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(54) Method and apparatus for controlling the cooling of molds for the controlled-pressure casting of metals.

(57) The invention relates to a method of controlling the cooling of the inner surfaces of the molds (8-8) used for the pressure-casting of metals, wherein, after the removal of a casting and the cleaning of said surfaces, the step of detecting the temperatures of said inner surfaces, is followed by a cooling step carried out by means of water sprays (4), each one of which cools a portion of said surfaces, so that at a given moment, after the said second step having been carried out, the entire surface is at the same optimum temperature to permit the coating or lining thereof, the amount of water to be sprayed being established automatically by a central electronic unit (7).

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"Method and apparatus for controlling the cooling of molds for the controlled-pressure casting of metals"

The invention relates to a method and an apparatus for the cooling of molds for the controlled-pressure casting of metals.

The process of controlled-pressure casting of metals for the production of thick slabs substantially consists of the casting of liquid metal, generally steel, into a mold constituted by mobile walls made of steel and graphite. At the beginning, the liquid metal is contained in a pressurized vessel arranged below the said mold. When a mold has been filled, a given period of time shall lapse to permit the cast metal to solidify completely. During this period of time suitable cooling means are applied to said walls. At the end of the solidification period, said mobile walls are displaced (opening of the mold) and the solidified metal product can be removed and conveyed to successive processing. Meanwhile, the mold with the mobile walls thereof is prepared for the successive working cycle with new liquid metal. Under normal conditions, this operative cycle is repeated an indefinite number of times.

The preparation of the mold consists in the removal of slags or other residues produced during the preceding cycle, and in the lining of the walls that will be contacted by the molten metal, with a thin layer of insulating material. Since the temperature of the walls is very high during said preparation step, this step is carried out by means of semiautomatic machines that require no personnel in proximity of said walls. The personnel operates the said machines from a remote control cabin.

The practical use has shown that the characteristics of the insulating lining mentioned above strongly affect the final quality of the solidified product. The material being used for said lining is made of mullite powder ($3Al_2O_3.2SiO_2$) or aluminia powder (Al_2O_3), materials of mineral origin which are widely used in iron metallurgy. It is not to be excluded that new materials will be selected for this purpose in the future. Regardless of the material being used, the layer applied to the walls shall have a well-definite thickness, a good consistency and a good adhesion to the walls.

It has been found that possible defects in the lining of the walls are associated locally with surface defects in the final solidified product, which involve burdensome adjusting or discarding measures. Moreover, the practical use has shown that one of the most important factors for a successful lining in the surface temperature of the walls, which shall have a well-definite value when the lining machine applies the insulating layer. This condition shall be achieved at every spot of the surface to be lined.

The walls are constituted by huge blocks of graphite, and during the normal operation they are priodically contacted by very large masses of liquid metal in the course of solidification. Due to the considerable thermic inertia of the walls and the fast rate at which the operative cycles follow each other, the average temperature of the walls is always much higher than the suitable temperature for lining. However, it is not the average temperature which is concerned, but rather the surface temperature, and the latter may be temporarily lowered down to levels which are suitable for the lining by an energetic action of surface cooling.

This method is followed at present in the existing plants of casting under controlled pressure, with the disadvantages described hereinafter.

According to the present operation practice, the surface cooling of the walls during the preparation step is effected by the same machine which effects the cleaning of the walls. This machine is equipped with large rotatable and translatable brushes and nozzles adapted to spray pressurized water. During the operation, the abundant jets of water, beside cleaning the walls, cool the same; a system of directive thermometers (pyrometers) gives the operators the temperature of the walls and when the said temperature has falled to suitable values, the cleaning machine is removed and the lining machine starts working.

This method is efficient to reduce the temperature of the faces, but it is not efficient as well to make the same uniform at every spot. In fact, the said directive thermometers show that at some spots the temperature departs from the ideal values, and said spots will likely show defects in the lining which, in turn, will cause surface defects in the finished product.

The reasons which prevent a more accurate control of the surface temperatures are listed below:

-the distribution of the temperature is not uniform even before starting the cooling, due to asymmetry factors connected to the solidification process;

-the cooling system by means of water jets is rather inaccurate and only partially enables a differentiation of the cooling at different spots;

-the presence of hot layers under the cooled layers causes undesired temperature rises which occur while corrections are being made elsewhere on the surface; this fact would require a further correction, while further disturbances would occur;

-the period of time available for this action is limited. because the industrial exploitation of the process has quantitative requirements in addition to the qualitative requirements; furthermore, it is necessary to comply with operational programs which are linked to the upstream processes (production of molten metal).

The invention aims to improve the industrial process called casting under controlled pressure, so as to obtain important advantages of qualitative, therefore economical, nature by a method and an apparatus which enable the cooling of the walls so as to control the temperature thereof with the higher accuracy than possible with the apparatus and methods used heretofore. Said higher accuracy has the purpose of achieving during the cooling operation, an established value of temperature spreading uniformly over the entire surface of the walls of a mold. The established temperature, reached at the moment when the insulating lining is carried out, helps a successful outcome of the insulating lining on the walls, which is a necessary requirement for obtaining good qualitative characteristics of the industrial product resulting from the controlled-pressure casting process.

This problem is solved by the invention with the method which is characterized in claim 1 and with the apparatus which is characterized in claim 3.

One embodiment of an apparatus for carrying out the method according to the invention will be described hereinafter by referring to the drawing diagrammatically showing in a perspective view an apparatus according to the invention.

The apparatus described hereinafter has been devised for the application to plants for casting under controlled pressure for the production of thick steel slabs of large dimensions. Said slabs are pieces having the weight of some tens of tons and a parallelepipedal shape, with dimensions within the following ranges:

length	8 to 12 metres
width	2 to 3 metres
thickness	0,15 to 0,40 metres

The last dimension is generally the most significant to qualify the technological characteristics of the production process. Slabs are the intermediate product in the cycle of production of plates and other rolled steel sections. The geometric simplicity of the shape of slabs and the fact of the mold being formed mainly by two large planar faces make this type of production most suitable for using the method and the apparatus according to the present invention. However, the said method and apparatus may be advantageously applied for the casting of other geometrical shapes and of other metals.

With reference to the drawing, the apparatus according to the invention substantially comprises the following parts:

- an automatic system for measuring the temperature,
- an automatic cooling system,
- a logic control unit.

The automatic system for measuring the temperatures is constituted by a bank of directive thermometers 1 (called hereinafter "pyrometers") mounted on a supporting structure 2 (called hereinafter "pyrometer carriage") which can be moved either by its own prime mover, or because it is mounted on movable parts of other machinery. The arrangement of the pyrometers on the pyrometer carriage is such that as a result of the movement of said carriage the temperature of all the surfaces to be lines can be measured and the measurements are carried out at successive and suitably programmed moments. Of course, we do not measure the temperatures of all the infinite points constituting the surface. However, it will be possible to measure the average temperature of surface portions that are sufficiently small and significant for the desired purposes. The pyrometer carriage 2 is provided with a data transmission system capable of transmitting to the logic control unit both the position of the carriage and the measurement effected by each individual pyrometer. The transmission system comprises a loop of screened cables 3, supported by guides and small trolleys which are carried by the carriage during its translational stroke.

The data measurement and transmission system described above may be implemented by other methods, if the latter ensure advantages of practical character. More particularly, if the surface to be measured has a sufficiently compact shape, the temperature measurement may be advantageously effected by a system of infrared-sensitive video cameras. In other cases wherein the data transmission via the loop of cables 3 is handicapped by obstacles included in the plant, the data transmission is effected by means of an emitter of electromagnetic or acoustical waves.

The automatic cooling system is constituted by a bank of pressurized water sprayers 4 (called hereinafter "sprayers") mounted on a supporting structure 5 (called hereinafter "sprayer carriage") which is moved either by its own motive means or because it is mounted on movable parts of other machinery. The arrangement of the sprayers 4 on the sprayer carriage 5 corresponds to the arrangement of the pyrometers 1 on the pyrometer carriage 2, whereby, upon the movement of the carriage, each spot of the surface may be submitted to the application of pressurized water at successive, suitably programmed moments. Moreover, a relationship is created between the areas submitted to measurement by each pyrometer and the areas submitted to application of water by each sprayer or bank of sprayers. The sprayers carriage 5 is fed with pressurized water from the central mains which also feed the other process machinery. On board of the carriage, a system of branched ducts feeds the sprayers 4, each one of which is shut off by a remotely-controlled valve. The sprayer carriage 5 is provided with a data transmission system permitting to transmit the position of the carriage to the logic control unit 7 and to receive therefrom the signal of the opening and closing of the shut off valves. This data transmission system comprises a loop of screened cables 6 supported by guides and small trolleys, and with a similar system it is implemented the feeding of pressurized water through flexible hoses.

It is possible as well to arrange the temperature measurement system and the spray cooling system on the same carriage, which thus will perform the functions of pyrometer carriage and sprayer carriage. Moreover, it is possible to arrange both systems on board of other movable machinery. In the preferred embodiment, both systems are arranged on board of the wall-cleaning machine.

The logic control unit 7 is constituted by an assembly of apparatuses for the reception, processing and transmission of data. Since the system may be implemented in various ways, by using components supplied by manufacturers of computers, only the logic functions carried out by the logic control unit 7 will be described herein.

Said functions are:

-Reception of the working cycle starting and stopping signals.

-Emission of the signals for starting and stopping the pyrometer carriage and sprayer carriage.

-Reception of the positional signals concerning the pyrometers carriage and the sprayer carriage.

-Reception of the pyrometer measurements.

-Storing of the pyrometer measurements.

-Control of the time-variable.

-Calculation of the amounts of water which are required to controllably cool each portion of the surfaces of the mold.

-Emission of the signals for opening and closing the shut off valves of each sprayer.

-Display of variables and other information.

-Reception of other information, transmitted either automatically or manually, and required for effecting the working cycles.

The operations of casting and solidification of the metal within a mold constituted by two walls 8, are carried out according to the previously used methods.

The step of cleaning the inner surfaces of the walls 8 is started by the operators as soon as the mold has been emptied. During this step, the inner surfaces of the walls 8 are sprayed with an amount of water capable of performing the cleaning and, at the same time, the preliminary cooling of the surfaces. During this step it is not necessary to measure the temperature or to perform procedures tending to increase the uniformity of the surface temperature. During this step, the action of the operators has the only purpose of improving the cleaning operations. On completion of this cleaning and uncontrolled cooling of the inner surfaces of the walls, the operator starts the successive step, the so-called controlled cooling step, which proceeds completely automatically in accordance with the pulses emitted by the control unit 7.

At the beginning of this step, the surface temperature of the walls 8 is comparatively low due to the surface cooling carried out during the cleaning step, but the inner layers of the walls 8 are much hotter because they retain the heat which has been accumulated during the solidification of metal.

As a result thereof, when the forced cooling is terminated, the surface temperature tends to rise due to the heat emerging from the interior, while an additional dispensation of pressurized water causes a further decrease of the surface temperature. The surface temperature of the walls 8, therefore, is in equilibrium between two opposed actions: the heating originating from the interior and the cooling effected from the exterior; this condition goes on until the heat stored in the inner layers is exhausted. Since the walls 8 have a considerable thickness, this phenomenon goes on during a sufficiently long time to permit to achieve the objects of the industrial process. The heating action of the inner layers, which in the procedure carried out with an empiric method is a disturbance and, therefore, one of the main causes of inaccuracy, in the controlled procedure ensures the indispensable effect opposing the external cooling action, which is liable to be suitably regulated. In order to achieve appreciable results, the phenomenon should be known and controlled in strictly quantitative terms.

On the basis of this premise, the automatic sequence of operations is described hereinafter.

The pyrometer carriage 2 receives the start signal and enters the mold to effect a scanning. During this action, the pyrometers 1 are directed toward the faces of the mold and continuously transmit the measurements of temperature which are received and stored in the control unit 7. With respect to the control system, the surface has been divided into zones, i.e., portions of surface having sufficiently small configuration and extension as to be valued in terms of average value with respect to both the measurements and the successive cooling action. During said scanning, the temperature of each surface zone is detected, preferably twice at different moments, whereby the system will be enabled to acquire the temperature and to calculate the heating curve. On completion of the scanning, the control system 7 has created a map, zone by zone, with the temperature and heating rate.

On completion of the scanning cycle, the forced cooling is started and is carried out by the sprayer carriage 5 which, by displacements controlled by the control unit 7, enters the mold and successively occupies the positions that are suitable for directing jets of pressurized water against the inner surface of the walls 8. Since a positional relation is established between the nozzles 4 and pyrometers 1 on the respective carriages, the cooling water may be dispensed in jets directed each time towards the same zones created by dividing the surface of the mold, in order to measure the surface temperature.

The control system, on the basis of the previously acquired data, calculates the amount of water required by each zone to be cooled down to the proper temperature. The control of the amount of water to be dispensed is effected zone by zone by means of shut off solenoid valves, the opening and closing of which is controlled directly by the control unit 7. It is, therefore, the task of the logic control unit 7 to determine and achieve the exact amount of sub-cooling of each zone, so that, when the cooling is over, all the zones reach thereafter and simultaneously the temperature which is suitable for the lining. Therefore, the logic control system 7 has the additional task of establishing the exact time to start the successive lining operation.

On completion of the forced cooling, the logic control unit 7 can control, if necessary, the pyrometer carriage to effect an additional scanning in order to check the result which has been obtained. In case the result is not satisfactory, the control unit 7 advances the programmed time of lining and starts a second cooling cycle to achieve a more accurate result.

On completion of the automatic cycle, the control unit 7 emits the end-of-cycle signal and displays to the operator the most suitable time to start the wall-lining cycle, on the display 9 of the unit 7.

The lining cycle is carried out according to the methods known previously to the subject invention. However, since it will be carried out on walls having a well-definite temperature, it will achieve much better quality results which, due to the reasons stated above, permit to obtain important improvements in the industrial process as a whole.

Claims

1. A method of cooling the inner surfaces of the walls (8) of the molds used for the controlled-pressure casting of metals, characterized by the following steps which are carried out after the emptying of the mold and after the cleaning and the preliminary cooling of the inner surfaces of the mold walls (8):

a) the step of spot-or zone-measuring the temperature of the mold walls (8), so as to obtain a chart of the temperature distribution on the said surface;

b) the step of transmitting the measured temperature values to an electronic processor (7) and of memorizing the said temperature values in the said processor;

c) the step of cooling upon control of the processor (7), the inner surfaces of the mold walls (7) by spraying on each spot or on each zone of said surfaces an amount of water, which is established by the processor (7) in relation to the memorized temperature of the respective spot or the respective zone, so as to obtain a substantially uniform temperature in all the spots or in all the zones of the surfaces of the mold walls (8).

2. The method according to claim 1, characterized in that the spot-or zone-measuring of the temperature of the internal surfaces of the mold walls (8) is effected by scanning the said inner surfaces with a bank of directive thermometers (1).

3. The method according to anyone of claims 1 or 2, characterized in that the cooling of the inner surfaces of the mold walls (8) is effected by sprinkling the said inner surfaces with a number of water jets directed toward the said surfaces and associated with the individual spots or zones in which the temperature is measured.

4. The method according to claim 3, characterized in that against each spot or each zone of the inner surface of the mold walls (8), in which the temperature is measured, a respective water jet is directed, which is proportionate to the said temperature.

5. The method according to claim 3, characterized in that the processor (7) establishes the average temperature of areas of the inner surfaces of the mold walls (8), which areas comprise more than one spot or zone at which the temperature is measured, and against each one of these areas a respective water jet is directed, which is proportionate to the said average temperature.

6. The method according to claim 1, characterized in that the processor establishes the amount of water to be sprayed against each spot or each zone in which the temperature is measured, and not only keeps into account the memorized measured temperature, but also the time elapsing be-

tween the measuring of the respective temperature and the starting of the subsequent spraying for cooling the inner surfaces.

7. The method according to claim 1 and one or more of claims 2 to 6, characterized in that the steps a), b), and c) are repeated twice.

8. An apparatus for carrying out the method according to any one or more of claims 1 to 7, characterized by comprising a temperature-detecting carriage (2) which is displaceable, preferably at a constant speed, along the inner surface of a mold wall (8), and is provided with a bank of directive thermometers (1) pointing toward the said mold wall (8) and connected to a processor (7).

9. The apparatus according to claim 8, characterized in that the directive thermometers (1) are arranged in at least one row extending transversely to the direction of displacement of the temperature-detecting carriage (2), and extending preferably throughout the extension of the mold wall (8) transversely to the said direction of displacement of the temperature-detecting carriage (2).

10. The apparatus according to claim 8 or 9, characterized in that the directive thermometers (1) consist of pyrometers.

11. The apparatus according to claim 8 or 9, characterized in that the directive thermometers (1) are video cameras sensitive to infrared emissions.

12. The apparatus according to any one or more of claims 8 to 11, characterized by comprising a sprayer carriage (5) which is preferably displaceable at a constant speed along the inner surface of one mold wall (8), and is provided with a bank of spray nozzles (4) pointing toward the said mold wall (8) and connected each to a cold water supply by means of a solenoid valve controlled by the processor (7).

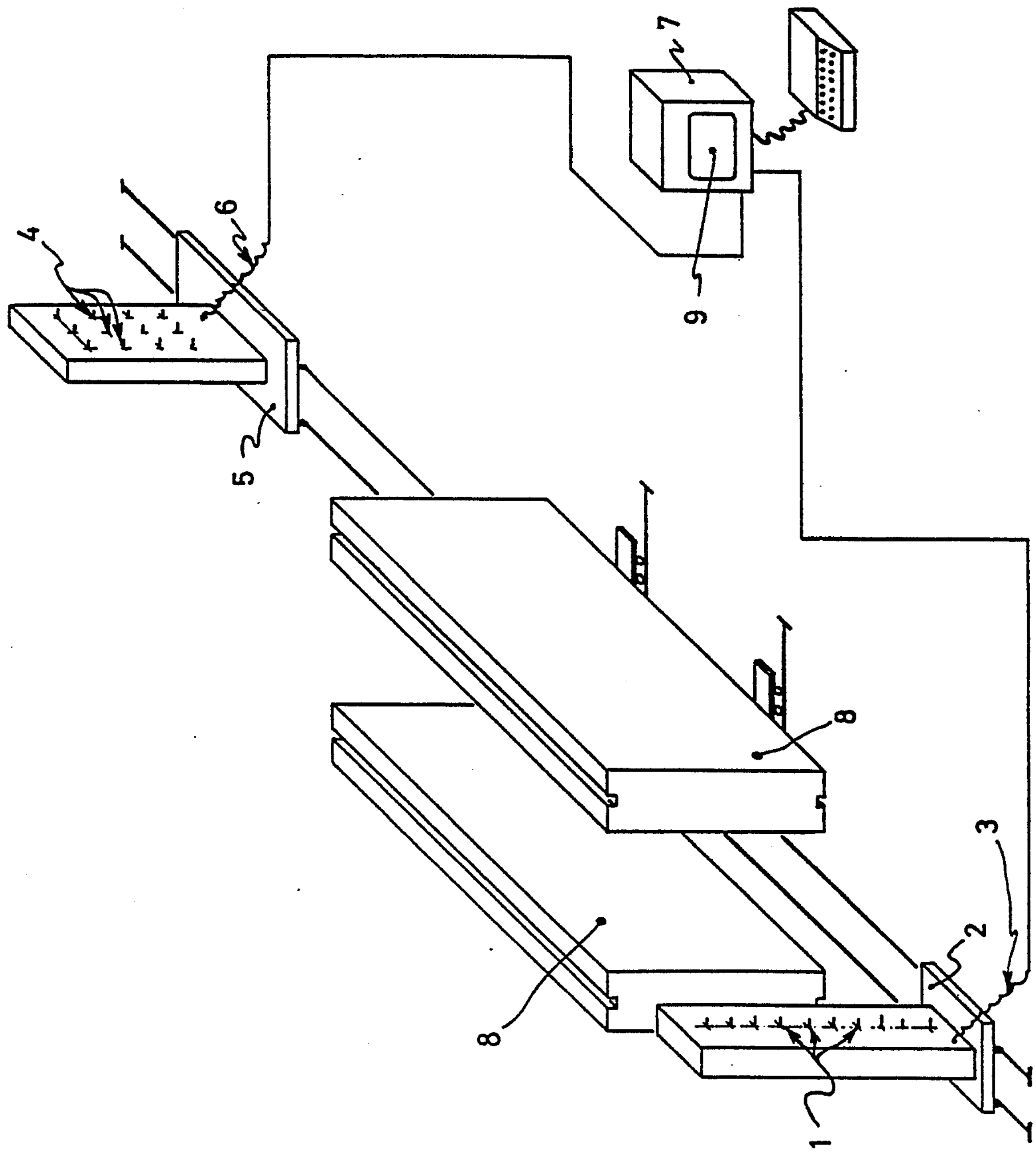
13. The apparatus according to claim 12, characterized in that the spray nozzles (4) are arranged in at least one row extending transversely to the direction of displacement of the sprayer carriage (5), and extending preferably throughout the extension of the mold wall (8) transversely to the direction of displacement of the sprayer carriage (5).

14. The apparatus according to any one or more of claims 8 to 13, characterized in that the temperature-detecting carriage (2) and the sprayer carriage (5) are assembled on the same carriage.

15. The apparatus according to any one or more of claims 8 to 14, characterized in that the temperature-detecting carriage (2) and the spray carriage (5) are integrated in accessory movable machines associated with the mold.

16. The apparatus according to any one or more of claims 8 to 14, characterized in that the temperature-detecting carriage (2) and the sprayer carriage (5) are integrated in the movable machine for cleaning the inner surfaces of the mold walls (8).

17. The apparatus according to any one or more of claims 8 to 16, characterized in that the directive thermometers (1) and/or the solenoid valves for feeding the spray nozzles (4) are connected to the processor (7) by means of cables (3, 6) or by means of electromagnetic or acoustic waves transmitting and receiving devices.



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