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(54) **Method and device for compensating for loss of metallostatic pressure during casting of molten metal onto a moving chilled surface.**

(57) A method and a device for compensating for loss of metallostatic pressure during the casting of molten metal 1 under gas pressure from a slit 5 in a container 3 onto a moving chilled surface 6 in which some of the molten metal 1 is allowed to penetrate into a chamber 12 maintained at a gas pressure different from the gas pressure in the container 3 and the extent to which the metal 1 penetrates into the chamber 12 is used to control an increasing or a decreasing of the gas pressure in the container 3 to compensate for the loss of metallostatic pressure. Preferably the extent of penetration is sensed by an electrically conductive probe 13 which is part of a circuit closable by the molten metal 1 coming into contact with the probe 13.

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METHOD AND DEVICE FOR COMPENSATING FOR LOSS OF METALLOSTATIC PRESSURE DURING CASTING OF MOLTEN METAL ONTO A MOVING CHILLED SURFACE

This invention relates to a method and a device for compensating for loss of metallostatic pressure during casting of molten metal under positive or negative gas pressure from a slit in a container onto a moving chilled surface.

Apparatus and processes for making wire or strip by casting molten metal from a slit in a container onto a moving chilled surface are described in United States patent specifications 3 522 836 and 4 142 571, the contents of which are herein incorporated by reference. The dimensions (especially the thickness) of the cast products are very sensitive to variations in the metallostatic pressure at the slit which means that it is essential to compensate quickly and sensitively for the loss of metallostatic pressure which occurs when the level of molten metal in the container falls as a result of molten metal being consumed by the process. Compensation is achieved by increasing the pressure of the gas above the molten metal but it has proved difficult to avoid over-compensation and to achieve a steady and controlled increase in pressure. It is an object of this invention to provide a method and a device for compensating for the loss of metallostatic pressure which enables the changes in gas pressure above the molten metal to be initiated by changes in the metallostatic pressure in the molten metal so that compensation becomes automatic and is accordingly both rapid and sensitive to small variations in metallostatic pressure.

A further problem associated with metal casting processes of this type is that monitoring the thickness of the metal casting by mechanical means is difficult. Therefore it is an object of a refinement of this invention to provide a method and a device for monitoring the thickness of the casting by reference to the rate of increase in the gas pressure in the container.

Accordingly this invention provides in a process for casting molten metal under (positive or negative) gas pressure from a slit in a container onto a moving chilled surface, a method for compensating for pressure variations in the molten metal by varying the gas pressure in the container wherein the method comprises

a) allowing a portion of the molten metal to penetrate a chamber in which there is a gas pressure different from the gas pressure in the container whereby the distance penetrated by the molten metal depends on the gas pressure in the chamber and on the combination of the pressure of the gas in the container with the metallostatic pressure in the molten metal,

b) sensing the presence of molten metal in the chamber by means which produces a response when the molten metal fails to penetrate to at least a pre-determined distance into the chamber and produces a counter-response when the molten metal penetrates to or beyond the pre-determined distance and

c) using the reponse to actuate pressure varying means to increase the gas pressure in the container and using the counter-response to actuate pressure varying means to decrease the gas pressure in the container.

In this way the compensating change in gas pressure in the container is determined by the extent of the penetration of the molten metal into the chamber which in turn is determined in part by the metallostatic pressure in the molten metal. For example, a fall in metallostatic pressure results in molten metal retreating from the chamber and as it moves away from the pre-determined distance, the sensing means produces a response which actuates the pressure varying means to increase the gas pressure in the container so compensating automatically for the fall in metallostatic pressure. On the other hand, an excessive increase in the combination of gas pressure and metallostatic pressure in the container (caused for example by over-compensation) causes molten metal to move back into the chamber producing a counter-response as the pre-determined distance is reached and a consequent decrease in gas pressure in the container. The system quickly settles down to a state in which the molten metal oscillates to and from the pre-determined distance with a vanishingly small amplitude so that the system responds quickly and sensitively to over- or under-compensation with the net result that the gas pressure in the container is increased very steadily as the molten metal is consumed by the casting process. It is preferred that at least at the start of the process, the gas pressure in the chamber is greater than the gas pressure in the container.

This invention also provides an apparatus for casting molten metal under (positive or negative) gas pressure from a slit in a container onto a moving chilled surface, a device for compensating for pressure variations in the molten metal by varying the gas pressure in the container wherein the device comprises

a) a chamber in communication with the container so that molten metal from the container can penetrate into the chamber,

b) means for establishing within the chamber a gas pressure different from the gas pressure in the container,

c) sensing means for producing a response when the molten metal fails to penetrate to at least a pre-determined distance into the chamber and for producing a counter-response when the molten metal penetrates to or beyond the pre-determined distance,

d) pressure varying means for increasing or decreasing the gas pressure in the container and

e) actuating means by which a response from the sensing means causes the pressure varying means to increase the gas pressure in the container and by which a counter-response from the sensing means causes the pressure varying means to decrease the pressure in the container.

Preferably the chamber is defined by a sleeve extending (preferably vertically) downwards into the container and having an open lower end through which the chamber is in communication with the container. Preferably the lower end of the sleeve is no more than 10mm from the base of the container.

The sensing means may be for example a float hinged at the pre-determined distance into the chamber so that as molten metal retreats from the pre-determined distance, the float produces a response by falling. Alternatively, as molten metal advances to the pre-determined distance the float produces a counter-response by rising. The float can be linked mechanically to the actuating means for the pressure varying means so that the fall (ie response) causes the pressure varying means to increase pressure in the container whilst the rise (ie counter-response) has the opposite effect.

Preferably the molten metal is sensed electrically by means of an electrically conductive probe which extends downwards into the chamber to the pre-determined distance and forms part of an electrical circuit which also includes the molten metal such that when the molten metal contacts the probe the circuit is closed and current can flow between the metal and the probe and when the metal does not contact the probe the circuit is open and no current flows. Therefore when the molten metal retreats away from contact with the probe, the response produced is a loss of current and when the molten metal moves back into contact, the counter-response produced is a current flow. The presence or absence of a current can be used to operate electrical actuating means for the pressure varying means in such a way that the absence of current causes the actuating means (for example a solenoid) to cause the pressure varying means to increase gas pressure in the container and the presence of current causes the opposite effects.

The pressure varying means may be any means capable of increasing or decreasing the gas pressure in the container on demand from the actuating means. The simplest means comprises a pressurising line and an evacuating line each closable by valves or by a common valve in such a way that when the pressurising line is open the evacuating line is closed and vice versa.

The chamber may be open to atmosphere or it may be closed so that it can be pressurised to super-atmospheric pressures. The use of super-atmospheric pressure in the chamber permits higher gas pressures to be used in the container which in turn leads to faster casting of the molten metal through the slit. A closed chamber also facilitates the use of an inert gas which may be necessary if the molten metal is reactive to air. Likewise the gas in the container may need to be inert.

The thickness of the metal casting depends on various parameters such as the speed at which the chilled surface moves, the dimensions of the slit, the clearance between the chilled surface and the slit, the nature of the molten metal (for example its viscosity and density) and the combined gas and metallostatic pressures in the container. In normal practice, these parameters can be pre-selected and kept constant except for the metallostatic pressure which decreases as the molten metal is consumed by the process and the gas pressure which is increased to compensate for the loss of metallostatic pressure. Therefore in normal practice (when in particular the dimensions of the slit and the speed of the chilled surface are kept constant) the rate at which metal is cast and therefore the thickness of the metal casting is directly proportional to the rate of increase in the gas pressure. More importantly, such is the steadiness with which the method and device of this invention enable the gas pressure to be increased that it has been discovered that the rate of increase of the gas pressure in the container can be used as an accurate monitor of the thickness of the metal casting. This avoids the need to use complicated thickness-monitoring systems downstream of the slit. Accordingly it is preferred to provide the apparatus with means for measuring the gas pressure in the container and more preferably with means for measuring the rate of increase of the gas pressure.

The invention is illustrated by the following embodiment which is described with reference to the drawing. The drawing is a diagrammatic representation of an apparatus incorporating a device according to this invention.

The drawing shows apparatus of the type used for casting molten metal 1 into metal strip 2. Molten metal 1 is contained within container 3 under pressure of a gas in space 4 and cast from slit 5 onto a moving chilled surface 6 provided by wheel 7 which rotates in the direction shown by the arrow. As molten metal 1 is consumed in the manufacture of strip 2, so level 8 of metal 1 in container 3 falls reducing the metallostatic pressure in molten metal 1 at slit 5. To avoid reducing the thickness of strip 2, it is necessary to compensate for the reduction in metallostatic pressure by increasing the gas pressure in space 4. This is done by introducing gas from a pressurising line 9 into space 4 via a damping reservoir 3a which serves to reduce any fluctuations in the pressure of gas supplied by line 9. The problem is to achieve a rapid and sensitive compensation for the reduction in metallostatic pressure whilst minimising the risk of over-compensation.

Rapid and sensitive compensation is achieved by incorporating pressurising line 9 into a device which also comprises an evacuating line 10, electrically operated actuating means 11 which can actuate pneumatic opening and closing of valves 9a and 10a provided on lines 9 and 10 respectively, a chamber 12 housing a metal probe 13, a source 14 of electrical energy and wires 15a, b and c. Probe 13, source 14, actuating means 11 and wires 15a, b and c together with metal container 3 and molten metal 1 comprise an open electrical circuit which can be closed by molten metal 1 moving into contact with probe 13.

Chamber 12 is defined by sleeve 12a which extends vertically downwards into container 3. Sleeve 12a has a closed upper end 12b which enables chamber 12 to receive a super-atmospheric pressure from pressure line 17 which is closable by valve 18. Lower end 12c of sleeve 12a is open and spaced about 5mm from the base of container 3 so that chamber 12 is in communication with container 3 which enables molten metal 1 to penetrate into chamber 12. Sleeve 12a is electrically isolated from metal container 3 by insulating bushing 16.

Electrically conductive metal probe 13 extends vertically downwards into chamber 12 and its tip 20 is located at a pre-determined distance of 15mm above the base of container 3. Probe 13 is electrically isolated from sleeve 12a by insulating plug 16a. When molten metal 1 penetrates into chamber 12 far enough to contact tip 20, a current flows between molten metal 1 and probe 13. Conversely when molten metal 1 retreats from contact with tip 20, no current flows.

Actuating means 11 comprises a solenoid (not shown) which actuates pneumatic opening and closing of valves 9a and 10a via pneumatic lines 9b and 10b. The solenoid is arranged so that when actuating means 11 is not receiving current, valve 9a is open and valve 10a is closed which means that pressure line 9 increases the gas pressure in space 4. The solenoid is also arranged so that when actuating means 11 does receive current, valve 9a is closed and valve 10a is open which means that evacuating line 10 decreases the gas pressure in space 4.

In operation molten metal 1 is consumed in making strip 2 and so the level 8 of molten metal 1 in container 3 falls and at the same time molten metal 1 falls away from contact with tip 20 of probe 13 and no current can flow into actuating means 11. In this situation valve 9a is open and valve 10a is closed so that the gas pressure in space 4 is increased by pressure line 9. The increasing gas pressure in space 4 compensates for the fall in metallostatic pressure and in particular causes molten metal 1 to move back into contact with tip 20 whereupon current again flows to actuating means 11. As soon as actuating means 11 receives current, valve 9a closes and valve 10a opens allowing evacuating line 10 to decrease gas pressure in space 4 causing molten metal 1 to retreat from contact with tip 20. In this way a pressure increasing and decreasing cycle is established and very quickly molten metal 1 oscillates into and out of contact with tip 20 with a vanishingly small amplitude. It has been found that this amplitude is small enough to permit compensation to variations in metallostatic pressure which is both rapid and sensitive to small variations in the metallostatic pressure.

The apparatus is also provided with a conventional instrument 21 for detecting the rate of change of gas pressure in space 4. If required instrument 21 can be calibrated so as to correlate the rate of change of pressure with the thickness of metal strip 2. Therefore if it is desired to make strip of a different thickness, the gas pressure in chamber 12 can be adjusted leading to a corresponding automatic adjustment of the gas pressure in space 4 and a consequent change in the rate of increase of the gas pressure in space 4 and ultimately a consequent change in the thickness of strip 2.

When level 8 of molten metal 1 in container 3 falls to the level of tip 20, the gas pressure in chamber 4 will become equal to the gas pressure in chamber 12. If it is required to continue operation of the process so that level 8 falls below tip 20, then it will be necessary for the gas pressure in space 4 to be increased so as to exceed that in chamber 12. In short, during the latter stages of the process the gas pressure in chamber 12 may be less than in container 3.

If it is sufficient to operate with a gas pressure in chamber 12 which is equal to that surrounding the apparatus, then the upper end of sleeve 12a can be left open and pressure line 17 and valve 18 become unnecessary.

It is also possible to provide an entry port into container 3 so that the molten metal 1 can be replenished by further supplies of molten metal during the casting process. However such replenishing supplies of molten metal may cause currents within the chamber which could make the control of pressure variations more difficult.

In an alternative embodiment, sleeve 12a may be made from an electrically non-conducting material such as alumina. This avoids the need to provide insulating bushings and plugs such as 16 and 16a. It also avoids the need for careful alignment of probe 13 for it will not be necessary to ensure probe 13 does not touch sleeve 12a if sleeve 12 a is non-conducting.

CLAIMS

1. In a process for casting molten metal 1 under gas pressure from a slit 5 in a container 3 onto a moving chilled surface 6, a method for compensating for pressure variations in the molten metal 1 by varying the gas pressure in the container 3 wherein the method comprises

a) allowing a portion of the molten metal 1 to penetrate a chamber 12 in which there is a gas pressure different from the gas pressure in the container 3 whereby the distance penetrated by the molten metal 1 depends on the gas pressure in the chamber 12 and on the combination of the pressure of the gas in the container 3 with the metallostatic pressure in the molten metal 1,

b) sensing the presence of molten metal 1 in the chamber 12 by means 13 which produces a response when the molten metal 1 fails to penetrate to at least a pre-determined distance into the chamber 12 and produces a counter-response when the molten metal 1 penetrates to or beyond the pre-determined distance and

c) using the response to actuate pressure varying means 9 to increase the gas pressure in the container 3 and using the counter-response to actuate pressure varying means 10 to decrease the gas pressure in the container 3.

2. A method as claimed in Claim 1 wherein at least at the start of the process, the gas pressure in the chamber 12 is greater than the gas pressure in the container 3.

3. A method as claimed in Claim 1 or Claim 2 wherein the gas pressure in the chamber 12 is super-atmospheric.

4. A method as claimed in any one of Claims 1 to 3 wherein the molten metal is sensed electrically by means comprising an electrically conductive probe 13 which extends downwards into the chamber 12 to the pre-determined distance and forms part of an electrical circuit which also includes the molten metal 1 such that when the molten metal 1 contacts the probe 13 the circuit is closed and current can flow between the metal 1 and the probe 13 and when the metal 1 does not contact the probe 13 the circuit is open and no current flows.

5. In apparatus for casting molten metal 1 under gas pressure from a slit 5 in a container 3 onto a moving chilled surface 6, a device for compensating for pressure variations in the molten metal 1 by varying the gas pressure in the container 3 wherein the device comprises

a) a chamber 12 in communication with the container 3 so that molten metal 1 from the container 3 can penetrate into chamber 12,

b) means for establishing within the chamber 12 a gas pressure different from the gas pressure in the container 3,

c) sensing means 13 for producing a response when the molten metal 1 fails to penetrate to at least a pre-determined distance into the chamber 12 and for producing a counter-response when the molten metal 1 penetrates to or beyond the pre-determined distance,

d) pressure varying means 9 and 10 for increasing or decreasing the gas pressure in the container 3 and

e) actuating means 11 by which a response from the sensing means 13 causes the pressure varying means 9 to increase the gas pressure in the container 3 and by which the counter-response from the sensing means 13 causes the pressure varying means 10 to decrease the pressure in the container.

6. A device as claimed in Claim 5 wherein the chamber 12 is defined by a sleeve 12a extending downwards into the container and having an open lower end 12c through which the chamber 12 is in communication with the container 3.

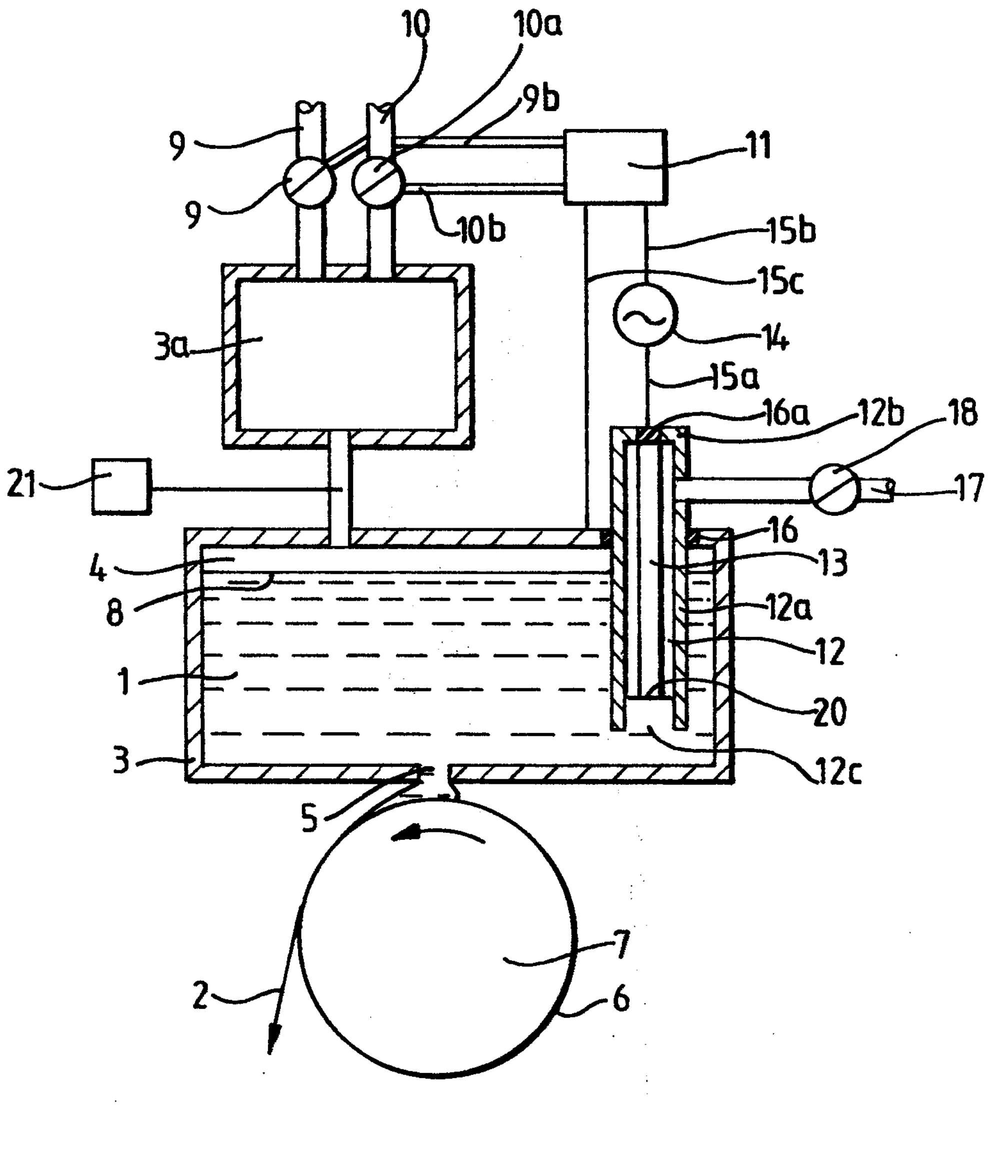
7. A device as claimed in Claim 5 or Claim 6 wherein the sensing means comprises an electrically conductive probe 13 which forms part of an electrical circuit with the molten metal 1 such that when the molten metal 1 contacts the probe 13 the circuit is

closed and current can flow between the metal 1 and the probe 13 and when the metal 1 does not contact the probe 13 the circuit is open and no current flows.

8. A device as claimed in Claim 7 wherein the actuating means 11 forms part of the circuit which includes the probe 13 and the molten metal 1 and the actuating means 11 is operable by the presence or absence of current such that when the current is present the actuating means 11 causes the pressure varying means 10 to decrease the gas pressure in container 3 and when current is absent, the actuating means 11 causes the pressure varying means 9 to increase the gas pressure in the container 3.

9. A device as claimed in any one of claims 5 to 8 wherein the chamber 12 is provided with means for providing a super-atmospheric gas pressure within chamber 12.

10. An apparatus as defined in Claim 5 and comprising a device as claimed in any one of Claims 5 to 9 and means 21 for measuring the gas pressure within container 3.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