United States Patent

Von Starck

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[54] APPARATUS FOR PRODUCING CONTINUOUSLY CAST SECTIONS WITH AGITATION OF THE LIQUID CORE

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[52] **U.S. Cl.** **164/251,** 164/282, 164/82

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

[58] **Field of Search** 164/49, 51, 82, 251, 273, 283, 164/282

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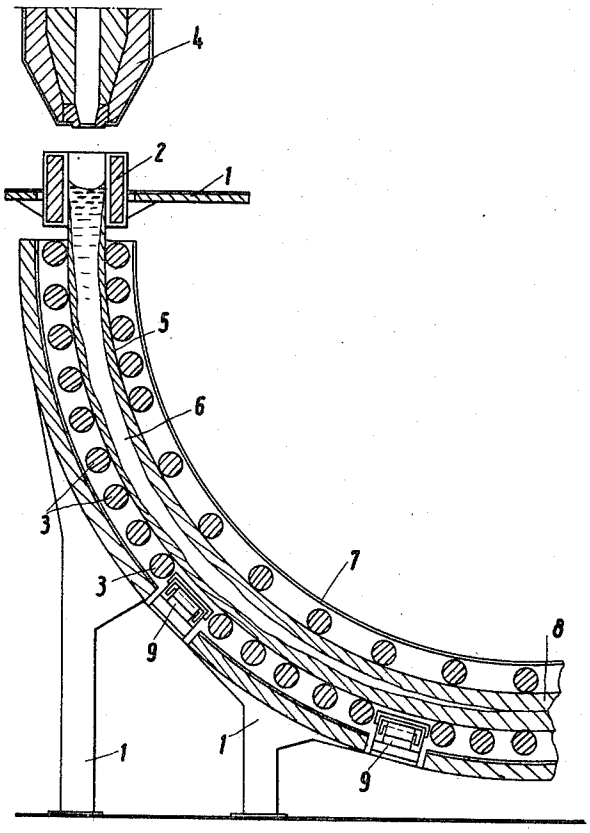
[57] **ABSTRACT**

A method and apparatus for continuously casting metal which is poured in molten form into an open ended mold where a thin exterior shell forms about a liquid core and the resulting casting continuously exists from the mold. In order to inhibit the formation of dendrite and other crystals and also concentration of impurities at the center, the cooling casting, after exiting from the mould, moves past a traveling field inductor which generates a traveling electromagnetic field having a component normal to the direction of movement of the casting, this field causing the liquid interior of the casting to be agitated.

5 Claims, 3 Drawing Figures



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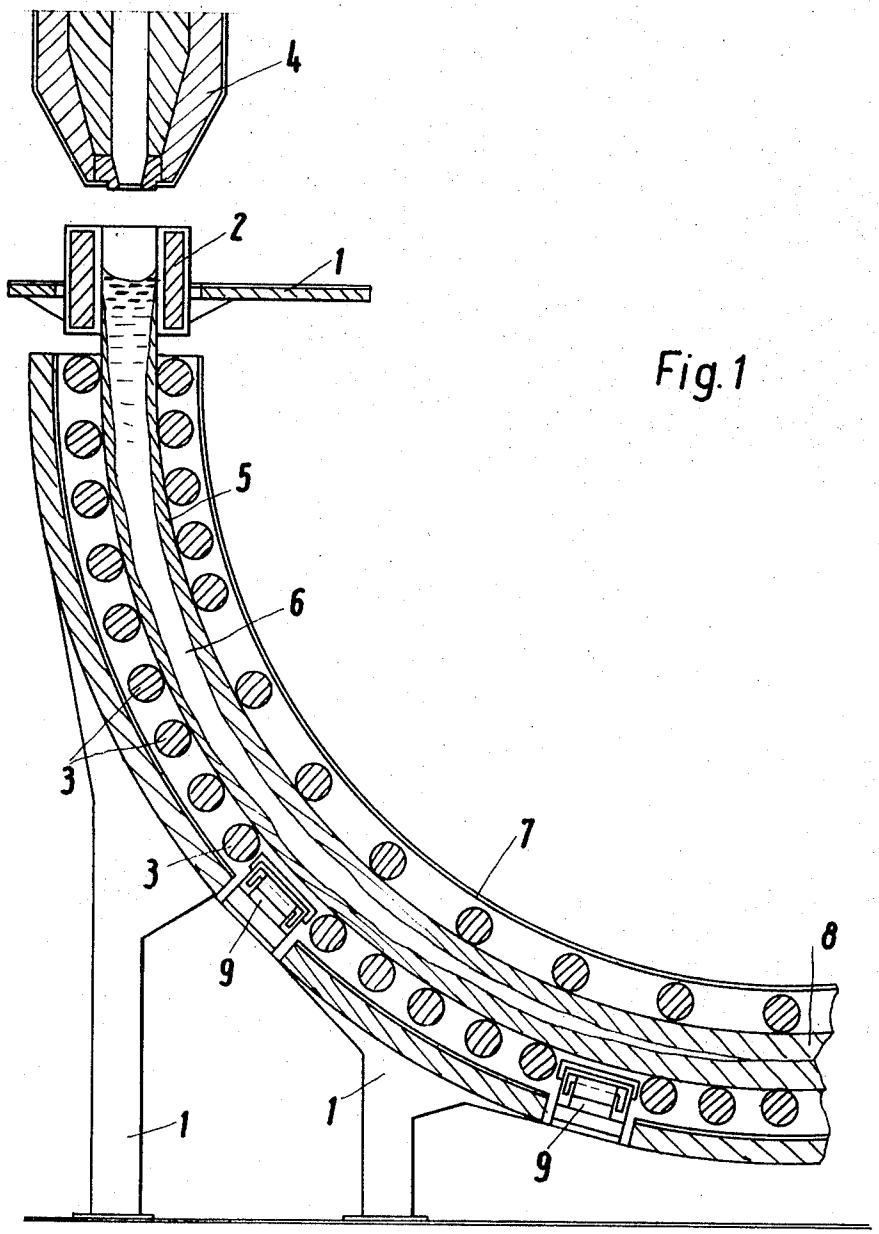

Fig. 1

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Fig. 2

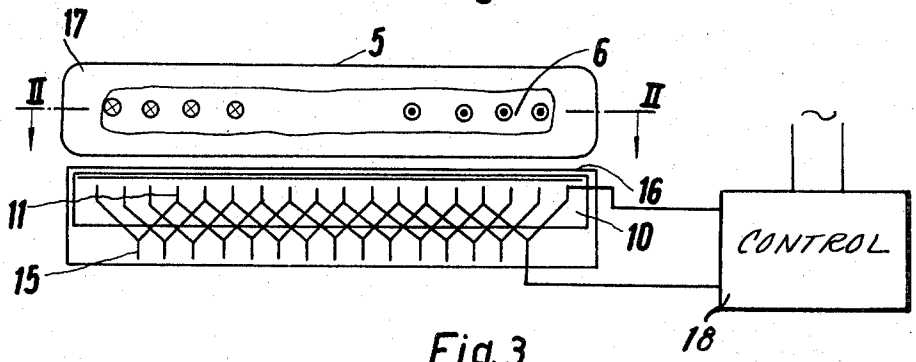
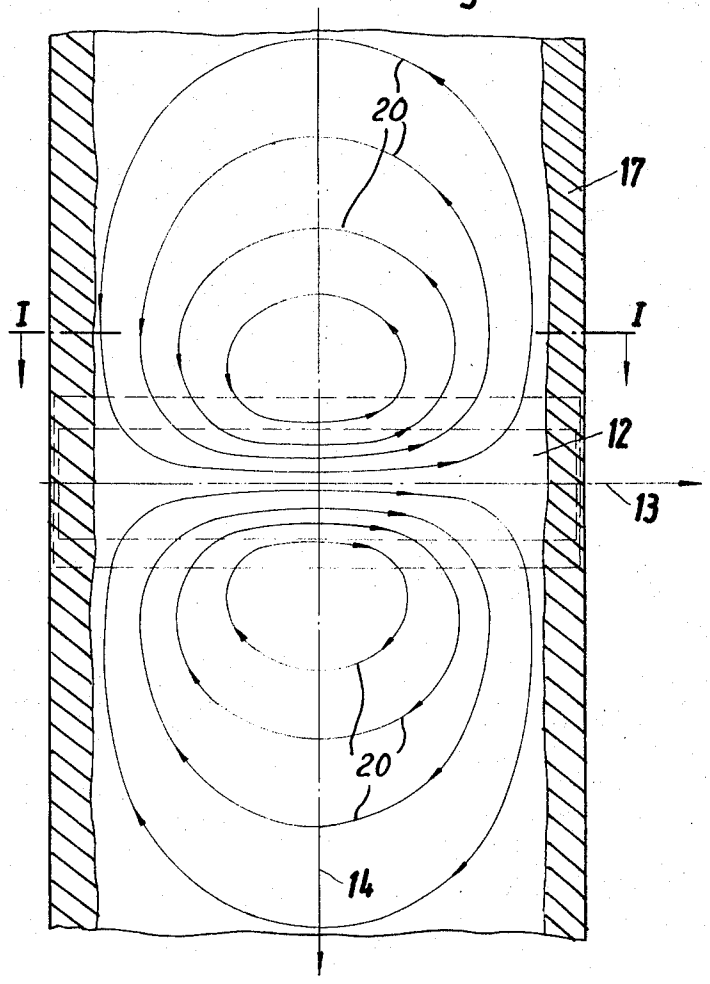


Fig. 3



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APPARATUS FOR PRODUCING CONTINUOUSLY CAST SECTIONS WITH AGITATION OF THE LIQUID CORE

This invention relates to a method and apparatus for continuously casting metal, particularly in rectangular shapes such as slabs, plates and the like.

In most continuous casting operations, the molten metal, for example molten steel, is usually poured continuously or intermittently into an open-ended mold. Inside the mold the metal contacts the cooled walls of the mold and solidifies from the exterior to the interior permitting a continuous casting comprising a thin shell about a liquid core to be withdrawn from the bottom of the open-ended mould. To prevent the bulging or cracking of this still-thin frozen shell which holds the liquid interior of the casting due to the ferrostatic pressure of the liquid interior, the emerging casting is usually guided a considerable distance between a system of supporting rollers and drive rollers, the drive rollers operating to withdraw the casting from the mold. During the time it takes a given length of casting to pass through this guiding system, the cooling and solidification of the casting progresses inwardly to the center until the entire cross section of the casting is finally solid.

However, this process of solidification is accompanied by a number of undesirable effects. First, it has been found that the freezing metal often forms dendrite and other crystals which extend from the outside surface towards the casting center. In subsequent treatment of the casting by rolling or forging this type of crystal orientation is undesirable. Further, particularly in the casting of steel ingots, solidification is accompanied by segregation of the impurities contained in the melt. Most of these are carried along by the solidification front resulting in a concentration of impurities at the center of the continuous casting.

In order to avoid these unwanted effects, it has previously been proposed to stir the freezing metal melt in the liquid core of the casting by subjecting that interior to an electromagnetically generated rotating field, which suppresses the development of the dendrites and the segregation of the impurities by inducing current flow in the liquid core which in turn causes circular flow of the liquid. To accomplish this, the casting, as it leaves the open-ended mould, is usually conducted through the stator of a three-phase motor, which by virtue of its rotating field causes the liquid metal in the core of the casting to be likewise rotated. However this arrangement has been found in practice not to be entirely satisfactory.

It is therefore the object of the present invention to provide an arrangement for controlling the solidification of continuous castings so that formation of undesirable dendrite crystals and the segregation of impurities are inhibited. This is accomplished in the embodiment of the invention described below by generating an electromagnetic field having a component normal to the path of travel of the casting through the mould. This field agitates the liquid center of the mold. More particularly, according to one embodiment of the invention, the field is produced by a traveling field inductor in the form of the stator of a linear motor located adjacent the casting at a position below the open-ended mold and disposed so that the direction of propagation of the generated traveling field contains at least one component normal to the direction of movement of the casting so that motion is imparted to the liquid metal in the interior of the casting. For the production of sections of rectangular or approximately rectangular section, for instance slabs and plates, and traveling field inductor is preferably disposed so that the direction of propagation of the generated traveling field is parallel or substantially parallel to the wider side of the casting.

Further in a preferred embodiment of the invention, means are provided for alternately energizing and de-energizing the traveling field inductor and/or for reversing its polarity whereby the generated motion of the metal may be altered by continuously or discontinuously varying the inductor voltage.

A particular embodiment of the invention is hereinafter described and illustrated in the accompanying drawings, in which

FIG. 1 is a schematic representation of a continuous casting plant for the production of slabs according

FIG. 2 is a section taken on the line I—I of FIG. 3, and

FIG. 3 is a section taken on the line II—II of FIG. 2.

Referring to FIG. 1, mounted on a suitably designed framework 1 is an open-ended mould 2 which is cooled by a liquid coolant which circulates through a suitable network (not shown). A supporting and withdrawing system comprising a plurality of rollers 3 is provided adjacent the exit of mould 2. The liquid metal is continuously or intermittantly poured into mould 2 from a pouring system 4, and, as the liquid metal contacts the cooled mould wall, it solidifies, thus forming a continuous metal casting 5 comprising a solid shell surrounding a liquid core 6. Casting 5 is continuously withdrawn from the bottom of mould 2 and passes through a supporting roller apron 7. As the casting 5 moves through apron 7, it solidifies progressively inwards from the external shell towards the center until finally the casting as shown, is solid throughout its cross section. The steel or other slab thus formed is then drawn at position 8 into a straightening or other machine (not shown).

According to one embodiment of the invention of this application, there are mounted in supporting frame 1, one or several traveling field inductors 9 each comprising a flat elongated and slotted laminated iron core 10 which carries a polyphase bar winding 11. In FIG. 1, two such inductors 9 are depicted. Bar winding 11 is designed so that upon application thereto of a polyphase electrical sine-wave voltage, the resultant current through winding 11 produces a traveling electromagnetic field in the form of a sine wave that is propagated along the length of inductor 9. Such windings are well known in the art and any suitable type can be employed. The direction of propagation of the traveling field is preferably parallel to the wider side face of casting 5 i.e. normal to the plane of the paper in FIG. 1.

Referring to FIGS. 2 and 3, the pole face 12 of a traveling field inductor 9, which is only schematically shown in this view, is mounted parallel to the wider side face of the casting 5 and the direction of propagation of the traveling field as shown by arrow 13 is normal to the direction of movement of the casting as shown by arrow 14.

Referring to FIG. 3 the traveling field inductor 9 comprises a laminated iron core 10 and the overhang 15 of a bar winding received into the slots of laminated iron core 10. A parting plate 16 of non-magnetic material preferably shields bar winding 11 from the radiant heat of hot casting 5 and is preferably separated from bar winding 11 by a suitable insulating layer.

While subject to the electromagnetic field, casting 5 already has a frozen outside shell 17 which encloses a core zone 6 that is still liquid. Under the effect of the traveling field which is generated by the inductor 9 and propagated in the direction of arrow 13, currents are induced in the liquid core 6 of the casting and, in cooperation with the traveling field, these currents cause the liquid metal to attempt to flow in the direction of propagation of the traveling field, as generally indicated by arrows 20. Thus on each side of the zone influenced by the inductor the flowing metal circulates through a butterfly shaped zone of return flow. Since casting 5 moves in relation to inductor 9, the movement of the circulating liquid core continuously changes direction and the result is a very effective agitating action on the liquid zone in the core.

Further, this continuous change in the direction of flow of the metal can be assisted by alternately energizing and de-energizing and/or changing the polarity of the traveling field inductors. Another way to further agitate the liquid core is to continuously or abruptly change the voltage applied to the inductor. In FIG. 2, a control circuit 18 is provided for permitting this action.

Many changes and modifications in the above embodiment of the invention can be made without departing from the scope of the invention. Accordingly, that scope is intended to be limited only by the scope of the appended claims.

What is claimed is:

1. In an apparatus for the continuous casting of metal of the type having an open ended casting mould for receiving molten metal to be cast and for forming a strand having a solidified

shell and a liquid core and means for supporting and cooling the strand after it is withdrawn from said mould so that said metal solidifies from the exterior to the interior to form a solid casting having a substantially rectangular shape, the improvement comprising means for generating an electromagnetic field in a cross-section of a portion of said casting which has not completely solidified including a linear traveling field inductor mounted for generating a traveling electromagnetic field in said portion with the direction of field propagation being substantially normal to the path of travel of said casting through said supporting and cooling means and extending across the wider side face of said casting so that the liquid interior of said casting is agitated.

2. In an apparatus as in claim 1, the further improvement including means for alternately energizing and de-energizing said traveling field inductor so as to change the pattern of the flow in said liquid interior.

3. In an apparatus as in claim 1, the further improvement including means for alternately changing the polarity of said traveling field inductor so as to change the pattern of the flow in said liquid interior.

4. In an apparatus as in claim 1, the further improvement including means for varying the voltage on said inductor so as to change the pattern of flow in said liquid interior.

5. In an apparatus as in claim 1, the further improvement including a plurality of said inductors mounted at different points along said mould.

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