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(54) **METHOD FOR CASTING IN A MOULD**

VERFAHREN ZUM GIESSEN IN EINE FORM

PROCEDE DE COULEE DANS UN MOULE

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Description

TECHNICAL FIELD

[0001] The present invention relates to a method, during casting of a cast strand in a mould which is open at both ends in the casting direction, of controlling and distributing a rotating magnetic field which is applied to act on and stir molten parts of the cast strand in the mould. The magnetic field is applied by means of a two-phase or polyphase stirrer arranged adjacent to the mould.

BACKGROUND ART

[0002] When a metal or a metal alloy, such as a steel, is cast in a mould, which is open at both ends in the casting direction, by means of a continuous or semi-continuous process, a melt is supplied to the mould by means of a free tapping jet, open casting, or through a casting tube, closed casting. When passing through the mould, a cast strand is formed by the melt being cooled. Before the cast strand leaves the mould, at least one solidified self-supporting surface layer on the casting strand has been formed. An uncontrolled flow of metal in the non-solidified portions of the cast strand entails problems, both from the point of view of quality and production engineering.

[0003] The flow of molten metal in the non-solidified portions of a cast strand can be controlled by means of a two-phase or polyphase mould stirrer to which is applied a rotating magnetic field to act on and stir the melt in these parts of the cast strand, electric currents then being induced in the melt. By cooperation between these induced electric currents and the applied magnetic field, forces arise which act on the melt and give rise to a rotation, a stirring, of the melt.

[0004] To attain the desired stirring power and hence a satisfactory metallurgical result, the movements of the melt must be controlled and distributed. This makes demands on the properties and field-strength distribution of the magnetic field applied to the melt, as well as on current intensity and current density and the direction of the induced electric currents. The demands vary between different casting processes, such as open and closed casting.

[0005] During closed casting, that is, when melt is supplied to the mould through a casting tube which opens out into the melt below the meniscus, a sufficiently strong stirring in the non-solidified parts of the cast strand is desired to ensure the desired metallurgical result regarding casting structure, etc.; however, stirring and flow rate at the meniscus should be avoided. In certain contexts, closed casting is referred to as casting with mould power since the upper surface of the melt is often covered with a so-called casting powder. A casting powder has a plurality of functions such as to thermally insulate the upper surface of the melt, protect it against oxidation and other reactions, and to prevent the adhe-

sion of the solidified surface layer to the mould wall, as well as to take up particles separated from the melt. Stirring of a metal surface covered with a casting powder should therefore be avoided to prevent the casting powder from being drawn down into the cast strand. With the prior art for stirring of molten parts of a cast strand, it is difficult simultaneously to attain sufficient stirring and to avoid drawing down casting powder during powder casting, closed casting.

[0006] During open casting, that is, when melt is supplied to the mould from a container, a ladle or tundish, by means of a free tapping jet, it is required that the flow rate at the meniscus is kept sufficiently high to obtain a desired metallurgical result. A sufficiently strong flow at the meniscus is obtained when the applied magnetic field exhibits a sufficiently high magnetic field strength at the meniscus.

[0007] To satisfy the above-mentioned requirements regarding the flow prevailing at the meniscus both when using open casting and closed casting according to the prior art, as is clear from German patent specification DE-C-38 19 493, a considerable displacement of the position of the magnetic field in relation to the meniscus in the axial direction of the mould is required. A sufficient displacement cannot normally be achieved by the variation in the position of the meniscus in the casting direction which is possible in a mould of the type referred to here, or by displacement in the casting direction of a stirrer designed and arranged in accordance with the prior art. Alternatively to displacing the position of the magnetic field relative to the meniscus, the current intensity of the current which is fed through the phase windings can be varied. However, this entails increased capital costs since the phase windings in such a case must be dimensioned based on the greatest possible current intensity. In addition, with an increased current intensity, the risk of powder being drawn down during powder casting increases.

[0008] As a consequence of the physical dimensions of known mould stirrers and the construction of the mould, the possibilities of displacing the mould stirrer in the axial direction of the mould during casting of weak rectangular objects, so-called billets, and to a certain extent also during casting of somewhat coarser objects, blooms, are essentially non-existent. This limits the possibilities of displacing the magnetic field relative to the meniscus to the possible variation of the position of the meniscus in the casting direction, which is usually less than 100 mm. The chances of obtaining optimum conditions, with one and the same stirrer, designed and arranged according to the prior art, both during open and closed casting by displacing the magnetic field and the meniscus relative to each other are consequently very poor. In the above mentioned document, DE-C-38 19 493, the stirrer is arranged movable in a housing outside the mould. Between the mould and the housing is a cooling device arranged. The distance between the stirrer and the mould, due to the cooling device and housing,

reduces the possibilities for the magnetic field to act in an optimum way for both open and closed casting.

[0009] One object of the invention is to suggest a method of controlling and distributing a rotating magnetic field which is applied to a cast strand present in a mould by means of two-phase or polyphase stirrers for stirring the non-solidified portions of a cast strand, whereby a sufficiently strong stirring to obtain the desired metallurgical result is ensured a certain distance down in the cast strand whereas the stirring near the meniscus can be controlled and checked such that optimum conditions can be offered with one and the same mould stirrer both during open and closed casting, such that sufficient stirring of the melt near the meniscus is obtained during open casting whereas this stirring is limited, inter alia to minimize the risks of powder being drawn down, during closed casting.

SUMMARY OF THE INVENTION

[0010] During continuous or semi-continuous casting of metal, molten metal or metal alloy, such as steel, is supplied to a mould which is open at both ends in the casting direction. In the mould the molten metal is cooled, and during the passage through the mould a cast strand is formed. When passing out of the mould, the cast strand exhibits at least one self-supporting surface layer and residual melt contained therein. The flow or the stirring of liquid metal in non-solidified portions of the formed cast strand is achieved and maintained by applying at least one rotating magnetic field to act on molten parts of the cast strand during the solidification of the metal. This rotating magnetic field is applied by means of a two-phase or polyphase mould stirrer arranged adjacent to the mould. The mould stirrer comprises two or more sub-stirrers. Each one of these sub-stirrers comprises at least one magnetic core and an ac-fed phase winding, arranged around the core, which are arranged in such a way that the magnetic field which is generated inside the mould, on a level with the cores, essentially comprises a magnetic field-strength component, B_y , oriented across the casting direction. According to the present invention, the phase windings included in the mould stirrer are arranged sufficiently near the inner wall of the mould and are designed in such a way that the magnetic field which is generated inside the mould on a level with the phase windings mentioned essentially comprises a magnetic field-strength component, B_z , oriented parallel to the casting direction. At the same time, the relative position in the casting direction is adjusted between the cores included in the mould stirrer and the upper surface of the melt, the meniscus. By changing the adjustment of the relative position, according to the invention, between the meniscus and the mould stirrer in the casting direction, an efficient and controlled stirring in the non-solidified portions of the cast strand is obtained and maintained, independently of whether the melt is supplied by means a casting tube

which opens out below the meniscus or by means of a free tapping jet which hits the meniscus from above. This is made possible since, for the invented method, a small change of the relative position between the meniscus and the stirrer results in large changes in the flow of the melt at and adjacent the meniscus. When the flow of the melt in the non-solidified portions of a cast strand is controlled according to the invented method, the differences in the orientation of the magnetic field strength between the levels at the phase windings and the cores, respectively, which are obtained when the cores are arranged and designed according to the invention, are utilized. The magnetic field-strength component across the casting direction, B_y , dominates on a level with the cores while at the same time the magnetic field-strength component parallel to the casting direction, B_z , dominates on a level with the phase windings. At a small change of the relative position between the mould stirrer and the meniscus in the casting direction, large changes are thus obtained in the action of a force which arises through the cooperation between the magnetic field-strength components B_y and B_z , respectively, and the electric currents induced in the melt by the magnetic field, and a transfer is made from a level where one field-strength component dominates to a level where another field-strength component dominates.

[0011] When the invention is applied to closed casting, where melt is supplied to the mould through a casting tube opening out under the meniscus,

- the cores included in the mould stirrer are arranged with their upper edge at a sufficiently large distance under the meniscus, preferably more than 25 mm under the meniscus, while at the same time
- the front edge of the phase winding is arranged sufficiently close to the inner surface of the mould wall, preferably more less than 150 mm from the inner surface of the mould wall, whereby the flow of the melt at and near the meniscus is braked by the generation and the application to the melt of braking moments on a level with the phase windings by the action of the force which arises when the component of the magnetic field in the casting direction, B_z , and the electric current which are induced in the melt by the magnetic field cooperate. These moments generated at the meniscus are directed in the opposite direction of the stirring induced in the melt by the component of the magnetic field across the casting direction, B_y . The cores included in the mould stirrer are suitably arranged with their upper edge 25 mm to 200 mm under the meniscus, while at the same time phase windings in the mould stirrer are arranged with their front edge 10 mm to 150 mm from the inner surface of the mould wall. This results in optimum conditions for closed casting, powder casting. The flow and turbulence of the melt at the meniscus are limited and controlled by the strong braking moments arising just below the meniscus,

while at the same time a powerful stirring is maintained somewhat down in the cast strand. This ensures the metallurgical effects of the stirring while at the same time minimizing the risk of non-metallic constituents, such as casting powder, being drawn down from the upper surface. By arranging the phase winding with its front edge near the mould wall and hence in this case the melt, a sufficiently strong magnetic field-strength component, B_z , is obtained, which is oriented parallel to the casting direction in order to form a sufficiently strong braking moment just below the meniscus. The braking moment arises just below the meniscus by the magnetic field-strength component, B_z , oriented parallel to the casting direction, cooperating with the electric currents I which are induced in the melt by the magnetic field and which at the meniscus deflect and essentially comprise a y component, I_y . The volumetric forces ($f_x = i_y \times b_z$) arising at the meniscus then become directed in the opposite direction of those volumetric forces which arise further down in the non-solidified portions of the cast strand and give rise to and maintain an efficient stirring in these parts. Since the induced currents on a level with the phase windings, arranged downstream of the cores, are not forced to deflect in the same way as at the meniscus, no strong, negative braking moment arises during the stirring. The same applies if the distance between the meniscus and the upper edge of the core is too large upstream of the core.

[0012] When the invention is applied to open casting, wherein melt is supplied to the mould by means of a free tapping jet which hits the upper surface of the melt, the meniscus, the cores included in the mould stirrer are arranged with their upper edge sufficiently near the meniscus, preferably less than 100 mm from the meniscus. In this way, a sufficiently strong flow is achieved and maintained at and near the meniscus by means of the forces which are generated by cooperation between the component of the magnetic field across the casting direction, B_y , and the electric currents induced in the melt by the magnetic field while at the same time the component B_z of the magnetic field, on a level with the above-mentioned phase windings, is applied near the surface of the meniscus without achieving any force directed opposite to the flow. By arranging the cores and the phase windings included in the mould stirrer in the same way, optimum conditions for open casting are obtained. A strong stirring is maintained at the meniscus and essentially no braking moment arises when the magnetic field on a level with the meniscus in this case substantially comprises a magnetic field-strength component, B_y , oriented across the casting direction, whereas the magnetic field-strength component, B_z , which is generated on a level with the phase windings and oriented parallel to the casting direction, does not act on the molten metal but is situated above or upstream of the meniscus.

[0013] As will be clear from the above, only a small displacement in the position of the meniscus relative to the magnetic field is required for changing the magnetic field which acts in the meniscus, with a mould stirrer with its cores and phase windings arranged according to the invention, in such a way that optimum flow conditions can be achieved and maintained with the same stirrer both during open and closed casting by means of a displacement of the position of the meniscus in the casting direction which is within the normal interval for known casting machines.

[0014] In a mould for continuous casting of weaker cast strands such as billets and blooms, when casting in the steady state, the position of the upper surface of the melt, the meniscus, can normally only be displaced in the casting direction by a distance smaller than 100 mm by means of a change of casting parameters such as the casting rate and the flow of molten metal into the mould. In spite of this very limited possibility of displacement of the position of the meniscus relative to the magnetic field, optimum conditions can be achieved both for open and closed casting when the cores and the phase windings included in the mould stirrer are arranged according to the invention. During closed casting, the cores are arranged with their upper edge 50 to 100 mm below the meniscus, while at the same time the phase windings included in the mould stirrer are arranged with their front edge 50 to 100 mm from the inner surface of the mould stirrer and, during open casting, the cores included in the mould stirrer are arranged with their upper edge less than 100 mm below the meniscus.

[0015] A two-phase or polyphase mould stirrer for carrying out the invented method, which is arranged in the form of two or more sub-stirrers, each one at least comprising one magnetic core and one ac-fed phase winding arranged around the core, in a preferred embodiment the phase windings included in the mould stirrer are arranged in the form of foil-wound coils, where the foil-wound coils are arranged with their front edge sufficiently close to the mould wall for the magnetic field which is generated inside the mould on a level with the foil windings to essentially comprise a magnetic field-strength component, B_z , oriented parallel to the casting direction, and for the foil windings to receive sufficiently indirect cooling from the cooling means arranged for cooling the mould.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] In the following the invention will be explained in greater detail and be exemplified by means of a preferred embodiment with reference to the accompanying figures. Figures 1 and 2 show the field-strength distribution and the moment which are obtained during open and closed casting, respectively, with a stirrer arranged according to the prior art, optimally placed relative to the meniscus. Figures 3 and 4 show a mould with a stirrer arranged according to the invention. Figure 5 shows the

distribution in a plane in the casting direction for the field strength and moment of the magnetic field as well as the magnetic field, the electric currents which are induced in the mould during stirring, and the forces which arise by cooperation between the magnetic field and induced currents when the cores and phase windings included in the mould are arranged and designed according to the invention during open casting, whereas Figure 6 shows the same during closed casting where the stirrer is located at essentially the same level in the mould whereas its location relative to the meniscus has been achieved by means of a possible displacement of the meniscus position for the mould.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] To control the stirring in the non-solidified portions 13 of a cast strand 11, by means of an applied rotating magnetic field, in such a way that a satisfactory metallurgical result can be achieved, demands are made regarding the properties and the field-strength distribution of the magnetic field applied to the non-solidified portions 13 of the melt. These demands vary between different casting methods, such as open and closed casting.

[0018] During open casting, it is required that the flow at the meniscus 17 should be sufficiently strong. This stirring is achieved, as shown in Figure 1, when a mould stirrer is adapted to apply a rotating magnetic field with its maximum magnetic field strength on a level with or directly under the meniscus. For a mould stirrer which is designed and arranged according to the prior art, this means that the iron cores 140a, 140b of the sub-stirrer should be arranged with their centre, which usually coincides with the field-strength maximum $B_{\max}$ of the magnetic field 21, below the meniscus 17.

[0019] During closed casting, the situation regarding the desired stirring of the melt at the meniscus 17 is the reverse, and the applied rotating magnetic field is arranged such that its field strength on a level with the meniscus is limited by applying the field-strength maximum $B_{\max}$ of the magnetic field at a level essentially under the meniscus 17-, whereby the magnetic field strength B on a level with the meniscus 17 is essentially lower than the maximum value $B_{\max}$ as is shown in Figure 2.

[0020] The distribution in the casting direction of the component B_{Ay} of the magnetic field strength and the component M_{Ay} of the moment, which act across the casting direction, in the y-direction, for a rotating magnetic field which according to the prior art is applied to act on non-solidified portions 13 of a cast strand 11 is shown in Figures 1 and 2. In order to satisfy the above-mentioned requirements regarding the flow conditions prevailing at the meniscus with one and the same mould stirrer, both during open casting according to Figure 1 and during closed casting according to Figure 2, a con-

siderable displacement in the casting direction of the position of the magnetic field relative to the meniscus 17 is required. Such a large displacement cannot be achieved with a normally possible variation of the meniscus position in the casting direction and/or the possibility to move the mould stirrer along the mould in the casting direction. The possibility of displacement of the position of the magnetic field by moving the mould stirrer in the casting direction is very limited, for reasons of space, in a plant for continuous casting of metal. On the one hand, the supporting and cooling functions of the mould only leave limited areas open for placing a stirrer, and, on the other hand, conventionally used phase windings in mould stirrers require that cooling means be arranged near them, which further limits the space for movements in the casting directions of stirrer coils and other parts included in a mould stirrer in relation to the mould. This means that during casting according to the prior art, where a magnetic field with a field-strength distribution, according to curve B_{Ay} in Figures 1 and 2, is applied to act on molten parts 13 of a cast strand 11 present in a mould and where the magnetic field for reasons of space cannot be applied such that sufficient stirring is obtained in the melt near the meniscus 17, the field-strength maximum of the magnetic field must greatly exceed the required value. This corresponds to the normal case during mould stirring according to the prior art, since the possibilities of adjustment of the position of the magnetic field relative to the meniscus 17 are normally limited to the possibility of varying the meniscus position in the casting direction. To achieve a satisfactory result with a mould stirrer, to which a magnetic field with a field-strength distribution according to curve B_{Ay} in Figures 1 and 2 is applied, the mould stirrer is usually oversized so that it can be fed with a higher current intensity and apply a magnetic field to the melt which, at the meniscus, exhibits a sufficient magnetic field strength to achieve the required flow at the meniscus 17. Thus, with one and the same stirrer and while utilizing normal possibilities of displacing the magnetic field and the meniscus 17 relative to each other, there are great difficulties in providing optimum conditions for both open and closed casting.

[0021] During continuous casting of weaker rectangular blanks, so-called billets, and often also during casting of blooms, the essentially non-existent possibilities, according to the prior art, of displacing the mould stirrer in the axial direction of the mould, as a result of the physical dimensions of the mould stirrer and the construction of the mould, together with the possibilities of variation of the meniscus position in the casting direction, by means of a change of casting parameters such as casting rate and the flow of metal into the mould, provide a possibility of displacing the position of the meniscus 17 relative to the magnetic field which is less than 100 mm.

[0022] During casting of metal in a mould, which is open in both ends in the casting direction, with cooled wall plates 12a, 12b, 12c, 12d, the metal melt is cooled

and formed into a cast strand 11. One or more mould stirrers is/are arranged to apply a rotating magnetic field to the non-solidified portions of the cast strand 13. The mould stirrers according to one embodiment of the invention, which is shown in Figures 3 and 4, comprise four sub-stirrers which are arranged adjacent to the wall plates 12a, 12b, 12c, 12d of the mould. The sub-stirrers comprise at least iron cores 14a, 14b, 14c, 14d and phase windings 15a, 15b, 15c, 15d arranged therearound and are surrounded by a yoke 16 of a magnetically conducting material, whereby the magnetic circuits are closed.

[0023] Figure 5 shows the distribution in a plane in the casting direction for the field strength and moments of the magnetic field as well as the magnetic field, the electric currents which are induced in the mould during stirring, and the forces which arise by cooperation between the magnetic field and the induced currents when the cores and the phase windings included in the mould are arranged and designed according to the invention during open casting, whereas Figure 6 shows the same during closed casting where the stirrer is located at essentially the same level in the mould whereas its location relative to the meniscus is achieved by means of a possible displacement of the meniscus position of the mould. Since the cores 14a, 14b, 14c, 14d and the phase windings 15a, 15b, 15c, 15d included in the mould stirrer are arranged and designed according to the invention, it is sufficient with that displacement of the position of the meniscus 17 relative to these 14, 15 which can be achieved with a normal displacement of the meniscus position in the casting direction for obtaining a distribution of that magnetic field 21 induced in the mould which by cooperation with induced currents 22 gives optimum flow conditions both during open and closed casting. The flow desired for the current casting situation is obtained essentially without any change of the field strength fed through the coil windings of the mould stirrer. To control and distribute the propagation and the magnetic field strength of the rotating magnetic field 21 applied to the non-solidified portions 13 of the cast strand, the cores 14a, 14b, 14c, 14d and the phase windings 15a, 15b, 15c, 15d included in the mould stirrers are arranged and designed according to that embodiment of the invention which is shown in Figures 3 and 4 where each one of the phase windings is designed in the form of a foil-wound coil. The foil-wound phase windings 15a, 15b, 15c, 15d are very compact and therefore need no separate cooling but are given sufficient indirect cooling through the cooling circuit of the mould. This results in great flexibility in the location and configuration of the phase winding 15a, 15b, 15c, 15d relative to the mould so that both a sufficient indirect cooling of the coil 15a, 15b, 15c, 15d and a distribution of the magnetic field strength in the casting direction can be obtained, by which it is possible, by means of small displacements in the casting direction of the relative position between meniscus and magnetic field, to greatly

influence the flow at the meniscus induced with the magnetic field. Preferably, it is sufficient with a displacement of the relative position between the meniscus 17 and the magnetic field which is smaller than the displacement of the meniscus position which is normally possible for the mould, which, for example for a casting machine for blooms or billets, is normally below 100 mm, thus making possible a sufficient change of the flow of the melt at the meniscus 17 whereby a good metallurgical result can be obtained both during open and closed casting in the mould. Compact foil-wound phase windings 14a, 14b, 14c, 14d can, of course, be used with the same advantages also with three-phase or polyphase mould stirrers.

[0024] These mould stirrers are then arranged at moulds where more poles than four can be arranged to control and distribute a magnetic field applied to the melt in a mould according to the invention. Preferably, in this compact mould stirrer, a magnetic feedback 16, a magnetic yoke, is arranged to form a magnetic circuit together with the iron cores 14a, 14b, 14c, 14d of the sub-stirrers. The magnetic yoke 16 is arranged to surround the mould and the sub-stirrers.

[0025] Further, as is also clear from Figure 5, during closed casting the cores 14a, 14b, 14c, 14d, 145 and the phase windings 15a, 15b, 15c, 15d included are arranged such that the propagation and magnetic field strength B of the rotating magnetic field applied to and acting on the non-solidified portions 13 of the cast strand are controlled and distributed in such a way that the flow of the melt at and adjacent the meniscus is braked because a force, which is directed opposite to the stirring induced in the melt by the component of the magnetic field across the casting direction, B_y , is achieved and maintained by the forces which are applied to the melt on a level with the phase winding by cooperation between the component of the magnetic field in the casting direction, B_z , and the electric currents which are induced in the melt by the magnetic field. In one embodiment of the invention, each one of the phase windings 15a, 15b, 15c, 15d included in the sub-stirrers is arranged with its front edge at a distance away from the melt which is smaller than 150 mm. Since the mould wall normally has a thickness which usually exceeds 8 mm, the phase winding is preferably arranged at a distance away from the inner surface of the mould wall of between 10 and 150 mm. In addition, the iron cores included in the sub-stirrers are arranged more than 25 mm below the meniscus, preferably 25 to 200 mm below the meniscus. During closed casting of weak rectangular blanks, so-called billets, and to a certain extent also during casting of somewhat coarser blanks, blooms, the phase windings included in the sub-stirrers are preferably arranged with their front edge at a distance from the inner surface of the mould wall, that is, from the melt, which lies within an interval of 50 to 100 mm, and the iron cores 14a, 14b, 14c, 14d included in the sub-stirrers are arranged with their upper edge 50 to 100 below the meniscus.

[0026] In a corresponding way, during open casting, the cores 14a, 14b, 14c, 14d and the phase windings 15a, 15b, 15c, 15d included are arranged such that the propagation and the magnetic field strength B of the rotating magnetic field applied to and acting on the non-solidified portions 13 of the cast strand are controlled and distributed in such a way that the flow of the melt at and adjacent the meniscus essentially comprises a magnetic field-strength component, B_y , oriented across the casting direction, which gives rise to a sufficiently strong stirring at the meniscus. In one embodiment of the invention, each one of the iron cores 14a, 14b, 14c, 14d included in the sub-stirrers is arranged with its upper edge less than 100 mm from the meniscus. During open casting of weak rectangular blanks, so-called billets, and to a certain extent also of somewhat coarser blanks, blooms, the iron cores 14a, 14b, 14c, 14d included in the sub-stirrers are preferably arranged with their upper edge less than 100 mm below the meniscus.

Claims

1. A method, during casting of metal, of controlling a flow of molten metal in non-solidified portions of a cast strand which is formed in a cooled mould which is open at both ends in the casting direction, wherein an efficient and controlled flow of molten metal in said non-solidified portions is achieved and maintained by applying at least one rotating magnetic field to act on the non-solidified portions of the cast strand such that the melt is stirred by the action of a force on the melt which arises by cooperation between the magnetic field-strength components of the magnetic field and the electric currents which are induced in the melt by the magnetic field, the magnetic field being applied to the melt by means of a two-phase or polyphase stirrer which is arranged outside the mould and which comprises two or more sub-stirrers, each one comprising a magnetic core (14a, 14b, 14c, 14d) and an ac-fed phase winding (15a, 15b, 15c, 15d) arranged around the core, the magnetic field on a level with the cores essentially comprising a magnetic field-strength component, B_y , oriented across the casting direction, and the magnetic field on a level with the phase windings essentially comprising a magnetic field-strength component, B_z , oriented parallel to the casting direction, **characterized** in that the phase windings (15a, 15b, 15c, 15d) included in the mould stirrer are arranged adjacent to the inner wall of the mould such that the magnetic field which is generated by the mould stirrer inside the mould on a level with the phase windings essentially comprises the magnetic field-strength component, B_z , oriented parallel to the casting direction, and that the flow of the melt at and adjacent the meniscus (17) is controlled by adjusting the position of the meniscus relative to the cores (14a, 14b, 14c, 14d) included in the mould stirrer such that the action of a force which arises in the melt at and adjacent the meniscus is changed by cooperation between the currents I induced in the melt and the field-strength components, B_y and B_z , respectively.
2. A method according to claim 1 during casting wherein melt is supplied to the mould by means of a casting tube which opens out below the upper surface of the melt, the meniscus, **characterized** in that the meniscus (17) is adjusted to a position relative to the cores (14a, 14b, 14c, 14d) included in the mould stirrer such that the upper edge of the cores will be positioned sufficiently far below the meniscus (17), whereby the flow of the melt at and adjacent to the meniscus is braked by the action of a force which arises by cooperation between the field-strength component B_z , on a level with the phase windings, and the electric currents I which are induced in the melt by the magnetic field adjacent to the meniscus since these forces are directed opposite to the forces F which are applied to act on the melt further down in the mould by cooperation between the component of the magnetic field across the casting direction, B_y , and the induced currents.
3. A method according to claim 2, **characterized** in that the meniscus (17) is adjusted such that the cores (14a, 14b, 14c, 14d) included in the mould stirrer are arranged with their upper edge more than 25 mm below the meniscus (17) while at the same time the phase windings (15a, 15b, 15c, 15d) included in the mould stirrer are arranged with their front edge less than 150 mm from the inner surface of the mould wall.
4. A method according to claim 2 or claim 3, **characterized** in that the meniscus (17) is adjusted such that the cores (14a, 14b, 14c, 14d) included in the mould stirrer are arranged with their upper edge 25 mm to 200 mm below the meniscus (17) while at the same time the phase windings (15a, 15b, 15c, 15d) included in the mould stirrer are arranged with their front edge 10 mm to 150 mm from the inner surface of the mould wall.
5. A method according to claim 2, 3 or 4, **characterized** in that the meniscus (17) is adjusted such that the cores (14a, 14b, 14c, 14d) included in the mould stirrer are arranged with their upper edge 50 mm to 100 mm below the meniscus (17) while at the same time the phase windings included in the mould stirrer are arranged with their front edge 50 mm to 100 mm from the inner surface of the mould wall.
6. A method according to claim 1 during casting

wherein melt is supplied to the mould by means of a free tapping jet which hits the upper surface, the meniscus, of the melt, **characterized** in that the meniscus (17) is adjusted to a position wherein the cores (14a, 14b, 14c, 14d) included in the mould stirrer are arranged with their upper edge sufficiently close to the meniscus (17) so as to achieve and maintain a sufficiently strong stirring at and near the meniscus by means of the action of a force which is applied to the melt by cooperation between the magnetic field-strength component of the magnetic field across the casting direction, B_y , and the electric currents I which are induced in the melt by the magnetic field while at the same time the magnetic field-strength component, B_z , of the magnetic field on a level with said phase windings is applied across the surface of the meniscus without generating any force directed opposite to the flow.

7. A method according to claim 6, **characterized** in that the meniscus (17) is adjusted such that the cores (14a, 14b, 14c, 14d) included in the mould stirrer are arranged with their upper edge less than 100 mm from the meniscus while at the same time the phase windings (15a, 15b, 15c, 15d) included in the mould stirrer are arranged with their front edge less than 150 mm from the inner surface of the mould wall.
8. A method according to claim 6, **characterized** in that the meniscus (17) is adjusted such that the cores (14a, 14b, 14c, 14d) included in the mould stirrer are arranged with their upper edge less than 100 mm below the meniscus while at the same time the phase windings (15a, 15b, 15c, 15d) included in the mould stirrer are arranged with their front edge less than 150 mm from the inner surface of the mould wall.

Patentansprüche

1. Verfahren zur Steuerung eines Stroms von geschmolzenem Metall während eines Gießvorgangs des Metalls in nicht-erstarrten Bereichen eines Gußstranges, der in einer gekühlten, an beiden Enden in Gießrichtung offenen Gußform gebildet wird, wobei ein effizienter und gesteuerter Strom an geschmolzenem Metall in den nicht-erstarrten Bereichen erreicht und durch Anlegen von mindestens einem magnetischen Drehfeld, das auf die nicht-erstarrten Bereiche des Gußstranges einwirkt, aufrecht erhalten wird, so daß die Schmelze durch Krafteinwirkung auf die Schmelze gerührt wird, welche durch das Zusammenwirken zwischen den magnetischen Feldstärke-Komponenten des Magnetfeldes und den in der Schmelze durch das Magnetfeld induzierten elektrischen Strömen hervorgeru-

fen wird, wobei das Magnetfeld mittels einer außerhalb der Gußform angeordneten, zwei- oder mehrphasigen Röhreinrichtung an der Schmelze angelegt wird, welche zwei oder mehrere zusätzliche Röhreinrichtungen aufweist, die jeweils einen Magnetkern (14a, 14b, 14c, 14d) und einen mit Wechselstrom versorgten, um den Kern angeordneten Wicklungsstrang (15a, 15b, 15c, 15d) aufweisen, wobei das Magnetfeld auf einer Höhe mit den Kernen im Wesentlichen eine quer zur Gießrichtung weisende, magnetische Feldstärken-Komponente B_y aufweist, und wobei das Magnetfeld auf einer Höhe mit den Wicklungssträngen im Wesentlichen eine parallel zur Gießrichtung weisende, magnetische Feldstärken-Komponente B_z aufweist, dadurch gekennzeichnet, daß

die in der Gußform-Röhreinrichtung enthaltenen Wicklungsstränge (15a, 15b, 15c, 15d) nahe der Innenwand der Gußform derart angeordnet sind, daß das durch die Gußform-Röhreinrichtung innerhalb der Gußform erzeugte Magnetfeld auf einer Höhe mit den Wicklungssträngen im Wesentlichen die parallel zur Gießrichtung weisende magnetische Feldstärken-Komponente B_z umfaßt, und daß der Strom der Schmelze bei und nahe dem Meniskus (17) durch Einstellen der Position des Meniskus relativ zu den in der Gußform-Röhreinrichtung enthaltenen Kernen (14a, 14b, 14c, 14d) derart gesteuert wird, daß die in der Schmelze bei und nahe dem Meniskus entstehende Krafteinwirkung durch Zusammenwirken der in der Schmelze induzierten Ströme I und den Feldstärke-Komponenten B_y bzw. B_z verändert wird.

2. Verfahren nach Anspruch 1 während eines Gießvorgangs, wobei die Schmelze der Gußform mittels einer Gießröhre zugeführt wird, die sich unterhalb der Oberfläche der Schmelze, dem Meniskus, aufweitete, dadurch gekennzeichnet, daß der Meniskus (17) in einer Position relativ zu den in der Gußform-Röhreinrichtung enthaltenen Kernen (14a, 14b, 14c, 14d) derart eingestellt wird, daß der obere Rand der Kerne in ausreichendem Maße unterhalb des Meniskus (17) liegt, wobei der Strom der Schmelze bei und nahe dem Meniskus durch die Krafteinwirkung abgebremst wird, welche durch Zusammenwirken der auf einer Höhe mit den Wicklungssträngen vorhandenen Feldstärke-Komponente B_z und den in der Schmelze nahe des Meniskus durch das Magnetfeld induzierten elektrischen Strömen I entsteht, da diese Kräfte zu den Kräften F entgegengerichtet sind, die aufgebracht werden, um in der Gußform weiter unten durch Zusammenwirken der quer zur Gießrichtung weisenden Magnetfeld-Komponente B_y und den induzier-

ten Strömen auf die Schmelze zu wirken.

3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß

der Meniskus (17) derart eingestellt wird, daß der obere Rand der in der Gußform-Rührereinrichtung enthaltenen Kerne (14a, 14b, 14c, 14d) mehr als 25 mm unterhalb des Meniskus (17) angeordnet ist, während gleichzeitig der vordere Rand der in der Gußform-Rührereinrichtung enthaltenen Wicklungsstränge (15a, 15b, 15c, 15d) weniger als 150 mm von der Innenfläche der Gußformwandung entfernt angeordnet ist.

4. Verfahren nach Anspruch 2 oder 3, dadurch gekennzeichnet, daß

der Meniskus (17) derart eingestellt wird, daß der obere Rand der in der Gußform-Rührereinrichtung enthaltenen Kerne (14a, 14b, 14c, 14d) 25 bis 200 mm unterhalb des Meniskus (17) angeordnet ist, während gleichzeitig der vordere Rand der in der Gußform-Rührereinrichtung enthaltenen Wicklungsstränge (15a, 15b, 15c, 15d) 10 bis 150 mm von der Innenfläche der Gußformwandung entfernt angeordnet ist.

5. Verfahren nach Anspruch 2, 3 oder 4, dadurch gekennzeichnet, daß

der Meniskus (17) derart eingestellt wird, daß der obere Rand der in der Gußform-Rührereinrichtung enthaltenen Kerne (14a, 14b, 14c, 14d) 50 bis 100 mm unterhalb des Meniskus (17) angeordnet ist, während gleichzeitig der vordere Rand der in der Gußform-Rührereinrichtung enthaltenen Wicklungsstränge (15a, 15b, 15c, 15d) 50 bis 150 mm von der Innenfläche der Gußformwandung entfernt angeordnet ist.

6. Verfahren nach Anspruch 1 während eines Gießvorgangs, wobei die Schmelze der Gußform mittels eines freien Abstich-Gießkopfes zugeführt wird, welcher die Oberfläche der Schmelze, den Meniskus, trifft, dadurch gekennzeichnet, daß

der Meniskus (17) in einer Position eingestellt wird, bei der der obere Rand der in der Gußform-Rührereinrichtung enthaltenen Kerne (14a, 14b, 14c, 14d) ausreichend nahe dem Meniskus (17) angeordnet ist, um bei und nahe dem Meniskus ein ausreichend starkes Rühren zu erreichen und aufrecht zu erhalten, und zwar mittels einer Krafteinwirkung, die durch Zusammenwirken der quer zur Gießrichtung weisenden magnetischen Feldstärke-Komponente des Magnetfeldes B_y und den in der Schmelze durch das Magnetfeld induzierten elektrischen Strömen I auf die Schmelze ausgeübt wird, während gleichzeitig die Magnetfeldstärke-Komponente B_z des Magnetfeldes auf einer Höhe mit den Wicklungssträngen quer zur Oberfläche des Menis-

kus zugeführt wird, ohne eine dem Strom entgegengerichtete Kraft zu erzeugen.

7. Verfahren nach Anspruch 6, dadurch gekennzeichnet, daß

der Meniskus (17) derart eingestellt wird, daß der obere Rand der in der Gußform-Rührereinrichtung enthaltenen Kerne (14a, 14b, 14c, 14d) weniger als 100 mm von dem Meniskus entfernt angeordnet ist, während gleichzeitig der vordere Rand der in der Gußform-Rührereinrichtung enthaltenen Wicklungsstränge (15a, 15b, 15c, 15d) weniger als 150 mm von der Innenfläche der Gußformwandung entfernt angeordnet ist.

8. Verfahren nach Anspruch 6, dadurch gekennzeichnet, daß

der Meniskus (17) derart eingestellt wird, daß der obere Rand der in der Gußform-Rührereinrichtung enthaltenen Kerne (14a, 14b, 14c, 14d) weniger als 100 mm unterhalb des Meniskus angeordnet ist, während gleichzeitig der vordere Rand der in der Gußform-Rührereinrichtung enthaltenen Wicklungsstränge (15a, 15b, 15c, 15d) weniger als 150 mm von der Innenfläche der Gußformwandung entfernt angeordnet ist.

Revendications

1. Procédé pour se rendre maître pendant la coulée de métal d'un courant de métal fondu dans des parties non solidifiées d'une barre de coulée qui est formée dans une lingotière refroidie qui est ouverte aux deux extrémités dans la direction de coulée, un courant efficace et dont on peut se rendre maître de métal fondu dans les parties non solidifiées étant obtenu et maintenu en appliquant au moins un champ magnétique tournant qui agit sur les parties non solidifiées de la barre de coulée, de manière à brasser la masse fondue par l'action d'une force sur la masse fondue qui provient d'une coopération entre les composantes d'intensité du champ magnétique et les courants électriques qui sont induits dans la masse fondue par le champ magnétique, le champ magnétique étant appliqué à la masse fondue au moyen d'un dispositif de brassage à deux phases ou polyphasé qui est disposé à l'extérieur de la lingotière et qui comprend deux sous-dispositifs de brassage ou plusieurs sous-dispositifs de brassage, chacun d'eux comprenant un noyau (14a, 14b, 14c, 14d) magnétique et un enroulement (15a, 15b, 15c, 15d) de phase alimenté en courant alternatif et disposé autour du noyau, le champ magnétique à un niveau des noyaux comprenant essentiellement une composante, B_y , d'intensité de champ magnétique disposée transversalement à la direction de coulée et le champ magnétique à un

- niveau des enroulements de phase comprenant essentiellement une composante, Bz, d'intensité de champ magnétique orientée parallèlement à la direction de coulée, caractérisé en ce que les enroulements (15a, 15b, 15c, 15d) de phase inclus dans le dispositif de brassage de la lingotière sont disposés de manière adjacente à la paroi intérieure de la lingotière, de façon que le champ magnétique qui est engendré par le dispositif de brassage de la lingotière à l'intérieur de la lingotière à un niveau des enroulements de phase comprennent essentiellement la composante, Bz, d'intensité de champ magnétique, orientée parallèlement à la direction de coulée et en ce que le courant de la masse fondue au ménisque (17) et à proximité du ménisque (17) est réglé en ajustant la position du ménisque par rapport au noyau (14a, 14b, 14c, 14d) inclus dans le dispositif de brassage de la lingotière de façon que l'action d'une force qui naît dans la masse fondue au ménisque et à proximité du ménisque soit modifiée par une coopération entre les courants I induits dans la masse fondue et les composantes, By et Bz, d'intensité de champ respectivement.
2. Procédé suivant la revendication 1, pendant la coulée, dans lequel de la masse fondue est envoyée à la lingotière au moyen d'un tube de coulée qui débouche en dessous de la face supérieure de la masse fondue à savoir le ménisque, caractérisé en ce qu'il consiste à mettre le ménisque (17) en une position relative par rapport aux noyaux (14a, 14b, 14c, 14d) inclus dans le dispositif de brassage de la lingotière de manière que le bord supérieur des noyaux soit placé suffisamment loin en dessous du ménisque (17), de sorte que le courant de la masse fondue au ménisque et à proximité du ménisque est freiné par l'action d'une force née d'une coopération entre la composante, Bz, d'intensité de champ à un niveau des enroulements de phase et les courants I électriques qui sont induits dans la masse fondue par le champ magnétique adjacent au ménisque, puisque ces forces sont de sens opposé aux forces F qui sont appliquées à la masse fondue plus bas dans la lingotière par une coopération entre la composante du champ magnétique transversalement à la direction de coulée, By, et les courants induits.
 3. Procédé suivant la revendication 2, caractérisé en ce qu'il consiste à régler la position du ménisque (17) de façon que les noyaux (14a, 14b, 14c, 14d) inclus dans les dispositifs de brassage de la lingotière soient disposés en ayant leur bord supérieur plus bas de plus de 25 mm que le ménisque (17), cependant que les enroulements (15a, 15b, 15c, 15d) de phase inclus dans le dispositif de brassage de la lingotière sont disposés en ayant leur bord avant distant de moins de 150 mm de la face intérieure de la paroi de la lingotière.
 4. Procédé suivant la revendication 2 ou la revendication 3, caractérisé en ce qu'il consiste à mettre le ménisque (17) en une position telle que les noyaux (14a, 14b, 14c, 14d) inclus dans le dispositif de brassage de la lingotière soient disposés en ayant leur bord supérieur plus bas de 25 mm à 200 mm que le ménisque (17), cependant que les enroulements (15a, 15b, 15c, 15d) de phase inclus dans le dispositif de brassage de la lingotière sont disposés en ayant leur bord avant éloigné de 10 mm à 150 mm de la face intérieure de la paroi de la lingotière.
 5. Procédé suivant la revendication 2, 3 ou 4, caractérisé en ce qu'il consiste à régler la position du ménisque (17) de façon que les noyaux (14a, 14b, 14c, 14d) inclus dans le dispositif de brassage de la lingotière soient disposés en ayant leur bord supérieur plus bas que le ménisque (17) de 50 mm à 100 mm, cependant que les enroulements de phase inclus dans le dispositif de brassage de la lingotière sont disposés en ayant leur bord frontal à une distance de 50 mm à 100 mm de la face intérieure de la paroi de la lingotière.
 6. Procédé suivant la revendication 1, pendant la coulée, dans lequel de la masse fondue est envoyée à la lingotière au moyen d'un jet libre de coulée qui heurte la face supérieure, à savoir le ménisque, de la masse fondue, caractérisé en ce qu'il consiste à mettre le ménisque (17) en une position dans laquelle les noyaux (14a, 14b, 14c, 14d) inclus dans le dispositif de brassage de la lingotière sont disposés en ayant leur bord supérieur suffisamment près du ménisque (17) de façon à obtenir et à maintenir un brassage suffisamment intense au ménisque et à proximité de celui-ci au moyen de l'action d'une force qui est appliquée à la masse fondue par une coopération entre la composante d'intensité du champ magnétique transversalement à la direction de coulée, By, et les courants I électriques qui sont induits dans la masse fondue par le champ magnétique, cependant que la composante, Bz, d'intensité du champ magnétique au niveau des enroulements de phase est appliquée transversalement à la surface du ménisque sans engendrer de force de sens opposé au courant.
 7. Procédé suivant la revendication 6, caractérisé en ce qu'il consiste à régler la position du ménisque (17) de façon que les noyaux (14a, 14b, 14c, 14d) inclus dans le dispositif de brassage de la lingotière soient disposés en ayant leur bord supérieur à moins de 100 mm du ménisque, tandis que les enroulements (15a, 15b, 15c, 15d) de phase inclus dans le dispositif de brassage de la lingotière sont disposés en ayant leur bord avant à moins de 150 mm de la face intérieure de la paroi de la lingotière.

8. Procédé suivant la revendication 6, caractérisé en ce qu'il consiste à régler la position du ménisque (17) de façon que les noyaux (14a, 14b, 14c, 14d) inclus dans le dispositif de brassage de la lingotière soient disposés en ayant leur bord supérieur plus bas de moins de 100 mm que le ménisque, cependant que les enroulements (15a, 15b, 15c, 15d) de phase inclus dans le dispositif de brassage de la lingotière sont disposés en ayant leur bord avant à moins de 150 mm de la face intérieure de la paroi de la lingotière.

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Fig. 1

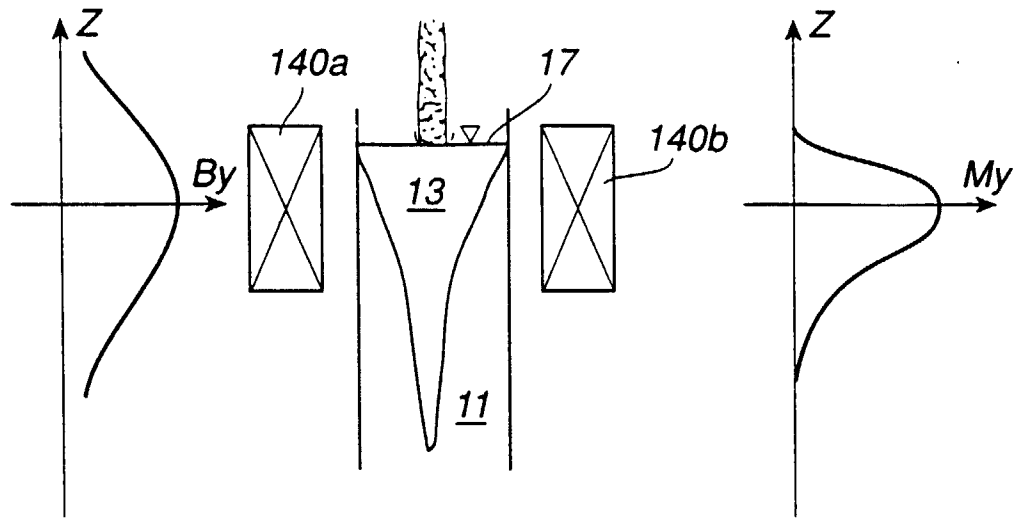


Fig. 2

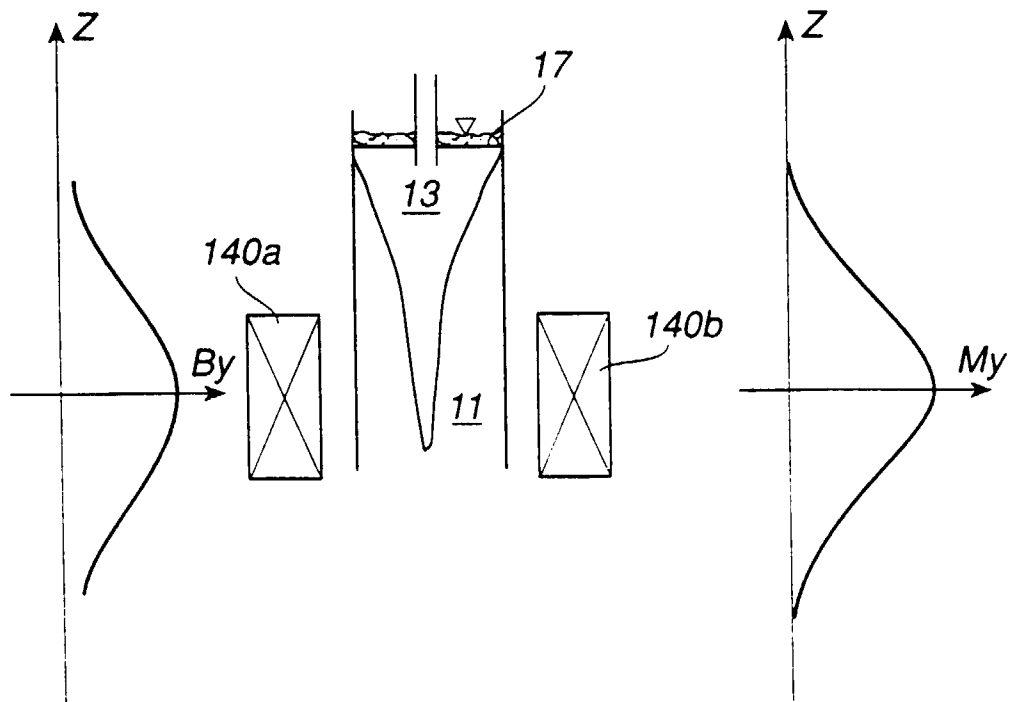


Fig. 3

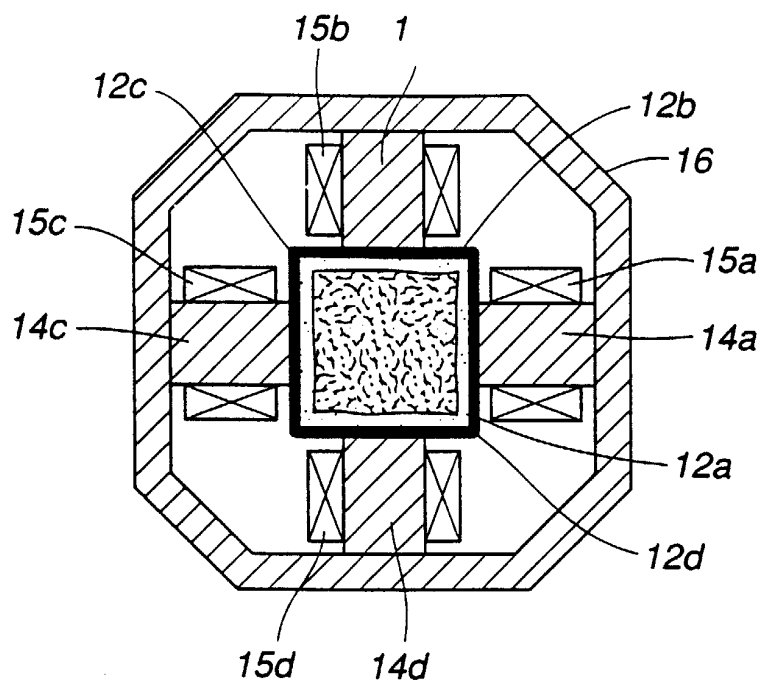


Fig. 4

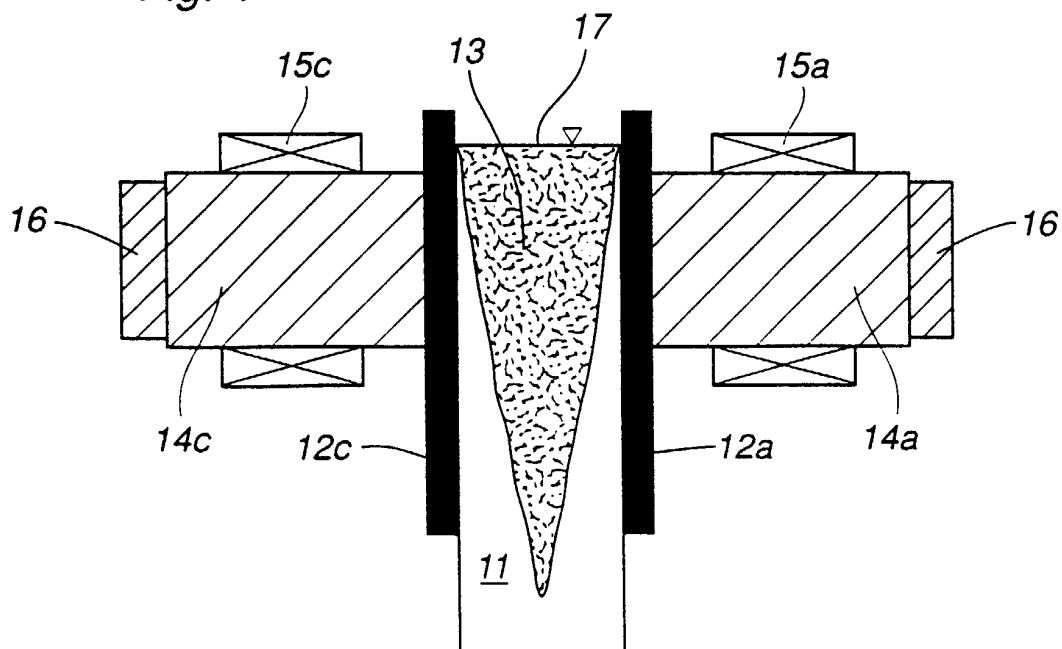


Fig. 5

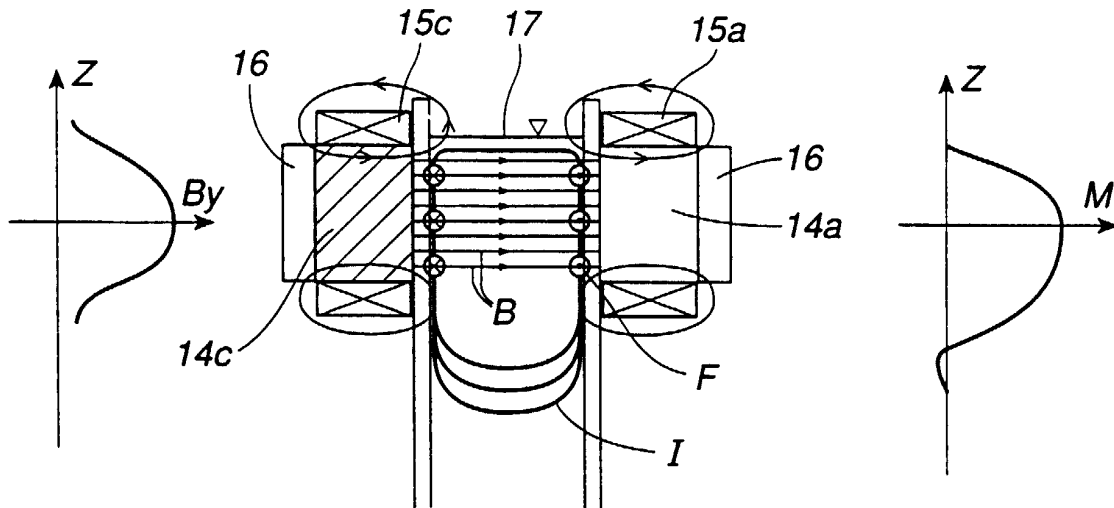


Fig. 6

