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(54) **METHOD AND DEVICE FOR EQUALIZING THE SOLIDIFICATION PROCESS OF A MOLTEN METAL PARTICULARLY PRODUCED DURING STRAND OR STRIP CASTING**

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(57) **ABSTRACT**

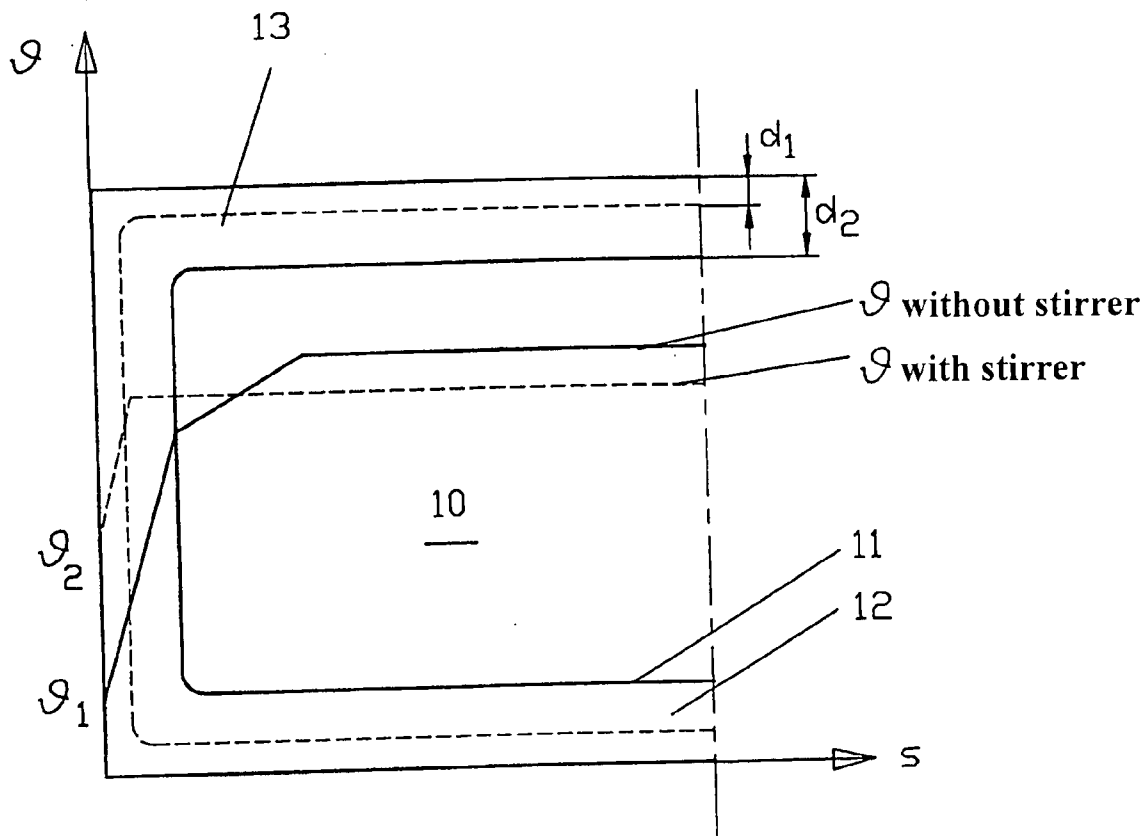
The invention relates to a method of equalizing a solidification process of molten metal produced, in particular, during strand or strip casting, wherein the molten metal (10) is subjected, in particular, to an electromagnetic stirring process, and wherein a magnetic field is applied to metal located upstream of the area of, in particular, the electromagnetic stirring process. According to the invention, it is provided that during the solidification process, at least one magnetic field is applied to an already solidified, at the outside, into a strand, region (11) of the molten metal (10). The invention also relates to a device for carrying out this process.

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T (Temperature)

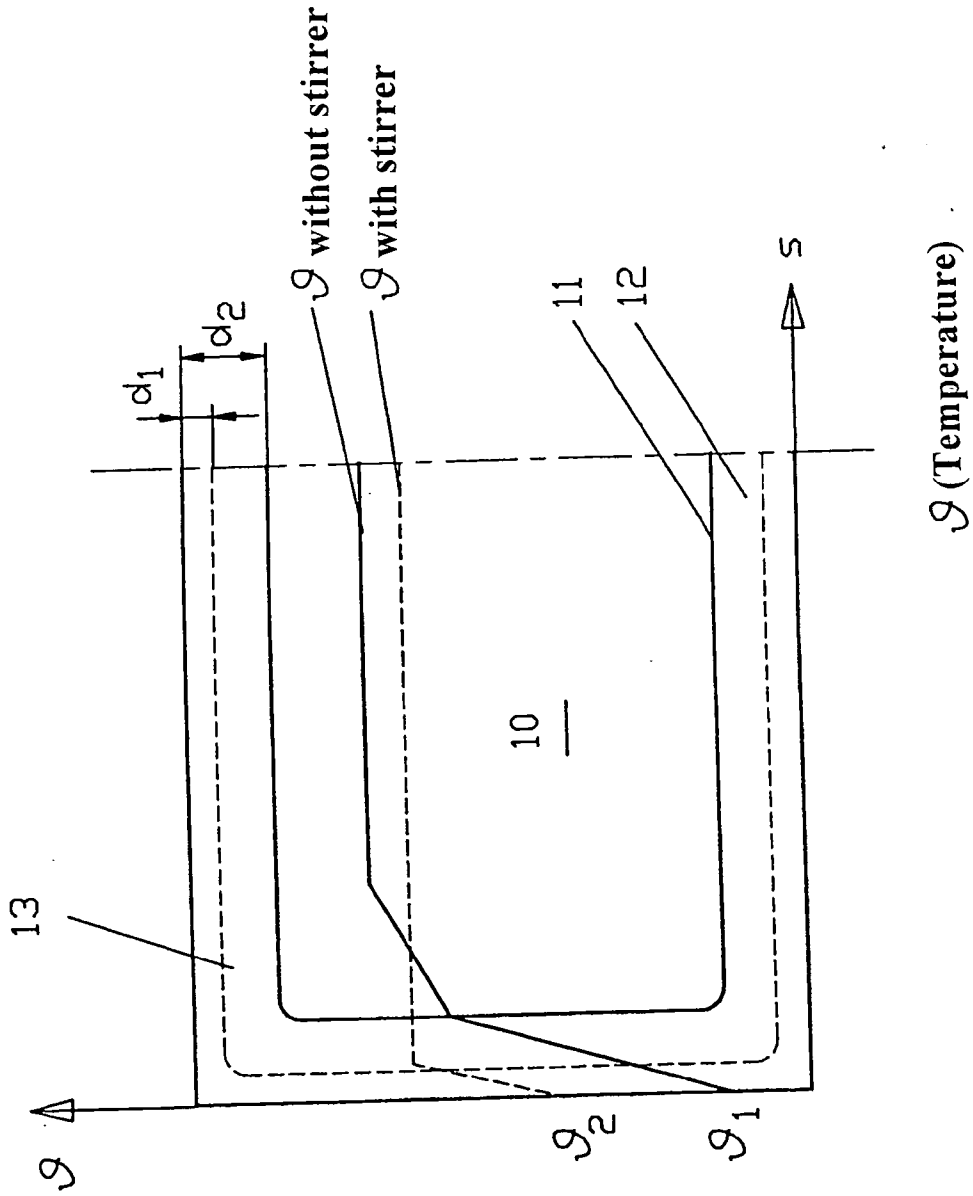


FIG.1

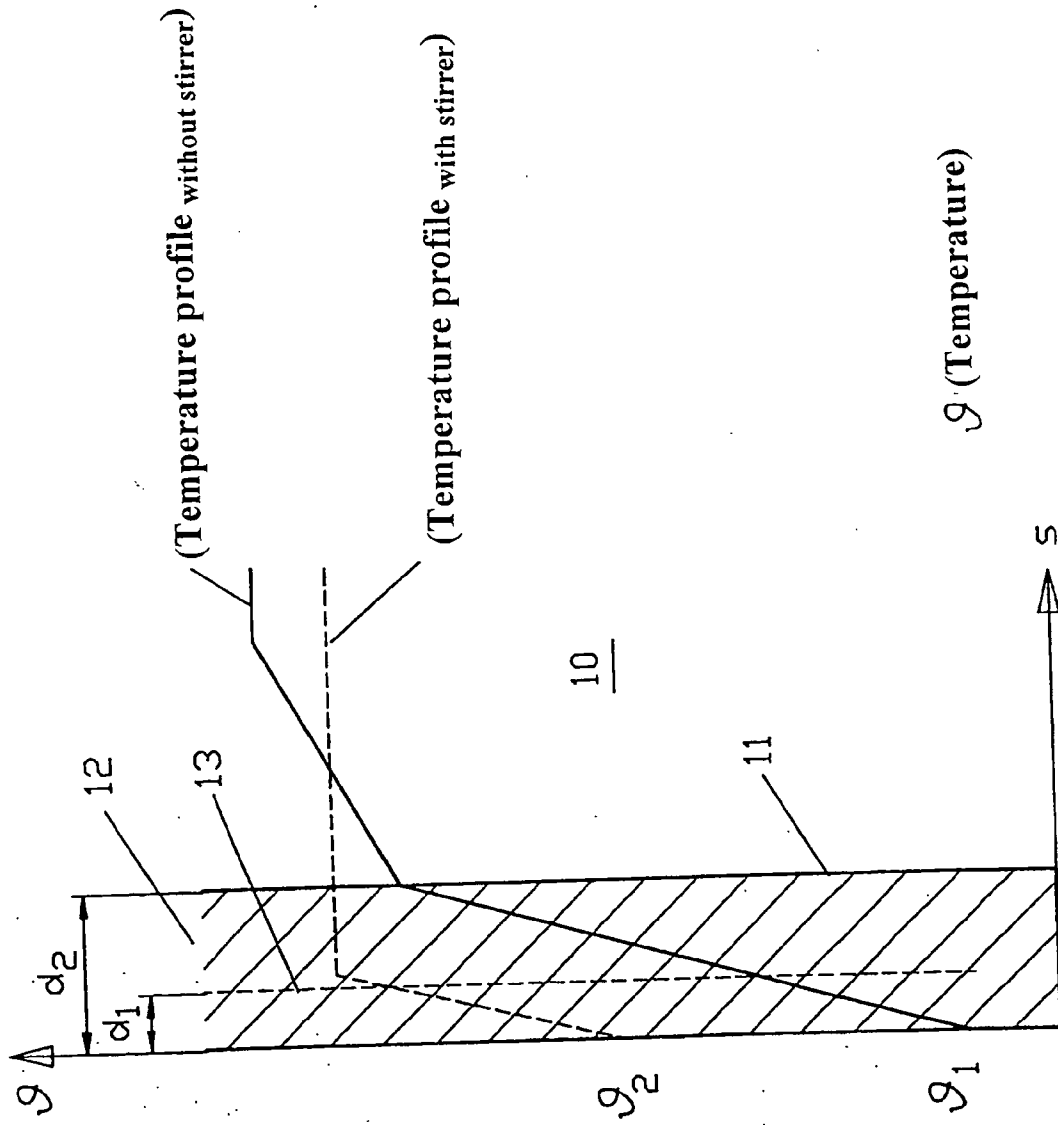


FIG. 2

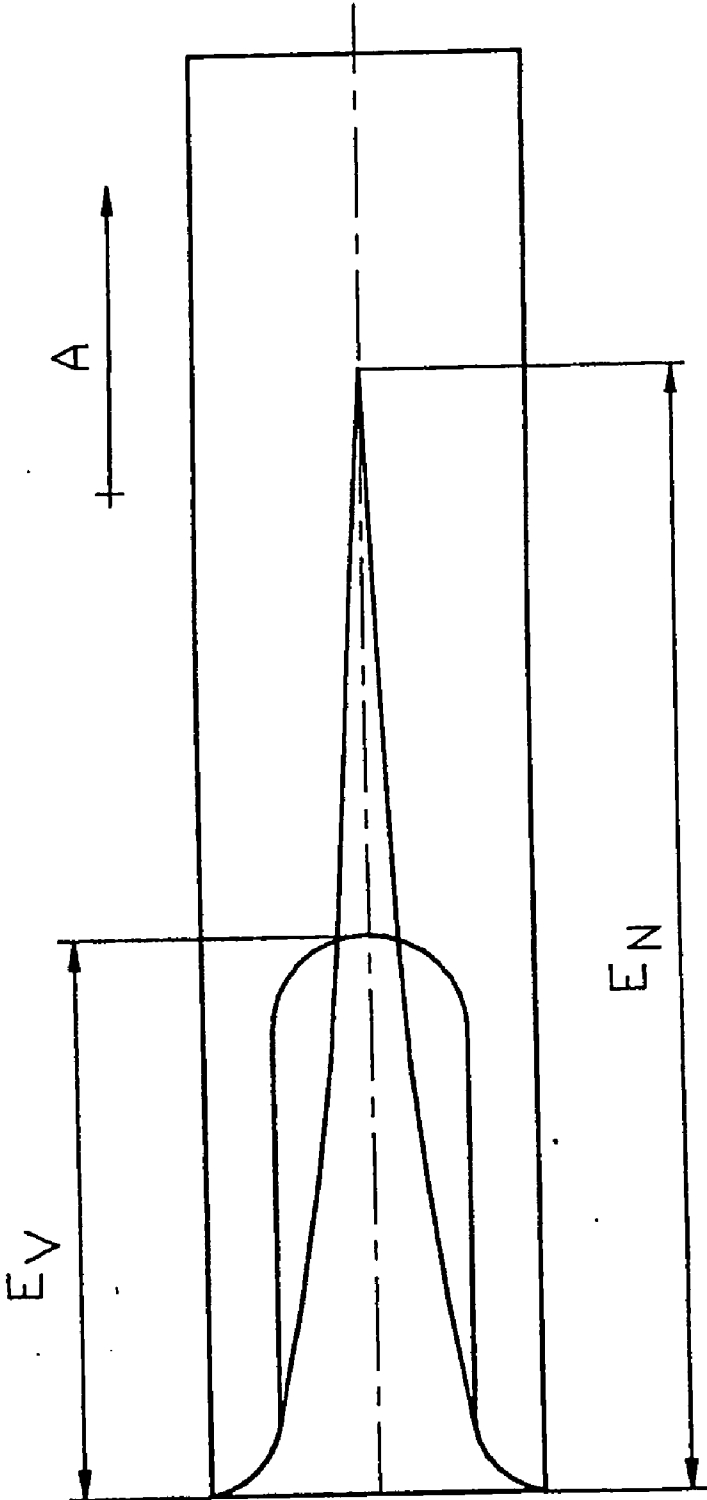


FIG.3

**METHOD AND DEVICE FOR EQUALIZING
THE SOLIDIFICATION PROCESS OF A
MOLTEN METAL PARTICULARLY
PRODUCED DURING STRAND OR STRIP
CASTING**

[0001] The invention relates to a method of and a device for equalizing solidification of molten metal produced, in particular, during strand or strip casting and wherein the molten metal is subjected, in particular, to an electromagnetic stirring process, wherein a magnetic field is applied, upstream of the area of, in particular, electromagnetic stirring, to the metal located there. The invention also relates, in addition, to a device for carrying out the process.

[0002] Basically, during a solidification process of a cast strip, e.g., on a cooled conveyor belt that transports the cast strip, large heat removal takes place at the bottom of the cast strip as well as at the upper surface and the narrow sides. As a result, a non-uniform temperature profile is formed over the strip cross-section and which creates, during a subsequent cooling process, stresses in the strip which can lead to warping of the strip. Because the contact of the cast strip and the conveyor belt, in particular, in width direction, is not constant and the removal of heat from the cast strip over its width is not uniform, it again leads to a non-uniform solidification structure.

[0003] In this connection, the prior art discloses different methods and devices with electromagnetic stirring in the region of liquid steel melt, by way of example, reference is made to the following publications:

[0004] U.S. Pat. No. 4,933,005 discloses an induction stirring method according to which, molten metal is electromagnetically stirred usually with intensity that produces turbulence in the molten metal, and upstream of the area of the electromagnetic stirring, a static magnetic field is applied with intensity to the molten metal and which is sufficient for reducing turbulence in the mentioned area to a smallest extent.

[0005] The described method is directed to improving inducting stirring applications where, among others, a free surface exists during stirring in molds and during electromagnetic stirring in ladles or other containers, and surface disturbances and distortions in meniscus should be reduced to a minimum.

[0006] Japanese Publication JP 06182502 A relates to a single metal strip-type caster in which it is suggested to provide an electromagnetic brake above a region of a molten metal and specifically at the drawing side of the metal belt rather than at a point of pouring molten metal on the belt, in order to prevent waving of the molten metal region and to obtain a metal strip with a flat surface without roughness. At the time of pouring of the molten metal from a tundish on a metal belt, waving is generated on the surface of the molten metal region by the pouring flow of the molten metal. The electromagnetic brake is provided above the molten metal regions and, in particular, at the drawing side of the metal belt rather than at the point of pouring molten metal. This arrangement eliminates waving in the direction of the metal belt as seen from the electromagnetic brake, and so a flat molten metal is formed. Therefore, due to the formation of a solidified shell without waving in the molten metal region, a flat surface shape of the surface of the solidified shell, without roughness, is achieved.

[0007] With regard to these two publications, it can be said that the known methods and devices cannot prevent the above-described problems.

[0008] The object of the invention is to improve and further develop the known methods and devices, while retaining the existing advantages, that the above-mentioned drawbacks are eliminated, wherein, in particular, optimization of a precise shape of a strand, a better control of a metallurgical length, and a better adaptation of the speed are achieved.

[0009] With regard to the method, the object of the invention is achieved by applying, during the solidification process, at least one magnetic field to an already solidified, at the outside, into a strand, region of the molten metal.

[0010] Thereby, in a simple way, the naturally developed temperature profile in a still molten core is homogenized by action of an electromagnetic field on the already solidified, at the outside, into a strand, melt. The uniform distribution of energy in the molten core provides always the most possible temperature at the inner side of the strand shell. As a result, the thickness growth of the shell is delayed, whereby the heat removal is increased. Due to a higher heat removal, the cast strip solidifies more rapidly. Overall, by producing a uniform temperature field over the cross-section of the molten core, the strand shell is heated somewhat again at the start of stirring, so that its thickness growth is delayed, and the shell, which remains warm longer and becomes thinner, only later acquires its mechanical characteristics. Thereby, it lies flatly on the cooled conveyor belt for a longer time which leads to reduction of inner stresses and of a possible high-arching of the edges.

[0011] According to an advantageous embodiment of the inventive method, the electromagnetic field is applied to an already solidified, at the outside, into a strand, region essentially at a bottom of the molten metal. In this area, as a rule, a greater heat removal takes place than at the upper surface and the narrow sides.

[0012] According to a further and last feature of the method, a position of the electromagnetic stirring process is adapted in the casting direction.

[0013] The object of the invention, with respect to the device, is achieved, according to the invention, by providing a device formed for applying, during the solidification process, at least one magnetic field to an already solidified, at the outside, into a strand, region of the molten metal. With respect to the advantages achieved thereby, in order to prevent repetition, reference is made to the described advantages of the method.

[0014] According to an advantageous embodiment of the inventive device, the device is formed for applying at least one electromagnetic field to an already solidified, at the outside, into a strand, region essentially at a bottom of the molten metal.

[0015] According to the last feature of the inventive device, it is provided that the position of the electromagnetic stirring process is adapted in the casting direction.

[0016] Further advantages and particularities of the invention follow from the dependent claims and the following description in which an embodiment of the invention, which is shown in the drawings, is explained in detail. In addition to the above-described combination of features, separate features or in other combinations form an essential part of the invention.

[0017] The drawings show:

[0018] FIG. 1 a schematic view of a temperature profile of the molten metal and of the strand shell with the use of the inventive method in comparison with the state of the art;

[0019] FIG. 2 an enlarged view of the left portion in FIG. 1; and

[0020] FIG. 3 a schematic view of solidified stretches of the molten metal in the casting direction.

[0021] The inventive method serves for equalizing the solidification process of molten metal which is designated with 10 in FIG. 1 and which is produced, in particular, during casting of strand or strip. The molten metal 10 is subjected to an electromagnetic stirring process, with a magnetic field being applied to the metal upstream of the area of the electromagnetic stirring. According to the inventive method, during the solidification process, at least one electromagnetic field is applied to an already solidified, at the outside, into a strand, region 11 of the molten metal 10.

[0022] This inventive feature provides the previously described advantages. A further advantage consists in that by producing a uniform temperature field over the cross-section of the molten core, the strand shell 12 is heated somewhat again at the start of stirring so that its thickness growth is delayed, and the shell 12, which remains warm longer and becomes thinner, only later acquires its mechanical characteristics. Thereby, it lies flatly on the cooled conveyor belt for a longer time which leads to reduction of inner stresses and of a possible high-arching of the edges. FIGS. 1 and 2 show a temperature profile of the molten metal 10 and the strand shell 12 with the use of the inventive method in comparison with the state of the art. It can be seen that the solidified region 11 of the metal 10 and, thus, the thickness d_2 of the strand shell 12 is substantially thicker than the solidified region 13 of the metal 10 at a delayed solidification and, thus, the thickness d_1 of the strand shell 12, see FIGS. 1 and 2. It is further shown the temperature profile of the molten metal 10 and the strand shell 12 wherein the temperature 9 with stirrer shows the temperature of the stirring process, and the temperature 9 without stirrer shows the temperature without the stirring process. It can be seen that the temperature without the stirring process raises noticeably faster and, finally, is at a higher level than the temperature with the stirring process.

[0023] According to an advantageous embodiment of the inventive process, it is contemplated to apply the electromagnetic field to the already solidified, at the outside, into a strand, region 11 essentially, at a bottom of the molten metal 10. It can further be provided to adapt the position of the electromagnetic stirring process in the casting direction.

[0024] FIG. 3 shows solidification stretches of the molten metal 10 in the casting direction shown with arrow A. The solidification stretch EN shows a normal solidification stretch, and the solidification stretch EV shows a shortened solidification stretch with stirring.

[0025] The present invention also relates to a device, not shown in the drawings, for carrying out the method, in particular, the electromagnetic stirring process in the molten metal 10. The device is formed for applying at least one electromagnetic field during the stirring process to an already

solidified, at the outside, into a strand, region 11 of the molten metal 10, preferably, at the bottom of the molten metal 10. It can further be provided for adaptation of the position of the electromagnetic stirring process in the casting direction.

LIST OF REFERENCE NUMERALS

- [0026] 10 molten metal
- [0027] 11 solidified region (of 10)
- [0028] 12 strand shell
- [0029] 13 solidified region at a delayed solidification
- [0030] A casting direction
- [0031] EN normal solidification stretch
- [0032] EV shortened solidification stretch

1. A method of equalizing a solidification process of molten metal produced, in particular, during strand or strip casting, wherein the molten metal (10) is subjected, in particular, to an electromagnetic stirring process, and wherein a magnetic field is applied to metal located upstream of the area of, in particular, the electromagnetic stirring process, characterized in that during the solidification process at least one magnetic field is applied to an already solidified, at the outside, into a strand, region (11) of the molten metal (10).
2. A method according to claim 1, characterized in that the electromagnetic field is applied to an already solidified, at the outside, into a strand, region (11) essentially at a bottom of the molten metal (10).
3. A method according to claim 1, characterized in that a position of the electromagnetic stirring process is adapted in a casting direction.
4. A device for equalizing a solidification process of molten metal produced, in particular, during strand or strip casting, and including means for subjecting the molten metal (10) in particular, to an electromagnetic stirring process, and means for applying a magnetic field to metal located upstream of the area of, in particular, the electromagnetic stirring process, characterized by a device formed for applying, during the solidification process, at least one magnetic field to an already solidified, at the outside, into a strand, region (11) of the molten metal (10).
5. A device according to claim 4, characterized in that the device is formed for applying at least one electromagnetic field to an already solidified, at the outside, into a strand, region (11) essentially at a bottom of the molten metal (10).
6. A device according to claim 4, characterized in that a position of the electromagnetic stirring process is adapted in a casting direction.

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