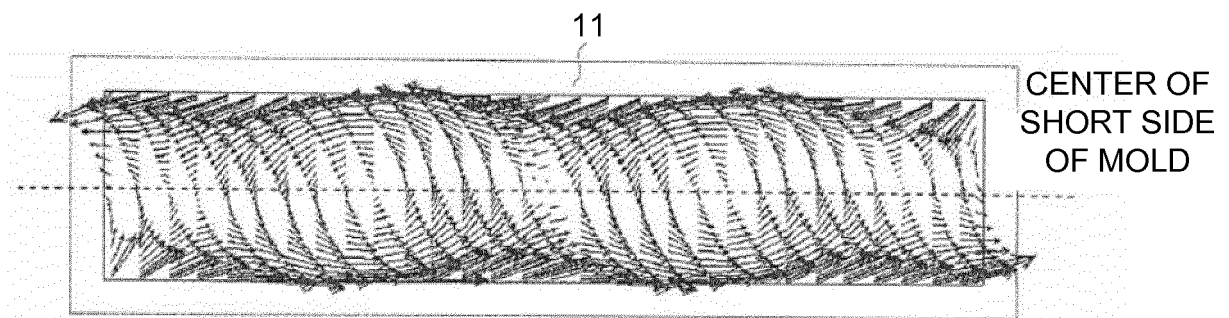


FIG. 3

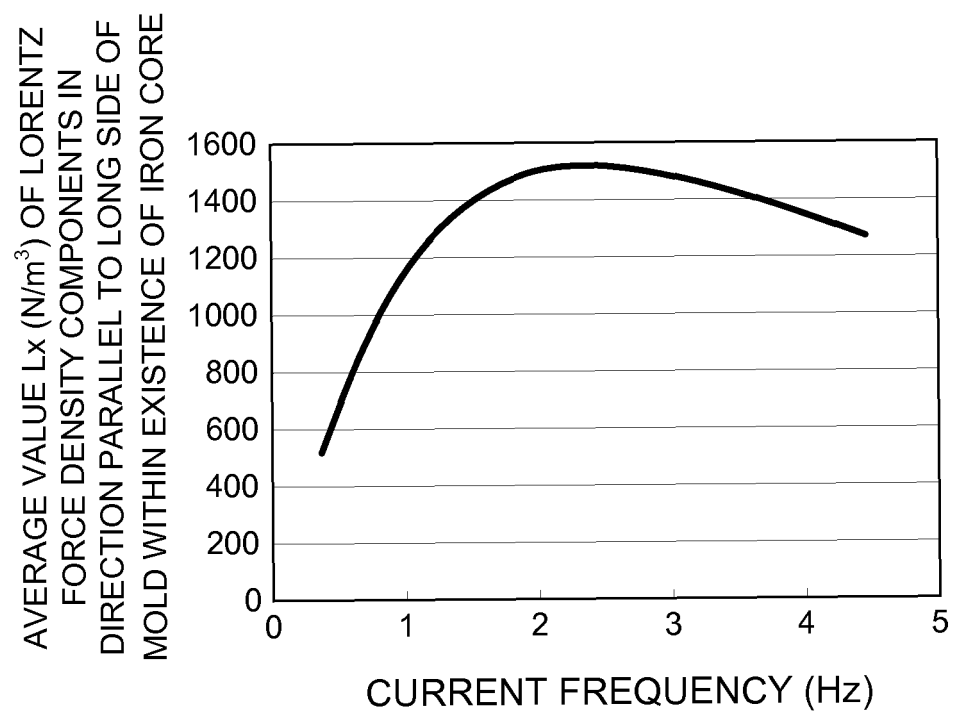


FIG. 4

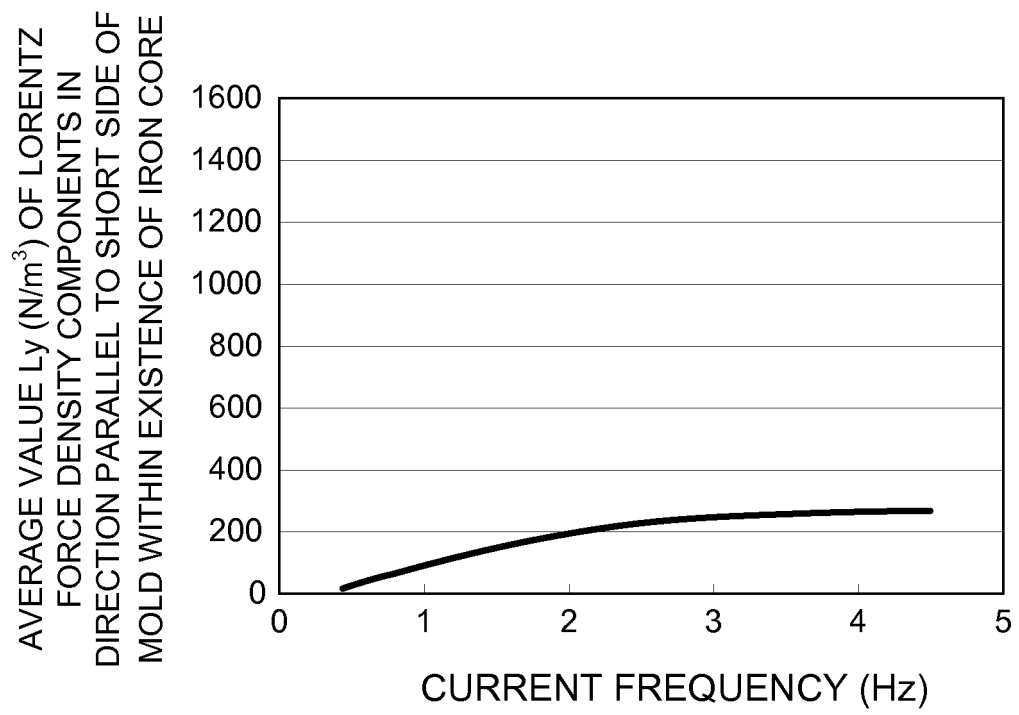


FIG. 5

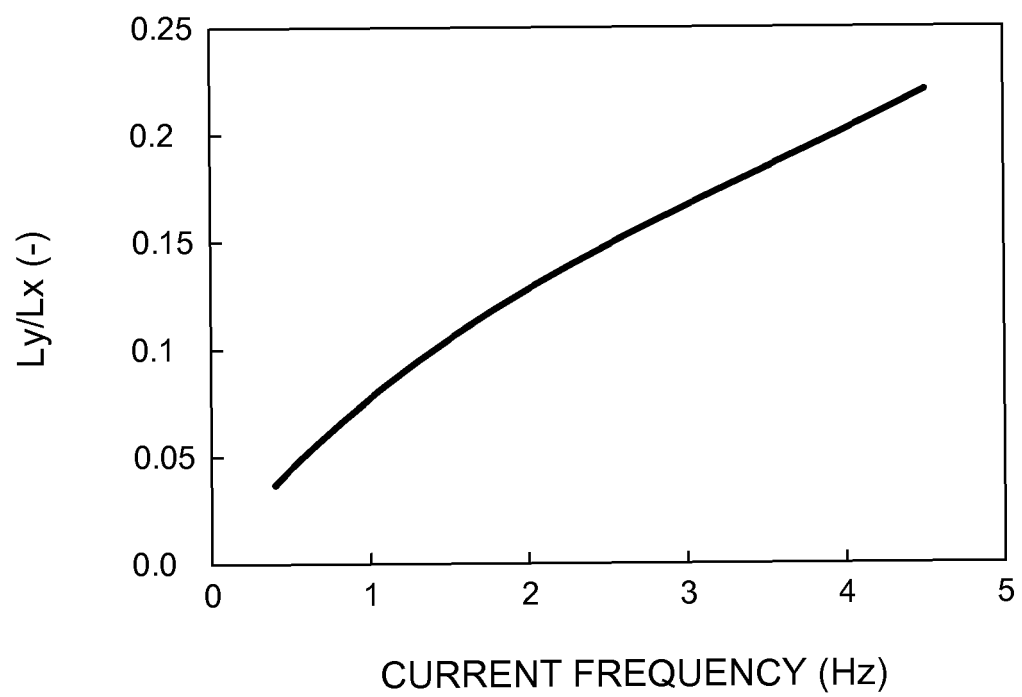


FIG. 6

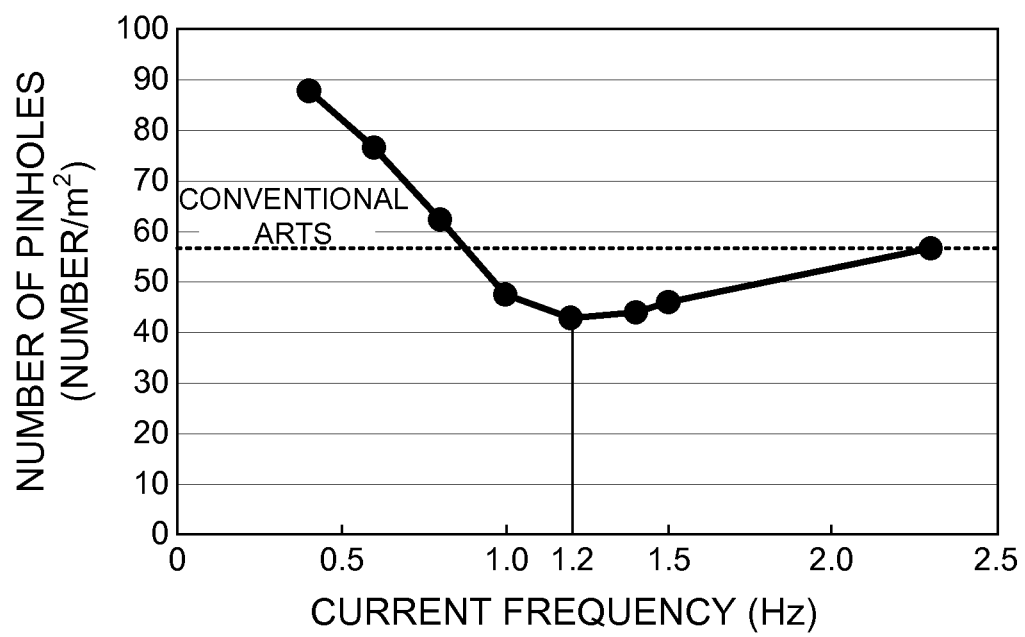


FIG. 7

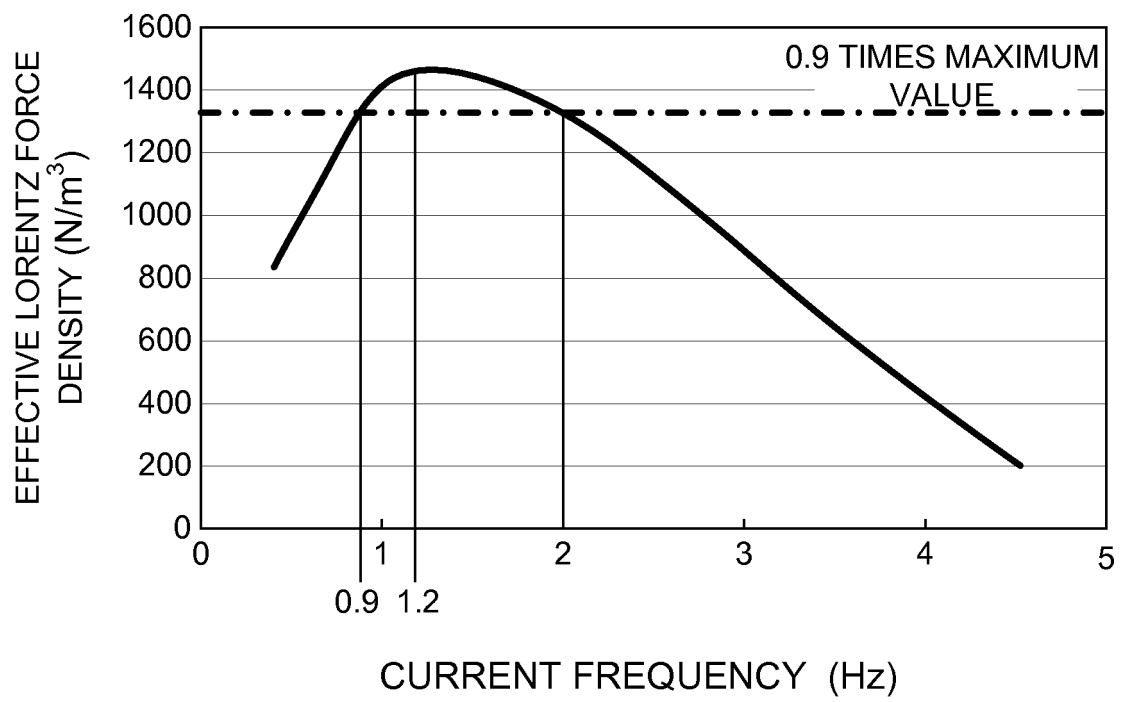
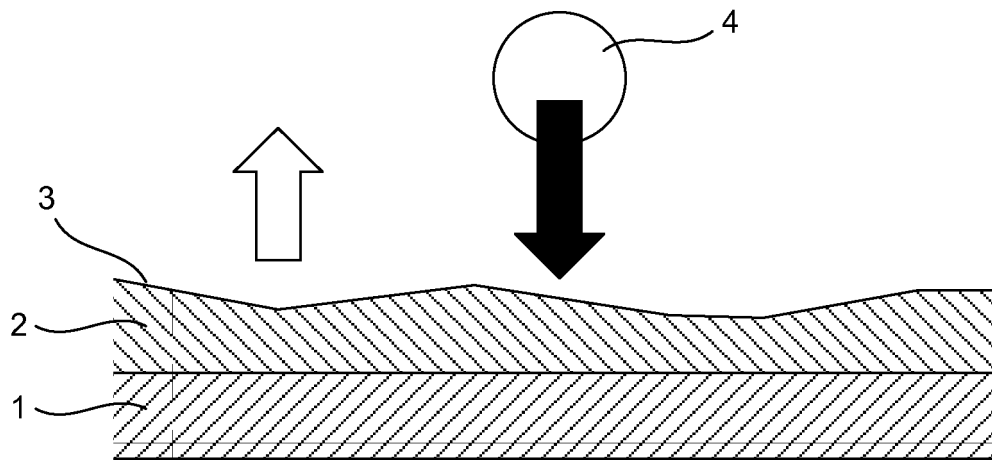


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/052627

A. CLASSIFICATION OF SUBJECT MATTER
B22D11/115 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B22D11/115

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2015
Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2004-322120 A (JFE Steel Corp.), 18 November 2004 (18.11.2004), claim 1 & US 2007/0272388 A1 & EP 1623777 A1 & WO 2004/091829 A1 & KR 10-2006-0002968 A	1
A	JP 2003-236644 A (Kobe Steel, Ltd.), 26 August 2003 (26.08.2003), paragraph [0023] (Family: none)	1
A	JP 2012-166209 A (Sumitomo Metal Industries, Ltd.), 06 September 2012 (06.09.2012), paragraph [0036] (Family: none)	1

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

* Special categories of cited documents:

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Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/052627

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Leonardo B. Trindade et al., Numerical Model of Electromagnetic Stirring for Continuous Casting Billets, IEEE TRANSACTIONS ON MAGNETICS, 2002.11, Vol.38 No.6, Page.3658-3660	1

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REFERENCES CITED IN THE DESCRIPTION

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