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Baumann

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[54] **APPARATUS FOR REGULATING THE SOLIDIFICATION OF THE LIQUID CORE IN A CONTINUOUS CASTING**

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[52] **U.S. Cl.** **164/250,** 164/49, 164/82

[51] **Int. Cl.** **B22d 27/02,** B22d 11/12

[58] **Field of Search** ..... 164/48-49, 51, 164/82, 251, 273 R, 282, 283, 250

[56] **References Cited**

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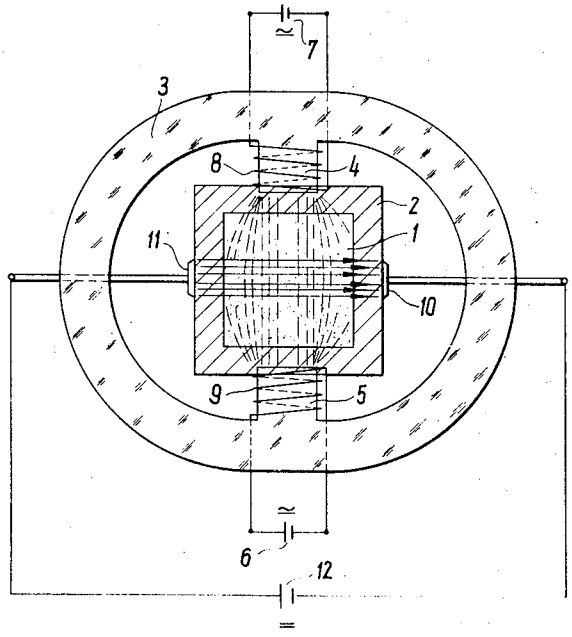
[57] **ABSTRACT**

To regulate the pressure exerted by the liquid core within a continuous casting as it solidifies, a magnetic field is established about the casting or strand in the region in which it contains a liquid core. Further, to increase or decrease the effect of the magnetic field, a d.c. field is established about the strand adjacent the magnetic field with the axis of its electrodes positioned perpendicularly to the axis of the poles of the magnetic field.

6 Claims, 3 Drawing Figures



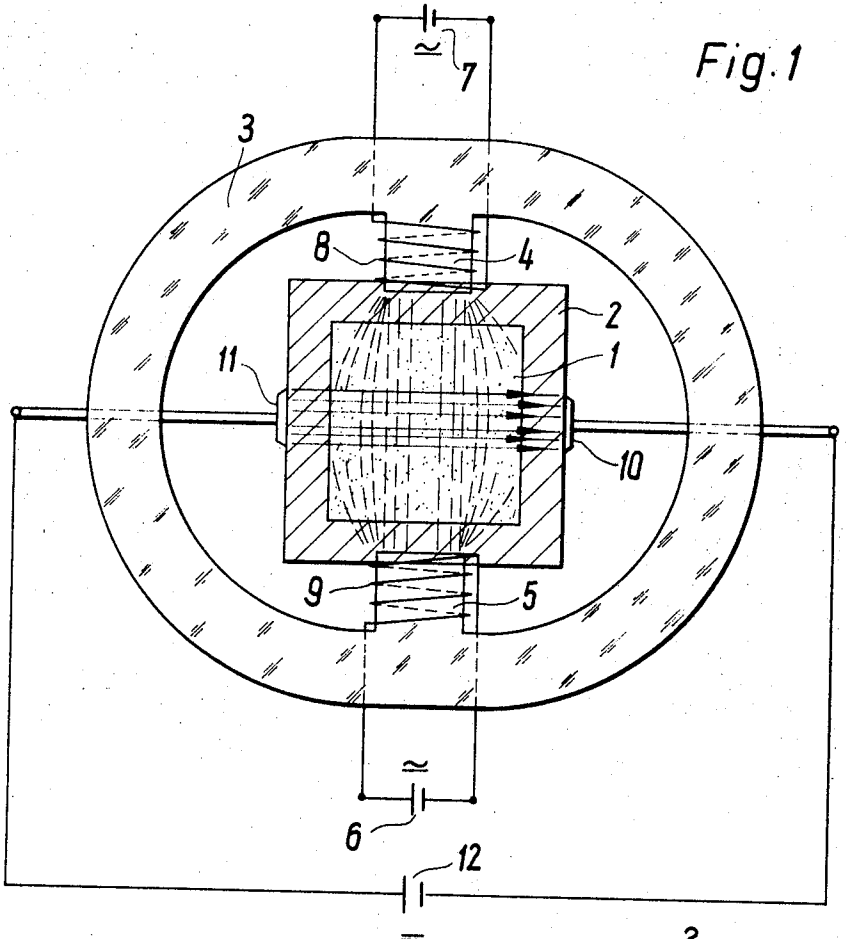


Fig. 1

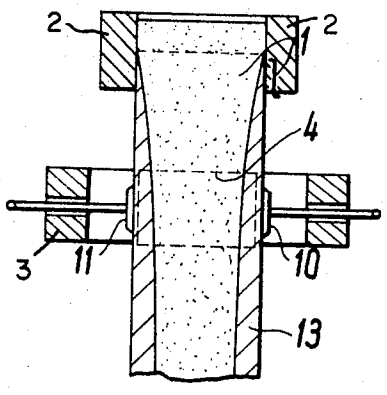


Fig. 2

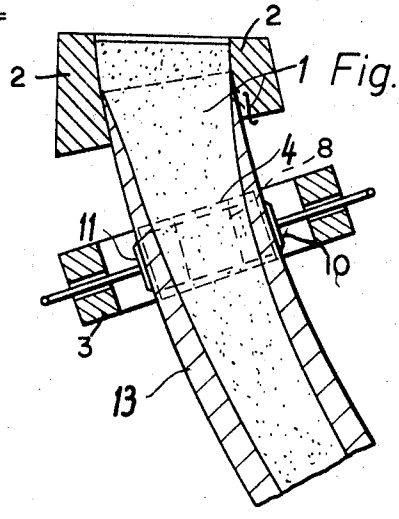


Fig. 3

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APPARATUS FOR REGULATING THE SOLIDIFICATION OF THE LIQUID CORE IN A CONTINUOUS CASTING

SUMMARY OF THE INVENTION

The present invention is directed to continuous casting plants and, more particularly, to a method of and apparatus for regulating the solidification of the liquid core within the casting or strand issuing from a continuous casting mold.

In continuous casting plants difficulties have been experienced in conducting the slowly solidifying strand or casting from its mold so that the integrity of the very thin solidified skin on the strand is maintained for preventing any breakthrough of the liquid core located interiorly of the skin. In arcuate continuous casting plants it is known that the liquid pool or core within the strand or casting extends from the mold to a point beyond the equipment used in withdrawing the strand from the mold. Accordingly, the forces acting on the strand as it is withdrawn from the mold and also when it is bent from the vertical into the horizontal position, if such is the case, must be maintained at such a level that undue stresses are not exerted on the strand which would cause a rupture in its skin and disturb its liquid core. As long as the core of the casting or strand is liquid, a hydrostatic or ferrostatic pressure acts on the casting shell.

The ferrostatic pressure increases as the lowest point of the liquid pool extends into the horizontal part of the support for the casting as it is withdrawn from the mold. As the necessary devices for withdrawing, bending, and straightening are applied to the casting before it is completely solidified, special care must be exercised in handling the casting due to the liquid condition of its core.

The conditions in the interior of the casting or strand are determined not only by the stresses exerted on it as it bears on supporting guide rollers, guide shoes and the like, but the formation of the desired homogeneous and crystalline structure within the strand are determined by the pressure exerted by the liquid core. The bottom layers of the strand, whether it is in an arcuate form or in a horizontal position, are subjected to a higher pressure and, as a result, cracks, shrink holes and other non-homogeneous conditions are developed in the interior of the strand.

Accordingly, the invention is based on the findings that the unsolidified or liquid core within the strand influences the final properties of the solidified product.

Therefore, the primary object of the present invention is to regulate the liquid condition of the core as the casting strand solidifies so that non-homogeneous conditions within the interior of the casting are avoided and external deformations, such as occur between casting support rollers, are prevented.

In accordance with the present invention, magnetic fields of force are arranged about the strand in a continuous casting plant in the region in which the interior of the strand is in a liquid condition for regulating the pressure exerted by the liquid core. Due to the application of the magnetic field, the hydrostatic pressure exerted by the liquid core at any point is at least partly if not completely eliminated. As a result, the solidification of the strand can be regulated into its very interior without encountering any of the difficulties previously experienced as a result of the pressure exerted by the liquid core. Further, the structure of the strand becomes more homogeneous and does not include any defects which have been responsible for much of the waste material in previous continuous casting operations. By employing the present invention, the solidification of the casting takes place so that a greater strength is developed in a shorter distance as the casting is withdrawn from the mold. Further, the elimination of the effect of the ferrostatic or hydrostatic pressure on the strand also reduces the bulges previously experienced between casting support points so that it is possible to eliminate the risk of a breakthrough of the liquid core at such points.

The method of the present invention is particularly advantageous for horizontal castings, since the pressure of the liquid core either can be reduced or at least oriented in the proper direction depending on the requirements of the individual casting.

In the past a magnetic field has been used for regulating the amount of liquid metal flowing through a pipe, such as disclosed in DAS No. 1,111,344. By arranging a magnetic yoke around the flowing liquid metal, an eddy current is induced into the liquid metal which reduces the velocity at which it flows. This arrangement serves to regulate the volume of the liquid metal flowing per unit of time.

Further, in DAS No. 1,123,090 electromagnetic forces are used to deflect a casting jet as it issues from a tank or to vary the shape of the casting jet which is influenced by the configuration of the outlet port and gravity.

However, these previously known methods for using electromagnetic forces are directed to the regulation of the flow of a liquid metal and they do not disclose any regulation of a liquid core within a solidified exterior layer in a continuous casting strand.

Another feature of the present invention involves the use of a variable d-c field in combination with the magnetic field for regulating the pressure of the liquid core prior to the point at which the casting completely solidifies. The variable d-c field can be used to increase or decrease the effect of the magnetic field. Accordingly, it is possible to regulate the force originating from the magnetic field in its line of action. When a magnetic field and a d-c field are used, their axes are arranged perpendicularly to one another and the increasing or decreasing action on the force in the magnetic field can be achieved by varying the polarity. By the combination of the magnetic field and d-c field a force can be generated for regulating the liquid core in a strand of any dimension or size.

As indicated above, in the apparatus embodying the present invention the oppositely disposed d-c electrodes are provided with reversible polarity and their axis is disposed perpendicularly to the axis of the poles of the magnetic field. Either an alternating or direct current can be used for the magnetic field and the strength of the field can be increased or reduced by means of the d-c electrodes. Moreover, it may be advantageous to work with a lower voltage but with a higher current intensity.

Another feature of the apparatus embodying the present invention is the use of a pair of opposite walls of the mold as electrodes. In such an arrangement the effect of the magnetic field can be employed in the region of the mold and can continue downstream of the

mold in the region where a liquid core continues to exist within the strand.

Moreover, it is possible to use the various guide elements of the continuous casting plant, such as the supporting rollers and guide shoes, as electrodes. The use of direct current permits such an application, because the low velocity at which the casting travels does not hinder the electric conduction.

Finally, it is possible to utilize the shell or skin of the casting as an electrode. In such an arrangement it is possible to afford a more intensive influence on the liquid core in the casting. This action can extend uniformly on all four sides of the casting for its entire length.

The mold itself and/or a terminal attached to the casting head can serve as a current lead.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which there is illustrated and described a preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic illustration of the invention with the continuous casting passing through a mold and being influenced by the perpendicularly arranged magnetic and d-c fields;

FIG. 2 shows a partial longitudinal sectional view of a continuous casting with a liquid core and with the casting shell serving as an electrode; and

FIG. 3 is another view similar to that shown in FIG. 2, however, displaying the continuous casting in an arcuate form.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. 1 a casting or strand 1 is enclosed on all four sides by coils 2 which also serve as the walls of a mold. Laterally encircling the casting 1 is a yoke 3 which is in engagement with the poles 4, 5 of a magnet, and the poles are disposed on opposite sides of the casting. The excitation of the magnetic field can be effected either by alternating or direct current through the current sources 6, 7 and the associated windings 8, 9. Accordingly, the yoke 3 produces a magnetic field. Superposed on the magnetic field is a d-c field which is generated by means of electrodes 10 and 11 connected to a d-c source 12. In the embodiment shown in FIG. 1, the electrodes 10, 11 are attached on the coils 2.

In FIGS. 2 and 3 it indicates that it is possible to attach the electrodes 10 and 11 directly to the casting shell in the region below the mold where a liquid core still exists within the casting. In this arrangement the current produced by the voltage from the current source 12 flows through the casting shell 13 in a larger region about the electrodes 10, 11.

By means of the present invention it is possible to counteract both in arcuate and horizontal continuous casting plants the gravity effect of the liquid core or at least to compensate for it. In any event, the pressure exerted by the liquid core can be regulated. Furthermore, it is possible to use special arrangements adapted to the respective pressures within the castings.

While a specific embodiment of the invention has been shown and described in detail to illustrate the application of the inventive principles, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. Apparatus for use in a continuous casting plant including a mold in which a strand is initially formed and said mold having an outlet from which the strand is withdrawn with a thin solidified skin and a liquid core so that the liquid core solidifies as the strand continues to move outwardly away from the outlet of said mold, wherein the improvement comprises a magnetic yoke disposed about the continuous casting strand in the region where the strand contains a liquid core, poles for said magnetic yoke positioned on opposite sides of the strand, means for supplying current to said poles for establishing a magnetic field around the strand, a pair of electrodes disposed on opposite sides of the strand with the axis of said electrodes arranged perpendicularly to the axis of said poles, and means for supplying a source of direct current to said electrodes and for reversing the polarity of said electrodes so that a small d-c field can be established for increasing or decreasing the force of the magnetic field on the liquid core within the continuous casting strand.

2. Apparatus, as set forth in claim 1, characterized therein that said mold has a rectangular shape and said electrodes are positioned on two opposite sides of said mold.

3. Apparatus, as set forth in claim 1, characterized therein that said mold has a rectangular shape so that said strand is rectangular in transverse cross section, said electrodes being located on opposite sides of said strand at a position spaced from the outlet from said mold.

4. Apparatus, as set forth in claim 1, characterized therein that said electrodes for the d-c field are applied to the surface of the strand after it is withdrawn from the mold.

5. Apparatus, as set forth in claim 1, characterized therein that said means for supplying current to said poles comprises a source of alternating current.

6. Apparatus, as set forth in claim 1, characterized therein that said means for supplying current to said poles comprises a source of direct current.

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