METAL CASTING APPARATUS WITH ELECTROMAGNETIC NOZZLE

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Fig. 1

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Fig. 2

Fig. 3

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ABSTRACT OF THE DISCLOSURE

A metal casting apparatus having a downwardly extending nozzle formed with an axial flow passage therethrough which communicates at the upper end thereof with a container so that molten metal in the container may flow out of the same through the axial flow passage of the nozzle, and in which electromagnetic means cooperate with an electric current which is passed through the stream of metal flowing through the nozzle and/or electrically conductive passages formed therein to control the flow of metal passing through the flow passage in dependence on the direction and magnitude of the electric current and the magnetic field produced by the electromagnetic means.

Background of the invention

The present invention relates to a metal casting apparatus including a downwardly extending nozzle through which molten metal flows in a stream during the casting operation. More specifically, the present invention relates to such a nozzle in which a stream of molten metal flowing therethrough can be regulated.

Various arrangements for regulating the stream of molten metal through a nozzle are known in the art, and the known arrangement usually comprises movable valve members located in the path of the stream of molten metal so that by movement of the valve members the flow of metal through the nozzle may be regulated.

It is an object of the present invention to provide for a nozzle arrangement which does not include any movable member for regulating the flow of molten metal therethrough.

It is an additional object of the present invention to provide for a nozzle arrangement in which control of the flow of molten metal therethrough is produced by electromagnetic forces.

More specifically it is an object of the present invention to provide for a nozzle arrangement enabling to obtain a fine adjustment of the rate of flow of molten metal.

Summary of the invention

With these objects in view, the metal casting apparatus according to the present invention mainly comprises a container adapted to contain a supply of molten metal, a downwardly extending nozzle of electrically non-conductive material formed with an axial flow passage therethrough and communicating with the bottom portion of the container for discharging a stream of molten metal therefrom. The nozzle is further formed with at least one pair of elongated cavities respectively arranged to opposite sides of the axis of the flow passage and communicating at least at opposite ends with the latter, the cavities to opposite sides of the axis being axially displaced with respect to each other in such a manner so that a portion of each cavity which communicates with the flow passage is arranged in a common plane substantially normal to the aforementioned axis with a corresponding portion of the other cavity, and the cavities are filled with electrically conductive material at least during flow of molten metal through the flow passage. The apparatus includes further current supply means connected to the molten metal for causing flow of electric current through the stream of molten metal and the electrically conductive material in the cavities so that the current will flow in the region of the aforementioned common plane along a path inclined at an angle to the axis of the flow passage, and electromagnetic means are arranged about the nozzle in the region of the aforementioned common plane for producing a magnetic field transverse to the axis of the flow passage and to the path of current in the region of the plane to produce thereby a force component retarding or accelerating the flow of metal through the flow passage depending on the direction and magnitude of the flow of the current and of the magnetic field.

The apparatus may also have the following characteristics in combination with those set forth above:

(a) The aforementioned cavities may be constituted by lateral channels;
(b) The lateral channels according to paragraph (a) may be filled with electrically conductive and refractory material;
(c) The electrically conductive and refractory material may be constituted by cermet, a product composed of ceramic material and a metal;
(d) The flow passage through the nozzle and the aforementioned cavities may have a cylindrical form; and
(e) The flow passage through the nozzle and the aforementioned cavities may have, in a plane normal to the axis of the nozzle, a rectangular cross section.

Basically, the invention comprises a metal casting apparatus in which a magnetic field created by an electromagnet acts on an electric current which passes through a stream of molten metal which flows out through a nozzle from a container of molten metal and in which the flow lines of the electric current do not coincide with the direction of flow of the metal. For this purpose, the passage through the nozzle through which current may flow is provided with a variation in its cross section formed by a pair of axially shifted cavities respectively located to opposite sides of the axis of the nozzle and arranged in such a manner so that a portion of each cavity which communicates with the flow passage is arranged in a common plane substantially normal to the axis of the nozzle with a corresponding portion of the other cavity to form with the actual flow passage a maximum cross section. This maximum cross section is subjected to a magnetic field produced by the electromagnet, which magnetic field is transverse to the axis of the nozzle.

It will be understood that in such an arrangement the lines of the electric current in passing through the aforementioned maximum cross section will be inclined to the axis of the nozzle and include with the flow of molten metal passing along the axis of the nozzle an angle differing from zero. Since, on the other hand, the magnetic field produced by the electromagnet will act on the portion of the flow passage in which the lines of electric current are inclined to the axis of the nozzle, the magnetic field will produce a force in direction normal to the lines of current according to the Law of Ampere, or according to Fleming's Rules. This force will have a component coinciding with the axis of the nozzle, which force component will be added or subtracted to the ferrostatic pressure and all other pressures acting on the stream of molten metal, depending on the direction of current flow through the metal and the direction of the magnetic field. The force thus produced permits there-
fore to regulate the outflow of the molten metal through the nozzle in a most precise manner by varying, respectively reversing the flow of electric current passing through the electrodes or the magnetic field produced by the electromagnet.

The invention aims to simplify the electromagnetic arrangement using the action of a magnetic field on an electric current by arranging the contacts for the electric current with the stream of metal away from the narrow passage of the nozzle so as to avoid the difficulties which would result from arranging the contact electrodes in the narrow cross section of the nozzle.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

Brief description of the drawing

FIG. 1 is a simplified schematic view of the apparatus according to the present invention;

FIG. 2 is a longitudinal cross section through a first embodiment of a nozzle according to the present invention;

FIG. 3 is a transverse cross-section taken along the line a-b of FIG. 2;

FIG. 4 is a longitudinal cross section through a second embodiment of a nozzle according to the present invention;

FIG. 5 is a transverse cross section taken along the line c-d of FIG. 4;

FIG. 6 is a longitudinal cross section through a third embodiment of a nozzle according to the present invention;

FIG. 7 is a transverse cross section through the nozzle of FIG. 6 taken along the line e-f;

FIG. 8 is a longitudinal cross section through a fourth embodiment of a nozzle according to the present invention; and

FIG. 9 is a transverse cross section taken along the line g-h of FIG. 8.

Description of the preferred embodiments

Referring now to the drawings, and more specifically to FIG. 1 of the same in which the overall arrangement of the casting apparatus according to the present invention is schematically illustrated, it will be seen that the apparatus according to the present invention mainly comprises the container 1 adapted to contain a supply of molten metal, for instance molten steel, and provided in the bottom wall thereof with a downwardly extending nozzle 2, only schematically shown in FIG. 1, through which a stream of molten metal may flow out from the container 1 into an ingot mold 5 of cast iron located beneath the nozzle 2. It is mentioned that the nozzle 2 is shown in FIG. 1 only schematically and various modifications of the nozzle according to the present invention are shown more clearly in FIGS. 2-9. A portion of the nozzle 2 is subjected to the magnetic field produced by an electromagnet, the poles 3 and 4 of which are schematically shown in FIG. 1. Electrical current is supplied to the electromagnet 3, 4 in a manner not shown in FIG. 1 and preferably in such a manner that the polarity of the poles 3 and 4 may be reversed, and the magnitude of the magnetic field produced by the electromagnet may be varied. The electrode 7 held by means not shown in FIG. 1 is arranged to dip into the molten metal in the container 1 and the electrode 7 is connected to a source of current 6 and this source of current is likewise connected to the conductive wall of the ingot mold 5 so that electric current will flow through the stream of molten metal passing from the container 1 through the nozzle 2 into the ingot mold 5.

In the arrangement illustrated, the current flowing through the stream of metal is a direct current which may have a magnitude from several thousand amperes and in this case the current flowing through the nozzle is likewise a direct current. However, the current flowing through the stream of metal may also be an alternating current, in which case the electromagnet has also to be supplied with alternating current of the same frequency and in such a manner that the electromagnetic field produced by the electromagnet is in phase with the vertical component of the current which creates a force permitting regulation of the outflow of the metal.

It is to be understood that the container may contain not only molten steel, but also other metals, such as for instance lead, copper, mercury, etc. Instead of the ingot mold another receptacle or a channel lined with refractory material may be used and in this case the source of electric current is connected to another electrode dipping in the metal contained in the receptacle or the channel, or the second electrode may be arranged downstream of the outlet end of the nozzle so that the stream of molten metal emanating therefrom. In any case, a current is preferably supplied to the stream of metal in such a manner that the direction of the current flow may be reversed and that the magnitude of the current may be varied in a well-known manner, not shown in the drawing.

FIGS. 2 and 3 illustrate a first embodiment of the nozzle according to the present invention. In this embodiment, the nozzle, which is formed in all embodiments disclosed from electrically non-conductive material, is substantially cylindrical and formed with a central cylindrical flow passage 8 therethrough, and with two likewise substantially cylindrical cavities 9 and 10, respectively located to opposite sides of the axis 11 of the nozzle and in such a manner that the cavities 9 and 10 communicate over the whole length thereof with the flow passage 8. The cavities 9 and 10 are respectively axially displaced with respect to each other in such a manner that a lower portion of the cavity 9 is at the same elevation as an upper portion of the cavity 10 so that at these portions the flow passage has its maximum transverse cross section. Two poles 3 and 4 of an electromagnet, formed from laminated soft iron, extend into corresponding holes in the nozzle into close proximity of the flow passage 8 in the region of the aforementioned maximum cross section. The poles are arranged in such a manner that the magnetic field indicated by the arrows B is located in a plane normal to the axis 11 of the nozzle. The direction of the flow of metal through the nozzle is indicated by the arrows A and the line of the current flowing through the metal are indicated in FIG. 2 by the dotted lines C.

As clearly shown in FIG. 2, the lines of current flow include in the region of the electromagnet an acute angle with the axis 11 of the nozzle and the electromagnetic field will therefore produce a force normal to the lines of current which will have a force component in direction of the axis of the nozzle and which will, depending on the direction of the current flow and the direction of the magnetic field, act in the same direction or in the opposite direction as the ferrostatic pressure so as to decrease or increase the speed at which the metal flows out through the nozzle.

FIGS. 4 and 5 illustrate a second embodiment of the nozzle according to the present invention. In the modification shown in FIGS. 4 and 5 the nozzle has in a plane normal to the axis 11 thereof a rectangular cross section and the central flow passage 12 as well as the lateral cavities 13 and 14 have likewise a rectangular cross section. The advantage of this embodiment is to obtain due to the decreased area of the flow passage a reduced force produced by the magnetic field which is greater than that obtainable with the nozzle shown in FIGS. 2 and 3 at otherwise identical electrical conditions.

In the modification shown in FIGS. 6 and 7, the cavities are constituted by lateral channels 15 and 16 which are separated from the central flow passage 17 by the
wells 18 and 19 so that the channels communicate only at the upper and lower ends thereof with the flow passage. As shown in FIG. 6, the lower end of the lateral channel 15 communicates with the central flow passage substantially in a common plane with the upper portion of the channel 16 which likewise communicates with the central flow passage. In this modification, the lines of current indicating by the dash lines C extend between the poles 3 and 4 of the electromagnet therefore in a direction normal to the flow of metal through the central flow passage, as indicated by the arrows A, and also normal to the magnetic field B so that under the same electrical condition the correction pressure due to the force produced by the magnetic field will reach its maximum. This is a special advantage of the modification illustrated in FIGS. 6 and 7. The lateral channels 15 and 16 may also be filled with liquid metal in the same way as in the preceding embodiments, but the lateral channels may also be filled, as is illustrated in FIG. 6, with an electrically conductive refractory material such as "Cermet,", a product composed of a ceramic material and a metal, for instance Cr₃O₃, Cr, Al₃O₃, Cr, or Al₂O₅. These ceramics have a resistance of the same magnitude as or a lower resistance than the liquid steel and are therefore especially suitable for nozzles serving for the outflow of ferrous materials, and for non-ferrous metal other electrically conductive and refractory materials, for instance graphite, may be used.

Finally, FIGS. 8 and 9 illustrate a fourth embodiment of a nozzle according to the present invention in which three lateral cavities 20, 21, and 22 are provided, arranged with respect to each other as clearly shown in FIG. 8 in such a manner that the upper and lower ends of the cavity 21 are arranged to one side of the axis of the nozzle respectively overlap in axial direction the lower end of the cavity 20 and the upper end of the cavity 22 arranged at the other side of the axis so as to form with the central flow passage maximum cross sections at the regions of the aforementioned overlaps and in which the portions of maximum cross section are subjected to the influence of a pair of electromagnets the poles of which are respectively designated with 23, 24 and 25, 26. The advantage of this modification is that the efficiency of the nozzle is multiplied by two since the lines of current C present, as indicated by the dotted lines in FIG. 6, two curves of S-shaped configuration which at their point of inflection include a considerable angle with the metal flow direction indicated by the arrows A, while being substantially normal to the vector B of the magnetic field.

The arrangement according to the present invention may be used with continuous or discontinuous casting of metal; it is particularly advantageous for the continuous casting of metal since it permits an extremely precise and fine regulation of the metal outflow from the nominal outflow caused by the ferrostatic pressure. It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of metal casting apparatus differing from the types described above.

While the invention has been illustrated and described as embodied in a metal casting apparatus with an electromagnetically controlled nozzle, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention. Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims.

1. A metal casting apparatus comprising, in combination, a container adapted to contain a supply of molten metal; a downwardly extending nozzle of electrically non-conductive material formed with an axial flow passage therethrough communicating with a bottom portion of the container for discharging a stream of metal therefrom; at least one pair of elongated cavities formed in said nozzle and respectively arranged on opposite sides of the axis of said flow passage and communicating at least at opposite ends with said flow passage, said cavities to opposite sides of said axis being axially displaced with respect to each other in such a manner so that a portion of each cavity which communicates with said flow passage is arranged in a common plane substantially normal to said axis with a corresponding portion of the other cavity, said cavity being filled with electrically conductive material at least during flow of molten metal through said flow passage; current supply means connected to所述 molten metal for the of flow of electric current through said stream of molten metal and the electrically conductive material in said cavities, so that said current will flow in the region of said common plane along a path inclined at an angle to the axis of said flow passage; and electromagnetic means arranged about said nozzle in the region of said common plane for producing a magnetic field transverse to said axis of said flow passage and to said path of current in the region of said plane to produce thereby a force component retarding or accelerating the flow of metal through the flow passage depending on the direction and magnitude of the flow of the current and of the magnetic field.

2. A metal casting apparatus as defined in claim 1, wherein said cavities are open at the sides thereof facing said axis so as to communicate over the whole length thereof with said flow passage.

3. A metal casting apparatus as defined in claim 1, wherein said cavities and said flow passage have in a plane normal to said axis a substantially circular cross-section.

4. A metal casting apparatus as defined in claim 1, wherein said cavities and said flow passage have in a plane normal to said axis a rectangular cross-section.

5. A metal casting apparatus as defined in claim 1, wherein said cavities are in the form of lateral channels communicating only at the upper and lower ends with said flow passage.

6. A metal casting apparatus as defined in claim 5, wherein said lateral channels respectively have in said common plane channel portions communicating with said flow passage and which are substantially normal to said axis of said flow passage.

7. A metal casting apparatus as defined in claim 5, wherein said lateral channels are filled with an electrically conductive refractory material.

8. A metal casting apparatus as defined in claim 7, wherein said electrically conductive and refractory material is constituting a cermet.

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