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(54) PROCESS AND APPARATUS FOR THE MANUFACTURE OF CERAMIC MOULDINGS

(71) We, DEMAG KUNSTSTOFFTECHNIK ZWEIGNIEDERLASSUNG DER DEMAG AKTIENGESELLSCHAFT, a German Body Corporate of, Rennweg 37, D-8500 Nurnberg, West Germany, do hereby declare the invention for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The invention relates to a process for the manufacture of mouldings of ceramic material and apparatus for the purpose. In the present context, a ceramic material is to be understood to be, for example, a mixture of quartz, kaolin, feldspar, water and known additives, for making porcelain or earthenware.

In conventional processes for the injection-moulding of ceramic materials, materials having a moisture content of at least 20% by weight, usually 22 to 25% by weight, such as are available as a result of conventional working-up processes on a filter press, have hitherto been used. Since mouldings of materials having such a moisture content are difficult to handle subsequently without damage, it is necessary, before release from the mould, to dewater the moulding to reduce the moisture content to at most 17%, that is to say a condition where it can be described as semi-hard. In order to carry out this dewatering it is essential to have porous moulds, which as a rule are made of synthetic resin with fillers and binders. However, such moulds have very poor resistance to wear and therefore have only a short working life. Furthermore, the dewatering process lengthens the moulding cycle time and objectionable flow formations are often formed in the mouldings produced.

It is therefore an aim of the invention to provide a moulding process for ceramic material in which a dewatering step is not required, so as to make it possible to use non-porous metallic moulds and/or reduce cycle times.

According to one aspect of this invention, there is provided a method for making a ceramic moulding, comprising: injecting into a split mould having impermeable walls plastic ceramic material having a moisture content of less than 20%, in an amount required for said moulding, through a sprue opening of the mould while the mould halves are kept at a slight distance apart and thus the mould cavity is not entirely filled by said material; and then closing the sprue opening and bringing the mould halves together thereby exerting a pressure on, and spreading, the material in the mould cavity.

Using this process it is possible to mould ceramic materials having a moisture content of less than 20%, and indeed in the range of 12 to 16%, so that a dewatering step is not necessary and mouldings which are free of flow formations and are hard enough to handle can be obtained immediately. The multi-stage process helps towards providing the desired uniform pressure distribution in the ceramic material contained in the mould cavity, and a resulting uniform structure of the finished moulding. In effect since pressure is exerted on the material contained in the mould cavity, not only during injection from the sprue side, but also after the partial filling of the mould cavity by the relative movement of the mould halves, the internal frictional factors which normally hinder pressure propagation in the material are avoided and more homogeneous compression can be achieved. According to a preferred feature of the method, additional pressure is exerted, from the sprue side, on the material in order to contribute to a further homogenisation of the structure of the moulding.

Preferably the injection speed may be varied during the injection process, and this can also be used to influence the structure and density of the moulding. Thus, for example, it is possible initially to employ a high injection speed in the course of the injection process, so that the material acquires a relatively high density in the edge regions of the mould cavity and the flow front is stabilised, and then to reduce the injection speed so that the density in the sprue region is reduced. Depending on the shape of the moulding being produced, the subsequent bringing together of the mould halves and any pressure additionally exerted from the sprue side, then produce a density equalisation.

Because a dewatering step is dispensed with, conventional solid metal moulds can be employed in performing the process according to the invention, and these moulds have a substantially longer working life than the delicate porous plastics moulds previously used. Furthermore, the process yields mouldings hard enough to handle, without a dewatering step and hence in a shorter cycle time, since the material has from the start a low moisture content corresponding to the desired "semi-hard" state. At the same time, the density and structure of the mouldings thus produced can be influenced within wide limits and can be kept more constant throughout the moulding.

It is possible in employing the process according to the invention, to effect mould release by electrical detachment, in which the mould halves, which are electrically insulated from one another and from the injection cylinder, are connected to opposite poles of a voltage source. This can produce detachment of the moulding from the mould cavity, and proves advantageous in cases in which there is a risk of sticking of the material to the mould.

Injection-moulding machines which permit a controlled bringing-together of the mould halves can be employed for carrying out the process according to the invention. Thus, for example, it is possible to employ a mould closing device in which the mould is first set, by an actuating device, to give a desired small spacing between the mould halves, after which a pressure-cushion device comes into operation in a controlled manner and effects the further closing of the mould.

A second aspect of the invention provides an injection moulding machine for the manufacture of ceramic mouldings, the machine having: a mould with impermeable mould walls and the mould halves of which are able to be set in a position where they are slightly apart from one another during injection of plastic ceramic material; an injection cylinder with an injection element movable therein to inject plastic ceramic material through a nozzle bore and a sprue opening of the moulding into the mould cavity; and an axially displaceable pin coaxial with the nozzle bore and sealingly slidable into the nozzle bore thereby to close the sprue opening before the mould is closed.

Such apparatus is particularly, though not exclusively, useful for carrying out the particular form of the process of the invention when the optional step of exerting additional pressure after closing the mould is required.

This apparatus makes it possible, after metering ceramic material and partially filling the mould cavity, to close the mould very rapidly on the sprue side by advancing the pin into the nozzle bore and, if desired, to exert pressure on the ceramic material in the mould cavity by applying a force to the pin. When the pin is in the bore, it acts as a non-return valve so that immediately after the closing of the mould, the treatment and metering processes required for the next injection cycle can commence within the injection cylinder.

Since the front face of the pin, in its advanced position, can be and usually will be flush with the adjacent parts of the wall of the mould cavity and itself forms a part thereof, mouldings which do not have a sprue can be produced. The front face of the pin can, for instance, be provided with a company stamp or trademark so that as is customary with ceramic articles, this appears, for example, on the underside of the moulding. The pin can, however, also be employed for compensating for fluctuations in the amount of material metered, by being advanced to a greater or lesser extent depending on the amount of material metered. In addition when the pin is within the bore it helps to prevent drying-out of ceramic material contained in the injection cylinder if the machine is temporarily stopped.

In order that the invention may be more clearly understood, the following description is given, merely by way of example, with reference to the accompanying drawings in which:-

Figure 1 shows a longitudinal section through the injection unit and the mould of an injection-moulding machine according to the invention, the parts of the injection-moulding machine not concerned with the present invention having been omitted;

Figure 2 shows a longitudinal section through the drive means of the pin, on an enlarged scale compared to Figure 1; and

Figure 3 shows the connection of the nozzle head of the injection cylinder to the mould, again on an enlarged scale compared to Figure 1.

The injection unit shown in Figure 1 is part of a complete injection-moulding machine and is connected with the usual further components which are not shown but which are needed for the correct execution of injection sequences.

The injection unit comprises an injection cylinder 1, in which an injection element, in the form of a screw 2 (although it could be a piston) is located in a rotatable and axially displaceable manner. Rotation of the screw is effective via a spur gear 3 and axial movement of the screw is effected via a hydraulic piston-cylinder arrangement 4,5. In order to permit the metering of an amount of ceramic material suited to a particular moulding, a limit switch control (not shown), for the piston 5 is provided in known manner.

Ceramic material is fed into the cylinder 1 from a hopper 7, in the lower region of which is provided a degassing line 8, which when the unit is set up, will be connected with a source of vacuum and serves to remove gas from the ceramic material entering the cylinder 1. Degassing of the material can additionally (or also exclusively) be effected via a degassing connection 9 in the wall of the cylinder.

A nozzle head 10 is firmly attached to the front end of the injection cylinder 1 (see Figure 3) and is at the same time firmly connected to a half of a mould 12 by means of flange bolts 11. The nozzle head 10 defines a nozzle bore 13 (see Figure 3).

The screw 2 in the cylinder 1 has a continuous axial bore 14 in which a pin 15, having a piston-like thickening 16 at its front (left as shown) end, is axially displaceable. The pin 15 can be actuated by a further piston-cylinder arrangement 17 (see also Figure 2), by means of which the pin 15 can be actively advanced and retracted independently of movement of the screw 2. The piston-cylinder arrangement 17 includes a cylinder 18 with a piston 19 displaceable therein which can be subjected to the pressure of a pressure medium on either side. The piston 19 is screw-threadedly attached to the rear end of a connecting rod 15' for the pin 15; an extension of the connecting rod 15', which is of stepped diameter, passing through a rear end-face plate 20 of the cylinder 18. At 21 and 22 are indicated feed/discharge lines for pressure medium for the cylinder 18.

The cylinder 18 is connected via an adjustment sleeve 23 to a housing 24 which adjoins the cylinder 4 for actuating the screw 2. The adjustment sleeve 23 allows the cylinder 18, and hence the position of the stroke of the piston 19 to be set. It is thus possible, for example, so to choose the position of the stroke of the piston 19 that when it is in its front terminal position the end face of the piston-like thickening 16 is flush with the front end face of the nozzle head 10 (as in Figure 1), i.e. it is flush with adjoining parts of the wall of the mould, so that the face of the piston-like thickening 16 forms, like the end face of the nozzle head 10, a part of the wall of the cavity formed in the mould 12. The length of the stroke of the piston 19 can also be adjusted by means of lock nuts 25, which are screwed onto an extension 26 of the connecting rod 15' which passes through a cover of the cylinder.

The mould 12 consists of two mould halves which are fixed to mould-mounting platens 30, 31. The mould-mounting platen 31 is displaceable along columns 33 by means of a mould closing device 32, which is only schematically indicated. The mould halves of the mould 12 are electrically insulated from one another in the parting plane, and an electrical insulating layer is also present between the mould-mounting platen 30 and the mould half corresponding thereto, while the nozzle head 10 is also electrically insulated from the mould-mounting platen 30 and there is no electrical connection between the piston-like thickening 16 of the pin 15 and the nozzle bore 13. This is achieved by reason of the piston-like thickening 16 carrying an insulating layer, or by reason of the thickening itself consisting of an electrically non-conductive material.

The preferred process according to the invention when performed with the above described apparatus takes place as follows:

As a result of adjustment of the adjustment sleeve 23, the cylinder 18 is set so that the end face of the piston-like thickening 16 of the pin 15 when in the advanced position is precisely at the end face of the nozzle head 10. The mould half connected to the movable mould-mounting platen 31 is brought up to the other mould half, leaving a slight gap (for example 0.5 to 2 mm when manufacturing a plate, as suggested in Figure 1). A limit switch arrangement for the axial actuation of the screw 2 is also set so that during the axial stroke of the screw a precisely metered amount of suitable ceramic material is forced through the nozzle bore 13 into the mould cavity. The injection cylinder 1 of course contains the ceramic material, in a plastic form and with a moisture content for instance 16%. At this time the pin 15 and its piston-like thickening 16 have been retracted into the axial bore 14 of the screw 2, as a result of the piston 19 being in its rear terminal position.

By applying pressure to the piston 5, the screw 2 is pushed forward within the injection cylinder 1, so that the amount of ceramic material determined by the stroke of the piston 5 is forced through the nozzle bore 13 into the mould cavity. Since this amount of ceramic material is suitably chosen for the article to be manufactured and the mould halves are not completely closed, the ceramic material does not at this stage completely fill the mould cavity, in particular it does not reach the rim regions. immediately after the screw has reached the front terminal position the piston 19 is subjected to pressure medium, so that the pin 15 moves outwards and its piston-like thickening 16 enters the nozzle bore 13. Since the cross-section of the thickening 16 precisely matches that of the nozzle bore 13, the mould is, as a result, sealed. Simultaneously, or immediately thereafter, the mould closing device 32 is actuated so that the mould halves are moved into a fully mould closed position. As a result of this, and as a result of the application of pressure by the pin 15, the ceramic material contained in the mould cavity becomes distributed therein. The pressure on the ceramic material from the sprue side can be controlled in a predetermined manner by appropriate application of pressure to the piston 19.

Since the drives for the screw 2 and the pin 15 are independent, the screw can be retracted during the period in which pressure is exerted by the pin in order to initiate the next metering sequence.

As electrical voltage can be applied to the two mould halves at the same time, in order to initiate the mould release sequence. Accordingly, after the mould 12 has opened, the moulding which is hard enough to be handled, at least to the extent that it can be passed to the further processing stages, for example firing, can be removed from the mould.

WHAT WE CLAIM IS:-

1. A method for making a ceramic moulding, comprising: injecting into a split mould having impermeable walls plastic ceramic material having a moisture content of less than 20%, in an amount required for said moulding, through a sprue opening of the mould while the mould halves are kept at a slight distance apart and thus the mould cavity is not entirely filled by said material; and then closing the sprue opening and bringing the mould halves together thereby exerting a pressure on, and spreading, the material in the mould cavity.

2. A method according to claim 1, wherein during or after the mould halves are brought together, additional pressure is exerted from the sprue side onto the material contained in the cavity of the mould.

3. A method according to claim 1 or 2 wherein the injection speed is varied during the injection step.

4. A method according to claim 3, wherein the injection speed is reduced during injection.

5. A method according to any preceding claim wherein a voltage is applied across the mould halves to assist release of the moulding.

6. A method according to any preceding claim wherein the ceramic material has a moisture content of between 12 and 16%.

7. An injection moulding machine for the manufacture of ceramic mouldings, the machine having: a mould with impermeable mould walls and the mould halves of which are able to be set in a position where they are slightly apart from one another during injection of plastic ceramic material; an injection cylinder with an injection element movable therein to inject plastic ceramic material through a nozzle bore and a sprue opening of the mould into the mould cavity; and an axially displaceable pin coaxial with the nozzle bore and sealingly slidable into the nozzle bore thereby to close the sprue opening before the mould is closed.

8. An injection-moulding machine according to claim 7, including a drive means operable independently of the drive of the injection element to move the pin.

9. An injection-moulding machine according to claim 7 or 8, wherein a nozzle head in which the nozzle bore is provided is firmly connected to a half of the split mould and itself forms a part of the wall of the mould cavity.

10. An injection-moulding machine according to any one of claims 7 to 9 wherein the part of the pin which can be inserted into the nozzle bore is of greater cross-sectional area than a shaft of the pin.

11. An injection-moulding machine according to claim 10, wherein the pin is coaxially within the injection element.

12. An injection-moulding machine according to any one of claims 7 to 11 wherein the mould halves are electrically insulated from one another and from the injection cylinder, and at least the part of the pin which can be inserted into the nozzle bore is electrically insulated from the nozzle bore or consists of an electrically non-conductive material.

13. An injection-moulding machine according to claim 12 wherein the mould halves are connected to opposite poles of a voltage source.

14. An injection-moulding machine according to any one of claims 7 to 13 including a piston-cylinder arrangement for moving the pin, such arrangement being adjustable in position relative to the injection cylinder.

15. An injection moulding machine according to claim 14 wherein the stroke of the piston of said arrangement is adjustable.

16. A process for making a ceramic moulding substantially as hereinbefore described with reference to the accompanying drawings.

17. An injection moulding machine constructed and arranged substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

18. A ceramic moulding made by the process of any of claims 1 to 6 and 16 or using a machine according to any one of claims 7 to 15 and 17.

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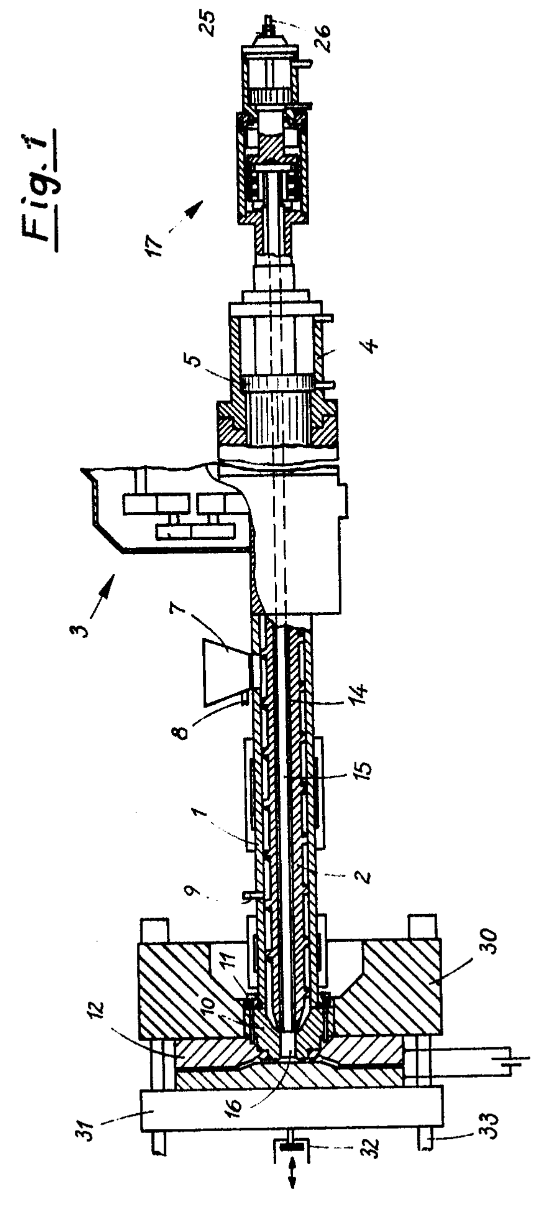
Fig. 1
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1567053 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

Fig. 2

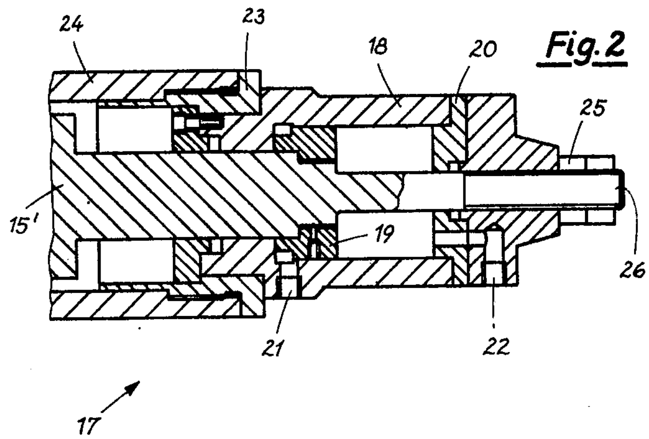

Fig. 3