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(57) Abstract

The invention relates to a molding tool and to a method of tempering a molding tool intended for the manufacture of objects from moldable material. The tool is comprised of at least two mold parts (1, 2) which delimit a mold cavity (3) when the mold is closed. The tool includes at least one sintered metal mold part (6, 7) having communicating pores. The mold parts include a plurality of mutually joined, sintered metal units (6A, 7A; 6B, 7B...) that include communicating pores. The outer mantle surface of the porous unit is impervious and the area that faces towards the cavity (3) has open or closed pores. Each porous unit includes fluid delivery and fluid discharge means. The method is characterized by tempering each mold unit independently of other mold units.
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Mold and method for its tempering

Background of the invention and prior art
The present invention relates to a molding tool for producing objects from moldable material and comprising at least one mold part which consists at least partially of sintered metal and which together with a counterpressure part delimits a mold cavity, and which tool includes means for delivering said material to the mold cavity and means for delivering and discharging fluid. The invention also relates to a method of tempering a molding tool.

Swedish Patent Specification 8501589-9 teaches the manufacture of mold parts from sintered metal such as to obtain mold parts that have communicating pores. A mold cavity is provided in the mold parts and the mold parts together form a mold in which objects can be molded from natural and synthetic polymers by injection-molding for instance. The mantle surfaces of the mold are closed after providing the mold cavity. The core of the known invention resides in the formation of a magazine in the pore system of the mold for temporary accommodation of air or any other gas that is generated in the injection-molding process. The gas departs from the magazine after each manufacturing cycle when the mold is opened.

Although the aforesaid method is highly effective, difficulties are encountered in controlling the temperature of different parts of the molding tool in certain applications. In certain cases, the pores also become blocked or clogged with secondary products that form during molding of the polymeric objects. For instance, when injection-molding thermoplastic material in steel molds, about 80% of the manufacturing cycle is often taken up by the cooling time. The plastic material is injected into the mold cavity through a gate or some other nozzle type at a temperature of about 200-250 C. The plastic object is cooled in the mold cavity or chamber by convection, and the heat is carried away by cooling with water that flows in passageways located outside the mold chamber or drilled in the mold steel.

The provision of cooling passageways in the mold steel often results in weakening of the mold construction. Naturally, this weakening relates primarily to narrow mold parts. A weak mold construction cannot be accepted. Consequently, cooling passageways are omitted in certain parts of the mold, resulting in a cooling deficiency. Another significant problem in this regard is one of providing cooling passageways in connection with a complex mold chamber. This results in uneven cooling or tempering of the mold chamber and therewith in a poorer quality of the molded object.
Another problem which often incurs is that because the flow paths are so long, by which is meant the distance from the injection location to the center point of the object, the moldable material is cooled excessively before the mold is completely filled. Consequently, certain inner parts of the mold often remain unfilled.

Uneven tempering of the mold chamber is thus a serious problem, both when working with thermoplastic materials and with thermosetting resins, and also when manufacturing molded objects from other materials.

Swedish Patent Application 8804644-6 describes a method of solving the aforementioned tempering problem and also the problem of blocking or clogging of the pores. This solution involves controlling the temperature of a molding tool intended for the manufacture of objects from natural or synthetic polymers. The tool includes one or more mold parts produced from sintered metal and having communicating pores obtained by compressing powdered material under high pressure and sintering at high temperatures and thereafter forming a mold cavity in the mold part or parts, wherein the pores are open towards the mold cavity whereas the outer mantle surface of the molding tool is impervious to leakage. The communicating pores are filled with a liquid having a high vaporization temperature, such as to provide heat buffer in the molding tool. The pressure of the liquid in the pores is controlled with the aid of an appropriate pressure generator which is connected to the communicating pores in the molding tool such that the pressure will be increased automatically so as to counteract the inner mold pressure with respect to the liquid in the pores as polymeric material is injected into the closed molding tool. The pressure is then lowered automatically when the tool is again opened, and the inner mold pressure disappears. The pores are therewith filled with said liquid preferably during the entire manufacturing cycle. The liquid prevents the pores being clogged by secondary products formed during molding of the polymeric objects, or by filling agent, etc., present in the polymeric material used. Instead of blocking the pores in the porous parts of the molding tool, the secondary products are enclosed in the polymeric product. The liquid is intended to absorb air, water vapor and other gases that may be generated during the molding process. These gases then depart from the liquid when the tool is opened after each manufacturing cycle. Because the liquid is uniformly distributed throughout the entire pore system, uniform tempering of the molding tool is achieved. If necessary, the tool may be heated or cooled by externally applied aggregate and/or by circulating a temperature regulating medium through passageways having impervious walls and arranged in the porous parts of the mold or optionally in remaining parts of said molding tool. The
molding tool temperature is normally controlled to a temperature level of about
+20 C and about +170 C. The solution provided in accordance with the Swedish
Patent Application 8804644-6 thus provides a temperature equalizing effect in the
molding tool, by distributing in the communicating pores a liquid that has a high
vaporization temperature. The patent application, however, does not describe
extreme cooling of the molding tool.

In certain instances, it is desirable to cool a molding tool down to a
temperature of 0 C or even to a temperature far below this temperature. This
applies in particular to certain thermoplastics, such as polypropylene and
polyethylene terephthalate. It has not earlier been possible to produce from these
plastics products that have a glass-clear appearance. Because of insufficient
cooling, such plastic products are imparted a cloudy appearance, either
completely or partially. The Swedish Patent Specification 9100663-5 (Publication
No. 466951) describes a solution to this cooling problem and teaches a method
for cooling a molding tool intended for the manufacture of objects from natural or
synthetic polymers. The molding tool includes one or more mold parts produced
from sintered metal and containing communication pores obtained by
compressing and sintering powdery material under high pressure and at high
temperatures respectively. This mold part or these mold parts are thereafter
provided with a mold cavity, with the outer mantle surface of the tool being
impervious to leakage. This known method is characterized by sealingly
connecting with the mold tool material, which contains a large number of small
communicating pores, one or more capillary tubes or the like which extend
through the outer impervious mantle surface of the tool. Gas in liquid form is
delivered through the capillary tubes. The liquid-state gas then converts to a
gaseous state through expansion in the molding tool externally of the capillary
tubes, therewith subjecting the tool to a pronounced cooling effect. The gas used
may be carbon dioxide, nitrogen gas or air. Naturally, the gas used is transformed
to its liquid phase by conventional compression of the gas phase. According to
one embodiment, the molding tool includes at least one expansion chamber
recessed through the outer impervious mantle surface of the tool. A capillary tube
through which the liquid-state gas is delivered opens out into the expansion
chamber, in which the liquid expands to a gaseous state and then disperses
through the communicating pores while cooling the molding tool. The capillary
tube may either open out freely into the expansion chamber or may lie against the
porous wall of said tool. It is essential that the expansion chamber is made
impervious against leakage to the outer mantle surface of the molding tool in both
cases. The molding tool may be provided with one, two or more expansion
chambers with associated capillary tubes, the number of expansion chambers provided being contingent on the size of the tool concerned, the desired cooling effect, etc. When the molding tool used comprises a movable and a fixed part, it is often suitable to include an expansion chamber in each of said two parts. The capillary tubes may also have a function other than the aforesaid function. For instance, they may also be used to evacuate gases from the mold cavity and out of the mold. These gases are often generated during molding of the polymeric material. For instance, when injection-molding a first procedural step after closing the mold and injecting plastic material thereinto may conveniently be to evacuate through the capillary tubes the gas that departs from the polymeric material and then introduce the liquid-state cooling gas through the capillary tubes. When, for instance, two capillary tubes with associated expansion chambers are provided, the liquid-state cooling gas may also be delivered through one capillary tube while simultaneously evacuating the gas departing from the polymer through the second tube.

The plastic material used is preferably a thermoplastic material, such as polypropylene, polyvinyl chloride, polyethylene, polyethylene terephthalate, etc. The invention functions equally as well, however, irrespective of the polymer used in the manufacture of objects in the molding tool. The aforesaid method can also be used to manufacture products from thermosetting resins.

When working with polypropylene in accordance with the described method, it is possible to produce products that are entirely glass clear, which as before mentioned was earlier impossible. This positive effect is achieved as a result of the extreme cooling of the mold afforded by the invention. Polypropylene has many positive properties in comparison with polyvinyl chloride, not least from an environmental aspect. Because polyvinyl chloride can be molded readily into glass-clear products in conventional working processes, this plastic has been used in many applications where polypropylene has been utilized to a very small extent.

The molding tool can be conveniently tempering to a temperature of from +50 C to 100 C or from 0 C to -100 C. The mold cavity can be formed so that the pores are open or closed to the mold cavity. It is also possible to form the mold cavity so that part of the pores bordering on the mold cavity will be closed while another portion of these pores will be open. When part of the pores bordering on the mold cavity are open, the cooling gas will, of course, come into contact with the plastic product produced during the molding process. When the mold is then opened, gas will seep out through the pores in the mold cavity. These gas quantities will be small, however. On the other hand, when the pores are closed to
the mold cavity a closed cooling gas system can be provided. The gas may thus be evacuated through, e.g., one capillary tube while delivering liquid-state cooling gas through another capillary tube.

When injection-molding objects that have large surface areas, high injection pressures are required and therewith commensurately large machines for generating this high pressure. Examples of such objects are waste bins, plastic crates and plastic furniture. The reason is because high subsequent pressures are required to counteract abnormally pronounced shrinkage. At low pressures, shrinkage increases to levels at which cracks are liable to form. Tensile strength limits are exceeded. An analysis has shown that when injecting plastic compound into a warm tool, full packing of the mold is achieved already at low pressures and that successive uniform "freezing" of the surfaces requires an accentuating pressure in order to avoid abnormal shrinkage.

Summary of the invention

An object of the present invention is to provide a method of producing large molded objects with the aid of a lower molding compound injection pressure than conventional methods. Another object of the present invention is to provide a method of producing large molded objects more quickly and with a lower rejection percentage than is typical at present. Still another object of the present invention is to provide a molding tool for the manufacture of large molded objects.

These objects are achieved with the inventive molding tool and method having the characteristic features set forth in respective independent Claims. Advantage embodiments of the invention are set forth in the dependent Claims.

In accordance with the present invention, this freezing process commences furthest away from the injection location and freezes the moldable material successively up to said injection location, as a result of individual tempering zones in the molding area of the tool. This is achieved by constructing the molding area from segments made of microporous steel and regulating the temperature individually in each segment or groups of segments. This results in quicker cycle times, i.e. shorter object manufacturing times, and smaller injection units and therewith much lower investment costs.

Thus, in accordance with the present invention, each mold part is comprised of a plurality of mold units which are joined together to form said mold part. In accordance with the invention, each mold unit can be considered as a mold part according to the known invention. Furthermore, a characteristic feature of the invention is that the temperature of each mold unit in the mold part is
regulated individually independently of the other units, such as to obtain a shorter cycle time.

According to one embodiment of the invention, all mold units are heated when delivering the warm moldable material, and the unit or units located furthest from the injection location are cooled first, and thereafter those mold units that are closer to said injection location.

Because the mold units are heated at the time of or prior to injecting the material, the material is able to penetrate distal parts of the mold cavity more readily without solidifying and forming a skin, which would otherwise reduce the cross-sectional area through which the material must pass. This considerably reduces the pressure required to ensure that the mold will be completely filled with moldable material. The pressure used in conjunction with the injection of said material can be reduced by a factor of three or more in comparison with known techniques. This greatly reduces the costs entailed by a system or plant intended for the manufacture of large molded objects.

**Brief description of the drawings**

The present invention will now be described in more detail with reference to a preferred exemplifying embodiments thereof and with reference to the accompanying drawings, in which:

Fig. 1 is a schematic longitudinal section view of a molding tool for the manufacture of large slightly conical vessels;

Fig. 2 is a schematic cross-sectional view of the tool shown in Fig. 1, taken on the line A-A in Fig. 1;

Fig. 3 is a schematic cross-sectional view of a tool intended for producing on a tube of large diameter a plastic coating for protecting weld joints; and

Fig. 4 illustrates schematically part of a molding tool which is intended to be joined together with other similar parts such as to form the tempering tool surface that comes into contact with the moldable material.

**Detailed description of various embodiments**

In Figs. 1 and 2, reference numeral 1 identifies a first mold half and reference numeral 2 identifies the complementary second mold half of the inventive molding tool. The mold halves 1 and 2 are movable in relation to one another, to enable the molded object to be removed from the mold. The mold halves present therebetween a chamber or cavity 3 which defines the walls of the object to be produced. The area of the first mold half 1 that faces towards the chamber 3 has a plurality of elements 6A, 6B, 6C..., which are joined together to
form an external defining layer of the chamber 3. Similarly, the area of the second mold half 2 facing towards the chamber 3 has a plurality of elements 7A, 7B, 7C..., which are joined together to form an external defining layer of the chamber 3. Each such element 6, 7 is provided with tubular means or capillary means (not shown) for the delivery of tempering medium, and tubular means or capillary means (not shown) through which the tempering medium used is discharged. These means are embodied in the respective elements 6, 7 through their impervious outer layers. The tubular or capillary delivery means may open into a chamber inwardly of the impervious outer layer, or against a porous metal surface.

Fig. 3 illustrates a molding tool for producing around a tube of large diameter a thin coating, preferably a plastic coating, for protecting a weld joint. The two semi-circular parts 11, 12 of the molding tool are held sealingly around a tube 19 by means not shown. Although not shown, each of the mold halves 11, 12 is provided at both ends with semi-circular shoulders whose inner diameters correspond to the outer diameter of the tube 19. These shoulders center the tool around the tube and also close the tubular chamber 13 in its longitudinal direction. The mold halves 11, 12 are also provided along their inner surfaces with porous steel cooling elements 16A, 17A, 16B, 17B... These elements also present tubular means or capillary means (not shown) for delivering tempering fluid and carrying away the used fluid. An inlet 15 for warm coating compound is disposed centrally between the two mold halves 11, 12.

Fig. 4 illustrates an example of one embodiment of a porous element 6 for producing the tempered area of the molding tool, e.g. according to one of the aforesaid embodiments. The area 26 has a surface which comes into contact with the material to be tempered and which has open or closed pores. The remaining sides, of which only three are shown, have surface layers which comprise closed pores. Tubular devices 21 and 22 which function to deliver and carry away fluid are inserted through the surface layer 23. The quantity of fluid delivered and carried away respectively and the temperature of the delivered fluid can be regulated individually with respect to each element 6 with the aid of control means adapted to this end, as illustrated schematically at 27.

When producing a large container for instance, as illustrated schematically in Figs. 1 and 2, warm fluid, for instance carbon dioxide gas, is delivered to the elements 6 and 7. A warm plastic compound for instance, is then introduced through the inlet 5 and spreads out in the chamber 3. When sufficient plastic compound has been introduced into the chamber 3, cooling of the plastic compound is commenced at a location furthest away from the inlet 5. Cooling fluid, for instance liquid carbon dioxide, is delivered to the element 6A and the
opposing elements 7A. All of the elements surrounding the chamber are cooled simultaneously. Cooling of the next row of surrounding elements 6B and 7B is then commenced. When cooling is completed, the manufactured object is removed from the mold by moving the mold half 2 axially away from the plastic compound inlet pipe 5 and the object is ejected.

A plastic layer is produced around a pipe or tube in an analogous manner, with the aid of the tool illustrated schematically in Fig. 3. Liquid plastic compound is injected into the closed tool through the inlet 15 while all elements 16 and 17 are heated with warm fluid. The plastic compound thereafter spreads in the chamber 13. When the plastic compound has completely filled the chamber 13 on the opposite side of the pipe as seen from the injection inlet, the warm fluid is replaced with cold fluid in the elements 16A and 17A along the entire longitudinal extension of the tube. The warm plastic compound is delivered to the mold until the chamber 13 is filled completely. The warm fluid in the elements 16B and 17B is replaced at this time with cold fluid, and thereafter in the following elements. When the whole of the plastic compound has solidified, the tool is opened and removed from the tube.

It will be understood that the present invention is not restricted to the aforesaid and illustrated embodiments thereof and that modifications and variations can be made within the scope of the following Claims. It will be noted in particular that the inventive tool and inventive method can be applied suitably for molding all moldable materials, such as natural and synthetic polymers, e.g. thermoplastics and thermostetting plastics, metals or metal alloys, ceramic materials, powder containing a binder for the manufacture of sintered bodies of, e.g., carbide metals, such as tungsten carbide.
CLAIMS

1. A molding tool for manufacturing objects from moldable materials, said tool comprising at least one mold part (1, 2; 11, 12) which is at least partially comprised of sintered metal and which together with a counterpressure means (1, 2; 11, 12) delimits a mold cavity (3; 13), and which includes means (5; 15) for delivering moldable material to the mold cavity, and fluid delivery and fluid discharge means (21, 22), characterized in that the mold part (1, 2; 11, 12) includes a plurality of mutually joined but individual mold units (6A, 7A; 16A, 17A; 6B, 7B; 16, 17B...) comprised of sintered metal having communicating pores, wherein the outer mantle area (23) of each porous mold unit that does not face towards the cavity (3; 13) is impervious, and the area (26) that faces towards said cavity has open or closed pores; in that each porous mold unit includes fluid delivery and fluid discharge means (21, 22); and in that the tool includes control means (27) for the individual control of fluid delivery to each mold unit (6A, 7A; 16A, 17A; 6B, 7B; 16B, 17B...).

2. A molding tool according to Claim 1, characterized in that the tool is comprised of two mold parts (1, 2; 11, 12) which together with the counterpressure means define the mold cavity (3; 13).

3. A molding tool according to Claim 1 or Claim 2, characterized in that the molding tool includes two mold parts (11, 12) which when closed surround a tubular conduit (19), wherein the tubular conduit (19) forms the counterpressure means and the mold parts (11, 12) surround said counterpressure means concentrically and in spaced relationship therewith.

4. A molding tool according to Claim 3, characterized in that the peripheral outer limitations of the tool are provided with shoulders which lie against the tubular conduit (19) when the tool is closed.

5. A molding tool according to Claim 1, characterized in that the counterpressure means is a body having a flat, concave or convex area which together with the mold part (1, 2; 11, 12) defines the cavity (3, 13).

6. A molding tool according to Claim 5, characterized in that the peripheral parts of the mold part (1, 2; 11, 12) has shoulders that project out towards the counterpressure means.

7. A molding tool according to Claim 1, characterized in that the counterpressure means is comprised of one mold part (1, 2; 11, 12).

8. A method of tempering a molding tool according to one or more of Claims 1-7, characterized by tempering each mold unit independently of remaining mold units.
9. A method according to Claim 8, characterized by tempering the molding tool in groups of at least two mold units.

10. A method according to Claim 8 or Claim 9, characterized by tempering the molding tool with carbon dioxide.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

**IPC6**: B29C 33/04

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

**IPC6**: B29C, B22D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**WPI, CLAIMS**

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<td>A</td>
<td>EP 0220040 A2 (EX-CELL-O CORPORATION), 29 April 1987 (29.04.87), figure 1, abstract</td>
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Further documents are listed in the continuation of Box C.

See patent family annex.

**Date of the actual completion of the international search**

7 June 1996

**Date of mailing of the international search report**

22-07-1996

**Name and mailing address of the ISA/Swedish Patent Office**

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