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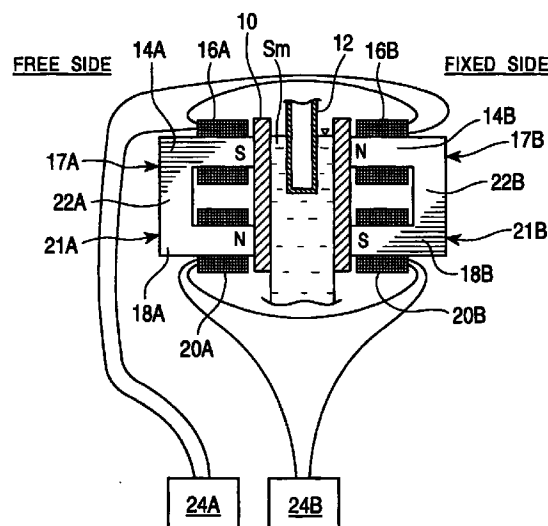
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(54) **ELECTROMAGNETIC BRAKING DEVICE FOR CONTINUOUS CASTING MOLD AND METHOD OF CONTINUOUS CASTING BY USING THE SAME**

(57) In a magnetic brake apparatus for a continuous casting mold having a pair of first and second upper electromagnets 17A and 17B which are oppositely placed near the rear faces of the opposing side walls of the continuous casting mold 10, and a pair of first and second lower electromagnets 21A and 21B which are oppositely placed thereunder, a static magnetic field being generated between each pair of electromagnets to stem the stream of the molten steel supplied to the casting mold by the static magnetic field, the apparatus has controlling units which independently control a current supplied to magnetic coils 16A and 16B being constituents of the first and second upper electromagnets and a current supplied to magnetic coils 20A and 20B being constituents of the first and second lower electromagnets.

The intensity of the magnetic field between the magnetic poles of the upper and lower electromagnets can, thereby, be readily and inexpensively varied during casting without restriction.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to magnetic or solenoid brake apparatuses for continuous casting molds and continuous casting methods using the same. The present invention particularly relates to a magnetic brake apparatus for a continuous casting mold which is suitably applied when a static magnetic field is generated in molten steel in a mold used in continuous casting to control the flow of the molten steel, and to a continuous casting method using the same.

Background Art

[0002] In general, in continuous casting of slabs, molten steel reserved in a tundish is introduced into a continuous casting mold via a sub-entry nozzle connected to the bottom of the tundish, although no drawing is shown. In this case, the flow rate of the molten steel discharged from the discharging opening of the sub-entry nozzle is significantly higher than the casting rate. Thus, when inclusions or/and bubbles in the molten steel are deeply penetrated and captured by solidified shells, these inevitably cause defects of the product. When the upward flow is dominant in the jet stream of the molten steel, the rise of the mold meniscus promotes fluctuation of the melt surface, resulting in adverse effects on the slab quality and casting operation.

[0003] In order to avoid such a problem, for example, Japanese Patent Laid-Open No. 3-142049 discloses a continuous casting technology for preventing the occurrence of the above-mentioned problem, in which a static magnetic field is applied to the molten steel in the casting mold to brake the flow of the molten steel in the casting mold.

[0004] Fig. 6A is a cross-sectional view of a main portion of a casting apparatus disclosed in the above-mentioned patent, and Fig. 6B is an enlarged longitudinal cross-sectional view of a part of Fig. 6A. In the drawings, numeral 101 represents a continuous casting mold comprising a pair of short side walls 101A and a pair of long side walls 101B, its inside being cooled by water. Numeral 102 represents a sub-entry nozzle for supplying the molten steel from a tundish (not shown in the drawing) to the casting mold 101. Numerals 103A and 103B represent iron core bodies for forming a magnetic path. Numerals 104A, 104B, 105A and 105B represent upper and lower magnetic poles (iron cores) which are connected to the iron core bodies 103A and 103B and extend along the width direction of the casting mold 101. Numeral 106 represents a magnetic field controlling means for controlling the intensity of the static magnetic field generated between the magnetic poles. The magnetic field controlling means 106 comprises a bracket 107 fixed to a support, a bracket 108 fixed to the iron core body 103B, a pivot pin connecting the two

brackets 107 and 108, and a hydraulic cylinder 110 fixed to the support in which the tip of the rod is engaged with the iron core body. Numeral 102B in the drawings represents a discharging opening of the sub-entry nozzle 102.

[0005] When the upper magnetic pole 104A at the left or A side in Fig. 6A is an N pole and the upper magnetic pole 104B at the B side is an S pole in the continuous casting mold 101, an A-to-B magnetic field is generated in the upper magnetic pole whereas a B-to-A magnetic field is generated in the lower magnetic pole. When molten steel is supplied into such a magnetic field, the upward flow is decelerated by the upper magnetic field while the downward flow is decelerated by the lower magnetic field. When the intensity of the static magnetic field is modified between the upper magnetic pole and the lower magnetic pole in the casting mold 101, the hydraulic cylinder 110 is operated by the magnetic field controlling means 106 so that the iron core body rotates around the pivot pin 109 to change the inter-pole distance of the upper magnetic poles.

Disclosure of the Invention

[0006] In the technology disclosed in the above-mentioned patent, a position sensor for exactly adjusting the distance, in addition to the hydraulic cylinder 110 and the pivot pin 109, is required. Thus, a wide space and many devices are required for a facility for adjusting the intensity of the static magnetic field. The patent also discloses another method for adjusting the magnetic field in which a nonmagnetic material is inserted in a part of the iron core. This method, however, has disadvantages, that is, the type, width of the slab and the intensity of the magnetic field in response to the casting speed cannot be changed without limitation in the casting process. Since exchange of the nonmagnetic material requires long periods of time, operation efficiency is significantly low.

[0007] The present invention has been accomplished for solving these problems, and it is a first object to provide a technology which can readily change the intensity of the magnetic field during casting without expensiveness and limitation.

[0008] It is a second object of the present invention to produce a high-quality cast product by achieving the first object.

Brief Description of the Drawings

[0009]

Fig. 1 is a cross-sectional view of a main portion which illustrates an outlined configuration of an embodiment in accordance with the present invention.

Fig. 2 is a schematic view of a combination of poles of magnetic fields.

Fig. 3 is a line graph illustrating the quality of a slab prepared in an example.

Fig. 4 is another line graph illustrating the quality of a slab prepared in an example.

Fig. 5 is a cross-sectional view of a main portion which illustrates an outlined configuration of another embodiment in accordance with the present invention.

Fig. 6 is an outlined cross-sectional view of a conventional casting mold.

Fig. 7 is a cross-sectional view of a main portion which illustrates an outlined configuration of another embodiment in accordance with the present invention.

Fig. 8 is a schematic view of another combination of poles of magnetic fields.

Fig. 9 is a schematic view of another combination of poles of magnetic fields.

(Reference Numerals)

[0010]

10	continuous casting mold
12	sub-entry nozzle
14A	upper iron core at the free side
14B	upper iron core at the fixed side
16A	upper coil at the free side
16B	upper coil at the fixed side
17A	first upper electromagnet
17B	second upper electromagnet
18A	lower iron core at the free side
18B	lower iron core at the fixed side
20A	lower coil at the free side
20B	lower coil at the fixed side
21A	first lower electromagnet
21B	second lower electromagnet
22A	connecting iron core
22B	connecting iron core
24A	current controlling unit
24B	current controlling unit
24C	current controlling unit
24D	current controlling unit
Sm	molten steel

Best Mode for Carrying Out the Invention

[0011] The embodiments of the present invention will now be described in detail with reference to the drawings.

[0012] Figs. 1 and 7 are cross-sectional views of a main portion illustrating outlined configurations of embodiments in accordance with the present invention. The magnetic brake apparatus in these embodiments in accordance with the present invention is applied to a continuous casting mold shown by reference numeral 10 in the drawings. The continuous casting mold 10 is substantially the same as that shown in Fig. 6. Cooling

water circulates through the interior of the side wall, and molten steel Sm is supplied to the continuous casting mold 10 through a discharging opening (not shown in the drawings) of a sub-entry nozzle 12. The magnetic brake apparatus in these embodiments has a first upper electromagnet 17A comprising an upper iron core 14A which is placed near the rear face of the side wall of the continuous casting mold 10 at the free side (the left side in the drawings) and lies slightly above the discharging opening of the sub-entry nozzle 12, and an upper magnetic coil 16A wound around the electromagnet; and a second upper electromagnet 17B at the fixed side (the right side in the drawings) in the position of the same height comprising an upper iron core 14B and an upper magnetic coil 16B. The first and second upper electromagnets 17A and 17B are oppositely placed with the continuous casting mold 10 intervening therebetween.

[0013] In Fig. 1, a first lower electromagnet 21A at the free side comprising a lower iron core 18A and a lower magnetic coil 20A, and a second lower electromagnet 21B at the fixed side comprising a lower iron core 18B and a lower magnetic coil 20B are provided below the upper electromagnet. These two electromagnets 21A and 21B are also oppositely placed. The upper iron cores 14A and 14B and the lower iron cores 18A and 18B are integrally formed with connecting iron cores 22A and 22B provided therebetween, and are magnetically connected to each other. In this embodiment, a current is supplied to these two upper magnetic coils 16A and 16B being constituents of the first and second upper electromagnets through an upper current controlling unit 24A, and independently, a current is supplied to these two lower magnetic coils 20A and 20B being constituents of the first and second lower electromagnets through a lower current controlling unit 24B. These currents are independently controllable.

[0014] That is, a current of a given ampere is applied to the two upper magnetic coils 16A and 16B, whereas a current of another ampere is applied to the two lower magnetic coils 20A and 20B. The intensities of the static magnetic fields between the upper electromagnets 17A and 17B and between the lower electromagnets 21A and 21B are independently adjustable.

[0015] In Fig. 7, a first lower electromagnet 21A at the free side comprising a lower iron core 18A and a lower magnetic coil 20A and a second lower electromagnet 21B at the fixed side comprising a lower iron core 18B and a lower magnetic coil 20B are provided below the upper electromagnets. These two electromagnets are also oppositely placed. The upper iron cores 14A and 14B and the lower iron cores 18A and 18B are integrally formed with connecting iron cores 22A and 22B provided therebetween and are magnetically connected to each other. Different currents are independently supplied to the four magnetic coils 16A, 16B, 20A and 20B through current controlling units 24A to 24D.

[0016] The operation of the embodiments will now be described.

[0017] In Fig. 1, when normal static magnetic fields are generated at the upper and lower portions, two current controlling units 24A and 24B independently control the currents for the upper electromagnets 17A and 17B and the lower electromagnets 21A and 21B. Thus, as shown in the relationship of the magnetic poles of the upper and lower electromagnets in Fig. 2, when the upper magnetic pole at the free side is an S pole, the opposing upper magnetic pole at the fixed side is an N pole, the lower magnetic pole at the free side is an N pole, and the lower magnetic pole at the fixed side is an S pole. That is, poles opposing each other across the molten steel and the upper and lower poles on the same side are different from each other. In this embodiment, in order to prevent capture of mold powder at the meniscus section of the molten steel, the upper magnetic field may be enhanced to moderate the fluctuation of the molten surface. In order to prevent penetration of non-metallic inclusions into the deep interior of the molten steel, the lower magnetic field may be lowered to suppress the downward flow of the molten steel in the casting mold. The upper and lower electromagnets can appropriately control the intensities of the magnetic fields to adequately control the flow of the molten steel depending on the purposes.

[0018] Thus, the quality of the cast slab is improved by casting while adequately controlling the intensities of the static magnetic fields by the upper and lower electromagnets in response to the width and type of the slab and the casting speed using the magnetic brake apparatus of this embodiment.

[0019] In Fig. 7, when normal static magnetic fields are generated at the upper and lower portions, the four current controlling units 24A to 24D independently control the currents for the corresponding electromagnets. Thus, as shown in the relationship of the magnetic poles of the upper and lower electromagnets in Fig. 2, poles opposing each other across the molten steel and the upper and lower poles on the same side are different from each other. In this case, the most effective results are achieved when the currents of the magnetic coils for the opposing poles are the same. In order to prevent capture of mold powder at the meniscus section of the molten steel, the upper magnetic field may be enhanced to moderate the fluctuation of the molten surface. In order to prevent penetration of nonmetallic inclusions into the deep interior of the molten steel, the lower magnetic field may be lowered to suppress the downward flow of the molten steel in the casting mold.

[0020] In conventional apparatuses, it is impossible to make the intensity of the upper or lower magnetic field zero even when the current to the magnetic coil is zero, because the upper and lower iron cores are magnetically connected to each other through the connecting iron core. In contrast, in this embodiment, the direction of the current of one magnetic coil between the two opposing electrodes is inverted by the current controlling units 24A to 24D so that the opposing magnetic

poles are the same as shown in Figs. 8 and 9. The intensity of the magnetic field thereby becomes zero.

[0021] Thus, in order to prevent inclusion of non-metallic impurities into the solid shell at the meniscus section for the purpose of securing the quality below the skin rather than capture of powder by the fluctuation of the molten surface, or in order to prevent capture of bubbles of argon gas blown into the steel so that the discharging opening of the sub-entry nozzle is not clogged, a magnetic field of zero between the upper electromagnets is effective when the flow of the molten steel is required at the meniscus section. This embodiment can readily perform such a control.

EXAMPLE)

[0022] An example of the embodiment will now be described.

[0023] Continuous casting was performed under the following conditions using a mold having a magnetic brake apparatus in accordance with the embodiment shown in Fig. 1 or 7 to produce a cast slab of low-carbon aluminum-killed steel. Its surface and internal quality was examined. Fig. 3 shows the results when the intensity of the lower magnetic field was fixed to 2,400 gauss while the intensity of the upper magnetic field was varied. On the other hand, Fig. 4 shows the results when the intensity of the upper magnetic field was fixed to 2,500 gauss.

[Casting Conditions]

[0024]

Casting speed:
2.5 m/min
Width of slab:
1,400 mm
Thickness of slab
220 mm
Intensity of lower magnetic field:
2,000 to 3,000 gauss
Intensity of upper magnetic field:
2,000 to 3,000 gauss

[0025] The results shown in Figs. 3 and 4 illustrate that adjustment of the intensity of the magnetic field in response to the operational conditions is significantly effective.

[0026] As described above, since the flow of the molten steel can be appropriately controlled in the casting mold in this embodiment, inclusion of non-metallic impurities into the molten steel pool by the jet stream of the molten steel and capture of mold powder into the molten steel by the fluctuation of the molten surface at the meniscus section are prevented. Accordingly, a high-quality slab can be produced with high efficiency.

[0027] Another embodiment in accordance with the

present invention will now be described.

[0028] Fig. 5 is a cross-sectional view, which corresponds to Fig. 1, of an outlined configuration of a magnetic brake apparatus in accordance with the present invention. The magnetic brake apparatus in this embodiment has no connecting iron cores 22A and 22B, shown in Fig. 1, for magnetically connecting the upper and lower iron cores at the free and fixed sides, and thus upper and lower iron cores 14A, 14B, 18A and 18B are magnetically independent of each other. Other configurations are substantially the same as those in the first embodiment.

[0029] Since the upper and lower iron cores at the same side are not magnetically connected to each other in this embodiment, the input current generates a magnetic field with a lower intensity than that in the above-mentioned embodiment. Similar control can, however, be performed and the static magnetic field of either the upper or lower electromagnet can be set to be near zero.

[0030] Although the present invention has been described in detail, the present invention is not limited to the above-mentioned embodiments and includes various modifications within a scope without departing from the gist of the present invention.

Industrial Applicability

[0031] According to the present invention as described above, the intensity of the magnetic field between the magnetic poles of the upper and lower electromagnets can be readily and inexpensively varied during casting without restriction.

Claims

1. A magnetic brake apparatus for a continuous casting mold comprising: a pair of upper electromagnets oppositely placed near the rear faces of the opposing side walls of the continuous casting mold, and a pair of lower electromagnets placed thereunder;

a static magnetic field being generated between these paired electromagnets to stem the flow of the molten steel supplied to the continuous casting mold by means of the static magnetic field; wherein the magnetic brake apparatus further comprises controlling means for independently controlling currents supplied to magnetic coils which are constituents of the electromagnets.

2. A magnetic brake apparatus for a continuous casting mold according to claim 1, wherein the magnetic brake apparatus has controlling means for independently controlling the current supplied to the magnetic coil being a constituent of the pair of

upper coils and the current supplied to the magnetic coil being a constituent of the pair of lower coils.

3. A magnetic brake apparatus for a continuous casting mold according to either claim 1 or 2, wherein an upper iron core and a lower iron core which are constituents of the upper electromagnet and the lower electromagnet, respectively, placed near the rear face at the same side of the opposing side walls of the casting mold are magnetically connected to each other.
4. A continuous casting method comprising continuously casting while stemming the jet stream of the molten steel supplied to the interior of the casting mold through a discharging opening of a sub-entry nozzle using a magnetic brake apparatus for a continuous casting mold according to any one of claims 1 to 3.

FIG. 1

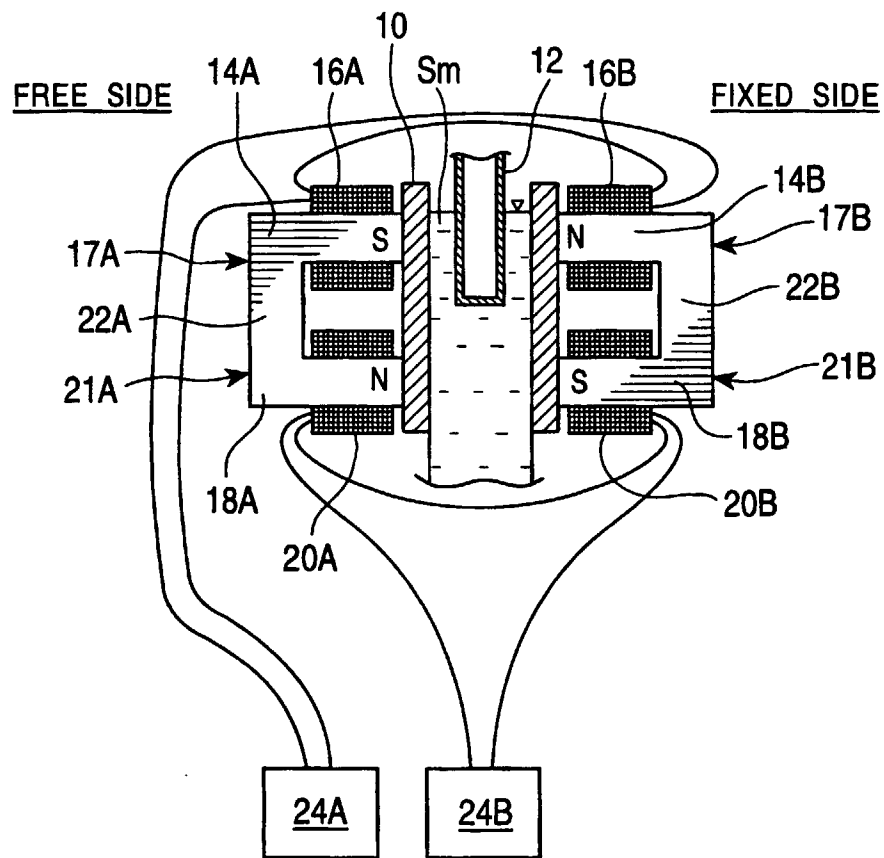


FIG. 2

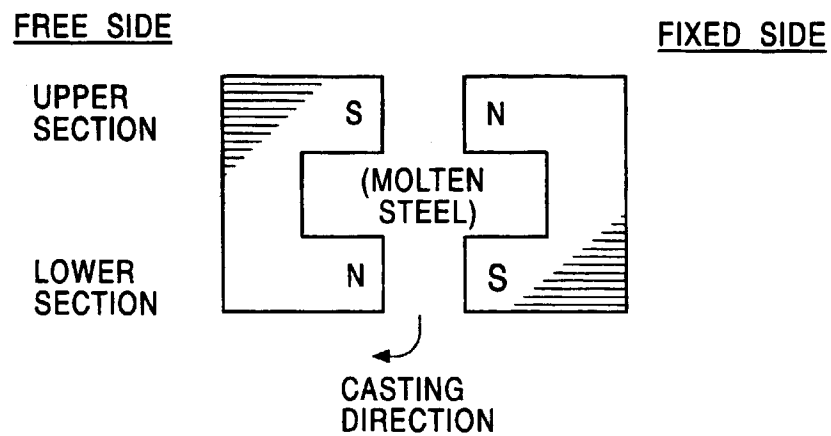


FIG. 3

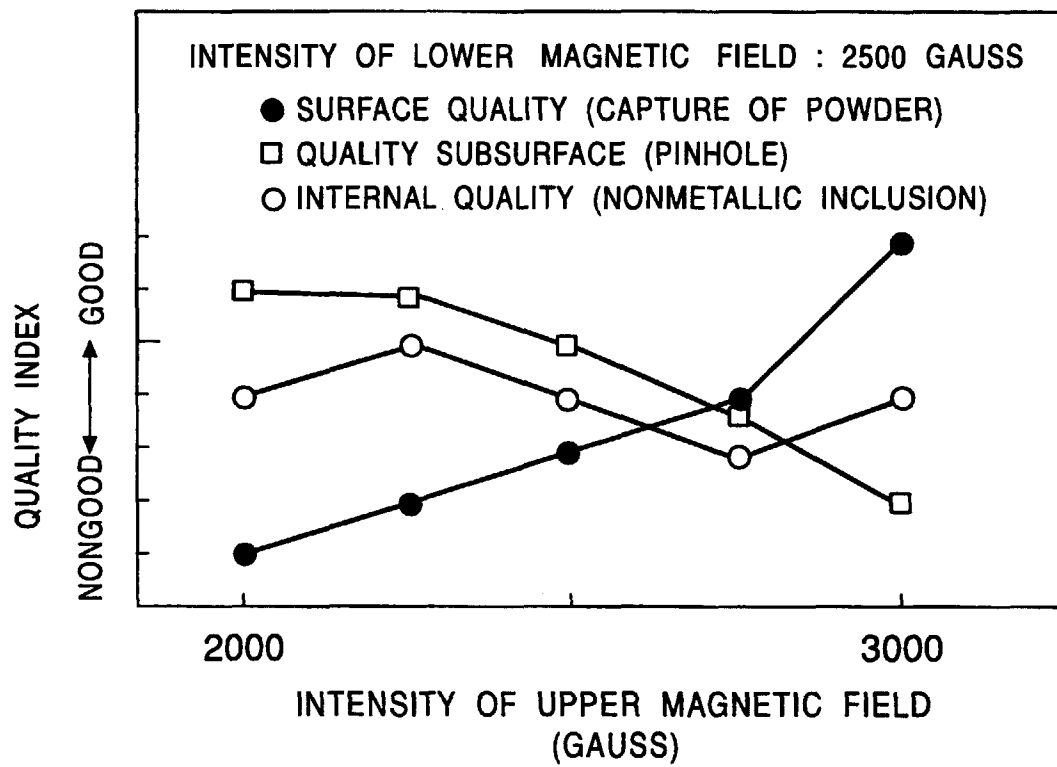


FIG. 4

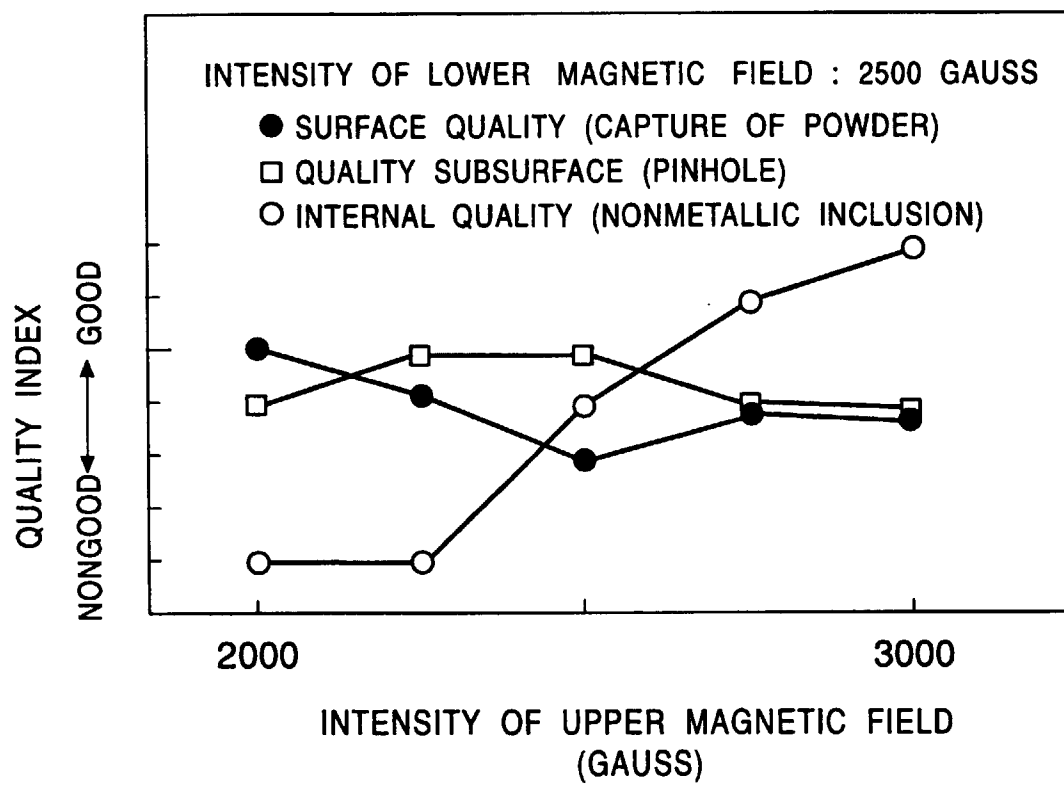


FIG. 5

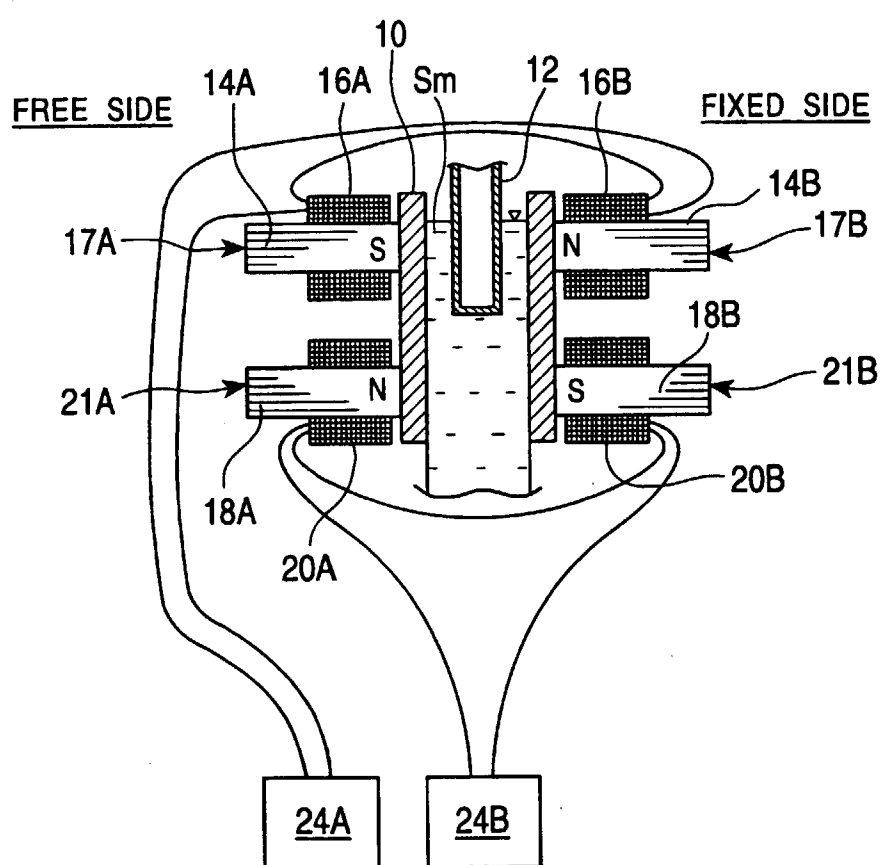


FIG. 6A

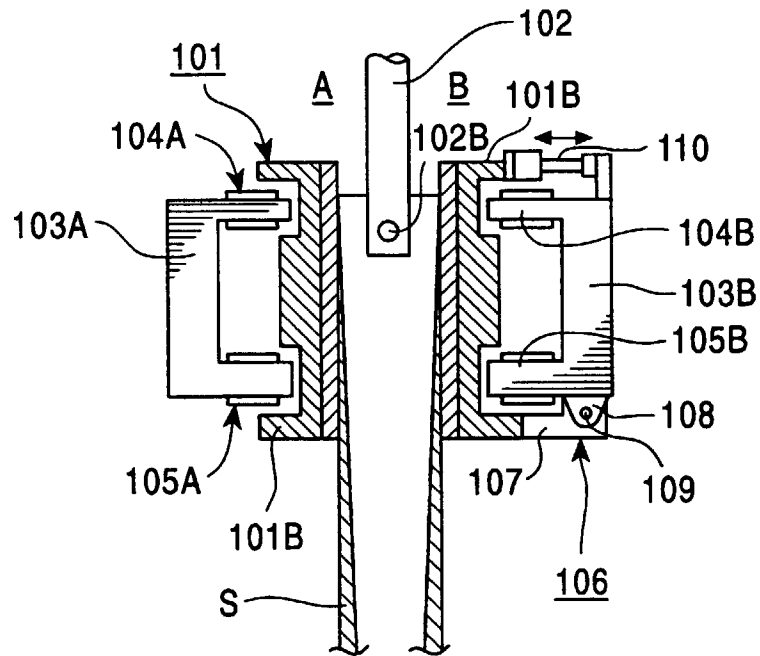


FIG. 6B

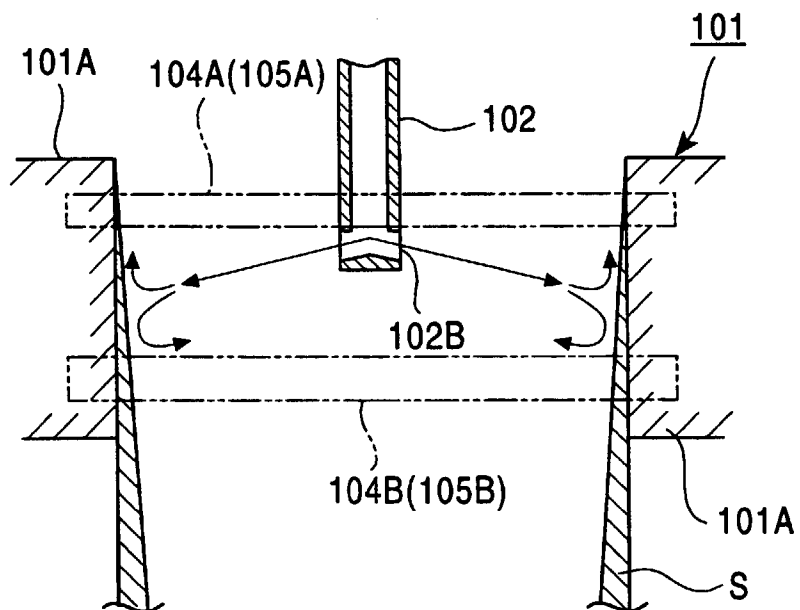


FIG. 7

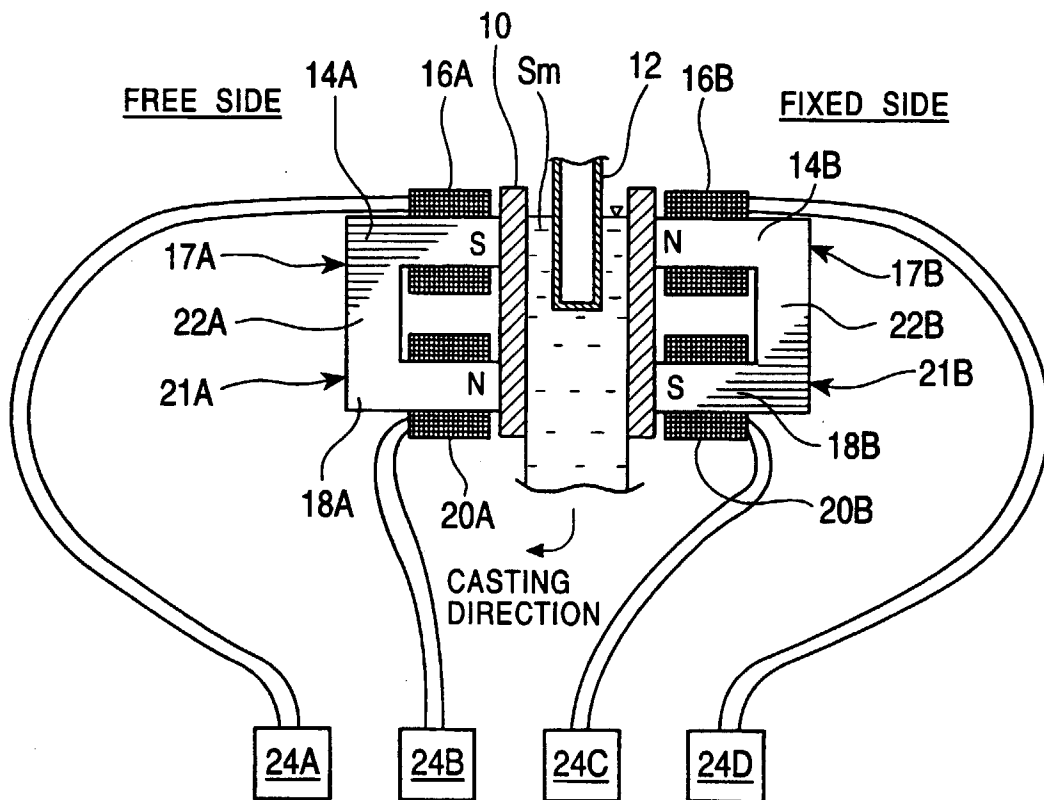


FIG. 8

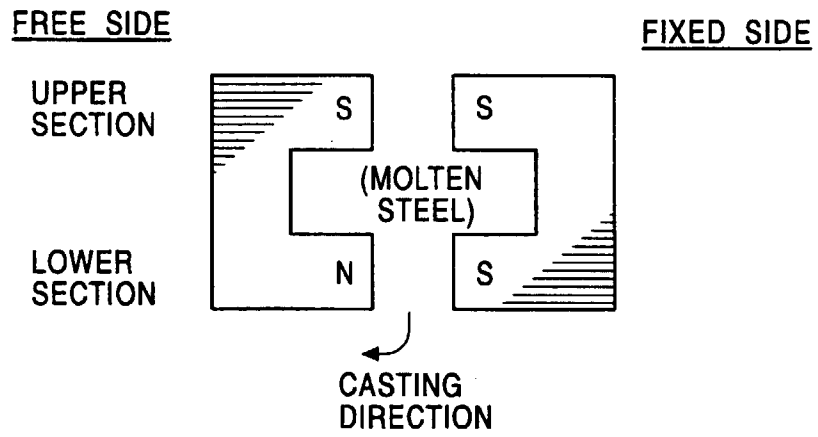
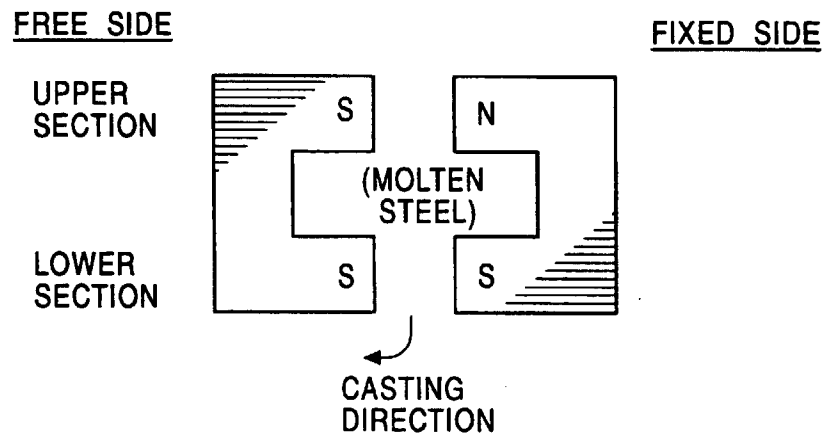


FIG. 9



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP98/02297

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl ⁶ B22D11/10		
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 ⁶ B22D11/00-11/22		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-1997 Kokai Jitsuyo Shinan Koho 1971-1997 Jitsuyo Shinan Toroku Koho 1996-1998		
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.
Y	JP, 8-10917, A (Sumitomo Metal Industries, Ltd.), January 16, 1996 (16. 01. 96), Par. Nos. [0020], [0029] ; Figs. 2, 3 (Family: none)	1-4
Y	JP, 3-142049, A (Kawasaki Steel Corp.), June 17, 1991 (17. 06. 91), Claims ; Fig. 1 & EP, 401504, A	1-4
☐ 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 August 18, 1998 (18. 08. 98)		Date of mailing of the international search report August 25, 1998 (25. 08. 98)
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