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(54) **ELECTROMAGNETIC COIL DEVICE FOR USE OF IN-MOLD MOLTEN STEEL CAPABLE OF SERVING BOTH AS ELECTROMAGNETIC STIR AND ELECTROMAGNETIC BRAKE**

(57) **PROBLEM:** To optimize the relationship between the inner and outer windings of a multi-function coil.

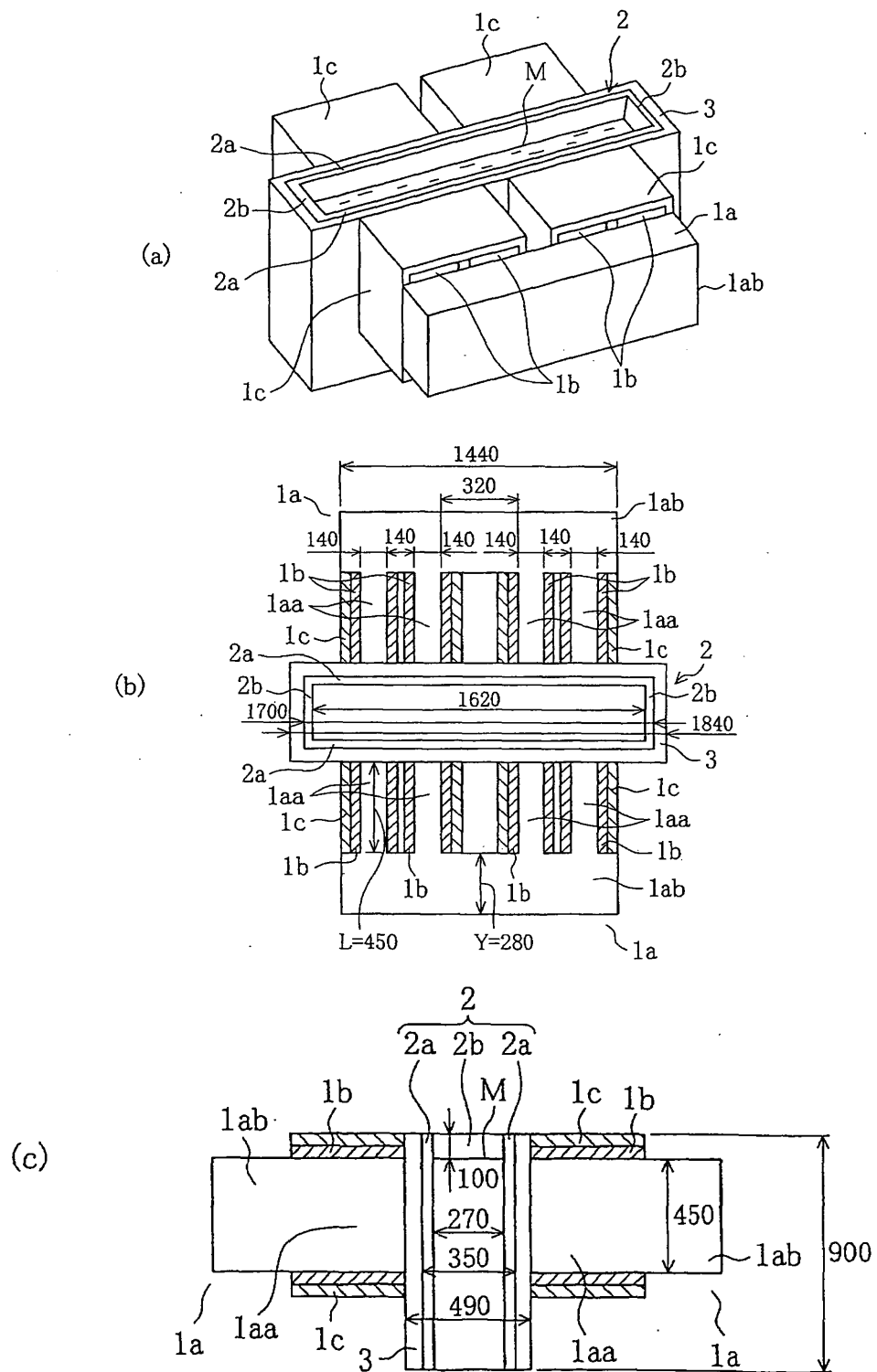
MEANS: An electromagnetic coil system for continuous casting of steel configured to selectively activate electromagnetic stirring and electromagnetic braking of molten steel by applying a direct current or at least a 3-phase alternating current to an electromagnetic coil. The electromagnetic coil is provided with two teeth 1aa extending from yoke 1ab. An inner winding 1b is provided around the two teeth 1aa, and an outer winding 1c is further provided around the outside. A number of coil turns of the outer winding 1c is equal to a number of coil turns -of the inner winding 1b, if the number of coil turns of the inner winding 1b is sufficient. The number of coil

turns of the outer winding 1c is greater than the number of coil turns of the inner winding 1b and no more than 2.5 times the number of coil turns of the inner winding 1b, if the number of coil turns of the inner winding 1b is insufficient. The electromagnetic coil is arranged so that there are n coils disposed on each wide side 1a, where n is a natural number greater than or equal to 2, and the core 1a of a magnetic material is disposed in a range extending in a vertical direction from a position of the meniscus and including an outlet port of immersion nozzle 4.

ADVANTAGEOUS EFFECT: Sufficient stirring performance and braking performance can be ensured, even if the inner winding does not have the necessary number of coil turns.

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Fig.1



Description

TECHNICAL FIELD

[0001] The present invention relates to an electromagnetic coil system for in-mold molten steel that is capable of serving both as an electromagnetic stirrer and as an electromagnetic brake, for use in continuous casting of steel while controlling the flow of in-mold molten steel.

BACKGROUND ART

[0002] In continuous casting of steel, controlling the flow of molten steel in the mold is of the utmost importance in the casting operation and in quality control of cast slabs. There are various methods for achieving flow control of molten steel, such as improving the shape of the immersion nozzle and applying an electromagnetic force to the molten steel in the mold. Of these methods, the application of an electromagnetic force to the molten steel in the mold has become widely used and is practiced by two main methods: electromagnetic stirring, which involves stirring the molten steel by means of an electromagnetic force; and electromagnetic braking, which applies a braking force to the molten steel outlet flow.

[0003] Electromagnetic stirring is known to have the effect of improving product quality, and is primarily used in the casting of high-grade materials. On the other hand, electromagnetic braking is used to prevent a reduction in product quality resulting from re-melting of a solidified shell when the outlet flow of molten steel collides against a solidified shell on the narrow sides of the mold by applying a braking force to the molten steel outlet flow. Electromagnetic braking is also used to increase the casting velocity by controlling the flow velocity of the molten steel flow below the meniscus.

[0004] These electromagnetic brakes and electromagnetic stirrers are both provided with electromagnetic coils with windings around their magnetic cores disposed on the back side of the mold. A core often employs iron, which is a ferromagnetic material, and is referred to as an iron core. An electromagnetic steel plate is employed as a core in electromagnetic stirring, which uses alternating current, in order to reduce core loss due to electromagnetic induction. A soft iron core is often used in an electromagnetic brake.

[0005] These electromagnetic coil systems typically have only a single function of either an electromagnetic brake or an electromagnetic stirrer.

[0006] Accordingly, the present inventors previously developed an electromagnetic coil system capable of serving both as an electromagnetic stirrer and as an electromagnetic brake (referred to below as a multi-function coil). See, for example, Patent Reference 1.

Patent Reference 1: Japanese Patent Application Kokai Publication No. 2007-007719

[0007] The geometry of the multi-function coil of the present invention is basically identical to that disclosed in Patent Reference 1. The multi-function coil also employs an electromagnetic coil structure disclosed in Patent Reference 2.

Patent Reference 2: Japanese Patent Application Kokai Publication No. S60-044157

[0008] FIG. 10 shows a multi-function coil 1 as disclosed in Patent Reference 2 in which two coils 1 are arranged in a continuous manner on a wide side 2a of a mold 2. This multi-function coil 1 employs a winding 1b (inner winding) around each two teeth 1aa, and a winding 1c (outer winding) around the outer side of the two teeth 1aa to form a single unit. Since the shape of the two teeth 1aa and the yoke 1ab forming a core 1a of this electromagnetic coil resembles the Greek letter π (pi), this multi-function coil 1 is called a pi-coil. In FIG. 10, Reference Numeral 2b is a narrow side of the mold 2, Reference Numeral 3 is a back-up plate, and Reference Numeral 4 is an immersion nozzle.

[0009] In an electromagnetic coil system, electromagnetic stirring capacity and electromagnetic braking capacity depend on the product of the current applied to the excitation coils and the number of coil turns. It is thus necessary to increase either the number of coil turns or the current, in order to enhance the performance of an electromagnetic coil system. However, increasing the current requires an increase in the cross-sectional surface area of the windings, which results in a decrease in the number of coil turns. Therefore, increasing the number of coil turns is the primary condition for enhancing the performance of an electromagnetic coil system. The same is true for a multi-function coil.

DISCLOSURE OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0010] However, since overlapping windings of an inner excitation coil and an outer excitation coil are required in a multi-function coil, ample space is needed to accommodate the windings. In particular, the inner excitation coil must be arranged in a limited space between the two teeth, and thus the number of coil turns is limited, resulting in a problem that the electromagnetic stirring capacity and the electromagnetic braking capacity are also limited.

[0011] The problem to be solved by the present invention is that in the multi-function coil previously disclosed by the applicant, since provided in a limited space between the two teeth a number of coil turns of the inner excitation coils was limited and, thus the electromagnetic stirring capacity and the electromagnetic braking capacity were also sometimes limited.

MEANS FOR SOLVING THESE PROBLEMS

[0012] The present invention is directed to a multi-function coil which is an electromagnetic coil system for in-mold molten steel serving both as an electromagnetic stirrer and as an electromagnetic brake for use in continuous casting of steel, by selectively applying electromagnetic stirring and electromagnetic braking on molten steel in a mold by applying a direct current or at least a 3-phase alternating current to an electromagnetic coil disposed around a wide side of a mold, thereby ensuring both electromagnetic stirring performance and electromagnetic braking performance, the electromagnetic coil system comprising:

an electromagnetic coil, and an at least a 3-phase alternating current source and a direct current source,

the electromagnetic coil having two teeth extending from a yoke, and

an inner winding being disposed around the outer side of each of these two teeth and an outer winding being disposed around the outside of the two teeth provided with these inner windings, thereby uniting the two teeth,

wherein a number of coil turns of the outer winding

1) is equal to the number of coil turns of the inner winding, if a sufficient number of coil turns of the inner winding can be ensured; or

2) is greater than and no more than 2.5 times the number of coil turns of the inner winding if the number of coil turns of the inner winding is insufficient,

wherein an n number of electromagnetic coils are arranged on each wide side of a mold, where n is a natural number greater than or equal to 2, and a core of a magnetic material formed from the yoke and the teeth is disposed in a range extending in a vertical direction from a position of the meniscus of the molten steel and including the outlet port of the immersion nozzle.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0013] According to the present invention, in an electromagnetic coil system configured to serve as both an electromagnetic stirrer and as an electromagnetic brake, sufficient electromagnetic stirring performance and electromagnetic braking performance can be obtained, of course, if the required number of coil turns are provided around the inner excitation coil, and even if there is sufficient space, and the required windings cannot be accommodated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

FIG. 1 shows a computation model of electromagnetic field analysis. FIG. 1 (a) is a perspective view of the entire model. FIG. 1 (b) is a horizontal sectional view. FIG. 1 (c) is a vertical sectional view.

FIG. 2 (a) and (b) are drawings showing the combinations of current phases of the multi-function coil disclosed in Japanese Patent Application No. 2007-150627.

FIG. 3 is a graph showing the relationship between the number of coil turns of the outer excitation coil and the magnetic flux density at the center of mold thickness.

FIG. 4 is a drawing showing magnetic flux density distribution at the center of mold thickness (contour lines with 10 equal intervals, starting with the maximum value for magnetic flux density). FIG. 4 (a) illustrates a case where the number of coil turns of the inner and outer excitation coils is equal, with 60 coil turns each. FIG. 4 (b) illustrates a case where the number of coil turns of the outer excitation coil is 100 coil turns.

FIG. 5 is a graph showing the relationship between the number of coil turns of the outer excitation coil and the maximum stirring force generated within the mold.

FIG. 6 is a graph showing the distribution of stirring force near the wide side of the mold when the number of coil turns of the outer excitation coil is varied.

FIG. 7 is a drawing showing the comparative positions of the stirring force and the flow velocity.

FIG. 8 is a graph showing the flow velocity distribution when the inner excitation coil has 60 coil turns, which is the ideal number of coil turns and the outer excitation coil has 60 coil turns, as well as the case when the inner excitation coil has 40 coil turns, which is lower than the ideal number of coil turns and the outer excitation coil has 100 coil turns.

FIG. 9 is a graph showing the flow velocity distribution when the inner excitation coil has 40 coil turns, which is lower than the ideal number of coil turns and the outer excitation coil has 120 coil turns, and the number of coil turns of the inner and outer excitation coils are equal, with 40 coil turns.

FIG. 10 shows diagrams describing the geometry of the multi-function coil. FIG. 10 (a) is a horizontal sec-

tional view, and FIG. 10 (b) is a vertical sectional view.

BRIEF DESCRIPTION OF THE REFERENCE NUMERALS

[0015]

1	Multi-function coil
1a	Core
1aa	Teeth
1ab	Yoke
1b	Inner winding
1c	Outer winding
2	Mold
2a	Wide side
2b	Narrow side
4	Immersion nozzle

PREFERRED EMBODIMENTS

[0016] In the multi-function coil previously disclosed by the applicant, there were a limited number of coil turns of inner excitation coils provided in a limited space between the two teeth, and thus the electromagnetic stirring capacity and the electromagnetic braking capacity were also sometimes limited. The object of the present invention is to ensure both electromagnetic stirring performance and electromagnetic braking performance by optimizing the relationship between the number of coil turns of the outer winding and the inner winding.

EMBODIMENTS

[0017] The present invention is described below, from the process of its initial conception to its solution of the problems of the prior art, and a preferred embodiment for implementing the present invention is described.

[0018] As described above, in a multi-function coil, there are two types of excitation coils, namely, inner and outer excitation coils, unlike prior art electromagnetic coil systems used in electromagnetic stirrers and electromagnetic brakes. Also, while the number of coil turns is limited by the space between the teeth in the case of the inner excitation coil, there is spatial leeway for increasing the number of coil turns in the case of the outer excitation coil.

[0019] Therefore, the number of possible coil turns can differ between the inner excitation coil and the outer excitation coil, but in the prior art, the relationship between the number of coil turns of the inner excitation coil and the outer excitation coil was not investigated.

[0020] Accordingly, the present inventors carefully studied the effect on multi-function coil performance when the number of coil turns of the outer excitation coil was varied with respect to the number of coil turns of the inner excitation coil which is limited by the interval between the teeth.

[0021] Performance of the multi-function coil includes the electromagnetic stirring capacity, which can be evaluated in terms of the stirring force resulting from the electromagnetic force generated in the molten steel. It also includes electromagnetic braking performance, which can be evaluated in terms of the magnitude of the electromagnetic flux applied to the molten steel.

[0022] If the number of coil turns of the outer excitation coil is increased, it is predicted that an electromagnetic brake used as a static magnetic field will simply have an increased magnetic flux density. However, a question arises as to whether electromagnetic stirring can be impaired if there is an electrical power differential between the outer excitation coil and the inner excitation coil due to an increase in the number of coil turns of the outer excitation coil.

[0023] Accordingly, the present inventors employed a computation model of electromagnetic field analysis to study changes in stirring force and electromagnetic flux density when the number of coil turns of the outer excitation coil was varied.

[0024] FIG. 1 shows a computation model of electromagnetic field analysis. FIG. 1 (a) is a perspective view of the entire model. FIG. 1 (b) is a horizontal sectional view. FIG. 1 (c) is a vertical sectional view. The numerals in the figure represent the dimensions (mm) of the parts of the model.

[0025] A non-magnetic stainless steel back-up plate 3 is disposed on the outer side of a copper mold 2, and an upper end of a core 1a is at the same height as the meniscus M. The number of coil turns of the excitation core is between 40-60 for the inner winding and 40-120 for the outer winding.

[0026] When activating electromagnetic stirring, alternating current is applied with a frequency of 4.0 Hz at 750 A. When activating electromagnetic braking, direct current of 900 A is applied.

[0027] The coil current phases during electromagnetic stirring exhibit the same combinations of current phases as those disclosed in Japanese Patent Application No. 2007-150627.

[0028] As shown in FIG. 2, excitation coils (a) - (c), excitation coils (d) - (f), excitation coils (g) - (i), and excitation coils (j) - (l) each form one electromagnetic coil. Excitation coils (a), (d), (g), and (j) are excitation coils which have the outer winding 1c to unify the two respective teeth 1aa.

[0029] Electromagnetic coils having the excitation coils (a) - (c) and the excitation coils (d) - (f) is disposed sequentially on one wide side 2a of the mold 2. Electromagnetic coils having the excitation coils (g) - (i) and the excitation coils (j) - (l) arranged on the other wide side 2a of the mold 2, are disposed facing the excitation coils (a) - (c) and the excitation coils (d) - (f).

[0030] In such an arrangement, phases U, V, and W having a phase difference of 120° in a 3-phase alternating current, are applied to the excitation coils (a) - (l) at the inner winding 1b for the teeth 1aa of the electromagnetic

coils in the sequence of the excitation coils, as shown in FIG. 2. In FIG. 2 (a), -W, +V, +U, +W, -V, -U, -W, +U, +V, +W, -U, and -V are applied sequentially to the excitation coils (a) - (l). In FIG. 2 (b), -W, +V, +U, -V, +U, +W, +V, -W, -U, +W, -U, and -V are applied.

[0031] On the other hand, during electromagnetic braking, current is applied in the same direction to all three windings 1b and 1c around the two teeth 1aa.

[0032] FIG. 3 is a graph showing the relationship between the number of coil turns of the outer excitation coil and the magnetic flux density at the center of mold thickness. FIG. 3 indicates that the magnetic flux density increases proportionately with the number of coil turns of the outer excitation coil.

[0033] FIG. 4 is a drawing showing magnetic flux density distribution at the center of mold thickness: FIG. 4 (a) illustrates a case where the number of coil turns of the inner and outer excitation coils is equal, with 60 coil turns each. FIG. 4 (b) illustrates a case where the number of coil turns of the outer excitation coil is 100 coil turns, while that of the inner excitation coil is 60. FIG. 4 shows contour lines with 10 equal intervals, starting with the maximum value for magnetic flux density.

[0034] FIG. 4 confirms that no great change in the magnetic flux density distribution occurs, even if the number of coil turns of the outer excitation coil is increased so as to exceed the number of coil turns of the inner excitation coil.

[0035] Next, the present inventors studied the electromagnetic stirring capacity when the number of coil turns of the outer excitation coil was increased so as to exceed the number of coil turns of the inner excitation coil.

[0036] FIG. 5 is a graph showing the relationship between the number of coil turns of the outer excitation coil and the maximum stirring force generated within the mold. FIG. 5 indicates that stirring force can be increased by increasing the number of coil turns of the outer excitation coil.

[0037] FIG. 6 is a graph showing the distribution of stirring force near the wide side of the mold when the number of coil turns of the outer excitation coil is varied. The distribution of stirring force shown in FIG. 6 is at a position 5 mm from the wide side of the mold at the position of the meniscus of the molten steel. The distribution of the stirring force is in the direction of the wide side at the position A-A' in FIG. 7.

[0038] FIG. 6 indicates that if the number of coil turns of the outer excitation coil is reduced to 40 (broken line) versus 60 coil turns for the inner excitation coil, there is reduced stirring force in all regions on the wide side of the mold. On the other hand, if the number of coil turns of the outer excitation coil is increased to 120 (dotted line), the stirring force increases in the opposite direction at the left end of the wide side of the mold, and the stirring force is less than 0 even at the center of the mold, even though the maximum stirring force increases.

[0039] Judging from this stirring force distribution, it can be concluded that if the target number of coil turns

is provided to the inner excitation coil, then the optimum result is achieved by forming the inner excitation coil and the outer excitation coil with the same number of coil turns. However, there are cases in which it is not possible to provide the target number of coil turns to the inner excitation coil because of the interval between the teeth. In such cases, it is thought to be possible that the required electromagnetic stirring can be achieved by increasing the number of coil turns of the outer excitation coil, even though it makes the stirring slightly worse.

[0040] As shown in FIG. 1 (b) and (c), the results of numerical analysis show that when producing a multi-function coil having teeth 1aa with a width of 140 mm and an interval between the teeth 1aa of 140 mm, a current of $750 \text{ A} \times 60$ Turns is needed during electromagnetic stirring.

[0041] However, if a copper pipe through which a current of at least 750 A can be flown is used as a winding of an excitation coil in a multi-function coil having teeth 1aa with an interval of 140 mm, there was not enough space for 60 coil turns for the inner excitation coil, so there was a limit of 40 coil turns.

[0042] FIG. 8 is a graph showing the distribution of flow velocity of molten steel. The solid line shows the case where the inner excitation coil has the ideal number of coil turns, namely 60 coil turns, and the outer excitation coil has 60 coil turns. The broken line represents a case where there are 40 coil turns for the inner excitation coil, which is fewer than the ideal number of coil turns, and 100 coil turns for the outer excitation coil (the ratio of outer coil turn to inner coil turn is 2.5).

[0043] The flow velocity of molten steel shown in FIG. 8 represents measurements taken at a position 5 - mm from the wide side of the mold at position of the meniscus. Measurements are taken in the direction of the wide side at the position A-A' in FIG. 7.

[0044] It can be concluded from FIG. 8 that if the number of coil turns for the inner excitation coil and the outer excitation coil is identical, namely 60 coil turns (solid line), then a flow velocity of at least 10 cm/sec occurs in almost all regions of the wide side of the mold, resulting in favorable stirring.

[0045] On the other hand, if the number of coil turns of the inner excitation coil is 40, and the number of coil turns of the outer excitation coil is 100 (broken line), then the flow velocity drops to 5 cm/sec at the center of the mold, but the flow velocity distribution is equivalent to that when the inner and outer excitation coils have an equal number of coil turns.

[0046] FIG. 9 is a graph showing the flow velocity distribution of molten steel. The solid line is for 40 coil turns, which is fewer than the ideal number of coil turns for the inner excitation coil, and illustrates the case where the number of coil turns for the outer excitation coil is 120 (the ratio of outer coil turn to inner coil turn is 3). The broken line represents the case where the inner and outer coil turns is equal, namely 40 coil turns.

[0047] FIG. 9 indicates that the flow velocity drops to

below 0 at the center of the mold, when the number of coil turns for the inner excitation coil is lower than the ideal number, and the number of coil turns for the outer excitation coil is 3 times that of the inner excitation coil, even though the maximum flow velocity increases.

[0048] This indicates that when the number of coil turns for the outer excitation coil is 3 times that of the inner excitation coil, the flow velocity becomes stagnant or reversed, and is thus unsuitable for electromagnetic stirring.

[0049] FIG. 9 also indicates that if the number of coil turns for the inner excitation coil is lower than the ideal number of coil turns, there is a large region in which the stirring force is insufficient and the flow velocity is on the order of 0, even if the number of coil turns of the inner and outer excitation coils is equal, and this is unsuitable for electromagnetic stirring.

[0050] As a result of the above findings, it was determined that the optimal number of coil turns for the excitation coils in a multi-function coil is an equal number of coil turns for the inner and outer excitation coils, in cases where it is possible to ensure a sufficient number of coil turns for the inner excitation coil.

[0051] On the other hand, it was determined that in cases where it is not possible to ensure a sufficient number of coil turns for the inner excitation coil, satisfactory electromagnetic stirring can be achieved if the number of coil turns for the outer excitation coil is greater than that of the inner excitation coil, and the number of coil turns is no more than 2.5 times greater.

[0052] Moreover, if the number of coil turns of the outer excitation coil is 100, then the magnetic flux density is 3179 Gauss during electromagnetic braking, and 2465 Gauss if the number of coil turns is 40. It was determined that the present invention can realize a magnetic flux density of at least 3000 Gauss, which is sufficient to achieve suitable electromagnetic braking performance.

[0053] The present invention was devised on the basis of the above results of electromagnetic numerical analysis, can achieve sufficient electromagnetic stirring performance and electromagnetic braking performance.

The present invention is directed to an electromagnetic coil system for in-mold molten steel serving both as an electromagnetic stirrer and as an electromagnetic brake for use in continuous casting of steel by selectively applying electromagnetic stirring or electromagnetic braking on molten steel in a mold by applying a direct current or at least a 3-phase alternating current to an electromagnetic coil disposed around a wide side of a mold.

[0054] An electromagnetic coil which is connected to at least a 3-phase alternating current source and a direct current source, is provided two teeth extending from a yoke. An inner winding is provided around the outer side of each of these two teeth, and an outer winding around the outside of the two teeth is provided with the inner windings, thereby uniting the two teeth.

[0055] If a sufficient number of coil turns of the inner winding can be ensured, then the number of coil turns of

the outer winding is equal to the number of coil turns of the inner winding, and if the number of coil turns of the inner winding is insufficient, then the number of coil turns of the outer winding is greater than and no more than 2.5 times the number of coil turns of the inner winding.

[0056] Additionally, an n number of the electromagnetic coils are arranged on each wide side, where n is a natural number greater than or equal to 2, and a core of a magnetic material formed from the yoke and the teeth is disposed in a range extending in a vertical direction from a position of the meniscus of the molten steel and including the outlet port of the immersion nozzle.

[0057] The present invention is of course not limited to the foregoing examples, and the embodiments can of course be suitably modified, as long as they are within the scope of the technical ideas recited in the claims.

[0058] For example, the alternating current does not have to be 3-phase, and as long as the current phase difference varies from 90° to 120°, it can be a multi-phase alternating current of a higher order.

INDUSTRIAL APPLICABILITY

[0059] The present invention described above can be applied to continuous casting using a curved mold, a vertical mold, or any mold shape, as long as it involves continuous casting. Moreover, the present invention can be applied not only to continuous casting of slabs, but also to continuous casting of blooms.

Claims

1. An electromagnetic coil system for in-mold molten steel serving both as an electromagnetic stirrer and as an electromagnetic brake for use in continuous casting of steel by selectively applying electromagnetic stirring and electromagnetic braking on molten steel in a mold by applying a direct current or at least a 3-phase alternating current to an electromagnetic coil disposed around a wide side of a mold,, the electromagnetic coil system comprising:

an electromagnetic coil, and at least a 3-phase alternating current source and a direct current source,

the electromagnetic coil comprising two teeth extending from a yoke, and

an inner winding being disposed around an outer side of each of the two teeth and an outer winding being disposed around an outside of the two teeth provided with the inner windings, thereby uniting the two teeth,

wherein a number of coil turns of the outer winding is equal to a number of coil turns of the inner winding, and

wherein an n number of electromagnetic coils are arranged on each wide side of a mold,

where n is a natural number greater than or equal to 2, and a core of a magnetic material formed from the yoke and the teeth is disposed in a range extending in a vertical direction from a position of the meniscus of molten steel and including the outlet port of the immersion nozzle. 5

2. An electromagnetic coil system for in-mold molten steel serving both as an electromagnetic stirrer and as an electromagnetic brake for use in continuous casting of steel by selectively applying electromagnetic stirring and electromagnetic braking on molten steel in a mold by applying a direct current or at least a 3-phase alternating current to an electromagnetic coil disposed around a wide side of a mold, 10 15 the electromagnetic coil system comprising:

an electromagnetic coil, and at least a 3-phase alternating current source and a direct current source, 20 the electromagnetic coil being provided with two teeth extending from a yoke, and an inner winding being disposed around the outer side of each of the two teeth and an outer winding being disposed around an outside of the two teeth provided with the inner windings, 25 thereby uniting the two teeth, wherein a number of coil turns of the outer winding is greater than or equal to 2.5 times a number of coil turns of the inner winding, and 30 wherein an n number of electromagnetic coils are arranged on each wide side of a mold, where n is a natural number greater than or equal to 2, and a core of a magnetic material formed from the yoke and the teeth is disposed in a range extending in a vertical direction from a position of the meniscus of molten steel and including an outlet port of the immersion nozzle. 35

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Fig.1

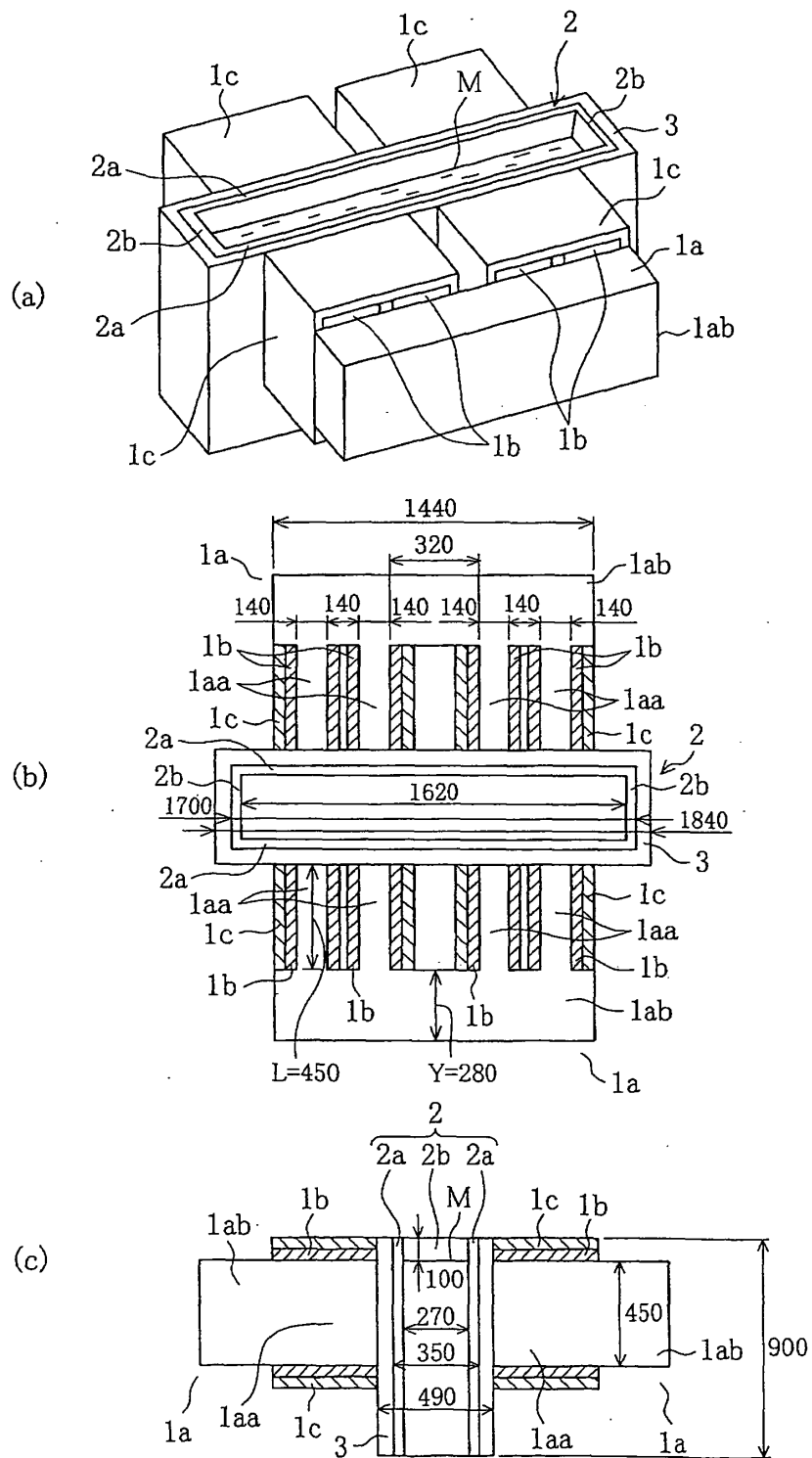


Fig. 2

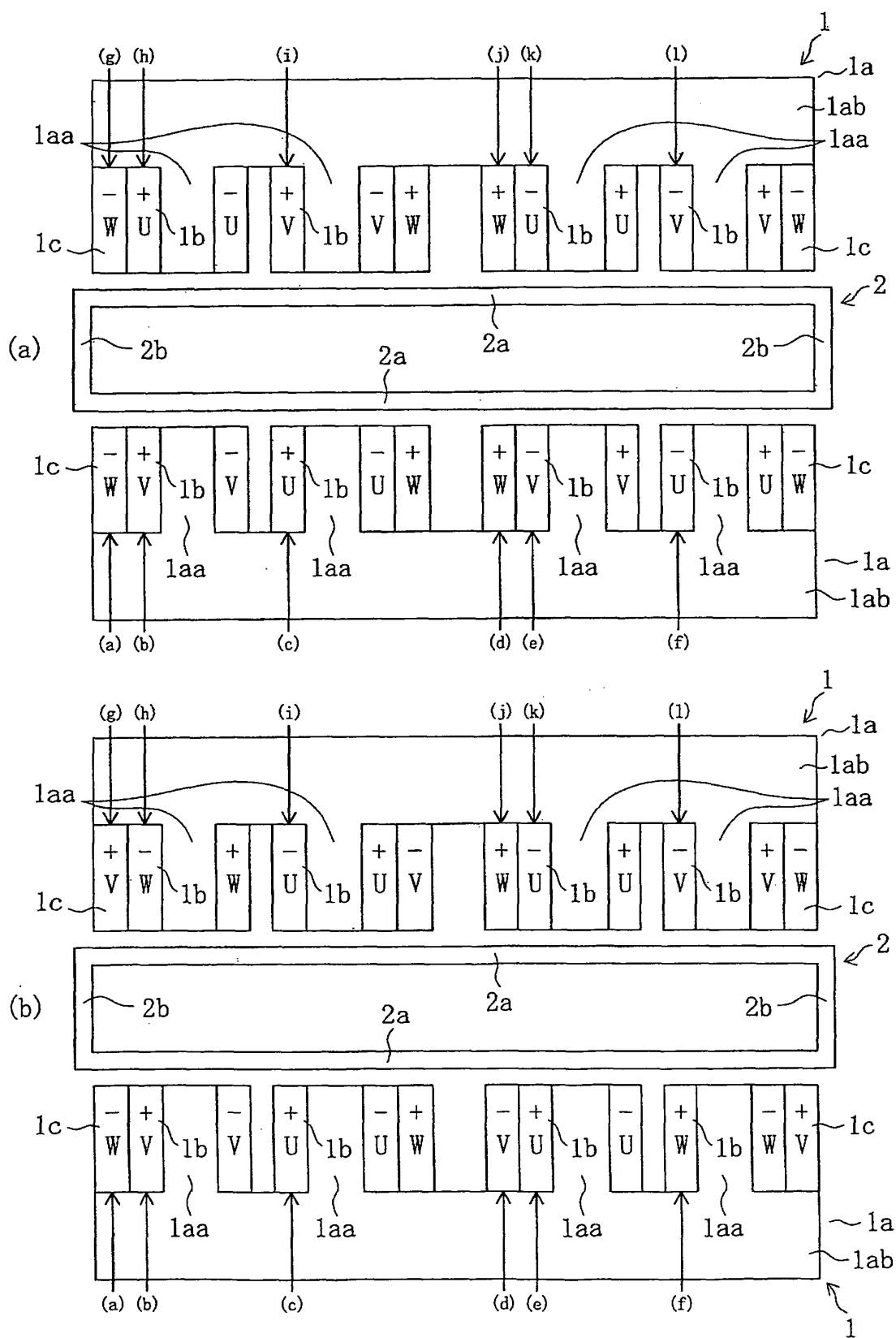


Fig.3

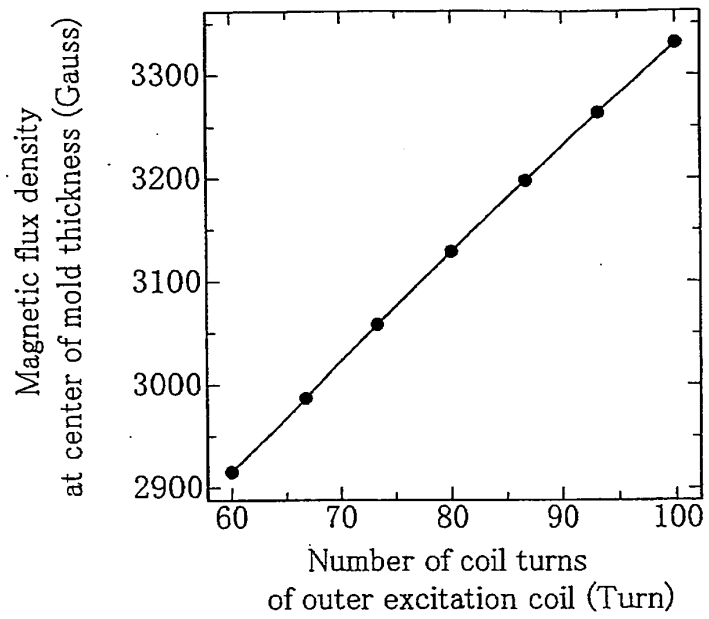


Fig.4

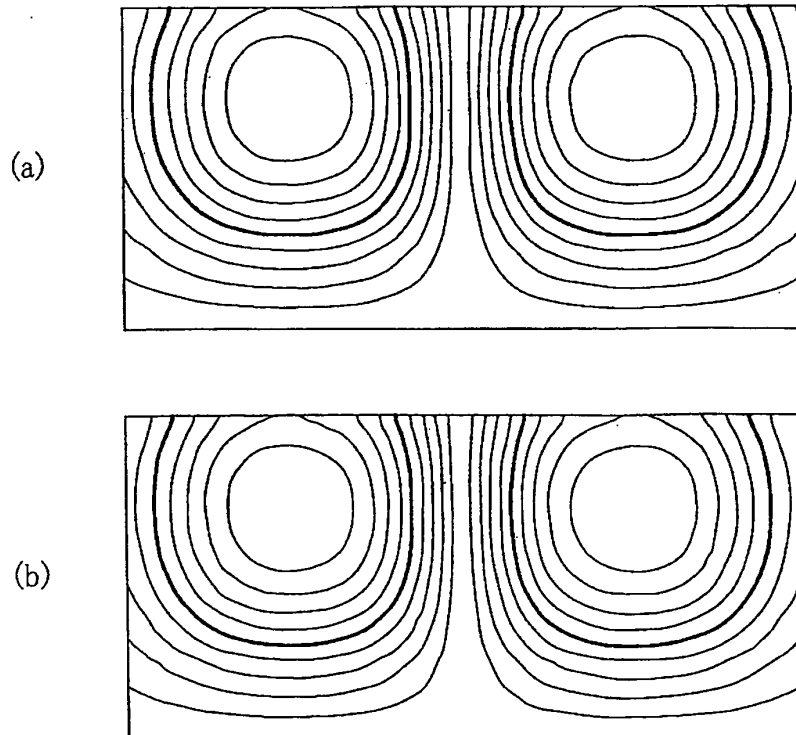


Fig5

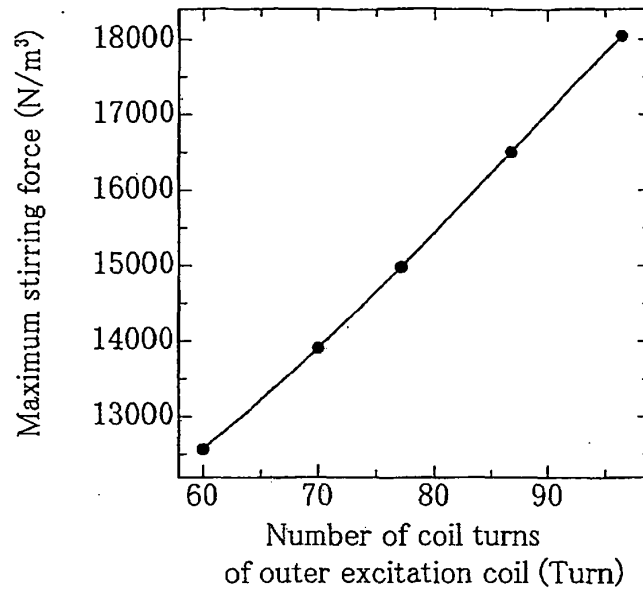


Fig6

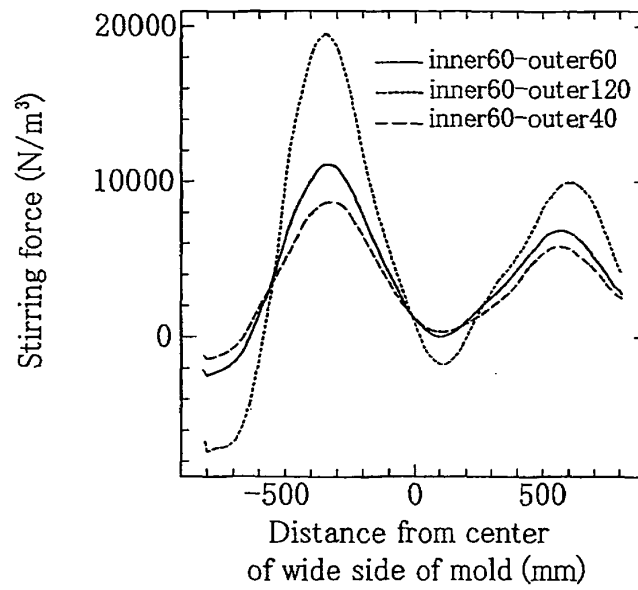


Fig7

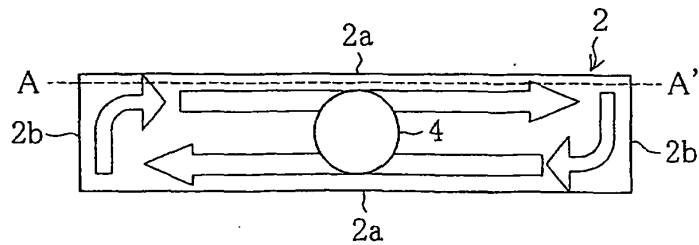


Fig.8

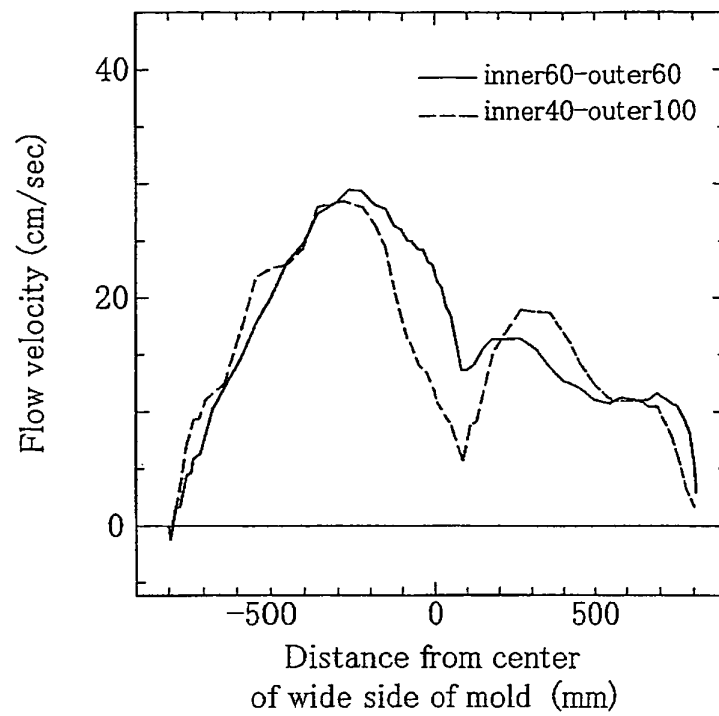


Fig.9

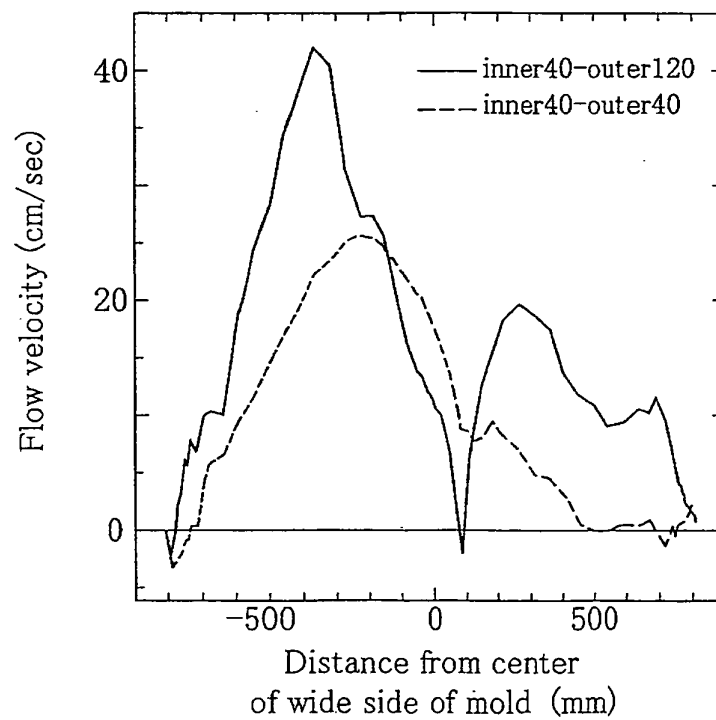
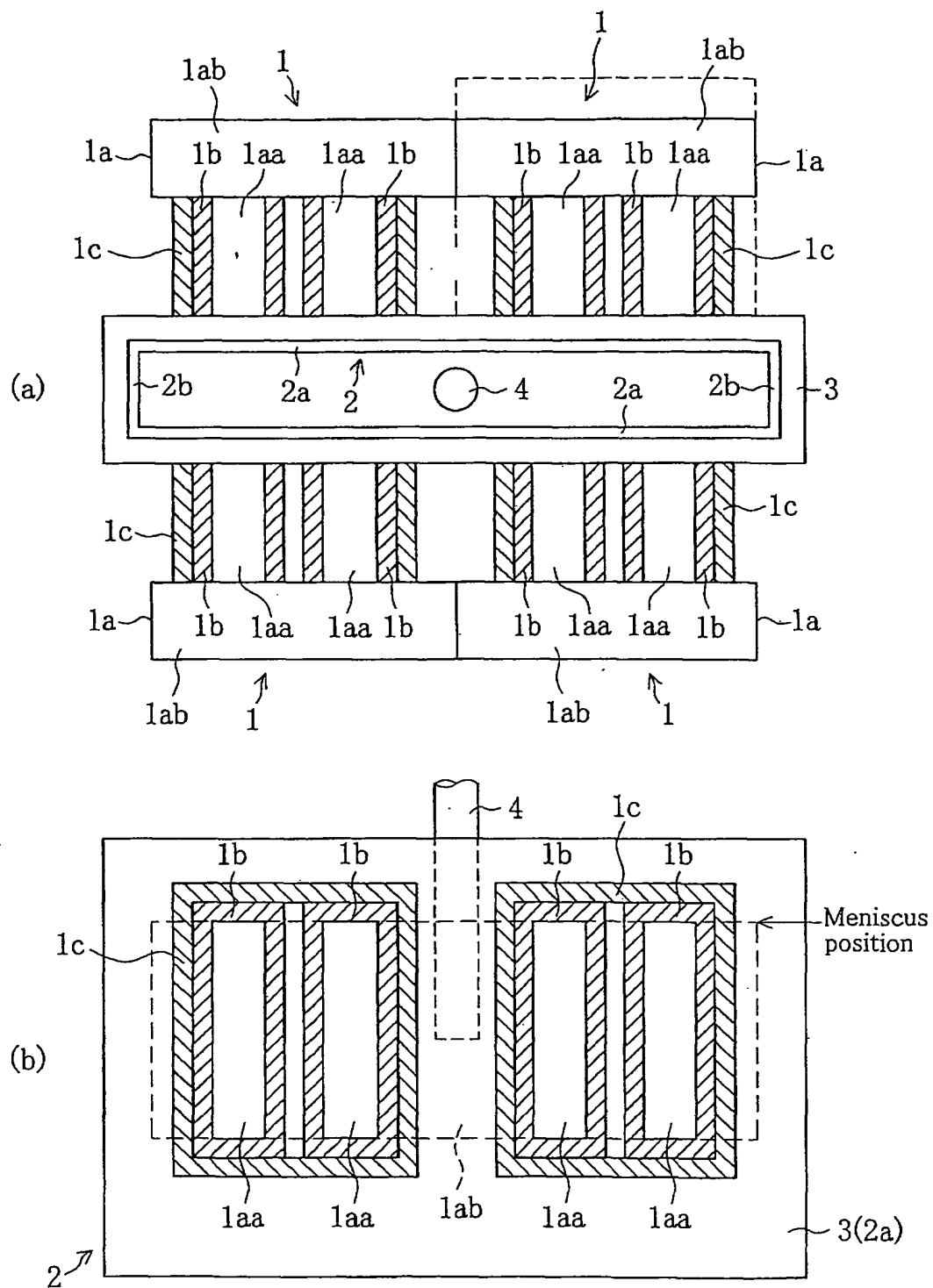


Fig.10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/068486

A. CLASSIFICATION OF SUBJECT MATTER <i>B22D11/04</i> (2006.01) i, <i>B22D11/11</i> (2006.01) i, <i>B22D11/115</i> (2006.01) i, <i>H01F5/00</i> (2006.01) i, <i>H01F7/20</i> (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) <i>B22D11/04</i> , <i>B22D11/11</i> , <i>B22D11/115</i> , <i>H01F5/00</i> , <i>H01F7/20</i> 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 1996-2008 Kokai Jitsuyo Shinan Koho 1971-2008 Toroku Jitsuyo Shinan Koho 1994-2008 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.
A	JP 2007-007719 A (Sumitomo Metal Industries, Ltd.), 18 January, 2007 (18.01.07), (Family: none)	1-2
A	JP 2001-009559 A (Kawasaki Steel Corp.), 16 January, 2001 (16.01.01), (Family: none)	1-2
A	JP 2000-000648 A (Kawasaki Steel Corp.), 07 January, 2000 (07.01.00), (Family: none)	1-2
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "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 14 November, 2008 (14.11.08)		Date of mailing of the international search report 25 November, 2008 (25.11.08)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2007007719 A [0006]
- JP S60044157 B [0007]
- JP 2007150627 A [0014] [0027]