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(54) **METHOD AND CONTROL DEVICE FOR CONTROLLING THE HEAT REMOVAL FROM A SIDE PLATE OF A MOLD**

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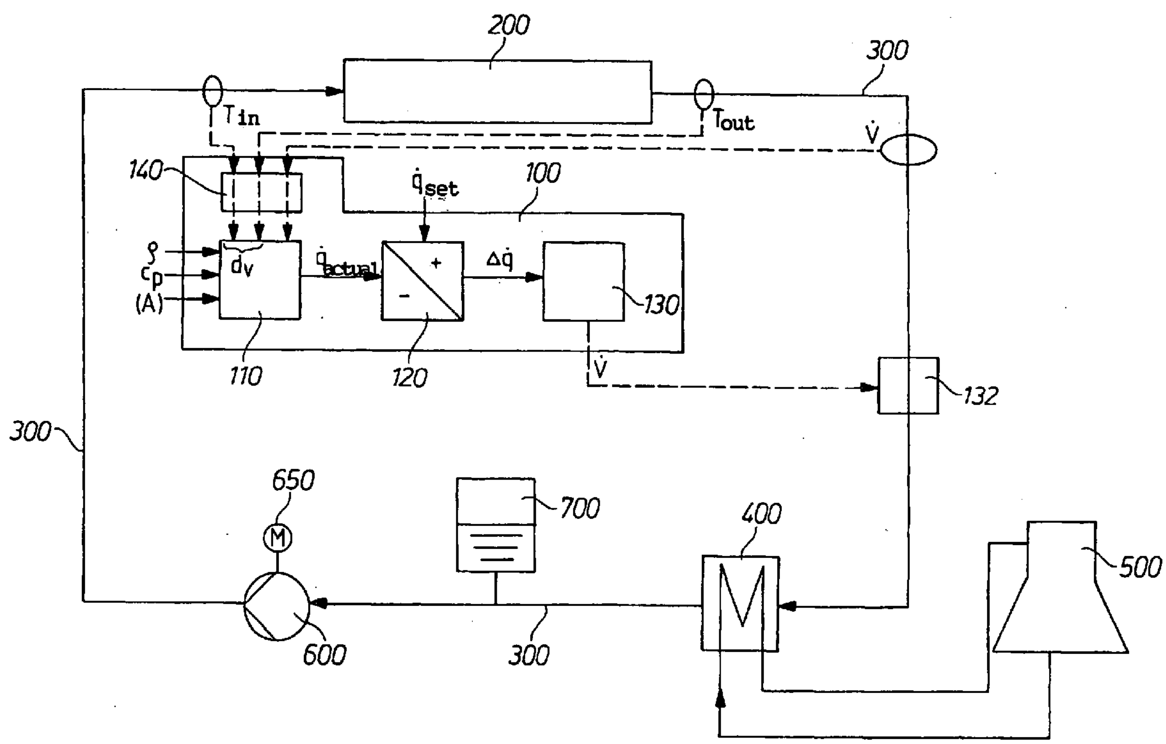
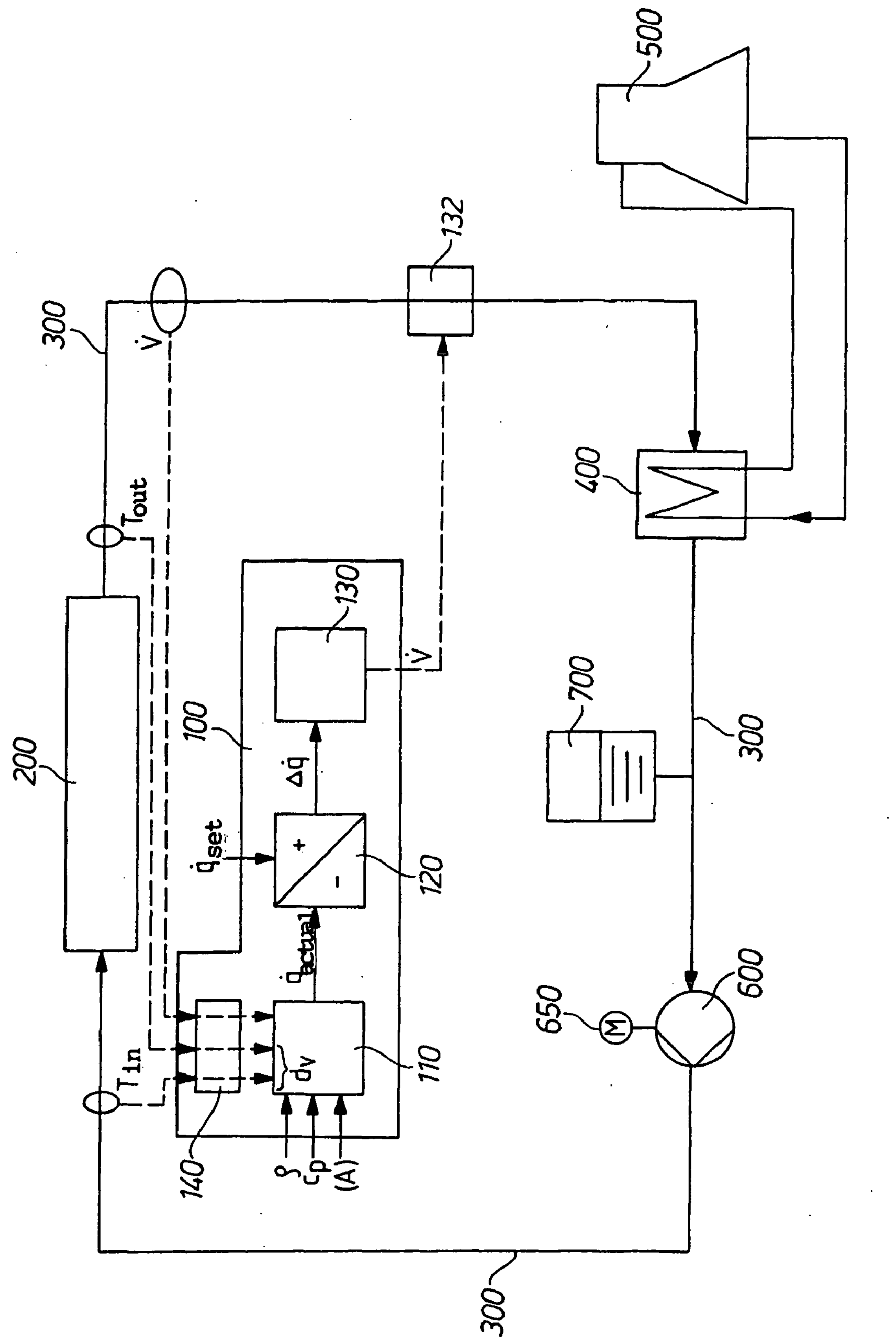
(57) **ABSTRACT**

The invention concerns a method and a control device for automatically controlling the heat dissipation $\dot{q}$ in a mold **200** for casting metal. The heat dissipation of the side plate of a mold is automatically adjusted to a preset set point $\dot{q}_{set}$ by suitable variation of the volume flow rate $\dot{\mathbf{V}}$ of a coolant **300** through the side plate. In accordance with the invention, to avoid the necessity, when different molds are used, of adapting the control of the heat dissipation each time to different thicknesses or coatings of the side plates or to different settings of the side plates during the casting operation or during the casting of different grades of steel, the actual value for the heat dissipation $\dot{q}$ during a steady-state casting operation is suitably computed on a current basis from, among other things, the difference in the temperature of the coolant **300** at the coolant outlet and the coolant inlet of the side plate **200** and material constants for the coolant.





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METHOD AND CONTROL DEVICE FOR CONTROLLING THE HEAT REMOVAL FROM A SIDE PLATE OF A MOLD

[0001] The invention concerns a method and a control device for automatically controlling the heat dissipation of a side plate of a mold in a continuous casting installation for casting metal in slabs, thin slabs, blooms, billets, or preliminary sections. The method of the invention is preferably used in standard slab casting installations and molds, which are operated at a much lower casting speed than thin-slab casting installations.

[0002] A method for controlling the heat dissipation in a side plate of a mold is known, for example, from European Patent EP 1 070 560 B1, in which the specific heat dissipation, also known as heat flux density, is controlled in a wide-side plate by suitable variation of the flow rate of the cooling water through the wide-side plate. The control occurs according to the thickness of the side plate, which is made of copper. A definite threshold value for the heat flux density is defined as a function of the grade of steel that is to be cast and of the casting flux that is used. This prior art is aimed solely at limiting the heat dissipation of the during the relatively short start-up period in a thin-slab installation with high casting speed.

[0003] Proceeding on the basis of this prior art, the objective of the invention is to provide a method and a control device for automatically controlling the heat dissipation in a side plate of a mold, which are characterized by automatic adaptation to a current or changed state of the side plates, especially during a steady-state casting operation.

[0004] The objective with respect to a method is achieved by the method claimed in claim **1**.

[0005] The cooling behavior of a mold and especially its side plates is a critical factor in determining the quality of the cast metal. The claimed method offers the great advantage over the prior art that it does not require the coolant circulation and especially the amount of coolant to be adapted or adjusted to the material, the thickness or the coating of a specifically used side plate, or its altered setting during a steady-state casting operation. In this respect, the claimed method and the claimed control of the heat dissipation automatically adapt to the given current state of the side plate used.

[0006] Another advantage is that the claimed control system does not require any presetting in regard to the particular grade of steel that is being cast.

[0007] An advantage of the claimed method is that it makes it possible to adjust the cooling behavior of the side plate and thus the quality of the cast metal as a function of only a single variable to be preset, namely, the quantity of heat to be dissipated.

[0008] Control of the heat dissipation during the casting start-up operation, in abnormal casting situations, as, for example, those caused by a change in the casting speed, or at the end of a casting operation is achieved by conventional control of the amounts of water; therefore, the method of the invention is expressly not applied to these types of operations and situations.

[0009] In accordance with two alternative embodiments, the method of the invention advantageously provides either automatic control of the specific heat dissipation (with respect to the active cooling surface of the side plate) or automatic control of the absolute heat dissipation (without reference to the active cooling surface of the side plate).

[0010] The measured values entering into the computation of the actual value for the heat dissipation, for example, the temperature of the coolant at the coolant inlet and outlet of the side plate and, optionally, the volume flow rate of coolant through the side plate, are advantageously averaged or filtered or buffered before they are introduced into the computation of the actual value for the heat dissipation. This has the advantage that the dynamic properties/components of the measured actual values are adapted to the, by comparison, relatively slow control of the heat dissipation by variations of the volume flow rate of the coolant.

[0011] The control of the heat dissipation on the narrow side of a mold in accordance with the method of the invention offers the advantage that the control also automatically adapts to states specific to the narrow side and automatically simultaneously compensates effects on the casting process caused by their variation. For example, changed settings in the width and/or the conicity of the side plate during the casting operation are automatically simultaneously compensated by the claimed method during the automatic control of the heat dissipation, without it being necessary to determine these states separately and then to supply them to the control device.

[0012] Simultaneous application of the method of the invention to two or more side plates of the mold guarantees that the heat dissipation is separately controlled for each of the side plates, but at the same time it advantageously allows the adjustment of a desired ratio for the heat dissipation values between the individual side plates. Adjustment of the desired ratio can be easily realized by predetermining the set points for the heat dissipation values for the individual side plates in the desired way. For example, it can be desirable for the heat dissipation values in the two opposite narrow-side plates of a mold to be the same or for the heat dissipation of the two wide sides together to be in a definite ratio to the heat dissipation of the two narrow sides together.

[0013] The objective with respect to a device is achieved by a control device for automatically controlling the heat dissipation in a mold. The advantages of this control device are the same as the advantages specified above with reference to the method of the invention.

[0014] Additional advantageous embodiments of the method of the invention and the device of the invention are objects of the dependent claims.

[0015] The invention is explained below with reference to the example illustrated in the sole drawing.

[0016] The drawing shows first of all the circulation of a coolant **300** through the side plate **200** of a mold. The heat produced in the mold during the casting of a metal, especially a steel, is removed from the side plate by means of a coolant **300**, which passes through cooling channels or cooling bores (not shown) in the side plate **200**. The coolant is typically cooling water that has been treated with a corrosion inhibitor, with glycol, oils, or alcohol. Alternatively, activated water or distilled water can also be used. Each of these coolants is characterized by individual material constants, such as the specific gravity p or the specific heat at constant pressure cp.

[0017] After it has passed through the side plate **200**, the now heated coolant **300** is cooled by passing it through a heat exchanger **400**, which is connected with a cooling tower. After it has been cooled, the coolant **300** is fed to a pump **600**, which is driven by a drive unit **650**. The pump **600** maintains the circulation of the coolant **300** and pumps the cooled coolant back through the cooling channels of the side plate **200**. In addition, the closed coolant circulation can have an expansion tank **700** (gas reservoir), especially for establishing a system pressure. A pump **600** in the system just serves for compensating drops caused by friction.

[0018] The present invention concerns a method associated with the coolant circulation described above and an associated control device **100** for automatically controlling the heat dissipation $\dot{q}$ of the side plate **200** during a steady-state casting operation to a possibly variably predetermined set point $\dot{q}_{set}$.

[0019] As the drawing shows, the control device **100** of the invention comprises a computing unit **110** for computing an actual value $\dot{q}_{actual}$ for the heat dissipation. The computing unit **110** computes this actual value by the following physical formula:

$$\dot{q}_{actual}=(\rho^* V^* c_p{}^* d_v)/A$$

where

[0020] $\dot{q}$: the heat dissipation [W/m^2]

[0021] ρ: the density of the cooling water [kg/m^3]

[0022] $\dot{V}$: the volume flow rate of the cooling water

[0023] c_p: the specific heat of the cooling water (at constant pressure) [kJ/(kg·K)]

[0024] d_v: the temperature difference T_{out}-T_{in} [K]

[0025] A: the active mold surface.

[0026] The computing unit **110** can be designed to compute the heat dissipation $\dot{q}$ as a specific physical quantity, i.e., with reference to the active cooling surface of the side plate A, or as an absolute physical quantity, i.e., without reference to the active cooling surface A. The active surface is calculated as the active length of the side plate multiplied by the active width of the side plate or multiplied by the active thickness of the side plate.

[0027] The density ρ of the coolant used in the computation of the actual value for the heat dissipation $\dot{q}_{actual}$ its specific heat c_p, and the possibly used active surface are each suitably supplied in advance to the computing unit as constants. By contrast, the temperatures T_{in} and T_{out} at the coolant inlet and coolant outlet of the side plate are each determined as current measured values; their difference d_v is used as a factor of proportionality in the computation of the heat dissipation. Finally, the volume flow rate $\dot{V}$ of the coolant per unit time through the side plate is supplied to the computing unit **110** as a current actual value. This can be accomplished either by making current measurements of the volume flow rate $\dot{V}$, as shown in the drawing, or by feeding it back to the computing unit **110** as a controlled variable from the output of the controller **130**, which is described below.

[0028] The drawing shows that the control device **100** has an averaging unit **140** for averaging or buffering the measured actual values with respect to time, especially the measured temperature values, before they are supplied to the computing unit **110**. High-frequency spectral components and dynamic components in these measuring signals are filtered out by this averaging or buffering, and in this way these measuring signals are adapted to the otherwise rather slow control mechanism for the heat dissipation in the side plate **200**.

[0029] As is also apparent from the drawing, the actual value for the heat dissipation $\dot{q}_{actual}$ produced by the computing unit **110** is supplied to a comparator **120** for computing a control deviation $\Delta\dot{q}$ for the heat dissipation. The comparator **120** computes this control deviation by subtracting the supplied actual value for the heat dissipation $\dot{q}_{actual}$ from a possibly also variably preset set point for the heat dissipation $\dot{q}_{set}$. Finally, the control deviation $\Delta\dot{q}$ is supplied to the controller **130**, which converts the current control deviation to a suitable variation of the volume flow rate $\dot{V}$ of the coolant **300** through the mold **200**. This conversion is carried out in such a way that the current heat dissipation, represented by the actual value $\dot{q}_{actual}$ is adapted to the preset set point $\dot{q}_{set}$ for the heat dissipation. The volume flow rate $\dot{V}$ is supplied as a control variable to the control system, in particular to a controlling valve **132** in the coolant circulation, so that said controlling valve **132** can properly adjust the volume flow rate of the coolant **300** through the side plate **200** for the present control variable.

In the claims:

1. A method for automatically controlling the heat dissipation $\dot{q}$ in at least one side plate (**200**) of a mold for casting metal to a preset set point $\dot{q}_{set}$ by suitable variation of the volume flow rate $\dot{V}$ of a coolant (**300**) through the side plate (**200**) according to a control deviation $\Delta\dot{q}$ in the form of the difference between the set point and an actual value $\dot{q}_{actual}$ for the heat dissipation, wherein the heat dissipation $\dot{q}$ is automatically controlled and the volume flow rate $\dot{V}$ is varied during a steady-state casting operation wherein the method is carried out for the side plate (**200**) in the form of a narrow-side plate of the mold, wherein, the width and/or the conicity of the narrow-side plate are changed during the casting operation.

2. A method in accordance with claim **1**, wherein the actual value for the heat dissipation $\dot{q}$ is computed on a current basis from, among other things, the difference between the actual temperature (T_{out}) of the coolant at the coolant outlet of the side plate and the actual temperature (T_{in}) of the coolant at the coolant inlet of the side plate (**200**) and material constants (ρ, c_p) for the coolant.

3. A method in accordance with claim **2**, wherein the heat dissipation is the specific heat dissipation, and the actual value for the specific heat dissipation is computed as follows:

$$\dot{q}(\rho^* V^* c_p{}^* d_v)/A$$

where

$\dot{q}$: the heat dissipation [W/m^2]

ρ: the density of the cooling water [kg/m^3]

$\dot{V}$: the volume flow rate of the cooling water [L/min]

c_p: the specific heat of the cooling water (at constant pressure) [kJ/(kg·K)]

d_v: the temperature difference T_{out}-T_{in} [K]

A: the active cooling surface of the side plate.

4. A method in accordance with claim **1**, wherein the heat dissipation is the absolute heat dissipation.

5. A method in accordance with claim **1**, wherein the actual values for the temperatures (T_{out}, T_{in}) and/or the volume flow rate $\dot{V}$ of the coolant are each measured on a current basis and then averaged or buffered, before they are used in the computation of the actual value for the heat dissipation $\dot{q}_{actual}$.

6. A method in accordance with claim **1**, wherein the coolant (**300**) is water treated with corrosion inhibitor, glycol or oil, activated water, or distilled water.

7. A method in accordance with claim **1**, wherein the set point $\dot{q}_{set}$ for the heat dissipation can be variably preset.

8. A method in accordance with claim **1**, wherein the method is carried out separately for two side plates (**200**) in such a way that the set points $\dot{q}_{set}$ for their respective heat dissipation values are in a desired ratio to each other.

9. A method in accordance with claim **8**, wherein the method is carried out separately for the two opposite narrow-side plates (**200**) of the mold in such a way that the heat dissipation for each of the two narrow-side plates is automatically adjusted to the same set point $\dot{q}_{set}$.

10. A control device (**100**) for automatically controlling the heat dissipation $\dot{q}$ in a side plate of a mold for casting metal, which comprises:

- a computing unit (**110**) for computing an actual value $\dot{q}_{actual}$ for the heat dissipation;
- a comparator (**120**) for computing a control deviation $\Delta\dot{q}$ for the heat dissipation by comparing the actual value for the heat dissipation with a preset set point; and
- a controller (**130**) for converting the current control deviation $\Delta\dot{q}$ to a suitable variation of the volume flow rate $\dot{V}$ of a coolant (**300**) through the mold (**200**) for automatically controlling the heat dissipation $\dot{q}$ of the mold,

wherein the computing unit (**110**) is designed to compute the actual value for the heat dissipation $\dot{q}_{actual}$ on a current basis from, among other things, the difference between the actual temperature of the coolant (**300**) at the coolant outlet of the mold and the actual temperature of the coolant at the coolant inlet of the side plate and material constants (ρ, c_p) for the coolant (**300**).

11. A control device (**100**) in accordance with claim **10**, wherein the computing unit (**110**) is designed to compute the actual value for the heat dissipation as follows:

$$\dot{q}=(\rho*\dot{V}*c_p*d_v)/A$$

where

$\dot{q}$: the heat dissipation [W/m^2]

ρ: the density of the cooling water [kg/m^3]

$\dot{V}$: the volume flow rate of the cooling water [L/min]

c_p: the specific heat of the cooling water (at constant pressure) [kJ/(kg·K)]

d_v: the temperature difference T_{out}-T_{in} [K]

A: the active cooling surface of the side plate.

12. A control device (**100**) in accordance with claim **10**, comprising at least one averaging unit (**140**) for averaging or buffering the measured actual values with respect to time, before they are supplied to the computing unit (**110**).

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