

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
3 January 2002 (03.01.2002)

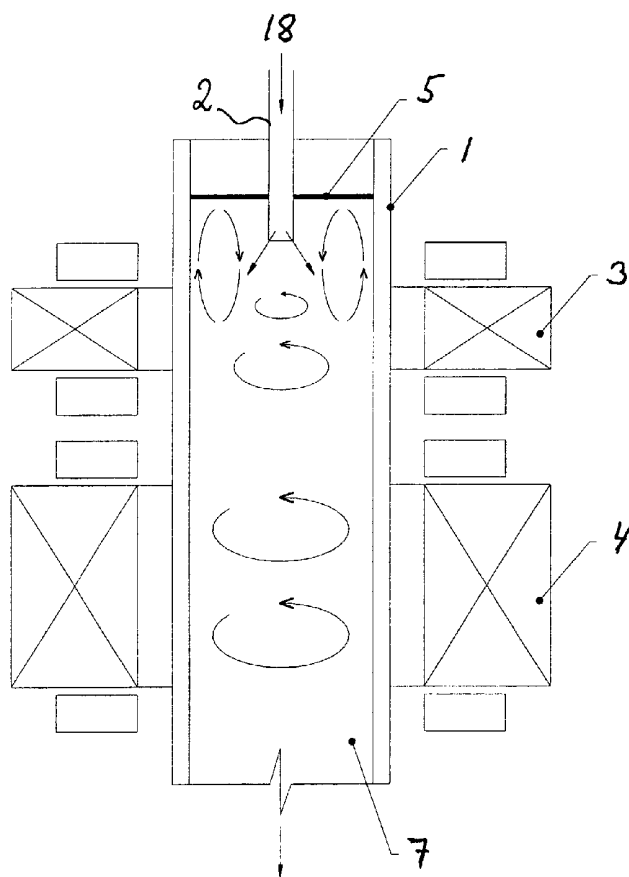
PCT

(10) International Publication Number
WO 02/00374 A1

- (51) International Patent Classification⁷: **B22D 11/115**
- (21) International Application Number: PCT/SE01/01498
- (22) International Filing Date: 27 June 2001 (27.06.2001)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
0002459-6 27 June 2000 (27.06.2000) SE
- (71) Applicant (for all designated States except US): **ABB AB**
[SE/SE]; Kopparbergsvägen 2, S-721 83 Västerås (SE).
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): **BEITELMAN, Leonid** [CA/CA]; 10 Parklawn Crescent, Thornhill, Ontario L3T 6X1 (CA).
- (74) Agents: **OLSSON, Jan** et al.; Bjerkéns Patentbyrå KB, Box 1274, S-801 37 Gävle (SE).
- (81) Designated States (*national*): AE, AG, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EC, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: METHOD AND DEVICE FOR CONTINUOUS CASTING OF METALS IN A MOLD



(57) Abstract: A device for continuous or semi-continuous casting of metals, comprising a casting mold (1) which is open in both ends in the casting direction, means (2) for supplying melt to the mold (1), a first electromagnetic induction coil (4) energized by A.C. current and adapted to induce a stirring motion to the melt (7) in the mold (1), and a second electromagnetic induction coil (3) arranged upstream of the first induction coil (4) and adapted to control the stirring motion of the melt in the region adjacent to the upper free surface (5) of the melt. The second induction coil (3) is arranged to be interchangeably energized by either D.C. or A.C. current. The invention also relates to methods for control of stirring motion in a casting mold (1).



WO 02/00374 A1



Published:

— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Method and device for continuous casting of metals in a mold

5 FIELD OF INVENTION

The present invention relates to a method and a device for continuous or semi-continuous casting of metals and alloys, e.g. steel, in a casting mold which is open in both ends in the casting
10 direction.

BACKGROUND OF INVENTION

Stirring of liquid steel in a continuous casting mold by means of
15 an externally applied low-frequency A.C. electromagnetic field is a well-established practice in continuous casting steel operations. Electromagnetic stirring, commonly known as EMS, is broadly employed in continuous casting of steel in order to improve quality of the as-cast product and process productivity. It
20 was established that control of stirring motion in the region closely adjacent to the melt free surface, commonly termed meniscus, is required to meet the conditions of different casting practices. Thus a certain intensity stirring motion in the meniscus region is necessary in order to control surface and subsurface porosity, subsurface inclusions and other defects in billets
25 and blooms produced from mainly Si-Mn deoxidized steel. The other casting practice, known as the submerged pouring under the mold powder, requires meniscus stability, and therefore it imposes restrictions to stirring motion at the meniscus. Besides
30 these two opposing requirements stemmed from casting practices, the direct correlation was established between certain groups of strand defects and stirring intensity in both the meniscus region and the mold bulk. Therefore the need for control of stirring motion in those regions of the casting mold has necessitated a number of techniques based on application of D.C. or
35 A.C. electromagnetic fields. Thus control of stirring motion in the

meniscus region of the mold by means of a horizontal D.C. magnetic field was described in the U.S. Patent No. 4,933,005. According to this patent, an externally applied D.C. magnetic field interacts with the stirring flow in the meniscus region
5 originated by the main stirrer. An electromagnetic force results from this interaction and this force opposes liquid metal motion, thereby reducing the velocity of that motion. This method of stirring velocity control has limitations. Within the configuration common for the equipment used for continuous casting of billets
10 and blooms, dimensions of the braking coil is restricted, as a result strength of D.C. magnetic field produced by the brake is sufficient only for reduction of stirring velocity at the meniscus up to 50 to 60 percent of the velocity original value.

15 Another known method in prior art with the objective to control stirring motion in the meniscus region is a dual-coil EMS system operating with A.C. current and described in the U.S. Patent No. 5,699,850. According to this patent, an induction coil arranged in the upper part of the mold in the meniscus region is energized
20 from a current source independent from the current source of the main stirrer arranged in a lower portion of the mold. Thus a rotating A.C. magnetic field produced by the upper induction coil is independently controlled with respect to the magnetic field of the main stirrer. When the rotational direction of magnetic fields
25 produced by the upper and the main stirrers coincides, stirring velocity in the meniscus region increases. This velocity increase can be controlled by the current input to the upper coil. In the case of rotational directions opposing each other, the upper stirrer becomes a magnetic brake with respect to the stirring flow in
30 the meniscus region. By adjusting current of the brake, stirring velocity in the meniscus region can be controlled within a range from its original value when there is no braking action applied, to virtual zero, when magnetic torque of the brake is in balance with the angular momentum of stirring flow in the meniscus re-
35 gion.

As a downside of this method, the braking action has an effect only on the azimuthal component of the fluid flows induced by stirring or by the impact of pouring stream discharging into the mold. The longitudinal component of these flows remains unaffected by the A.C. magnetic field produced by the upper induction coil. These longitudinal fluid flows, depending on their intensity, produce a significant turbulence to the melt at the meniscus and in the region adjacent to the meniscus, therefore affecting operating conditions of casting practice and product quality.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a more flexible control of stirring velocity and melt flow, i.e. liquid metal flow, in the meniscus region of the melt in a mold of continuous casters used for the production of e.g. billets and blooms.

The object of the invention is achieved by a device having the characteristics of claim 1, a method having the characteristics of claim 7 and a method having the characteristics of claim 11.

According to the present invention, the upper induction coil, here denominated "the second induction coil", of a dual-coil stirring system is energized either by D.C. or A.C. current depending on the desired effect on the stirring motion of the melt in the region adjacent to the upper free surface of the melt, whereas the main induction coil, here denominated "the first induction coil", is always operating as a stirrer energized A.C. current, i.e. producing an A.C. magnetic field.

The second induction coil is preferably energized by A.C. current from an independent source with respect to the main stirrer, i.e. with respect to the first induction coil. When the stirring system is used with the casting utilizing metering nozzle and there is a need to enhance the stirring motion in the meniscus

region, the upper induction coil operates in the mode of assisting to the main stirrer. A.C. current is also used to energize the upper induction coil when a full or nearly full reduction of stirring velocity at the meniscus is required with the submerged pour casting practice.

A partial reduction of stirring velocity at the meniscus can be achieved by applying horizontal DC magnetic field. Such a partial braking action is required with the casting utilizing either metering nozzle or submerged entry nozzle and stirring velocity at the meniscus is needed to be controlled within a range of up to 60 or 50 percent of its original value. In this case D.C. current is used in order to energize the upper induction coil. Experience has shown that such braking intensity is sufficient in many instances of the submerged pour casting practice and for the casting through metering nozzle. At high levels of stirring intensity, the further reduction of stirring velocity is achieved by applying an A.C. magnetic field. Switching current from A.C. to D.C. and vice versa is preferably accomplished by electronic and programming means, which constitute a part of the system power supply. Fluid flows in the meniscus region arising from stirring produced by the main stirrer, discharging stream of liquid metal, and/or movement of the mold will interact with the horizontal D.C. magnetic field produced by the upper induction coil. As a result of the interaction between the horizontal D.C. magnetic field and the fluid flows crossing the magnetic field at any angle different from 0 degrees, magnetic forces will arise and impede motion of these flows. The maximum interaction is reached at a 90 degree angle between the magnetic field and fluid flow. As a result, velocity of stirring motion and longitudinal flows, including discharging straight down pouring stream, will be reduced. Turbulence in the meniscus will thus be reduced, resulting in improved meniscus stability, process operating conditions and cast product quality.

Thus considering interchangeability of A.C. and D.C. magnetic

fields which are provided by a single stirring system and produced by the same induction coil arranged in the meniscus region of a casting mold, this invention brings significant improvements in flexibility of controlling stirring velocity and turbulence at the meniscus and results in an increased effectiveness of metallurgical performance and efficiency of the stirring system.

The invention is a further improvement of the method and the apparatus of dual-coil stirring system. This invention is broadly applicable to all electroconductive materials, i.e. metals and alloys, which can be stirred electromagnetically and where control of stirring motion is required within some region or regions with minimal if any at interference with stirring motion of other regions of the liquid metal columns. The invention is applicable to a wide variety of special orientations of casting mold. The mold can be arranged vertically, horizontally or inclined.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be explained in more detail with reference to different embodiments, disclosed by way of example only, and with reference to the figures attached.

Fig 1 discloses schematically a dual-coil stirring system with respect to a casting mold in accordance with one embodiment of the invention;

Fig. 2 is a single-line diagram of possible electrical connections for the induction coils of a device according to an embodiment of the invention,

Fig. 3 is a graphical representation of the relationship between current of a DC magnetic brake and stirring velocity at the meniscus and in the mid-plane of an electromagnetic stirrer in a column of mercury, and

Fig. 4 is a graphic representation of the axial profiles of measured stirring velocity in a mercury pool of square cross section for a dual-coil EMS system operating with and without an A.C. and D.C. magnetic field brake.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Fig 1 discloses a device for continuous or semi-continuous casting of metals according to an embodiment of the invention. The device comprises a casting mold 1, which is open in both ends in the casting direction, and means 2 for supplying hot melt 7 to the mold. The device is provided with a dual-coil electromagnetic stirring (EMS) system, comprising a first induction coil 4 and a second induction coil 3. The second induction coil 3 is arranged at the top end of the mold, upstream of the first induction coil 4. Consequently, the first induction coil 4 is arranged downstream of the second induction coil 3. The first induction coil 4 is operating as a stirrer and is energized by A.C. current producing an A.C. magnetic field. The first induction coil 4 constitutes an A.C. electromagnetic stirrer and is designed, when energized, to induce a rotary motion about the longitudinal axle of the mold 1 to the molten metal 7 within the mold 1. In Fig 1 the melt is supplied to the mold by means of a casting tube 2 which opens out below the upper surface of the melt, the meniscus 5. It is of course also possible to utilize other types of means for supplying melt to the mold 1.

According to the invention, the second induction coil 3 is interchangeably energized by either D.C. or A.C. current depending on the desired effect on the stirring motion of the melt in the region adjacent to the upper free surface 5 of the melt. In order to control the type of current supplied to the second induction coil 3, the device is preferably provided with means 12, schematically indicated in Fig 2, for switching the current to the second induction coil 3 from A.C. to D.C. and vice

versa. Switching current from A.C. to D.C. and vice versa is preferably accomplished by electronic and programming means 12, which constitute a part of the system power supply.

5 The second induction coil 3 is preferably energized by A.C. current from an independent source with respect to the first induction coil 4. According to a preferred embodiment of the invention, a first power source 10 is provided for supplying A.C. current to the first induction coil 4, and a second power source 11
10 is provided for interchangeably supplying A.C. and D.C. current to the second induction coil 3. Said first and second power sources are schematically indicated in Fig 2. The means for switching current from A.C. to D.C. and vice versa are schematically indicated at 12 in Fig 2. Consequently, either A.C.
15 or D.C. current can be selected to energize the second coil 3. This arrangement allows for independent control of stirring actions of either of the first or the second induction coils, regardless of directional pattern of stirring produced by the first induction coil 4.

20 According to a preferred embodiment of the invention, the first induction coil 4 comprises a series of coils 8 arranged around the periphery of the casting mold 1. These coils 8 are preferably of multi-phase and multi-pole arrangement. It is also preferred
25 that the second induction coil 3 comprises a series of coils 9 arranged around the periphery of the casting mold 1. These coils 9 are preferably also of multi-phase and multi-pole arrangement.

According to an aspect of the invention, the second induction
30 coil 3 is capable of providing at least three different modes of operation, namely

- a first mode in which the second induction coil 3 is energized by A.C. current and the rotational direction of the magnetic
35 field produced by the second induction coil 3 coincides with the rotational direction of the magnetic field produced by the

- first induction coil 4, the magnetic field produced by the second induction coil 3 thereby enhancing the velocity of the stirring motion induced in the region of the melt adjacent to the upper free surface 5 of the melt by the first induction coil 4, the stirring velocity of the melt in said region being controlled by adjusting the value of the A.C. current supplied to the second induction coil 3,
- a second mode in which the second induction coil 3 is energized by A.C. current and the rotational direction of the magnetic field produced by the second induction coil 3 opposes the rotational direction of the magnetic field produced by the first induction coil 4, the magnetic field produced by the second induction coil 3 thereby reducing the velocity of the stirring motion induced in the region of the melt adjacent to the upper free surface 5 of the melt by the first induction coil 4, the stirring velocity of the melt in said region being controlled by adjusting the value of the A.C. current supplied to the second induction coil 3, and
 - a third mode in which the second induction coil 3 is energized by D.C. current so as to produce a horizontally directed D.C. magnetic field, which induces electromagnetic forces in the melt 7 opposing the direction of fluid flows, in transversal as well as longitudinal spatial planes of the mold 1, in the region of the melt adjacent to the upper free surface 5 of the melt, the magnetic field produced by the second induction coil 3 thereby reducing the velocity of the stirring motion induced in the region of the melt adjacent to the upper free surface 5 of the melt by the first induction coil 4, the velocity of longitudinal flows produced in the melt 7 by the stirring action of the first induction coil 4 as well as longitudinal flows produced by continuously discharging melt into the mold 1.
- The desired mode of operation is selected among the above-mentioned modes depending upon the casting process em-

ployed. The desired effect of the second induction coil 3 on the stirring motion of the melt in the region adjacent to the meniscus 5 varies with the type of casting process employed.

5 According to the invention, the second induction coil 3 is energized either by D.C. or A.C. current in order to produce a braking action in the mold meniscus region for improvement of stirring motion control. Also, a metallurgical effectiveness of the EMS system is achieved. Braking action performed with A.C.
10 magnetic field may control stirring velocity at the meniscus within a wide range including virtual zero velocity. The negative impact produced by the braking on stirring motion in the mold bulk is such that stirring velocity in this region can be reduced by as much as 20 percent. Providing the braking action by a
15 horizontal D.C. magnetic field can control stirring velocity in the meniscus region within the range of up to 50 percent of the velocity original value without affecting stirring motion in the mold bulk. This is sufficient for most of the requirements of the continuous casting steel practice with submerged pouring.

20 The braking action originated from the interaction between a horizontal D.C. magnetic field produced by the second induction coil 3 and rotating stirring flow in the meniscus region is mostly confined within the boundaries between the meniscus and the
25 bottom end of the magnetic brake. The stirring motion within the mold bulk produced by the main stirrer, i.e. the first induction coil 4, remains practically unaffected by the braking action in the meniscus region produced by a horizontal D.C. magnetic field.

30 The intensity of the rotational flow in the melt 7 is characterized by its rotational (angular) velocity U which, in turn, depends on the parameters of the magnetic torque and its spatial distribution within the melt, and the size and geometry of the mold cross-section. For a relatively small axisymmetrical geometry system,
35 e.g. cylindrical or square cross-section, the magnetic torque can be defined in accordance with the following expression:

$$T = 0.5 \pi f \sigma B^2 R^4 L$$

where:

- 5 T is the magnetic torque produced by a 2-phase or 3-phase A.C. magnetic field,
f is the current frequency,
 σ is the liquid metal electrical conductivity,
B is the magnetic flux density,
10 R is the stirring pool radius, and
L is the length of stirrer iron yoke.

The independent control of stirring motion at the meniscus 5 provided by the interchangeable use of A.C. or D.C. current for energizing the second induction coil 3 enables a greater flexibility and accuracy of the stirring process control as well as control of turbulence in the meniscus region caused by longitudinal fluid flows introduced by the first induction coil 4, pouring stream, indicated at 18 in Fig 1, and oscillating motion of the mold 1.

20 Reduction of fluid flow motion in both transversal and longitudinal planes by the D.C. brake, i.e. the second induction coil 4 when energized by D.C. current, occurs due to arising electromagnetic force, i.e. the Lorentz force, as a result of the interaction between D.C. magnetic field and moving electroconductive fluid flow in accordance with the following expressions:

$$F = B \times J$$

30 $J = \sigma (E + U B)$

where:

- J is the induced current density within the melt,
U is the velocity of the melt flow, and
35 E is the electric potential.

As electromagnetic force F depends on the magnitude of both magnetic flux density B and fluid flow velocity U , it is apparent that a significant increase of current is required in order to reduce fluid flow velocity to the near zero level. In many situations of the continuous casting practice such velocity reduction is not necessary. As shown in FIG. 3, stirring velocity at the meniscus of a pool of mercury was reduced from the original 7.3 rad/s to 2.7 rad/s at the D.C. current input of 250A. Linear extrapolation of velocity reduction suggests that 335A is required to reduce stirring velocity for a virtual zero level.

Stirring velocity reduction in the meniscus region by means of D.C. brake exerts also a breaking impact on stirring velocity at the mid-plane of the main EMS, i.e. the first induction coil 4, similar to the effect produced by the A.C. brake. Figures 3 and 4 show that stirring velocity at the mid-plane of the EMS was approximately 11.7 rad/s or 86% of the original value of 13.6 rad/s when stirring velocity at the meniscus was reduced by the D.C. brake to 2.7 rad/s.

The present invention provides an improved method of controlling liquid metal motion in both horizontal and longitudinal directions within the mold meniscus region. The longitudinal component of liquid metal motion induced by the main EMS and by other means, such as the pouring stream of liquid metal discharging into the mold will be minimized by employing induction coils in the form of the stirrer modifier, i.e. the second induction coil, arranged around the melt meniscus region and energized by D.C. electric current, whereas more complete control of stirring velocity, i.e. its azimuthal component, is achieved by using A.C. magnetic field produced by the stirrer modifier.

The expression "induction coil", as used in this description and the appended claims, also embraces an induction coil comprising several individual coils, as illustrated in Fig 2.

The invention is of course not in any way restricted to the preferred embodiments described above, but many possibilities to modifications thereof will be apparent to a man with ordinary skill in the art without departing from the basic idea of the invention such as defined in the appended claims.

CLAIMS

1. A device for continuous or semi-continuous casting of metals, comprising a casting mold (1) which is open in both ends in the casting direction, means (2) for supplying melt to the mold (1), a first electromagnetic induction coil (4) energized by A.C. current and adapted to induce a stirring motion to the melt (7) in the mold (1), and a second electromagnetic induction coil (3) arranged upstream of the first induction coil (4) and adapted to control the stirring motion of the melt in the region adjacent to the upper free surface (5) of the melt, **characterized** in that the second induction coil (3) is arranged to be interchangeably energized by either D.C. or A.C. current.
2. A device according to claim 1, **characterized** in that the device comprises means (12) for switching the current to the second induction coil (3) from A.C. to D.C. and vice versa.
3. A device according to claim 1 or 2, **characterized** in that a first power source (10) is provided for supplying A.C. current to the first induction coil (4), and that a second power source (11) is provided for interchangeably supplying A.C. and D.C. current to the second induction coil (3).
4. A device according to claim 3, **characterized** in that the second power source (11) is provided with electronic and programming means (12) for converting it from an A.C. current source into a D.C. current source and vice versa.
5. A device according to any of the preceding claims, **characterized** in that the second induction coil (3) comprises coils of multi-phase and multi-pole arrangement spaced peripherally around the mold (1).
6. A device according to any of the preceding claims, **characterized** in that the first induction coil (4) comprises coils of

multi-phase and multi-pole arrangement spaced peripherally around the mold (1).

7. A method for control of stirring motion in a casting mold (1) for continuous or semi-continuous casting of metals, which mold (1) is open in both ends in the casting direction, melt being supplied to the mold (1), a stirring motion being induced to the melt (7) in the mold (1) by means of a first electromagnetic induction coil (4) energized by A.C. current, the stirring motion of the melt in the region adjacent to the upper free surface (5) of the melt being controlled by means of a second electromagnetic induction coil (3) arranged upstream of the first induction coil (4), **characterized** in that the second induction coil (3) is interchangeably energized by either D.C. or A.C. current.

8. A method according to claim 7, **characterized** in that the current to the second induction coil (3) is switched from A.C. to D.C. and vice versa by switching means (12).

9. A method according to claim 7 or 8, **characterized** in that the first induction coil (4) is supplied with A.C. current from a first power source (10), and that the second induction coil (3) is interchangeably supplied with A.C. and D.C. current from a second power source (11).

10. A method according to claim 9, **characterized** in that the second power source (11) is converted from an A.C. current source into a D.C. current source and vice versa by electronic and programming means (12).

11. A method for control of stirring motion in a casting mold (1) for continuous or semi-continuous casting of metals, which mold (1) is open in both ends in the casting direction, melt being supplied to the mold (1), a stirring motion being induced to the melt (7) in the mold (1) by means of a first electromagnetic induction coil (4) energized by A.C. current, the stirring motion of the melt

in the region adjacent to the upper free surface (5) of the melt being controlled by means of a second electromagnetic induction coil (3) arranged upstream of the first induction coil (4), **characterized** in that the second induction coil (3) is
5 capable of providing three different modes of operation, namely

- 10 - a first mode in which the second induction coil (3) is energized by A.C. current and the rotational direction of the magnetic field produced by the second induction coil (3) coincides with the rotational direction of the magnetic field produced by the first induction coil (4), the magnetic field produced by the second induction coil (3) thereby enhancing the velocity of the stirring motion induced in the region of the melt adjacent to the upper free surface (5) of the melt by the first induction
15 coil (4), the stirring velocity of the melt in said region being controlled by adjusting the value of the A.C. current supplied to the second induction coil (3),
- 20 - a second mode in which the second induction coil (3) is energized by A.C. current and the rotational direction of the magnetic field produced by the second induction coil (3) opposes the rotational direction of the magnetic field produced by the first induction coil (4), the magnetic field produced by the second induction coil (3) thereby reducing the velocity of the
25 stirring motion induced in the region of the melt adjacent to the upper free surface (5) of the melt by the first induction coil (4), the stirring velocity of the melt in said region being controlled by adjusting the value of the A.C. current supplied to the second induction coil (3), and
- 30 - a third mode in which the second induction coil (3) is energized by D.C. current so as to produce a horizontally directed D.C. magnetic field, which induces electromagnetic forces in the melt (7) opposing the direction of fluid flows, in
35 transversal as well as longitudinal spatial planes of the mold (1), in the region of the melt adjacent to the upper free

- 5 surface (5) of the melt, the magnetic field produced by the second induction coil (3) thereby reducing the velocity of the stirring motion induced in the region of the melt adjacent to the upper free surface (5) of the melt by the first induction coil (4), the velocity of longitudinal flows produced in the melt (7) by the stirring action of the first induction coil (4) as well as longitudinal flows produced by continuously discharging melt into the mold (1),
- 10 the mode of operation being selected depending upon the casting process employed.
- 15 12. A method according to claim 11, **characterized** in that the first induction coil (4) is supplied with A.C. current from a first power source (10), and that the second induction coil (3) is interchangeably supplied with A.C. and D.C. current from a second power source (11).
- 20 13. A method according to claim 12, **characterized** in that the second power source (11) is converted from an A.C. current source into a D.C. current source and vice versa by electronic and programming means (12).

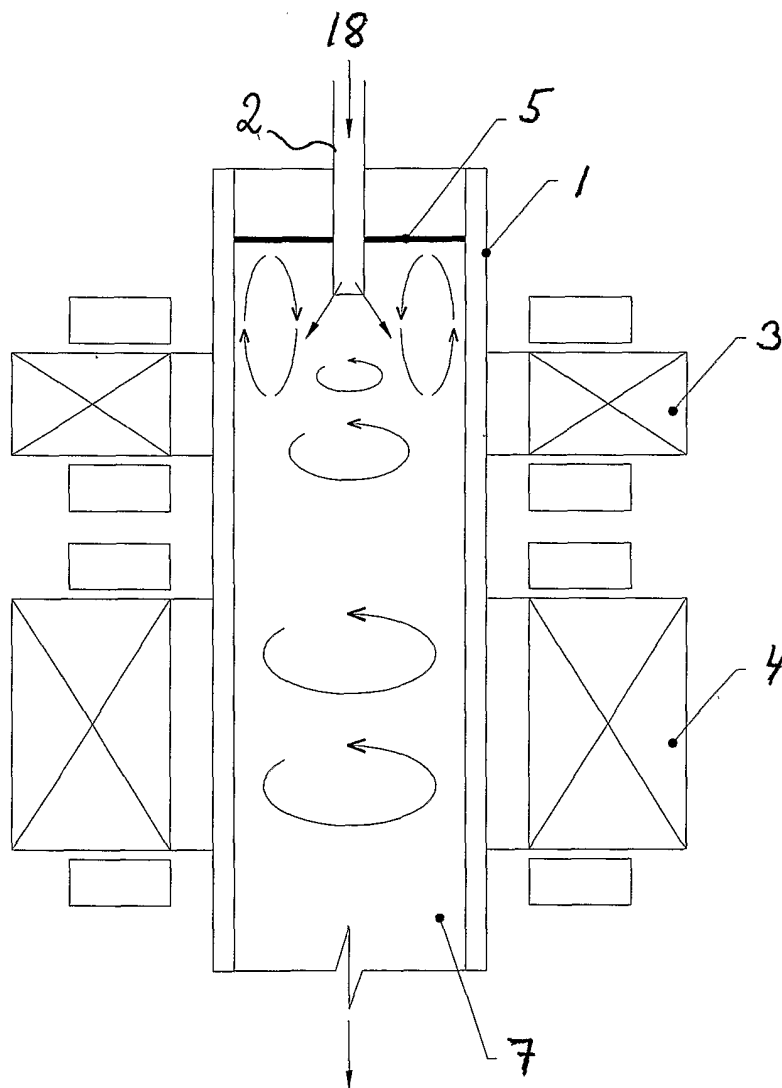


Fig. 1

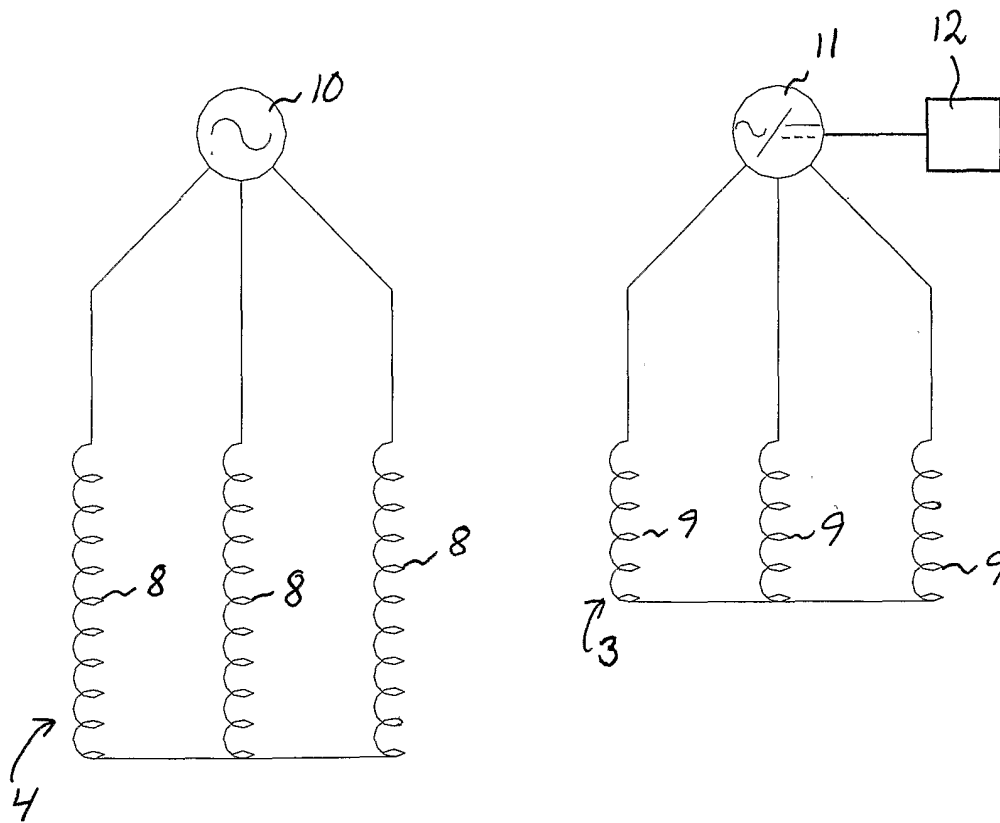


Fig. 2

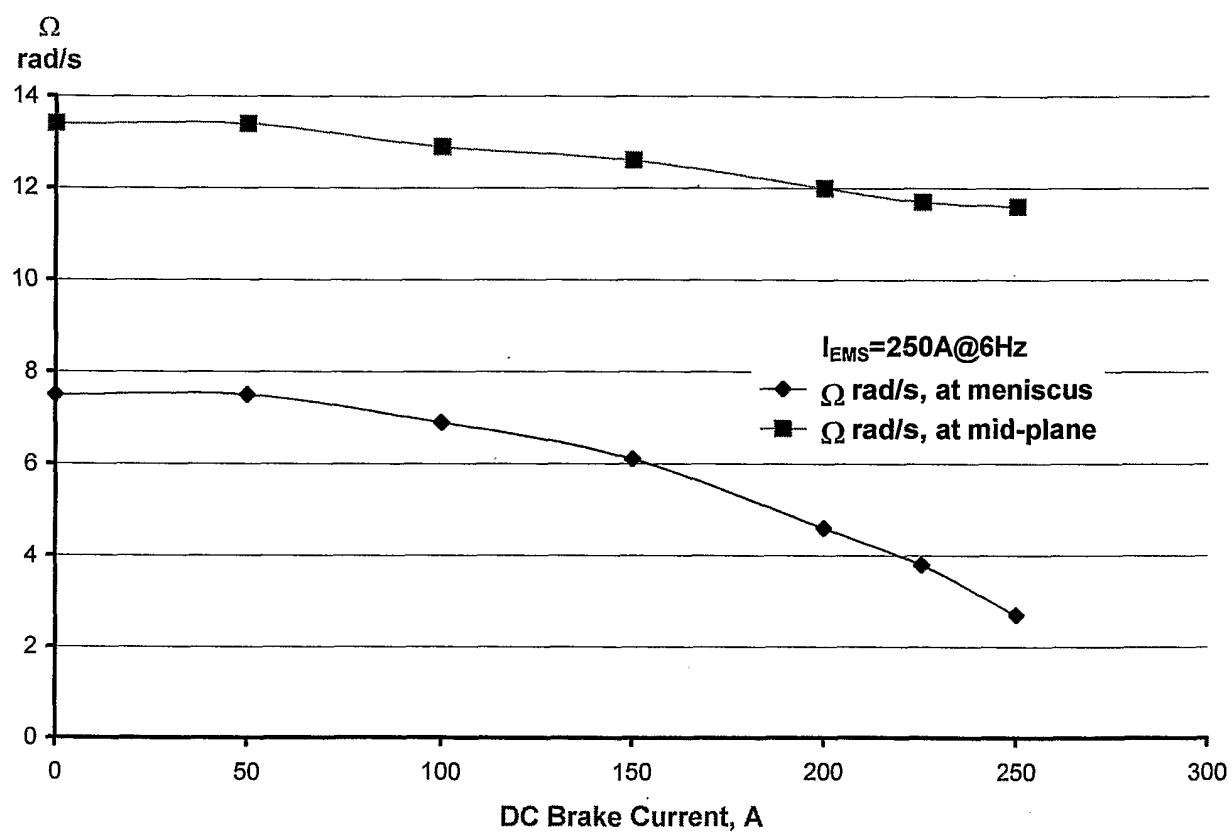


FIG. 3

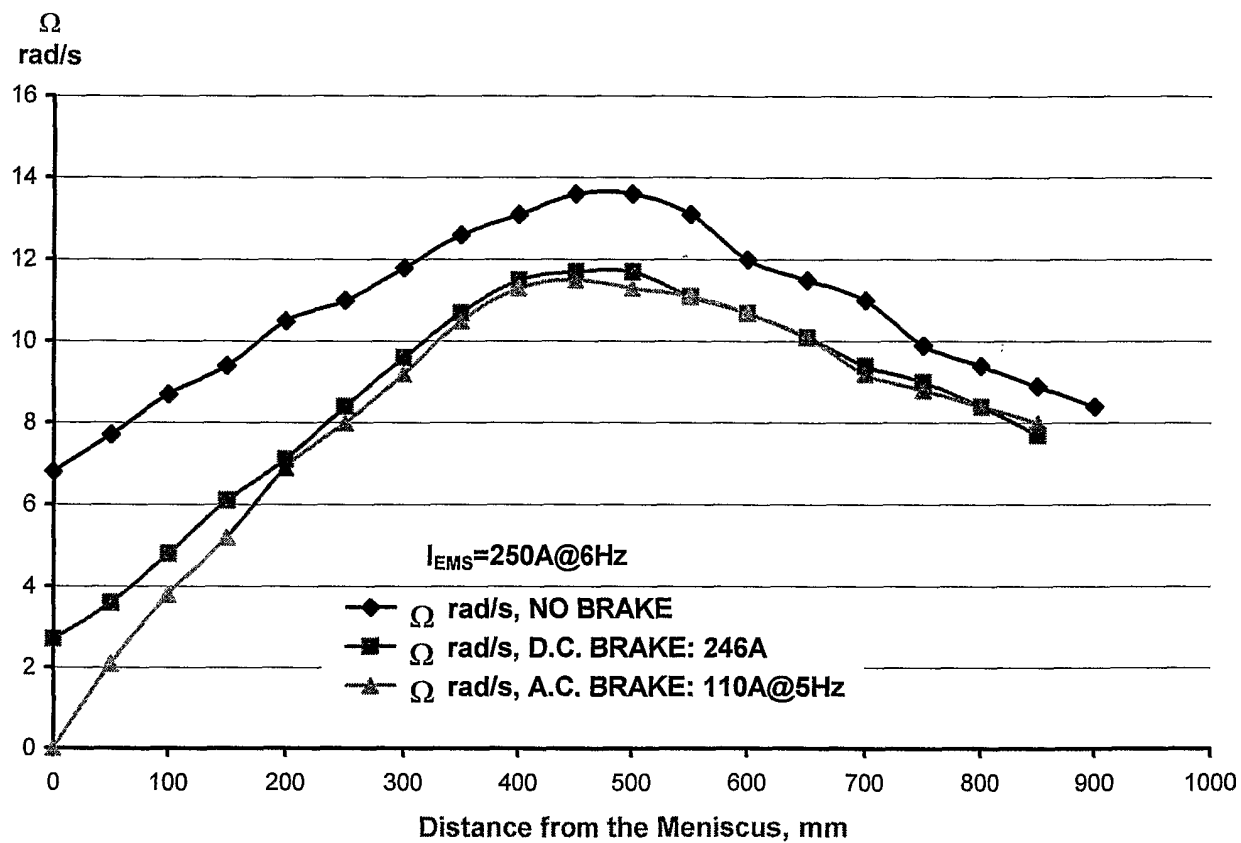


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 01/01498

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B22D 11/115

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)

IPC7: B22D

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

SE,DK,FI,NO classes as above

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

WPI, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4933005 A (MULCAHY ET AL), 12 June 1990 (12.06.90), figure 1, abstract, the claims --	1,7,11
Y	US 5699850 A (BEITELMAN ET AL), 23 December 1997 (23.12.97), abstract, the claims, figures --	1,7,11
Y	WO 9930856 A1 (ROTELEC S.A.), 24 June 1999 (24.06.99), page 12, line 10 - line 15, claims 8, 9 -----	1,7,11

☐ 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

1 October 2001

Date of mailing of the international search report

05 -10- 2001

Name and mailing address of the ISA/

Swedish Patent Office
Box 5055, S-102 42 STOCKHOLM
Facsimile No. +46 8 666 02 86

Authorized officer

Ulf Nyström/BS
Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

03/09/01

International application No.

PCT/SE 01/01498

Patent document cited in search report			Publication date	Patent family member(s)		Publication date
US	4933005	A	12/06/90	AT	96350 T	15/11/93
				CA	2016988 A	21/02/91
				DE	69004264 D,T	24/02/94
				EP	0489057 A,B	10/06/92
				SE	0489057 T3	
				ES	2045943 T	16/01/94
				WO	9102609 A	07/03/91

US	5699850	A	23/12/97	AT	154767 T	15/07/97
				CA	2153995 A	21/07/94
				DE	69403950 D,T	11/12/97
				EP	0679115 A,B	02/11/95
				ES	2106501 T	01/11/97
				WO	9415739 A	21/07/94
				JP	2779344 B	23/07/98
JP	9001301 A	07/01/97				

WO	9930856	A1	24/06/99	AU	735023 B	28/06/01
				AU	1438199 A	05/07/99
				BR	9813655 A	03/10/00
				CN	1282280 T	31/01/01
				EP	1039979 A	04/10/00
				FR	2772294 A,B	18/06/99
				US	6164365 A	26/12/00
